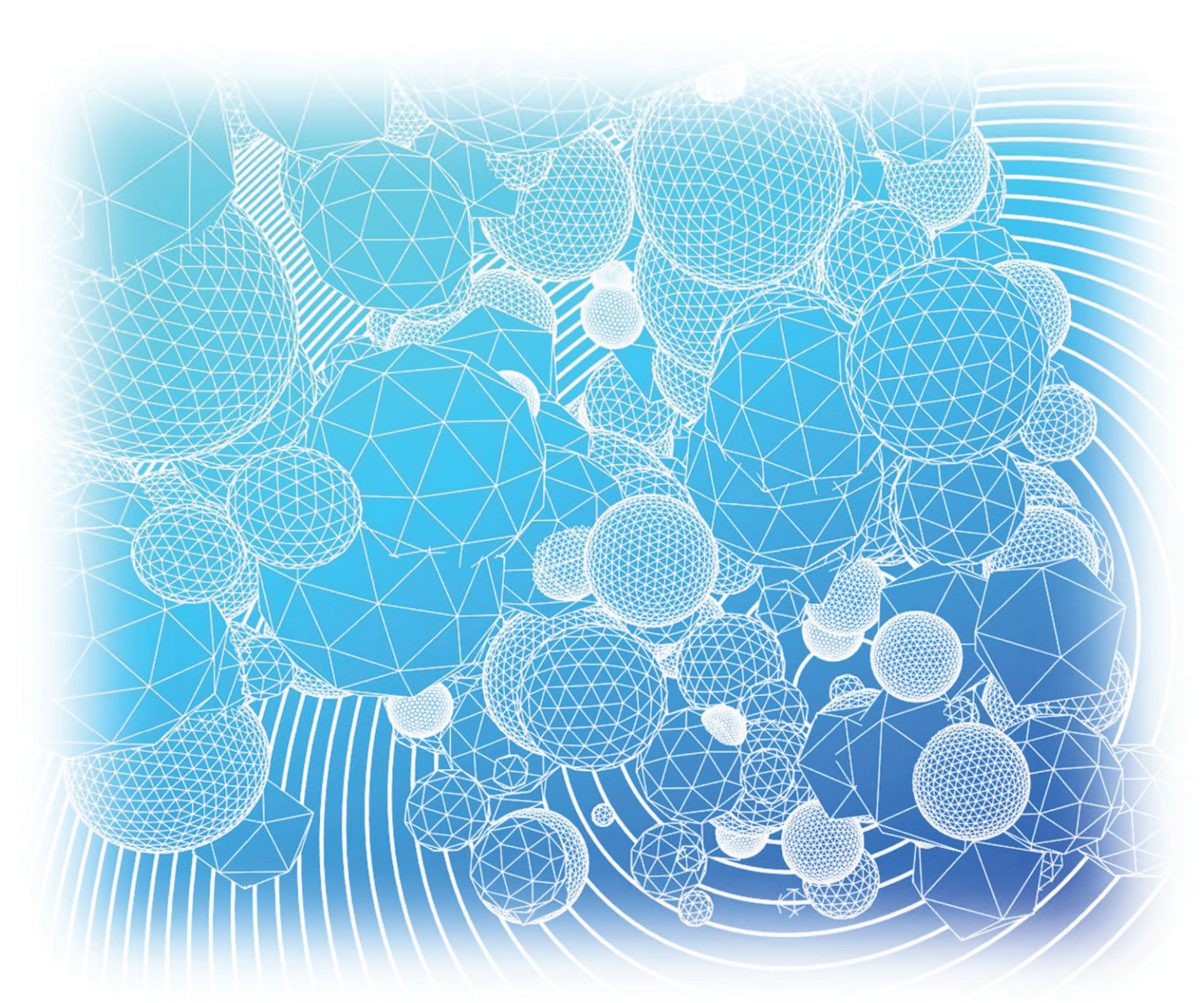

Human Health and Ecological Risk Assessment, Application of Alternative Waste Technologies Materials to Agricultural Land

Prepared for: NSW EPA

30 August 2019

Document History and Status

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It is prepared in accordance with the scope of work and for the purpose outlined in the Section 1 of this report.

The methodology adopted and sources of information used are outlined in this report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information provided was false.

The interim HHERA was prepared in October 2018 and was updated with additional information in and finalised in August 2019 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

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Glossary of Terms

ADI	Acceptable Daily Intake
ANZECC	Australia and New Zealand Environment and Conservation Council
AT	Averaging Time
BGL	Below Ground Level
BTEX	Benzene, toluene, ethylbenzene and total xylenes
BW	Body Weight
CF	Unit Conversion Factor
CoPC	Chemicals of Potential Concern
ED	Exposure Duration
EF	Exposure Frequency
EPA	Environment Protection Authority
ET	Exposure Time
HHRA	Human Health Risk Assessment
HI	Hazard Index
HIL	Health Investigation Level
HQ	Hazard Quotient
HSL	Health Screening Level
LOR	Limit of Reporting
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
PAH	Polycyclic aromatic hydrocarbon
RfC	Reference Concentration
RfD	Reference Dose
RME	Reasonable maximum exposure
SA	Surface area
TC	Tolerable Concentration
TDI	Tolerable Daily Intake
TDS	Total Dissolved Solids
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organisation

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Executive Summary

Environmental Risk Sciences Pty Ltd has prepared an updated assessment of the human health and ecological risks posed by application of mixed waste organic outputs (MWOO) generated at Alternative Waste Treatment facilities to agricultural land.

Mixed waste from red-lid garbage bins is processed at Alternative Waste Treatment (AWT) facilities to produce mixed waste organic outputs (MWOO). These materials have been permitted for application to land (agriculture, forestry and mine rehabilitation) under a resource recovery order and exemption issued by NSW EPA. When the use of these materials commenced there was limited information available. In addition to regulating their use, NSW EPA commissioned a research program which was undertaken between 2011 and 2017.

The risk assessment process involves estimating concentrations of chemicals that may be in the MWOO that could be present in the environment after the material is applied to land. Once the concentrations in the environment that people or organisms may be exposed to have been estimated, they are compared with toxicity reference values to determine risk. If the concentrations people might be exposed to are higher than the toxicity reference values risks are higher than preferred. If concentrations are lower, then the risks are low and acceptable.

Toxicity reference values are values that Australian or international health authorities have determined should be protective of heath. Determining toxicity reference values involves reviewing the scientific literature to find the lowest dose that caused no effects. This dose is then divided by a number of uncertainty factors depending on how much and what type of data is available, so these toxicity reference values are much smaller than any of the doses used in studies where no effects were seen.

Calculating how much people or organisms may be exposed to involves making a number of assumptions about how people might be exposed. If the site specific situation where this material might be applied is well understood then these assumptions can be tailored to what might actually occur. When a more generic calculation is required, as is the case here due to the number of sites where this material may have been applied, the assumptions need to be more worst case to ensure risks are not underestimated for the wide range of potential exposures at the various sites.

An Interim HHERA was prepared in October 2018 (provided in **Appendix B**) which highlighted some potential risks. In October 2018, the resource recovery order and exemption were revoked.

Additional work was undertaken in late 2018 and 2019 to allow the assessment to be refined. These investigations included further sampling and analysis of MWOO for PBDEs and PFAS, bioaccessibility measurements for PBDEs, review of a range of exposure assumptions used in the calculations. In addition, this update has also reviewed the chemicals that were previously parked in the NSW EPA commissioned research program due to a lack of guidelines.

Parked Chemicals and Additional Facility Data

In regard to human health, all the parked chemicals were assessed. In addition, the data provided by the facilities from routine monitoring has all been assessed. In regard to human health, there were no chemicals that were present above relevant guidelines in either MWOO that has not been mixed into soil (i.e. undiluted) or when a more refined assessment was undertaken.

In regard to ecological health, an assessment has been undertaken using aquatic effects data converted into soil guidelines as recommended in the ASC NEPM when terrestrial ecotoxicology information is limited which is the case for many of the chemicals analysed in MWOO. This assessment has identified a range of chemicals that may pose an ecological risk including iron, atrazine, endosulfan, dicamba, mercury, di-ethylhexyl phthalate (as total phthalates) and di butyl phthalate. It is also noted that for some contaminants like copper and zinc, the concentrations present in MWOO were highly variable. The maximum concentrations were well above acceptable values but occurred in only one or two samples from the whole dataset. Using the 95th percentile concentration, risks from these contaminants were estimated to be acceptable. No further assessment is possible at this time.

In regard to livestock watering using water affected by leachate from MWOO, all chemicals were present at concentrations well below screening guidelines for livestock health.

In regard to using water affected by leachate from MWOO for irrigation, most chemicals were present at concentrations well below screening guidelines for irrigation except for ammonia, MCPA, MCPP, PBDEs and phenol. However, it is unlikely that water affected by MWOO leachate would be regularly used for irrigation at a particular location, so these guidelines are conservative. No further assessment is possible at this time.

PBDEs

The key assumptions that have been used in this assessment include:

- People live at a site for 29 years as adults and 6 years as children and the PBDE chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- People eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO (even though chickens were not permitted to be kept on land treated with MWOO)
- People drink 100% of the milk they consume each year from dairy cows kept at the site on land that has been treated with the MWOO
- People eat 35% of the meat they consume each year from cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of fruit, vegetables or wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO (even though vegetables were not permitted to be grown on land treated with MWOO)
- The PBDEs found in the MWOO are up to 30% available to be taken up by livestock
    - PBDEs (Br1 to Br9) – 12% *(based on the upper end of the values for samples containing more than 1 mg/kg PBDEs (Br1 to Br9))*
    - PBDEs (Br1 to Br9) – 30% *(based on the upper end of the values for samples containing less than 1 mg/kg PBDEs (Br1 to Br9))*
    - DecaBDE – 4% *(based on the upper end of the values for samples containing more than 2 mg/kg DecaBDE)*
    - DecaBDE – 15% *(based on the upper end of the values for samples containing less than 2 mg/kg DecaBDE)*
- Background intake of PBDEs from household articles (like TVs, furniture, computers etc) takes up 80% of the allowable amount (as per the toxicity reference value) of these

chemicals so the risk estimates here are based on comparing the concentrations people might be exposed to with 20% of the reference dose determined by health authorities
- Cattle ingest 0.5 kg soil per day.
- Cattle are present in a paddock treated with MWOO for either 183 days per year (i.e. 6 months of the year) or 52 days per year (i.e. 14% of the year) to provide more realistic estimates of exposure.
- Transfer factors of 0.53 for uptake into meat and 0.01 for uptake into milk have been assumed for PBDEs (Br1 to Br9).

Direct Contact

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present results in the following:

- Almost all scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied directly to the ground surface is estimated to be higher than the reference dose for PBDEs until it is trampled in

Home Grown Produce

Cropping Land (i.e. incorporated into the soil)

Based on the updated risk estimates for ingestion of home grown produce where MWOO was incorporated into the soil**,** the potential for PBDEs to be present results in the following:

- Where people may consume home grown fruit and vegetables on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) indicate exposure is estimated to be higher than the reference dose for PBDEs
- Where people may consume home grown wheat/oats on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) indicate exposure is estimated to be lower than the reference dose for PBDEs
- Where people may consume home grown eggs on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) indicate exposure is estimated to be equal to the reference dose for PBDEs

Grazing Land (i.e. not incorporated into the soil)

It is noted that the regulation governing the application of MWOO to agricultural land requires that livestock not be permitted to graze on the land for the first month after it is applied. Once livestock begins to graze on the treated land, they will trample the material into the top 2 cm of soil and so are likely to mix the MWOO into the soil over weeks to months.

Based on the risk estimates for ingestion of home-grown produce where MWOO was not incorporated into the soil when it was initially applied or when it was trampled into the top 2 cm of soil, the potential for PBDEs to be present results in the following:

- There was likely to be a peak uptake of PBDEs into livestock when, after the one month exclusion period, they began to graze on land where MWOO was applied. This results in scenarios where people who consume home grown milk or meat on a regular basis

produced from grazing land where MWOO has been applied directly to the ground surface are estimated to be exposed to levels higher than the reference doses for PBDEs

- Once the MWOO has been trampled into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce but remain above the reference dose for PBDEs where cattle graze in a paddock for up to 6 months of a year.
- Once the MWOO has been trampled into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce to levels equal to or below the reference dose for PBDEs where cattle graze in a paddock for 52 days per year.

PFAS

The key assumptions that have been used in this assessment include:

- People live at a site for 29 years as adults and 6 years as children and the PFAS chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- People eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO (even though chickens were not permitted to be kept on land treated with MWOO)
- People drink 100% of the milk they consume each year from dairy cows kept at the site on land that has been treated with the MWOO
- People eat 35% of the meat they consume each year from cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of fruit, vegetables or wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO (even though vegetables were not permitted to be grown on land treated with MWOO)
- PFAS found in the MWOO are 100% available to be taken up by livestock
- Background intake of PFAS has been determined to be 10% of the reference dose determined by health authorities

Cropping Land (i.e. incorporated into the soil)

Based on these risk estimates, the potential for PFAS to be present where MWOO was incorporated into the soil, results in the following conclusions:

- All scenarios where people may come into contact with soil and/or consume any type of produce on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference doses for PFAS

Grazing Land (i.e. not incorporated into the soil or trampled into top 2 cm of soil)

It is noted that the regulation governing the application of MWOO to agricultural land requires that livestock not be permitted to graze on the land for the first month after it is applied. Once livestock begins to graze on the treated land, they will trample the material into the top 2 cm of soil and so are likely to mix the MWOO into the soil over weeks to months.

Based on the risk estimates for direct contact and ingestion of home-grown produce where MWOO was not incorporated into the soil when it was initially applied or when it was trampled into the top 2 cm of soil, the potential for PFAS to be present results in the following conclusions:

- Scenarios where people may come into direct contact with soil on a regular basis from land where MWOO has not been incorporated into the soil or has been trampled into the top 2 cm of soil indicate exposure will be below the reference doses for PFAS
- There was likely to be a peak uptake of PFAS (i.e. PFOS related chemicals and PFOA related chemicals) into livestock when, after the one month exclusion period, they began to graze on land where MWOO was applied. This results in scenarios where people who consume home grown milk or meat on a regular basis produced from grazing land where MWOO has been applied directly to the ground surface are estimated to be exposed to levels higher than the reference doses for PFAS
- Once the MWOO has been trampled into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce to be below the reference doses for PFAS

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Section 1. Introduction

1.1 Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned by NSW EPA to assess the human health and ecological risks posed by application to agricultural land of mixed waste organic outputs (MWOO) generated at Alternative Waste Treatment facilities.

Some mixed waste from red-lid garbage bins is processed at Alternative Waste Treatment (AWT) facilities to produce mixed waste organic outputs (MWOO). These materials have been permitted for application to land (agriculture, forestry and mine rehabilitation) under a resource recovery order and exemption issued by NSW EPA. The most recent versions of these instruments were issued in 2014. The order and exemption are included in full in **Appendix A**.

When the use of these materials commenced there was limited information available about them. In addition to regulating their use, NSW EPA commissioned a research program which was undertaken between 2011 and 2017.

The information available from the research program was used for an initial conservative/worst case assessment to determine potential risks from the use of this waste over the last decade. The interim HHERA report is provided in **Appendix B**.

In October 2018, the resource recovery order and exemption were revoked. In addition, a range of matters for which conservative assumptions were made in the interim HHERA that could be refined were identified. Additional work to collect relevant information to allow more appropriate assumptions to be used was undertaken and the results have been used in this refined HHERA.

1.2 Objectives

1.2.1 Interim HHERA

The overall objective of the interim HHERA undertaken in October 2018 was to use worst case modelling with the limited information available to quantify the risk to human health and the environment resulting from land application of MWOO to agricultural land.

The assessment focused on chemicals that may be present in MWOO that were classified as high or very high priority in a hazard assessment undertaken by the then NSW Office of Environment and Heritage.

Specifically, the assessment was to address the following questions:

- What is the risk to human health and the environment from past applications to land of MWOO in agriculture in NSW? (Agriculture includes broadacre cropping, grazing animals (sheep, cattle), fruit trees (blueberries), tea trees, sugar cane) The key focus areas to be covered are the risks of:
    - Uptake into edible crops (wheat, oats, barley), fruit (blueberries) and then human consumption of those crops;
    - Uptake into grazing animals (cattle and sheep) via direct ingestion of soil and ingestion of pasture and then human consumption of animal products (meat, milk) from those animals;

- Direct exposure to humans from contact with soil (via direct ingestion, inhalation or dermal pathways).

- What is the risk that surface or ground water bodies may be contaminated by past and/or future applications to land of MWOO?
- Is there a risk to human health or the environment from PFAS found in MWOO?
- If risks are identified above, how long will the risk remain?

It is important to note that the interim assessment focused on evaluating potential risk for on farm consumption of food stuffs by people living on a farm which has had MWOO applied. The risk calculations provided did not address the commercial food supply.

The chemicals identified by the then NSW OEH that needed to be considered in the assessment for the solid MWOO materials were:

Human Health

- PBDEs (Polybrominated diphenyl ethers)

Ecological

- Aluminium
- Copper
- Manganese
- Zinc
- Phenol
- Bis-2-ethylhexyl adipate
- Di-2-ethylhexyl phthalate
- Bisphenol A
- Penta brominated diphenyl ether
- Electrical conductivity/salinity

The chemicals identified by the then NSW OEH that needed to be considered in the assessment for leachate from solid MWOO materials were:

Human Health

- Antimony
- Arsenic
- Cadmium
- Lead
- Nickel

Ecological

- Aluminium
- Barium
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron

- Lead
- Mercury
- Nickel
- Tin
- Zinc
- Sulfate
- Sulfide
- MCPA
- Ammonia
- Nitrate
- Phosphorus
- Electrical conductivity/salinity

Agricultural uses – Livestock watering

- Copper

Agricultural Uses – Irrigation

- Copper
- Iron
- Manganese
- Molybdenum
- Nickel
- Dicamba
- Phosphorus
- Electrical conductivity/salinity

The report detailing this assessment is provided in **Appendix B**.

1.2.2 Updated HHERA

The interim HHERA considered potential risks associated with the presence of a range of chemicals identified in MWOO, where the greatest risks identified were in relation to the presence of PBDEs.

As the interim HHERA was conducted as a conservative /worst case assessment, the report identified that there were some areas/aspects which could be refined with additional data. These additional data were collected and this HHERA has used the information to generate a more refined assessment of risk.

Further information was collected in regard to the following matters:

- Further chemical analysis of MWOO as supplied by various facilities;
- The bioavailability and bioaccessibility of PBDEs in soil and plastic when consumed by cattle grazing on land to which MWOO had been applied (interim HHERA assumed 100 % bioavailability);
- The quantity of soil ingested by grazing cattle per day considering different climatic conditions, application methods and grazing practices across a calendar year (interim HHERA assumed static 2.4 kg/animal/day and 10cm soil mixing);
- Half-life of PBDEs in soil (the interim HHERA did not consider a half-life); and
- Transfer factors for PBDEs in soil to meat/milk.

The additional work was primarily overseen by the Independent Scientific Review Panel on Soil and Chemistry established by the Office of the Chief Scientist and Engineer (OCSE).

The refined HHERA has been designed to answer the following questions from the scope of work prepared by NSW EPA:

- How does the human health and ecological risk identified in the interim HHERA from past applications of MWOO to agricultural land in NSW change based on the OCSE report?
- What is the risk to human health and ecological receptors from PFAS from past applications of MWOO to agricultural land in NSW based on the new/additional data?
- How does the human health and ecological risk identified in the interim HHERA from past applications of MWOO to agricultural land in NSW change based on the additional AWT facility data?
    - Is it possible to assess the risk for chemical mixtures and, if so, what is this risk?
- Can the human health and ecological risk for the parked chemicals be assessed? If so, what are these risks?
- Provide an expanded explanation regarding the range of chemicals for which ecological risk was assessed in the context of the limited range of chemicals for which terrestrial toxicity data actually exists.

Uptake of persistent chemicals via consumption of grass by livestock has been added into the exposure scenario calculations.

It is important to note that the refined assessment also focused on evaluating potential risk for on farm consumption of food stuffs by people living on a farm which has had MWOO applied. The risk calculations provided do not address the commercial food supply.

1.3 Methodology and Scope of Works

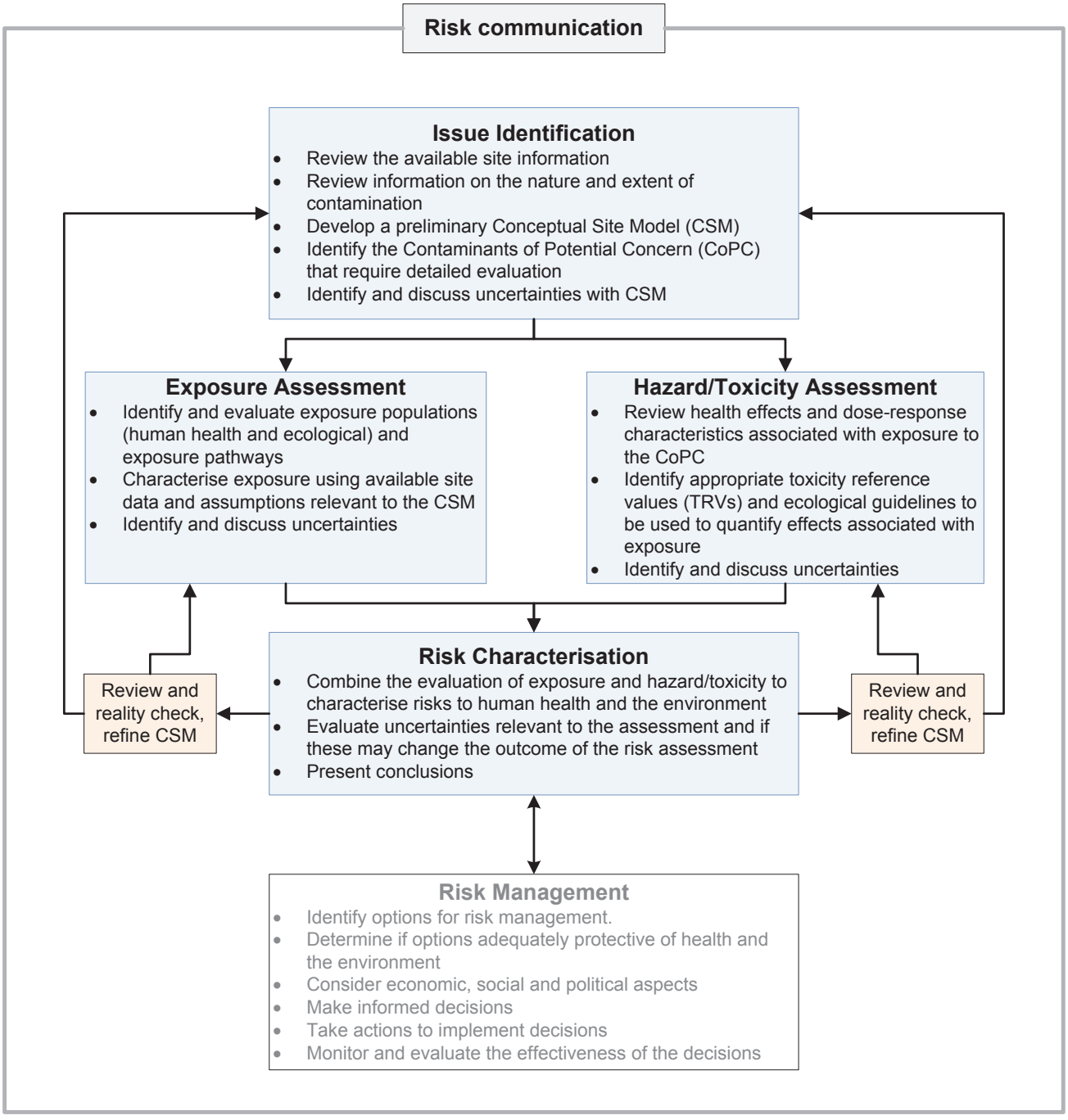
The approach taken for the quantitative assessment of human health risks is in accordance with guidelines/protocols endorsed by Australian regulators, including:

- enHealth (2012a) Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a)
- enHealth (2012b) Australian Exposure Factor Guide (enHealth 2012b)
- ASC NEPM (2013) National Environmental Protection Measure – Assessment of Site Contamination including:
    - Schedule B1 Investigation Levels for Soil and Groundwater (NEPC 1999 amended 2013d)
    - Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013a)
    - Schedule B5 Guideline on Ecological Risk Assessment (NEPC 1999 amended 2013b)
    - Schedule B6 Guideline on Risk Based Assessment of Groundwater Contamination (NEPC 1999 amended 2013f, 2013)
    - Schedule B7 Guideline on Health-Based Investigation Levels (NEPC 1999 amended 2013e)
    - Toolbox Note – Key principles for the remediation and management of contaminated sites

- Technical guidance in relation to the assessment of vapour risks (CRC CARE 2011, 2013; Davis et al. 2009).
- ANZECC Guidelines on Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000)

The above documents are supplemented by protocols and guidelines developed by international agencies such as the USEPA (USEPA 1989, 1991, 2002, 2004, 2009b) as required.

The overall approach to health risk assessment recommended by the enHealth national risk assessment guidance document is outlined in the following **Figure** (enHealth 2012a).



Following this guidance, the assessment has been undertaken to include the following:

- Summary of Interim HHERA (**Section 2**);
- Summary and discussion of additional information collected in 2019 (**Section 3**);
- Reassessment of Parked Chemicals (**Section 4**)
- Updated Exposure Assessment for Human Health - PBDEs (**Section 5**);
- Updated Exposure Assessment for Human Health - PFAS (**Section 6**);
- Identification of relevant toxicological information and data for the key chemicals (**Section 7**);
- Quantification and characterisation of the risks to human health and consideration of the uncertainties in the assessment of risk (**Section 8**);
- Conclusions (**Section 9**).

Section 2. Interim HHERA

2.1 Introduction

In October 2018, an initial human health and ecological risk assessment was prepared to evaluate the potential risks posed by the use of MWOO on agricultural lands. This assessment is provided as **Appendix B** of this report.

Background information about MWOO and the process of risk assessment for chemicals present in the environment was provided in the Interim HHERA and has not been repeated here (See **Section 2** of the Interim HHERA in **Appendix B**).

The HHERA used the results of the screening assessment from the NSW EPA commissioned research program to determine the contaminants that needed detailed assessment. No additional screening of data was undertaken as part of the HHERA.

The detailed assessment included evaluation of the chemicals listed in Section 1.2 of the interim HHERA. In addition, potential exposure to per and polyfluoroalkyl substances (PFAS) was also assessed as data on these chemicals had been collected after the completion of the NSW EPA commissioned research program.

2.2 Assessment Approach

The potential for exposure to chemicals contained within MWOO was quantified using industry best practice and guidance available from (enHealth 2012a; NEPC 1999 amended 2013a; USEPA 1989, 2002, 2009b).

The assessment addressed potential worst-case exposure to the key chemicals in soil and exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and therefore health risk.

The quantification of exposure has involved consideration of the following:

- Identification of relevant ***exposure parameters*** for each of the identified exposure pathways and receptors. The magnitude of the exposure is a function of a number of variables (termed exposure parameters), which describe the physical, and behavioural parameters relevant to the potentially exposed population. Exposure parameters which are considered representative have been selected. Where available, additional exposure data has been obtained from Australian sources (enHealth 2012a; NEPC 1999 amended 2013a); and
- Estimation of the ***chemical concentration*** in each medium relevant to the receptor groups and exposure pathways. This has involved the use of maximum concentrations reported in surface soil. Potential dust concentrations have been estimated on the basis of a particulate emission factor (that relates the concentration in air to that in soil) derived from guidance provided by the USEPA (USEPA 2002).

The targets of this assessment are the farmers/farm workers that may be exposed to land where these materials have been applied and consume produce grown at the farm. The general public are unlikely to be exposed to these materials.

The NSW EPA commissioned research program compared the measured levels of chemicals in MWOO after application to a site (i.e. when incorporated into soil) to the national guidelines for soil that is of suitable quality for backyards for low density residential areas (i.e. ASC NEPM low density residential health investigation levels (HIL-A)).

The scenario for calculating the HIL-A guidelines for low density residential housing involves assuming people are exposed to the contaminants in soil through:

- Incidental ingestion of 50 mg soil per day for adults and 100 mg per day for children every day of the year for 29 years for adults and 6 years for children;
- Soil coming into contact with 1/3 of the skin surface area for adults and almost half of the skin surface area for children every day of the year for 29 years for adults and 6 years for children – the calculations assume the soil stays on the skin until the next shower;
- Inhalation of dust while outside for 4 hours every day of the year for 29 years for adults and 6 years for children.
- Uptake into home grown fruit and vegetables and consumption of those (10% of dietary intake for fruit and vegetables)

For sites where these materials are applied to agricultural land, it is possible that additional exposure may occur while undertaking a range of agricultural activities including:

- Grazing of livestock (cattle/sheep)
- Cropping (wheat/oats/barley)
- Keeping poultry (for the purpose of producing eggs)
- Horticulture (blueberries)

These agricultural activities are not included in the low density residential scenario assumed for the ASC NEPM so require separate evaluation.

The pathways listed in **Table 1** are those that were assessed in the interim HHERA.

Table 1 Summary of Key Exposure Groups and Pathways

Receptor	Exposure Pathway/Mechanism
Farmers/farm workers	Incidental ingestion of surface soil and dust (tracked indoors) Dermal contact with surface soil and dust (tracked indoors) Inhalation of impacted dust generated from surface soil Ingestion of chemicals in home grown produce at site (consumed on farm) Ingestion of chemicals in eggs from poultry kept at the site (consumed on farm) Ingestion of chemicals in milk from cattle kept at the site (consumed on farm) Ingestion of chemicals in meat from livestock kept at the site (consumed on farm)

It is important to note that this assessment has focused on evaluating potential for on farm consumption of food stuffs by people living on a farm where MWOO was applied to paddocks. The risk calculations provided do not address the commercial food supply.

It is also noted that MWOO can be applied to land used for broad acre agriculture. The definition for broad acre agricultural use means application to land where the land is used for agriculture. It specifically excludes the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.

Risks have been estimated for a range of produce types including some of those listed above even though such uses are not permitted uses where these materials are applied – eggs and vegetables, in particular. This is to provide information for management.

The methodologies used to undertake calculations are those described in national and international guidance for risk assessment including:

- enHealth Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a)
- enHealth Australian Exposure Factor Guide (enHealth 2012b)
- ASC NEPM National Environmental Protection Measure – Assessment of Site Contamination including:
    - Schedule B1 Investigation Levels for Soil and Groundwater (NEPC 1999 amended 2013d)
    - Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013a)
    - Schedule B5 Guideline on Ecological Risk Assessment (NEPC 1999 amended 2013b)
    - Schedule B7 Guideline on Health-Based Investigation Levels (NEPC 1999 amended 2013e)
- USEPA Risk Assessment Guidance for Superfund (USEPA 1989, 1991, 2001b, 2004, 2009b)

Detailed description of the calculations and the results of the calculations is provided in the interim HHERA report in **Appendix B**.

2.3 Findings

The findings of the interim HHERA are provided below.

This assessment is a worst-case type of assessment. The key assumptions that were made when assessing exposure of people to MWOO (for PBDEs or PFAS) include:

- People live at a site for 29 years as adults and 6 years as children and the chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- MWOO is incorporated into the top 10 cm of soil at the time it is applied to a site
- The PBDEs or PFAS found in the MWOO are 100% available to be taken up (this is unlikely for PBDEs due to the nature of these chemicals which means they are likely to be strongly absorbed into the soil and MWOO materials but is appropriate for PFAS given the nature of those chemicals)
- Background intake of PBDEs from household articles (like TVs, furniture, computers etc) takes up 80% of the allowable amount (as per the toxicity reference value) of these chemicals
- Background intake of PFAS takes up 10% of the allowable amount (as per the toxicity reference value) of these chemicals
- People drink 100% of the milk they consume each year from dairy cattle kept at the site on land that has been treated with the MWOO

- People eat 50, 75 or 100% of the meat they consume each year from beef cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO
- Even though MWOO was not permitted for use in areas where vegetables are grown or chickens are kept for eggs, potential for exposure via these pathways have been assessed to provide sufficient understanding for management advice
- Assuming MWOO was used in an area where fruit or vegetables are grown, people eat 35% of fruit and vegetables they consume each year from plants grown in the land that has been treated with MWOO
- Assuming MWOO was used in an area where chickens are kept, people eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO

This assessment has not evaluated the potential risk to the commercial food supply for food types grown at sites where these materials have been applied. Given the large number of farms that supply such food types into the commercial food supply, it is not possible that a person, who does not live on one of these farms, would consume food from such a site on a daily basis.

Based on the assessment presented in this report, the potential for PBDEs to be present in surface soil after application of MWOO results in the following:

- Risks for people who come into contact with soil where these materials have been applied are low and acceptable (i.e. exposure via ingestion of soil, dermal contact with soil and inhalation of dust)
- Risks for people who consume any type of produce on a regular basis (i.e. all year round based on the assumptions listed above) from land where these materials have been applied are not acceptable and such exposure should be avoided.

Based on the assessment presented in this report, the potential for PFAS to be present in surface soil after application of MWOO results in the following:

- Risks for people who come into contact with soil and/or consume any type of produce on a regular basis (i.e. all year round based on the assumptions listed above) from land where these materials have been applied are low and acceptable

Based on the assessment presented in this report, the potential for various chemicals to be present in groundwater or surface water after leaching from the MWOO results in the following:

- Risks for people who come into contact with such surface or groundwaters are low and acceptable

This assessment could be further refined to allow a more realistic/site-specific consideration of the risks if more information was available about actual measured concentrations of PBDEs in soil at sites where these materials have been applied.

It is expected that ecological risks at sites where these materials have been applied will be relatively low for both soil and surface/groundwater and are unlikely to need management.

It is expected that risks for water that may be impacted by leaching or runoff from soil treated with these materials, where that water is used for agricultural purposes (livestock watering or irrigation), will be relatively low and do not need management.

Section 3. Additional Information – 2019

3.1 General

The assessment of exposure and risk described in the Interim HHERA was based on a limited amount of data about the concentration of these brominated flame retardants in MWOO.

The assessment also used a number of conservative/worst case assumptions in calculating how people might be exposed to PBDEs present in MWOO.

The risks estimated in the Interim HHERA were elevated using the worst case assumptions.

Australian guidance on how to undertake risk assessment indicates that risk assessments can be refined with more information (enHealth 2012a; NEPC 1999 amended 2013a).

The first step when refining a risk assessment is to determine what parameters are driving the risk calculations. Once these parameters are identified, then assessors can determine if there are ways to adjust those parameters with more realistic values.

These adjustments can be possible due to:

- collection of more information (obtaining more results for parameters already measured)
- measuring some parameters that had not previously been measured to replace assumed values
- reviewing the literature to determine if assumed values are the most appropriate given the situation
- refining the assumptions about how people might be exposed based on a better understanding of how people or other organisms may be exposed to MWOO

Any such adjustments need to be based on robust science.

3.2 Additional Work Overseen by Office of Chief Scientist and Engineer

The Office of the Chief Scientist and Engineer were asked to establish the Independent Scientific Review Panel on Soil and Chemistry to determine what additional work would be relevant and useful and to oversee that work. The report describing this work is provided in **Appendix C**.

The first aspect where more information was required was understanding the range of concentrations of chemicals like PBDEs could be present in MWOO. The Panel undertook additional sampling of stockpiles of MWOO to expand the dataset and provide a better understanding about how much of these chemicals may be present in MWOO. Further discussion of these results and the previous PBDE results is provided in **Section 3.3**.

In addition, the Panel looked at a number of the parameters used in calculations in the Interim HHERA and undertook literature reviews and some experimentation to determine more appropriate values for these parameters where possible. The parameters used in estimating exposure for people that have been updated based on this additional work include:

- Bioavailability/bioaccessibility of PBDEs in MWOO for cattle (impacts on estimate of uptake into meat and milk)
- Ingestion of soil by cattle (impacts on estimate of uptake into meat and milk)

- Proportion of time cattle will spend on treated areas (impacts on estimate of uptake into meat and milk)
- Transfer factors for uptake into meat and milk

3.3 Updated Assessment of Concentrations of PBDEs in MWOO

In late 2018, the Independent Scientific Review Panel on Soil and Chemistry established by the Office of the Chief Scientist and Engineer undertook additional sampling of stockpiles of MWOO from a number of facilities in order to better inform the assessment of risk posed by PBDEs that may be present in MWOO. A total of 63 additional samples were collected which included samples, controls and duplicates.

3.3.1 Sampling

In both the NSW EPA commissioned research program and in the more recent investigation by OCSE samples of MWOO were collected from stockpiles of material.

For the NSW EPA commissioned research program, the following occurred:

- Facility A – a small stockpile was prepared by the facility on each occasion when sampling occurred. Sampling was undertaken by taking a shovel full of MWOO from at least 5 locations through the stockpile. For each shovel full, some of the material on the shovel was transferred into a jar for analysis (i.e. grab sample). Another amount of material on the shovel was placed in a bucket to contribute to a composite sample. Some material from each of the 5 different shovels of MWOO was placed in the composite bucket. The material in the bucket was then shaken and rotated to mix the material. The laboratory was sent a small sub-sample of this composite sample.
- Facility B – the facility split the existing stockpile of MWOO at the facility using a front end loader when those doing the sampling arrived. This allowed them to access the middle of the large stockpile present at the site. The same approach to collecting grab and composite samples was used as described for facility A.

Sampling for PBDEs occurred over 2 sampling events in 2013 and 2014 during the NSW EPA commissioned research program. Additional sampling events occurred between 2011 and 2014 but did not include analysis for PBDEs. All of the sampling events between 2011 and 2014 were designed to cover different climatic seasons which allowed for any differences in feedstock material due to seasonal social habits to be considered.

Each of the sampling events spanned several weeks and multiple composite and grab samples were collected. At each sampling event, material that had most recently completed the treatment process was sampled. This material was, therefore, representative of material ready to leave the site for use.

For each sampling event, 5 grab samples and 1 composite sample (from the 5 grabs) were collected every fortnight for 8 weeks.

Chemical analysis was focused on the composite samples with some grab samples also analysed for most contaminants. However, a smaller subset of samples was analysed for PBDEs in comparison to other contaminants as these contaminants were only included in the research

program at a late stage. The laboratory required 10 g of MWOO (after drying) for analysis for PBDEs.

It is understood that one composite sample from each facility from the 2013 sampling event was sent for analysis. For the 2014 sampling event one composite sample from each facility was sent for analysis. Due to the large variability in the concentrations of PBDEs, the 2014 composites analysed were resampled and sent for analysis along with sub samples from the other 3 composites collected per facility. This resulted in 6 samples in total for analysis from each facility.

These resamples are not considered to be "replicate" analysis as:

- MWOO is highly variable material.
- What is present in the two separate sub-samples would depend on how well the composite sample was mixed on each occasion prior to the sub-sample being taken. *(This is somewhat dependent on particle size – if everything was ground to a very fine particle size then sub samples should be fairly consistent – in this case, MWOO has quite a wide size range so the inclusion of one larger particle containing higher levels of chemicals like PBDEs may have a significant impact on the concentration in one sub-sample but not the next)*.
- The laboratory only uses 10 g of the MWOO in the analysis – how they take such a small amount out of the sub-sample will impact on the final result (i.e. how they mix the sample and how they scoop out the material) as will the potential for a single piece of material that may contain high levels of a contaminant like PBDEs to be present in this small amount taken for the analysis.

As a result, there were 12 individual results for the levels of PBDEs in MWOO. These results were based on material collected from two out of the five facilities generating MWOO.

To get an improved understanding of the range in concentrations for PBDEs in MWOO, the OCSE Panel undertook additional sampling and analysis.

For the more recent OCSE investigation, the following occurred:

- Sampling was undertaken at 5 facilities
- Samples were collected from stockpiles at each facility
- The surface layer of MWOO was removed prior to sampling to allow access of material that had not been as exposed to the elements
- Grab samples were collected using a shovel from various locations across the stockpile
- 2 L of material from each shovel load was transferred to a bucket to form the composite sample
- Once all portions of the grab samples were added to the composite bucket, the bucket was mixed by rolling
- Further mixing by coning and quartering was undertaken.
- The composite samples were then sub-sampled (150-400 g wet weight) and that sub sample was sent to the laboratory

There were slight variations in the numbers of grab and composite samples taken at each facility:

- Facility A – 1 large stockpile was available at this facility; 10 composite samples were collected

- Facility B – all MWOO material at this facility is mixed with food organic and garden organic (FOGO) material prior to sale. As a result, the only material available at the site for sampling was MWOO mixed with FOGO (1 stockpile from which 2 composites were collected) and FOGO only (1 stockpile from which 2 composites were collected).
- Facility C – 1 large stockpile was available at this facility; 10 composite samples were collected
- Facility D – samples were collected from 2 stockpiles of material intended for agricultural use and 4 stockpiles of material intended for non-agricultural uses. 10 composite samples (based on 5 grab samples/composite) were collected from 1 of the agricultural use stockpiles and 1 composite sample was collected from the other agricultural use stockpile and each of the non-agricultural use stockpiles
- Facility E – stockpiles at this facility consisted of material intended for non-agricultural uses. There were 10 stockpiles and 1 composite sample was collected for each stockpile

As a result, there were 35 composite samples from agricultural use material, 14 composite samples of non-agricultural use material and a number of field duplicate samples that were sent for analysis. As per normal practice, the laboratory also undertook duplicate analysis of some of the primary samples – a random choice of a small number of samples – laboratory duplicates. There was a total of 56 individual samples including field and laboratory duplicates

Field duplicates are designed to give some understanding of how variable the material being sampled may be. For example, field duplicates of sediment or soil can be widely variable while field duplicates of a river water sample are more likely to be quite similar. In this case, it would be expected that field duplicates of MWOO would be quite variable.

Laboratory duplicates are designed to show that all the sample preparation and analytical methods are operating as expected. It is expected that laboratory duplicates should be quite similar although there may be some variability due to sub-sampling a variable solid material.

The results for these two different types of duplicate samples should be assessed separately as they are used for different purposes.

3.3.2 Results

Table 2 lists summaries of the original data and the data from the Panel Study for the facilities that processed MWOO for use in ***agricultural situations***. **Table 3** provides the combined data for the original HHERA compared to the combined data from the more recent investigation. The data in **Table 3** have been used for this risk assessment.

Table 2 PBDE Concentrations (Detail) – Agricultural Samples

PBDE Fraction	Minimum (ng/g)	Maximum (ng/g)	Average (ng/g)	95th Percentile (ng/g)
Facility A – Original Study				
SUM Br1 to Br9	486	710000	121000	533000
DecaBDE	3000	7500	4200	6800
Facility A – Panel Study				
SUM Br1 to Br9	200	33740	3411	16140
DecaBDE	430	13300	2734	8353
Facility B – Original Study				
SUM Br1 to Br9	40	204	102	189

PBDE Fraction	Minimum (ng/g)	Maximum (ng/g)	Average (ng/g)	95th Percentile (ng/g)
DecaBDE	54	810	240	660
Facility B – Panel Study				
SUM Br1 to Br9	70	147	110	144
DecaBDE	150	250	200	245
Facility C – Panel Study				
SUM Br1 to Br9	260	658	379	563
DecaBDE	590	1810	956	1612
Facility D – Panel Study				
SUM Br1 to Br9	500	2890	944	2020
DecaBDE	860	11500	2290	7550

Table 3 **PBDE Concentrations (Summary) – Agricultural Samples**
(Reported as mg/kg for ease of comparison with Interim HHERA)

PBDE Fraction	Minimum (mg/kg)	Maximum (mg/kg)	Average (mg/kg)	95th Percentile (mg/kg)
Original Study				
SUM Br1 to Br9	0.04	710	61	530
DecaBDE	0.054	7.5	2.2	6.8
Panel Study				
SUM – Br1 to Br9	0.072	33.8	1.5	1.9
DecaBDE	0.150	13.3	1.91	5.0

One sample in the original dataset had very high concentrations of the various PBDE fractions. In the more recent data, there were also a few samples with higher levels. No samples in the more recent data had concentrations approaching the maximum concentrations reported in the original data.

There may be differences in the concentrations of these chemicals in MWOO at different facilities. Some facilities have concentrations of PBDEs (Br1 to Br9) less than 1 mg/kg while others have concentrations above 1 mg/kg ranging up to 34 mg/kg in the more recent data and up to 710 mg/kg in the original data. This may be due to different sources of material used to make up MWOO. For example, one facility is known to blend MWOO with composted food and garden organics prior to testing and application.

3.3.3 Variability and Analytical Quality

The results for PBDEs vary over quite a wide range.

It is noted that the PBDEs are present in small plastic particles within the MWOO. In most cases, PBDEs were used as additive flame retardants where they are not chemically bound into the plastic. It has been shown that, in this form, they can bloom to the surface of plastics in articles and that they can be attached to dust in homes and distribute around a house (Jones-Otazo et al. 2005).

Large variability is not unusual for environmental samples especially soils or sediments where chemicals are sorbed onto some soil particles and not others. For contaminated sites, it is possible to have concentrations across a site ranging from background to very large values depending on how the site has been contaminated.

For example:

- a service station where there has been a leak from an underground storage tank – most of the site will have no detections for petroleum hydrocarbons in soil but there may be sufficient leakage from the tank that actual product (i.e. petrol or diesel) may be pooling in the area immediately around the tank.
- a mineral ore body where very high levels of the relevant metal would be present in the area where the ore body is located with much lower levels in the surrounding soils.
- sediments which are known to be extremely heterogeneous – perhaps due to the nature of the sediments and the interaction with tides and currents which accumulates particles more likely to have contaminants attached in one part of an investigation area while other less contaminated particles of a different size class get pushed or washed into a different area (Simpson et al. 2005)
- sediment heterogeneity can also be due to the action of sediment organisms or bacterial action and these variations can result in uptake into organisms which is highly variable across a small area (Simpson et al. 2005)

In particular, this variability is not unexpected for concentrations of PBDEs in environmental samples. A study was undertaken by American researchers to look at the levels of PBDEs in food in the US given findings that body burdens of these chemicals (as measured in blood or adipose tissue) were quite different between people living in the US and in Europe. It had been assumed that food was likely to be a significant source of these chemicals for people and perhaps the difference in body burdens was due to differences in what was present in food (Schecter, Arnold et al. 2006). They found that there was little difference in the levels in food and that the difference in body burdens must come from another source – later proposed to be dust in houses. They also reported that body burdens of PBDEs measured in the people with the highest concentrations in the National Report on Human Exposure to Environmental Chemicals study by the Centres for Disease Control in the US (CDC 2009) had levels that were around 100 times higher than the mean levels in the community. This was a much larger difference between high end and mean exposure than for other chemicals to which people are exposed in the environment. Birnbaum and Cohen Hubal (2006) also noted that there was significant variability in lipid adjusted levels of PBDEs in blood in the general population – more than 100 fold range (Birnbaum & Hubal 2006).

Other studies have investigated the levels of PBDEs in soil around e-waste recycling or other industrial facilities. One study reported PBDE concentrations in e-waste (i.e. televisions, computer monitors, printers and other electrical appliances). Concentrations ranged up to a total of 175 g/kg (i.e. 17.5%). The mean value was 10.8 g/kg (i.e. 1.1%). The dominant PBDE reported in these samples was Deca BDE which made up over 90% of the total PBDEs. This study also collected dust and surface soil samples at a recycling site. Concentrations in these samples ranged from 1960 to >340000 ng/g (i.e. 1.96 to >340 mg/kg) for the total PBDEs and 910 to >320000 ng/g for DecaBDE (Li et al. 2014).

An identified issue in the scientific literature is that PBDEs are more likely to show a wider than normal range in concentrations in environmental samples than for many other chemicals.

A comparison of the results for the field duplicates for the PBDE measurements is provided in **Table 4**. A comparison of the results for the laboratory duplicates is provided in **Table 5**.

The relative percent difference is the parameter recommended for use in comparing replicate analyses in the ASC NEPM (NEPC 1999 amended 2013c). It is calculated by dividing the difference

between the two measurements by the average of the two measurements and multiplying by 100 to convert to a percentage.

Table 4 Summary of Field Duplicate Results

Chemical/Sample	Primary Sample Result (ng/g)	Field Duplicate Result (ng/g)	Relative Percent Difference
NSW EPA commissioned Study			
Facility A Composite 3			
SUM – Br1 to Br9	703000	514	200%
DecaBDE	7510	3630	70%
Facility B Composite 3			
SUM – Br1 to Br9	43	65	41%
DecaBDE	54	100	60%
Panel Study			
Facility A Composite 11			
SUM – Br1 to Br9	33730	715	192%
DecaBDE	13300	2000	148%
Facility C Composite 3			
SUM – Br1 to Br9	302	366	19%
DecaBDE	870	1190	31%
Facility D Composite 11			
SUM – Br1 to Br9	1100	660	50%
DecaBDE	1740	860	68%

Table 5 Comparison of Laboratory Duplicate Results

Chemical/Sample	Primary Sample Result (ng/g)	Laboratory Duplicate Result (ng/g)	Relative Percent Difference
Panel Study			
Facility A Composite 8			
SUM – Br1 to Br9	830	701	17%
DecaBDE	970	1000	3%
Facility B Control			
SUM – Br1 to Br9	4.4	4.2	5%
DecaBDE	1.5	1.5	0%
Facility C Composite 10			
SUM – Br1 to Br9	355	440	21%
DecaBDE	590	1030	54%
Facility D Control (mulch)			
SUM – Br1 to Br9	5.1	4.1	22%
DecaBDE	2	1.5	29%

It is normal to expect relative percent differences between duplicates to be less than 30%, particularly for laboratory duplicates where the same container of material is being sub-sampled by staff in the laboratory. In this case, the laboratory duplicates do compare well. Most results show a difference between the two measurements of less than 30%.

For the field duplicates, the relative percent differences are much higher especially for samples with high levels. This indicates that the material is difficult to sample in a consistent way and that there may be particles that contribute significant levels of PBDEs that are particularly difficult to sample. Given what is known about the sources of these chemicals in MWOO, this is not unexpected.

This variability in MWOO is also supported by information on other contaminants in MWOO.

The routine monitoring data collected by the facilities included results for reanalysis of the same sample on occasion. Some of the results of these reanalyses included:

- Nickel 258 mg/kg compared to 28 mg/kg on reanalysis
- Lead 1500 mg/kg compared to 100 mg/kg on reanalysis
- Selenium 35 mg/kg compared to 2 mg/kg on reanalysis
- Arsenic 30 mg/kg compared to 7 mg/kg on reanalysis
- Copper 1600 mg/kg compared to 160 mg/kg on reanalysis
- Copper 1300 mg/kg compared to 100 mg/kg on reanalysis
- Zinc 3200 mg/kg compared to 390 mg/kg on reanalysis
- Lead 1500 mg/kg compared to 210 mg/kg on reanalysis
- Copper 65000 mg/kg compared to 5500 mg/kg on reanalysis
- Zinc 35000 mg/kg compared to 3000 mg/kg on reanalysis

In addition, the concentrations in MWOO were usually of the order of 100-500 mg/kg for copper and 100-800 mg/kg for zinc but for each of these metals there were occasional samples that had much higher levels – up to 65000 mg/kg for copper and 35000 mg/kg for zinc. This level of variability is higher than that reported for the PBDEs.

There is also a discussion of the high variability for some contaminants in MWOO in the report detailing the results of the NSW EPA commissioned research program. For copper, most samples reported concentrations less than 500 mg/kg with occasional samples reporting concentrations up to more than 9000 mg/kg. For nickel, most samples reported concentrations less than 100 mg/kg with occasional samples reporting concentrations up to almost 3000 mg/kg.

Specifically, the variability in PBDEs concentrations in MWOO is not unexpected for a number of reasons including:

- MWOO is prepared from the mix of materials that come from red lid bins collected kerbside across Sydney and other urban areas – these contain a wide mix of materials
- PBDEs are present in a wide range of materials where they contribute between 5 and 30% of the total weight of each of those materials so when present they can contribute significant load to a sample
- Approximately 100000 tonnes of MWOO was produced each year (total for all facilities)
- The initial NSW EPA commissioned research program measured PBDEs in 12 samples of approximately 10 g of MWOO each
- The OCSE Panel study measured PBDEs in 34 samples of MWOO for agricultural uses (10 g used in laboratory per sample)
- Other chemicals were also found to be highly variable in these materials with occasional samples reporting very high levels
- Field duplicate results showed variability in excess of the normal accepted range even though sampling was undertaken carefully to get samples that were as representative and homogeneous as possible
- A wider range of results for PBDEs in environmental samples compared to many other contaminants is an issue that has been identified previously in the scientific literature
- Variability is a normal part of environmental sampling.

The ASC NEPM also provides the following guidance in relation to extreme values in a dataset based on guidance by the USEPA (USEPA 2000a, 2006a, 2006b, 2006c). The following excerpt is Section 13.2.3 from ASC NEPM Schedule B2 (NEPC 1999 amended 2013c).

> *Potential outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected (USEPA 2006c). Outliers may result from:*
>
> - *transcription errors*
> - *data-coding errors*
> - *measurement problems*
> - *true extreme values (hotspots).*
>
> *Graphical displays of data, for example probability plots (concentration plotted against cumulative frequency), and x-y scatter plots (for example, ratios of contaminants expected to be associated with each other), can assist with identifying outliers. Evaluation of a combination of graphical displays with reference to relevant site layout diagrams is recommended.*
>
> *It can be tempting to dismiss unexpectedly high values as 'outliers'; however, this is not good practice, as a more thorough examination of the reasons for these unexpected values may lead to new insights into the data (such as the presence of an unsuspected hotspot of contamination) or to reconsideration of underlying assumptions about the data and its distribution.*
>
> *Potential outliers should be checked for human error due to transcription/data-coding errors and invalid measurements from malfunctioning equipment. The former may be corrected whereas the latter can properly be discarded. Following the procedure outlined in Section 13.1 (of Schedule B2 of the ASC NEPM) should minimise the impact of outliers from these causes.*
>
> *If an outlier is not due to human error, then consider the available qualitative information regarding the data provenance and the site history and discard the outlier only if there is documentation to support the belief that the outlier is not part of the population under study. In all such cases, describe the population that the outlier belongs to and justify why this population is not considered relevant to the study objectives (e.g. elevated PAH due to presence of road bitumen fragments as opposed to contamination in soil derived from fuel leaking from an above-ground storage tank).*
>
> *Discarding an outlier from a data set should be done with extreme caution as environmental datasets often include legitimate extreme values (USEPA 2006c). The decision taken should be based on scientific reasoning and be fully documented. Repeat sampling close (<1 m) to the original location may provide greater certainty in the decision process.*

The dataset for PBDEs in MWOO does contain an extreme high value, however, investigations have been undertaken to ensure that it did not result from an error at the laboratory or due to transcription errors. Given what is understood about the source of PBDEs in MWOO, it is a probable true value. Consequently, it has been retained in the data for consideration in this HHERA in accordance with national guidance.

It is acknowledged that high levels like the maximum reported were not likely to have occurred very often during the production of MWOO but the material for which the high concentration was reported was present in a stockpile that was provided for application to land. Therefore, the average

concentration of PBDEs in MWOO calculated using the full dataset has been used in estimating risks in this HHERA.

3.3.4 Determination of Exposure Concentrations

Using this information and the application rate of this material to agricultural lands, concentrations in soil after 1 application have been determined for PBDE (Br1 to Br9) and for DecaBDE. Application to cropping areas and to grazing land has been considered.

PBDEs (Br1 to Br9)

For cropping areas, an application rate of 10 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. This results in a concentration in soil 130 times lower than that reported for the original MWOO material.

The following concentrations have been considered in the assessment for agricultural land when MWOO is incorporated into the top 10 cm of soil – i.e. cropping areas:

- Overall Dataset
  - Mean – 0.1 mg PBDEs (Br1 to Br9)/kg
  - Maximum – 5.5 mg PBDEs (Br1 to Br9)/kg
  - Minimum – 0.0003 mg PBDEs (Br1 to Br9)/kg
  - 95th percentile – 0.15 mg PBDEs (Br1 to Br9)/kg
  - Median – 0.004 mg PBDEs (Br1 to Br9)/kg

These concentrations are relevant for the assessment of exposure for ingestion of vegetables, crops and eggs as well as direct contact with soil.

For grazing land, it is assumed that livestock can be exposed to undiluted MWOO or MWOO that has been trampled into the top of the soil layer beneath the grass. It is noted that the regulation of MWOO required that livestock not be reintroduced to treated areas for at least 30 days after treatment.

The following concentrations have been considered in the assessment for agricultural land when MWOO is not incorporated into the soil – grazing areas (i.e. no dilution):

- Overall Dataset
  - Mean – 15 mg PBDEs (Br1 to Br9)/kg
  - Maximum – 710 mg PBDEs (Br1 to Br9)/kg
  - Minimum – 0.04 mg PBDEs (Br1 to Br9)/kg
  - 95th percentile – 20 mg PBDEs (Br1 to Br9)/kg
  - Median – 0.5 mg PBDEs (Br1 to Br9)/kg

The following concentrations have been considered in the assessment for agricultural land when MWOO is not incorporated into the soil but has been trampled into the top of the soil layer. It is assumed that MWOO is applied at a rate of 10 tonnes/hectare, with a mixing depth of 2 cm and a soil bulk density of 1300 kg/m^3. This results in a concentration in soil 26 times lower than that reported for the original MWOO material.

- Overall Dataset
  - Mean – 0.6 mg PBDEs (Br1 to Br9)/kg
  - Maximum – 27 mg PBDEs (Br1 to Br9)/kg

- Minimum – 0.002 mg PBDEs (Br1 to Br9)/kg
- 95th percentile – 0.8 mg PBDEs (Br1 to Br9)/kg
- Median – 0.02 mg PBDEs (Br1 to Br9)/kg

These two sets of concentrations are relevant for the assessment of exposure for ingestion of meat and milk as well as direct contact with soil.

DecaBDE

For cropping areas, an application rate of 10 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. This results in a concentration in soil 130 times lower than that reported for the original MWOO material.

The following concentrations have been considered in the assessment for agricultural land when MWOO is incorporated into the soil – cropping areas:

- Overall Dataset
  - Mean – 0.02 mg DecaBDE/kg
  - Maximum – 0.1 mg DecaBDE /kg
  - Minimum – 0.0004 mg DecaBDE /kg
  - 95th percentile – 0.07 mg DecaBDE /kg
  - Median – 0.008 mg DecaBDE /kg

These concentrations are relevant for the assessment of exposure for ingestion of vegetables, crops and eggs as well as direct contact with soil.

For grazing land, it is assumed that livestock can be exposed to undiluted MWOO or MWOO that has been trampled into the top of the soil layer beneath the grass. It is noted that the regulation of MWOO required that livestock not be reintroduced to treated areas for at least 30 days after treatment.

The following concentrations have been considered in the assessment for agricultural land when MWOO is not incorporated into the soil – grazing areas (i.e. no dilution):

- Overall Dataset
  - Mean – 2 mg DecaBDE /kg
  - Maximum – 13 mg DecaBDE /kg
  - Minimum – 0.05 mg DecaBDE /kg
  - 95th percentile – 9 mg DecaBDE /kg
  - Median – 1 mg DecaBDE /kg

The following concentrations have been considered in the assessment for agricultural land when MWOO is not incorporated into the soil but has been trampled into the top of the soil layer. It is assumed that MWOO is applied at a rate of 10 tonnes/hectare, with a mixing depth of 2 cm and a soil bulk density of 1300 kg/m^3. This results in a concentration in soil 26 times lower than that reported for the original MWOO material.

- Overall Dataset
  - Mean – 0.08 mg DecaBDE /kg
  - Maximum – 0.5 mg DecaBDE /kg
  - Minimum – 0.002 mg DecaBDE /kg
  - 95th percentile – 0.4 mg DecaBDE /kg
  - Median – 0.04 mg DecaBDE /kg

These two sets of concentrations are relevant for the assessment of exposure for ingestion of meat and milk as well as direct contact with soil.

The exposure assessment calculations have been undertaken using the approaches outlined in **Section 4** (and as was undertaken in the Interim HHERA). The exposure assessment and risk calculations are provided in **Appendix F**.

3.4 Other Matters Addressed by OCSE

3.4.1 Bioavailability/bioaccessibility of PBDEs in MWOO for cattle

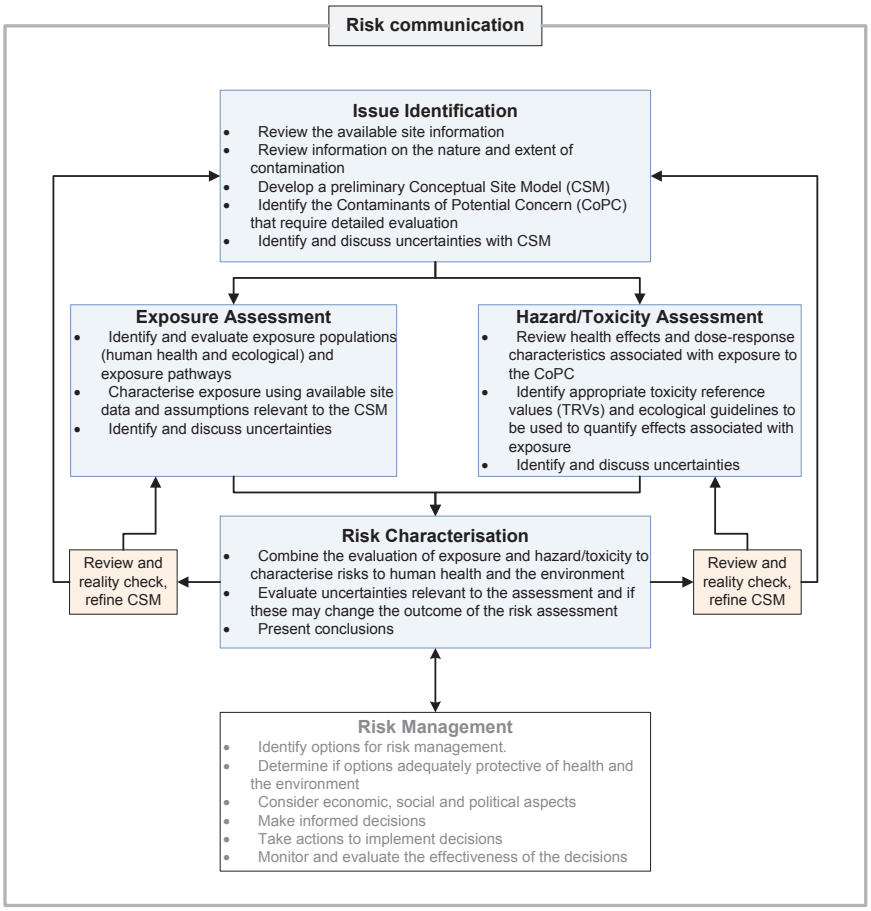
The Independent Scientific Review Panel on Soil and Chemistry commissioned UniSA to undertake an investigation of the bioaccessibility of these chemicals in MWOO.

Background

When material like MWOO or soil is analysed to measure the amount of a chemical that is present, the analytical methods used by the laboratory are designed to extract all of the chemical from the material. For example, when concentrations of metals are of interest, samples are digested in strong acid at elevated temperature. This does not reflect how much of a metal in a soil sample would be available to be taken into the body of an organism that might consume some of that soil. However, it does clearly indicate the total amount of the metal that is present – the worst case. The same applied for the analysis of PBDEs undertaken by NMI – the extraction method (hot solvent under pressure) is designed to obtain a measure of the total amount of these chemicals present in the sample.

Once the total amount of chemical is known, then further consideration of whether that total amount might escape into the environment or how it might move around in the environment or within organisms can be undertaken.

Australian guidance describes the risk assessment process using the following figure:



The following discussion focuses on the exposure assessment part of the process (enHealth 2012a; NEPC 1999 amended 2013a).

Estimating exposure involves taking what is known about the material of interest (e.g. total concentration of the chemical of interest in soil or MWOO) and combining that with how people might be exposed to the chemical in the environment and how the chemical might be available (or not) in the environment. From this an estimate of how much of the chemical a person might take in on average over time can be determined.

The basic calculation for estimating exposure is as follows:

$$DailyChemicalIntake_{Ing} = C_s \bullet \frac{IRs \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs	= Concentration of chemical of interest in treated soil (mg/kg) (total concentration as determined by standard analytical method)
IRs	= Ingestion rate of soil (mg/day)
FI	= Fraction of daily ingestion that is derived from contamination source (unitless), taken as 1
B	= Bioavailability or absorption of chemical via ingestion (unitless), taken as 1
CF	= Conversion factor of $1x10^{-6}$ to convert mg to kg
EF	= Exposure frequency (days/year) (i.e. over how many days per year exposure might occur)
ED	= Exposure duration (years) (i.e. over how many years exposure might occur)
BW	= Body weight (kg)
AT	= Averaging time for threshold exposures, (=ED x 365 days)
AT(NT)	= Averaging time for non-threshold exposures (=70 years x 365 days)

Basically, this calculation takes the concentration of the chemical in the material and the amount of the material that a person may incidentally ingest (adjusted as appropriate depending on the nature of the material – using bioaccessibility, how much of daily ingestion of soil comes from the relevant site etc) to determine how much of the chemical they might consume on a single occasion then averages that over a year based on how many times that type of situation arises.

The guidance documents provide a set of default values for these parameters that are relevant for use in a risk assessment. These default values are based on reasonable worst case exposure for common situations and are used to calculate national guidelines. The Interim HHERA made extensive use of these default values.

It is possible, however, to adjust these values when more is known. For example, where sufficient information is available to tailor an assessment for the specific situation at a site or where a range of values for the parameters are used to understand the range of risks that could occur in a specific situation for different ways exposure could occur.

The parameters that can be adjusted to better estimate exposure include:

- Concentration of the chemical of interest in soil or other materials (where more information is collected)
- Ingestion rate (there is little information that is available or can be collected to allow this one to be adjusted)
- Bioavailability (discussed below)
- Fraction from site of interest (if a person who might be exposed does not live at a site or where work only requires them to visit on occasion this can be adjusted)
- Days per year exposure may occur (if a person who might be exposed does not live at a site or where work only requires them to visit on occasion this can be adjusted)
- Number of years exposure may occur (if a person who might be exposed does not live at a site or where work only requires them to visit on occasion this can be adjusted – however, for threshold chemicals such as PBDEs or PFAS changing the number of years a person may be exposed does not change the estimate of risk as the calculation ensures the number of years cancels out (i.e. it is included in both numerator and denominator))

Further discussion of the other parameters will occur in other sections. Discussion here focuses on the concept of bioavailability.

Bioavailability describes how much of a chemical can move from material like soil or MWOO into the body when people (or other organisms) incidentally ingest the material. Once it is inside the body it may be able to cause impacts.

It is normal practice when undertaking human health risk assessments to assume a contaminant will be 100% bioavailable for uptake into organisms (cattle, people or other organisms) unless additional site-specific and chemical-specific information is available to allow a change. This assumption was used in the Interim HHERA when assessing uptake by cattle into meat or milk and when assessing uptake by people from meat or milk.

However, the entire amount of a chemical (as measured by the standard analytical methodologies) present in soil or material like MWOO is not necessarily bioavailable so additional information can be gathered to allow an adjustment.

Bioavailability of a contaminant in soil or material like MWOO varies depending on the source of the contamination, the age of the contamination, the conditions under which aging of the contamination has occurred, how exposure is occurring and differences between individual people.

For a chemical present in solid material like soil or MWOO to be bioavailable, it needs to be able to dissolve out of the soil/MWOO and move into the gastrointestinal fluids once it has been ingested. Once in these fluids, it must then be able to move across from the gastrointestinal tract into the blood to circulate around the body where it can cause damage or be stored or be excreted.

Some chemicals are well bound into soil or materials like MWOO. Some chemicals are more loosely bound into such materials. Other chemicals can be highly water soluble and so are easily dissolved out of such materials.

Where chemicals are part of the structure of the solid materials (mineral ores, clays, silts, ashes), bioavailability is very low. Where chemicals tightly adhere onto the outside of particles, bioavailability is also likely to be very low. Where chemicals are loosely bound into a material, bioavailability may be quite variable – at times quite low and other times quite high. Where chemicals are highly water soluble, bioavailability will always need to be assumed to be 100%.

Brominated flame retardants are incorporated into plastics using two methods. Some are added into the plastic when it is being manufactured and get chemically incorporated into the plastic polymer – i.e. reactive uses. Others are just mixed into the molten plastic when it is being moulded – i.e. additive uses. Bioavailability is likely to be low for reactive uses but is likely to be quite variable for additive uses. PBDEs were mainly used as additive flame retardants.

In addition, brominated flame retardants like PBDEs are very insoluble in water and are likely to adhere strongly to organic carbon. This will also limit their bioavailability.

Finally, PBDEs are quite large molecules especially decaBDE so their ability to cross the membrane of the gastrointestinal system and move into the blood may also be lower than for other types of smaller chemicals. This will also limit their bioavailability.

It is, therefore, unlikely that PBDEs would be 100% bioavailable from material like MWOO as was assumed in the Interim HHERA for cattle, in particular (as the cattle are directly exposed to MWOO whereas people are exposed to PBDEs taken up into meat or milk by cattle).

The same issues relating to bioavailability for people are relevant for cattle. In this assessment, uptake of PBDEs from incidental ingestion of soil containing MWOO by cattle is an important exposure pathway for people as these chemicals can be accumulated in meat or milk in the cattle which people then consume.

Unfortunately, it is not straightforward to measure bioavailability of a chemical present in soil (or other solid material) for people or other organisms.

Bioaccessibility is commonly adopted as a surrogate measurement for bioavailability. Bioaccessibility measures how much of the contaminant can dissolve into the gastrointestinal fluids only. It does not assess how much of the contaminant moves across the stomach or intestinal membranes into blood to move around the body to reach areas where impacts could occur.

Not all of a contaminant that dissolves in the gastrointestinal fluids may cross membranes to move into the blood (it depends on the chemical of interest) but for these risk calculations it is assumed

that all of the bioaccessible fraction can move into the body. This means a bioaccessibility measurement is a conservative estimate of the bioavailable fraction.

Investigation

Samples of MWOO were provided to the University of South Australia to be analysed for the bioaccessible fraction of PBDEs when this material is consumed by cattle.

Methods are commercially available at UniSA for assessing bioaccessibility of lead, arsenic and polycyclic aromatic hydrocarbons in people (https://people.unisa.edu.au/albert.juhasz). These methods are not routinely applied for use in cattle or for assessing PBDEs.

The approach taken by UniSA for assessing bioaccessibility was based on their existing methods for other organic contaminants – in particular, polycyclic aromatic hydrocarbons (PAHs). The methodology used was developed based on the Physiologically Based Extraction Test (PBET) with variations recommended by a number of researchers (Cave et al. 2010; Collins et al. 2013; Gouliarmou et al. 2013; Tilston et al. 2011).

In this case, the material of interest (MWOO) was mixed into simulated gastrointestinal fluids containing a piece of silicone cord which acts as a sorption sink allowing a concentration gradient for PBDEs to form which mimics the kinetics expected within an organism.

The material was held under these conditions for 24 hours for most samples tested and for a range of time periods up to 120 hours for two initial samples. It is understood that the material ingested by cattle can remain in the gastrointestinal system for up to 120 hours.

There were two forms of MWOO that were assessed. The testing separately assessed the bioaccessibility of PBDEs in MWOO in its original or unground form and MWOO that had been ground during sample preparation for chemical analysis. The ground material consisted of smaller particles with larger surface areas. As might be expected, the ground material provided a larger bioaccessible fraction. The results for the ground material were not used in this HHERA as they would overestimate the likely bioaccessibility in the environment.

Results

The results for the initial two samples assessed over 120 hours are reported in **Table 6**. Results for the rest of the samples assessed only over 24 hours are reported in **Table 7**.

One gram of sample was tested in all cases. The bioaccessible fraction was determined by dividing the cumulative result for the bioaccessible amount by the total concentration in the original MWOO sample. This fraction is then converted to a percentage by multiplication by 100.

Table 6 Bioaccessibility Results – Two Initial Samples

Sample	Time (hours)	PBDE – Br1 to Br9		Deca BDE	
		Cumulative bioaccessible (ng/sample)	% Bioaccessible	Cumulative bioaccessible (ng/sample)	% Bioaccessible
Total Concentration – Original Sample	--	2.86 mg/kg (i.e. 2860 ng/g)		11.5 mg/kg (i.e. 11500 ng/g)	
Unground MWOO	6	61-65	2	51-62	0.5
	12	106-114	4	93-112	1

Sample	Time (hours)	PBDE – Br1 to Br9		Deca BDE	
		Cumulative bioaccessible (ng/sample)	% Bioaccessible	Cumulative bioaccessible (ng/sample)	% Bioaccessible
	24	172-175	6	202-216	2
	48	245-246	9	330-343	3
	120	308-330	11	469-496	4
Ground MWOO	6	96	3	71	1
	12	163	6	127	1
	24	243	9	237	2
	48	312	11	387	3
	120	406	14	587	5

The results shown in **Table 6** indicate that these chemicals continue to come out of the MWOO over time – i.e. the amount of chemical does not drop off or slow with time. This means the longer the material could stay in the stomach of the cattle, the more could come out of the MWOO and be taken up by cattle into meat or milk.

The samples collected during the assessment of bioaccessibility for the unground MWOO sample reported in **Table 6** were analysed in duplicate at each time period which is why the results are listed as a range. The samples for the ground MWOO sample reported in **Table 6** were analysed individually at each time period, hence only one result is listed for each time period.

The results listed in **Table 7** are just those for the unground samples assessed for 24 hours (i.e. most relevant for the way cattle may be exposed). As described above, one gram of sample was used in the test, allowing the bioaccessible fraction to be determined by dividing the cumulative result for the bioaccessible amount by the total concentration in the original MWOO sample. This fraction is then converted to a percentage by multiplication by 100.

Table 7 Bioaccessibility Results – Other Samples

Sample	PBDE – Br1 to Br9			Deca BDE		
	Total Conc (ng/g)	Bioaccessible (ng/sample)	% Bioaccessible	Total Conc (ng/g)	Bioaccessible (ng/sample)	% Bioaccessible
Sample 1	1712	70-98	4-6	4010	91-155	2-4
Sample 2	902	85-102	9-11	2920	82-115	3-4
Sample 3	1239	144-152	12-12	4320	146-170	3-4
Sample 4	577	102-113	18-20	1210	104-117	9-10
Sample 5	578	106-128	18-22	1810	94-122	5-7
Sample 6	476	107-128	22-27	1450	87-92	6
Sample 7	359	95-114	26-32	830	88-127	11-15
Sample 8	547	183-217	33-40	1110	251	23

It is noted only 9 individual samples were tested overall which is a small number and none of the samples with higher concentrations were tested. The samples chosen for this analysis had concentrations ranging from 359 to 2860 ng/g (7 fold range) for PBDE (Br1 to Br9). This compares to the overall range of PBDE (Br1 to Br9) concentrations reported for the whole dataset of 30 to 710000 ng/g (23000 fold range). The samples tested had concentrations of PBDE (Br1 to Br9) in the lower range for MWOO especially for the MWOO samples from Facilities A, C, D and E (where MWOO did not get blended with other organic wastes).

In addition, this was the first time this approach had been used to assess bioaccessibility for cattle. The testing used a method which, although based on a validated approach, was adjusted for the type of chemical and type of organism of interest. These adjustments could not be validated within the timeframe available for the work.

These matters limit the understanding of variability in the bioaccessibile fraction for PBDEs in MWOO that can be obtained from this dataset. Even across this small range of concentrations, the bioaccessible fraction is quite variable – approximately 10 fold variation.

These results definitely indicate that assuming 100% of the PBDEs in MWOO were bioavailable in the Interim HHERA was an overestimate as expected. These results provide evidence to allow the determination of a more appropriate value to be used for adjusting this assumption in the calculations in this refined assessment.

To undertake the assessment two values were chosen for each chemical grouping. The values chosen for each grouping were based on an upper end value from each end of the concentrations used for the testing. This also allows some account of the higher bioaccessibility likely if the material remains in the stomach for longer than 24 hours.

For this assessment, the following values have been chosen for use in the calculations:

- PBDEs (Br1 to Br9) – 12% *(based on the upper end of the values for samples containing more than 1 mg/kg PBDEs (Br1 to Br9))*
- PBDEs (Br1 to Br9) – 30% *(based on the upper end of the values for samples containing less than 1 mg/kg PBDEs (Br1 to Br9))*
- DecaBDE – 4% *(based on the upper end of the values for samples containing more than 2 mg/kg DecaBDE)*
- DecaBDE – 15% *(based on the upper end of the values for samples containing less than 2 mg/kg DecaBDE)*

3.4.2 Ingestion of soil by cattle

In the original calculations it was assumed that cattle ingested 2.4 kg of soil per day incidentally as they consumed grass (i.e. soil/MWOO consumed attached to grass roots and along with grass). This value was sourced from a document by the American Petroleum Institute which developed guidelines for situations where livestock could be exposed to soil or water that had been contaminated by petroleum hydrocarbons (API 2004).

The API document determined this value from quite limited data that were collected primarily in the 1980s. The value used to determine guidelines was based on the maximum amount reported in any of the studies cited rather than a long-term average which would be more realistic.

NSW DPI reviewed the available literature and it appears that this value may have been based on a particular situation during a study which occurred for a short time. Estimated soil ingestion rates reported in the literature where conditions were more similar to those in NSW indicated a range of soil ingestion rates between 0.1 and 1.5 kg soil per day.

Further review of guidance documents by NSW DPI identified the USEPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities published in 2005 which recommends assuming dairy cattle incidentally ingest 0.4 kg soil per day and beef cattle incidentally ingest 0.5 kg soil per day (USEPA 2005).

The exposure assessment calculations have been updated using 0.5 kg soil per day. The revised calculations are provided in **Appendix F**.

In addition, there was discussion in the OCSE report about the way MWOO might fall between individual grass plants onto the surface of the soil to be mixed in prior to ingestion by livestock. This has been incorporated into the assessment by assuming MWOO is trampled into the top 2 cm of soil by livestock as indicated by DPI.

3.4.3 Proportion of time cattle spend on treated areas

In the exposure assessment undertaken in the Interim HHERA, it was assumed that the cattle would be present on areas treated with MWOO for the entire year. However, a review by NSW DPI of the information available about how MWOO was applied to grazing land determined that it was not usually applied to all or most of the paddocks at a farm. In fact, the average amount of the total area (i.e. assuming the entire property can be used for grazing) treated was 14%.

For most farms, there will be areas that are not relevant for treatment with MWOO or useful for grazing cattle (e.g. area where farm house or sheds storing equipment are located). The amount of land at a farm that falls into this category will vary between farms but this does mean that for some farms more than an average of 14% of the area available for grazing will have been treated.

It is also noted that keeping cattle on one paddock throughout an entire year is unlikely to be feasible as feed would not last under such conditions. Cattle are moved around paddocks to ensure access to appropriate amounts of grass for grazing. This means that assuming the cattle are present in one treated paddock over the entire year is not realistic.

The exposure assessment calculations have been updated assuming cattle are present in a paddock treated with MWOO for either 183 days per year (i.e. 6 months of the year – worst case) or 52 days per year (i.e. 14% of the year) to provide more realistic estimates of exposure. The revised calculations are provided in **Appendix F**.

3.4.4 Transfer Factors

The Independent Scientific Review Panel on Soil and Chemistry reviewed the transfer factors used in the Interim HHERA. These values were sourced from the Californian OEHHA (OEHHA 2012).

Table K1 in Appendix K of the OEHHA document provides the values listed in **Table 8** for transfer factors for polychlorinated biphenyls and polychlorinated dioxins and furans. These values were used for the PBDEs as values were not available for these chemicals.

Table 8 Transfer Factors (OEHHA 2012)

Chemical	Transfer Factor		
	Milk	Meat	Eggs
Polychlorinated Biphenyls (PCBs)			
PCB 77	0.001	0.07	6
PCB 81	0.004	0.2	10
PCB 105	0.01	0.6	10
PCB 114	0.02	0.9	10
PCB 118	0.03	1	10
PCB 123	0.004	0.2	10
PCB 126	0.04	2	10
PCB 156	0.02	0.9	10

Chemical	Transfer Factor		
	Milk	Meat	Eggs
PCB 157	0.01	0.5	10
PCB 167	0.02	1	10
PCB 169	0.04	2	10
PCB 189	0.005	0.2	10
Unspeciated (i.e. total PCBs)	0.01	0.2	10
Polychlorinated dioxins and furans (PCDD/Fs)			
2378-TCDD	0.02	0.7	10
12378-PeCDD	0.01	0.3	10
123478-HxCDD	0.009	0.3	10
123678-HxCDD	0.01	0.4	10
123789-HxCDD	0.007	0.06	7
1234678-HpCDD	0.001	0.05	5
OCDD	0.0006	0.02	3
2378-TCDF	0.004	0.1	10
12378-PeCDF	0.004	0.1	30
23478-PeCDF	0.02	0.7	10
123478-HxCDF	0.009	0.3	10
123678-HxCDF	0.009	0.3	10
234678-HxCDF	0.008	0.3	5
123789-HxCDF	0.009	0.3	3
1234678-HpCDF	0.02	0.07	3
1234789-HpCDF	0.003	0.1	3
OCDF	0.002	0.02	1
Unspeciated	0.001	0.03	6

These transfer factors were determined from studies where cattle were exposed to these chemicals in feed over relevant time periods. These chemicals have similar characteristics to PBDE so given limited information about uptake of PBDEs into cattle the transfer factors for PCBs were adopted in the Interim HHERA. The value chosen for use in the original calculations for PBDEs (Br1 to Br9) was the highest value reported in **Table 8** for any of the PCB or dioxin congeners. For DecaBDE, the value for OCDD (octa chlorinated dioxin) was adopted.

The review by OCSE considered the impact of the actual mix of PBDEs present in the MWOO samples and calculated a weighted transfer factor that considered the relevant mix of the congeners and the transfer factors recommended in OEHHA (2012) for each of the relevant congeners.

The value recommended for use from this assessment is 0.53 instead of 2 for uptake into meat. If the ratio between these two values is applied to the transfer factor for milk, the value recommended for use in this assessment becomes 0.01 instead of 0.04.

The calculations using these updated transfer factors are provided in **Appendix F**.

3.5 Other Refinement Work

A number of other amendments have been made to the assessment. These include:

- Change in transfer factor for fodder/wheat

The transfer factor for wheat/fodder was taken from a study reported by Yang et al. (2018). As noted when this matter was discussed in the Interim HHERA, the summary of uptake into a range of plant

species reported transfer factors into crop species averaging around 0.1 and factors for uptake into a range of grass species ranging between 5 and 19 with most in the range 5-8.

Further review of the paper has identified that the grass species reported in this summary were arctic species that were exposed to very low levels of PBDEs in soil (Chen et al. 2015; Dawn Pier et al. 2002; Wang, S et al. 2014; Wang, Y et al. 2011; Zhu et al. 2015). The literature does report that there is an inverse relationship between soil concentration and uptake for these chemicals and the similar family of chemicals – PCBs. Consequently, the summarised uptake factors from studies where the plants had been exposed to concentrations similar to those under investigation for this assessment were further reviewed. An updated value of 0.1 was chosen for this assessment as a reasonable upper end estimate for PBDEs (Br1 to Br9) and 0.01 for DecaBDE (Yang et al. 2018).

- Inclusion of uptake via fodder into accumulation calculations for cattle

In the original assessment uptake of these chemicals into meat and milk was based solely on consumption of the MWOO material by the cattle directly through ingestion of soil containing MWOO. This update has also considered the potential for these chemicals to be taken up into the grass grown in paddocks treated with MWOO resulting in cattle being exposed to these chemicals via incidental ingestion of soil (and MWOO mixed into the soil) and via consumption of fodder grown in areas treated with MWOO.

Section 4. Parked Chemicals and Routine Monitoring Data - Screening

4.1 Background – Parked Chemicals

In addition to the chemicals assessed in the Interim HHERA, a range of chemicals were measured in MWOO samples, but they were not able to be screened due to a lack of relevant guidelines (NSW EPA 2018). These chemicals included those listed in **Table 9** for measured levels in solid MWOO and **Table 10** for measured levels in MWOO leachate (NSW EPA 2018).

It is noted that the parked chemicals for MWOO leachate in regard to ecological protection are all nutrient based (phosphorus, nitrogen, major ions). No additional assessment of these parameters has been undertaken as these are parameters that provided benefit to the soil when MWOO was applied. These nutrients have also been removed from the other lists for solid MWOO and leachate.

Table 9 Parked Chemicals – MWOO (solid)

Human Health Based	Ecological Based
Aluminium	Iron
Iron	Fluoranthene
Lithium	Fluorene
Strontium	Phenanthrene
Titanium	Pyrene
Acenaphthene	3-Methylphenol
Fluoranthene	4-Methylphenol
Fluorene	Di-n-octyl phthalate
Di-ethylhexyl adipate (DEHA)	Atrazine
Fipronil	Bifenthrin
Metalaxyl	Endosulfan
Prometryn	Fipronil
Thiabendazole	Chlordane
Permethrin	Prometryn
Dicamba	Permethrin
Organotins (monobutyl, dibutyl and tributyltin)	2,4,5-T
	Dicamba
	Organotins (monobutyl, dibutyl and tributyltin)
	PBDEs

Table 10 Parked Chemicals – MWOO (leachate)

Drinking Water Based	Livestock Watering Based	Irrigation Based
Aluminium	Antimony	Antimony
Cobalt	Barium	Barium
Iron	Iron	Strontium
Lithium	Lithium	Tin
Strontium	Strontium	Titanium
Tin	Tin	3-methylphenol
Titanium	Titanium	4-methylphenol
Vanadium	3-methylphenol	Phenol
Zinc	4-methylphenol	2,4,5-T
3-methylphenol	Phenol	2,4-D
4-methylphenol	2,4,5-T	MCPA
PBDEs	2,4-D	MCPP

Drinking Water Based	Livestock Watering Based	Irrigation Based
Ammonia	MCPA	Triclopyr
	MCPP	PBDEs
	Triclopyr	Ammonia
	PBDEs	NOx-N (nitrate + nitrite)
		Sodium adsorption ratio

As part of this updated assessment, further work has been undertaken to determine if it is now possible to undertake a screening assessment for these chemicals.

4.2 Background – Monitoring Data

The Interim HHERA, used data from the research program that was undertaken by the then NSW OEH, DPI and others (NSW EPA 2018).

Routine monitoring data have become available. The new monitoring data have been screened using the same approach undertaken in the NSW EPA commissioned research program. There are some chemicals included in the additional data that were not assessed in the original assessment or did not have guidelines so additional sources for guidelines have been reviewed to allow the calculation of relevant guidelines for use in screening.

The chemicals covered in the routine monitoring data included:

- Antimony
- Arsenic
- Beryllium
- Boron
- Cadmium
- Chromium
- Cobalt
- Copper
- Lead
- Manganese
- Mercury
- Molybdenum
- Nickel
- Selenium
- Tin
- Vanadium
- Zinc
- sum DDTs
- Aldrin
- Dieldrin
- Chlordane
- Heptachlor
- Hexachlorobenzene
- Lindane
- Benzene hexachloride
- total PCBs

- Acenaphthene
- Naphthalene
- Acenaphthylene
- Fluorene
- Phenanthrene
- Anthracene
- Fluoranthene
- Pyrene
- Benzo[a]anthracene
- Chrysene
- Benzo[b&k]fluoranthene
- Benzo[a]pyrene
- Indeno[123cd]pyrene
- Benzo[ghi]perylene
- Dibenz[ah]anthracene
- total PAHs
- Di-ethylhexyl phthalate
- Dibutyl phthalate
- total Phthalates
- Brodifacoum
- Chlorpyrifos
- Cypermethrin
- Dichlofluanid
- Emamectin benzoate
- Permethrin
- Profenofos
- Simazine
- Tebuconazole
- Monobutyltin

No additional data for MWOO leachate have become available.

4.3 Additional Sources of Guidelines for Screening

4.3.1 Human Health

The standard Australian approach for calculating a soil or water guideline for the protection of human health can be applied for a chemical not listed in sources of Australian guidelines, if it is possible to find a toxicity reference value such as a reference dose from a reputable source. For many of the chemicals listed in **Table 9** or **10**, it is possible to find such toxicity reference values so guidelines can be determined for screening.

Pesticides

For pesticides, the Australian Pesticides and Veterinary Medicines Authority publishes reference doses for all pesticides registered for use in Australia and, also, for some pesticides that are no longer registered for use. This list is reviewed and republished every year (APVMA 2019). Reference doses for all of the pesticides of interest in this assessment were sourced from this reference except for two older persistent pesticides that are no longer permitted for use in Australia – lindane and benzene hexachloride. Reference doses for these have been sourced from the USEPA Regional Screening Levels (USEPA 2019a).

Pesticides listed in **Sections 4.1** or **4.2** in regard to human health that do not have relevant soil guidelines include fipronil, metalaxyl, prometryn, thiabendazole, permethrin and dicamba, brodifacoum, chlorpyrifos, cypermethrin, dichlofluanid, emamectin benzoate, profenofos, simazine and tebuconazole. There are also pesticides listed in **Section 4.2** that do have relevant soil guidelines available in Australia. These pesticides include DDTs, aldrin, dieldrin, chlordane, heptachlor, hexachlorobenzene, lindane and benzene hexachloride. These guidelines are listed (and referenced) in **Section 4.4**.

The ASC NEPM provides health investigation levels for soil for a range of chemicals. It also includes a calculator spreadsheet showing how those values were calculated. This calculator can be used to undertake calculations for chemicals that were not assessed within the ASC NEPM to ensure consistency in the calculations.

Using the HIL Calculator, a value for HIL-A can be calculated for the pesticides that do not have a existing relevant soil guideline. The spreadsheet showing these calculations is provided in **Appendix D**. The values determined using this approach are listed in **Table 11**.

Values for Koc, Kow and Diffusivity in water (Dw) were required to allow calculation of uptake into plants. Values for these parameters were sourced from the US Risk Assessment Information System or calculated using the USEPA model EPI-SUITE (RAIS; USEPA 2012). Where a value for diffusivity in water could not be sourced for an individual chemical, a worst case value of $1x10^{-5}$ cm^2/s was used (USEPA 2001a). Values for emamectin benzoate were not available from these sources but were listed by the APVMA (APVMA 1999).

The toxicity reference value for assessing exposure via inhalation was determined by converting the oral acceptable daily intake into a reference concentration assuming a 70 kg person and a breathing rate of 20 m^3 per day (USEPA 2009b).

Table 11 Screening Guidelines for Pesticides

Chemicals	Toxicity Reference Value (mg/kg bw/d)	Screening Guideline (mg/kg)
Benzene hexachloride	0.008[U]	400
Brodifacoum	0.0000005[A]	0.0008
Chlorpyrifos	0.003[A]	60
Cypermethrin	0.05[A]	1000
Dicamba	0.03[A]	20
Dichlofluanid	0.03[A]	80
Emamectin benzoate	0.002[A]	2$
Fipronil	0.0002[A]	4
Lindane	0.0003[U]	6
Metalaxyl	0.03[A]	4000

Chemicals	Toxicity Reference Value (mg/kg bw/d)	Screening Guideline (mg/kg)
Permethrin	0.05[A]	3000
Profenofos	0.0001[A]	0.2
Prometryn	0.03[A]	100
Simazine	0.005[A]	20
Tebuconazole	0.03[A]	80
Thiabendazole	0.3[A]	6000

Notes:

[A] APVMA ADI List for Pesticides (APVMA 2019)

[U] USEPA Regional Screening Levels (USEPA 2019a)

$ Koc and log Kow Value for Emamectin benzoate based on figures reported in (APVMA 1999)

None of the chemicals listed for assessment in relation to human health impacts from MWOO leachate are pesticides so no screening guidelines based on concentrations in water have been determined.

Other Chemicals

Toxicity reference values for many of the other chemicals that were parked have been sourced from the USEPA Regional Screening Levels database (USEPA 2018) (and its related supporting information).

SOLID

Using the HIL Calculator (as discussed above), a value for HIL-A can be calculated for these chemicals. The spreadsheet showing these calculations is provided in **Appendix D**.

Values for Koc and Kow were sourced from the US Risk Assessment Information System or the USEPA model EPI-SUITE (RAIS; USEPA 2012). Where a value for diffusivity in water could not be sourced for an individual chemical, a worst case value of $1x10^{-5}$ cm^2/s was used (USEPA 2001a)

The toxicity reference value for assessing exposure via inhalation was determined by converting the oral acceptable daily intake into a reference concentration assuming a 70 kg person and a breathing rate of 20 m^3 per day (USEPA 2009b).

The guidelines calculated using this approach are listed in **Table 12**.

LEACHATE

Using the toxicity reference values and the methodology used by NHMRC Australian Drinking Water Guidelines, screening guidelines for leachate can be developed (NHMRC 2011 updated 2018).

The calculation involves assuming 10% of the reference dose (daily intake likely to be without effect) can be sourced from drinking water where 2 L of water is ingested per day for a person weighing 70 kg.

The calculation is as follows:

$$Drinking\ water\ guideline = \frac{Tolerable\ daily\ intake\ x\ body\ weight\ (70\ kg)\ x\ 0.1\ (i.e.\ 10\%)}{Ingestion\ rate\ (2\ L\ per\ day)}$$

The guidelines calculated using this approach are listed in **Table 12**.

Table 12 Screening Guidelines for Other Parked Chemicals (Solid and Leachate)

Chemicals	Toxicity Reference Value (mg/kg bw/d)	Screening Guideline – Solid (mg/kg)	Screening Guideline – Leachate (mg/L)
Aluminium	1[U]	60000	3.5
Cobalt	0.0014[U]	NR	0.005
Iron	0.7[U]	40000	2.5
Lithium	0.002[U]	70	0.007
Strontium	0.6[U]	500	2
Titanium	1[W]	70000	3.5
Tin	0.6[U]	NR	2
Vanadium	0.005[U]	NR	0.02
Zinc	0.3[U]	NR	1
3-Methylphenol 4-Methylphenol	0.05[U]	NR	0.2
Acenapthene	0.06[U]	1000	NR
Fluoranthene	0.04[U]	2000	NR
Fluorene	0.04[U]	1000	NR
Di-ethylhexyl adipate	0.6[U]	20000	NR
Organotins (mono, di and tributyl tin)	0.0003[U]	20	NR
PBDEs (Br1 to Br9)	0.0001[N]	NR	0.0004

Notes:

[N] National Environment Protection (Assessment of Site Contamination) Measure Schedule B7 Appendices (NEPC 1999 amended 2013e)

[U] USEPA Regional Screening Levels (USEPA 2019a)

[W] *Limited data from the WHO Environmental Health Criteria (EHC24) indicates that where studies have been undertaken, they don't show any effects even at quite high exposures. One study reported no effects in rats fed 100 g/kg food daily over 30 days. This converts to 5000 mg/kg bw/d. A value of 1000 mg/kg bw/d has been adopted as the NOEL for this assessment with uncertainty factor of 1000 applied given the minimal information about the study. The TDI, therefore, becomes 1 mg/kg bw/d (JECFA 2000; WHO 1982).*

NR Not relevant

4.3.2 Ecological

Toxicity Based Criteria

For this assessment, ecological criteria for screening levels in solid MWOO have been identified as follows:

- Where available, terrestrial guidelines that have been derived by other jurisdictions have been considered. Guidelines developed using approaches consistent with those adopted in the NEPM have been adopted in preference to other guidelines.
- Where guidelines are not available for terrestrial environments (due to a lack of data), but guidance is available for the protection of aquatic environments, an equilibrium partitioning method can be adopted, as outlined in the ASC NEPM (NEPC 1999 amended 2013b). This approach is detailed below. It is noted that in Australia, this is not a preferred method, however, in the absence of sufficient studies and data on terrestrial species it has been utilised.

$$RBC_{soil} = \frac{K_{soil\ water}}{\rho} \times AQ_{water} \times 1000$$

Where:
RBC = risk-based soil guideline (mg/kg)
AQ_{water} = Aquatic guideline (mg/L)

Ksoilwater = Unitless Kd partitioning coefficient
ρ = soil bulk density of saturated soil (kg/m^3) (default assumption in Australian ecological assessments = 1500 kg/m^3)

The guidance document from which this equation has been taken notes that Kd values need to be converted to a unitless value in accordance with the following equation (European Chemicals Bureau 2003).

$$K_{soil\ water} = F_a * \text{Unitless Henrys Law Constant} + {}_w + F_{solid} * \frac{Kd}{1000} * \text{bulk density of solid compartment of soil}$$

Where:
Ksoil water = unitless version of Kd
Fa = fraction of air in soil (default assumption by ECB = 0.2)
Fw = fraction of water in soil (default assumption by ECB = 0.2)
Fsolid = fraction of solid in soil (default assumption by ECB = 0.6)
Bulk density of solid fraction of soil (default assumption by ECB = 2500 kg/m^3)
Unitless Henrys Law Constant (value is chemical specific)

Calculations using this approach are provided in **Appendix D**.

Table 13 Screening Guidelines for Other Parked Chemicals (Solid)

Chemicals	Water Quality Guideline (mg/L)	Screening Guideline – Solid (mg/kg)
Iron	0.3	7.5
3-methylphenol 4-methylphenol	0.1	0.1
Fluoranthene	0.001[A]	0.2
Fluorene	0.001[A]	0.3
Phenanthrene	0.0006[A]	0.03
Pyrene	0.0006[A]	0.1
Di-n-octyl phthalate	0.002[U3]	0.8
Organotins (monobutyl, dibutyl and tributyltin)	0.006[A]	0.0003
Atrazine	0.013[A]	0.01
Bifenthrin	0.000012[E2]	0.08
Endosulfan	0.0002[A]	0.004
Dicamba	0.01	0.002
Chlordane	0.00008[A]	0.02
Fipronil	0.01[E1]	0.02
Permethrin	0.011[U1]	4
Prometryn	0.8[U2]	2
2,4,5-T	0.036	0.02
Heptachlor	0.09[A]	11
Lindane	0.2[A]	2
Hexachlorocyclohexane	0.09[U3]	0.8

Notes:

#	Screening Guideline taken from Project 3 Table 7 (NSW OEH 2016) or as per label
A	Australian and New Zealand Water Quality Guidelines (ANZG 2018)
E1	EFSA Pesticide Assessment (lowest LC50 /10 = PNEC) (EFSA 2006)
E2	EFSA Pesticide Assessment (lowest NOEC /1 = PNEC) (European Food Safety Authority 2011)
U1	USEPA Reregistration Eligibility Decision (RED) Permethrin (USEPA 2009a)
U2	USEPA Reregistration Eligibility Decision (RED) Prometryn (USEPA 1996a)
U3	USEPA ECOTOX database (USEPA 2019b)

4.3.3 Livestock Watering

The standard Australian approach for calculating a guideline for livestock watering can be applied for a chemical not listed in relevant Australian guidelines, if it is possible to find a toxicity reference value such as a reference dose from a reputable source (ANZECC/ARMCANZ 2000).

For many of the chemicals listed in **Table 10** in regard to stock watering, there are no toxicity reference values specifically for livestock species but the values for humans can be used as a conservative basis. Some adjustment is required to the values developed for people. The approach adopted here is that outlined by the American Petroleum Institute in the document developing guidelines for protecting livestock in regard to petroleum hydrocarbons (API 2004). The approach takes the no observed effect level reported for laboratory animals (same value as used in calculating the reference dose for people). This value is then scaled for the size of the livestock compared to the laboratory animals using the following equation without additional safety factors used in developing such values for people.

$$Scaling\ Factor = \left(\frac{BW test\ species}{BW\ livestock\ species}\right)^{0.25}$$

Where:
$BW_{test\ species}$ = body weight of test species (kg) – 0.35 kg for rat
$BW_{livestock\ species}$ = body weight of livestock species (kg) – 500 kg (NSW DPI advice)

Using this calculation, a scaling factor for cattle of 0.16 has been determined in the API document. It is noted that the API document also contains scaling factors for calves, sheep and goats. **Table 14** lists the values determined in the API document (API 2004).

Table 14 Scaling factors for livestock (API 2004)

Stock	Body Weight (test species) (kg)	Body Weight (livestock species) (kg)	Scaling Factor
Dairy Cattle	0.35	500$	0.16
Beef Cattle	0.35	500$	0.16
Calves	0.35	50	0.29
Sheep	0.35	57	0.28
Goat	0.35	30	0.33
Horse	0.35	550	0.16

$ Body weight for cattle has been updated from values listed in API 2004 to values provided by NSW DPI

The factor for cattle has been adopted for this assessment as it is appropriate for cattle and conservative for smaller stock.

The chemicals in MWOO leachate relevant for livestock watering that need assessment include:

- Antimony
- Barium
- Iron
- Lithium
- Strontium
- Tin
- Titanium
- 3-methylphenol

- 4-methylphenol
- Phenol
- 2,4,5-T
- 2,4-D
- MCPA
- MCPP
- Triclopyr
- PBDEs (Br1-Br9)
- PBDEs (Deca)

Information used to develop human health based toxicity reference values has been sourced from similar sources as discussed already such as the USEPA Regional Screening Levels and Schedule B7 appendices from the ASC NEPM (APVMA 2019; NEPC 1999 amended 2013e; USEPA 2019a).

The determination of toxicity reference values for livestock for these chemicals is shown in **Table 15**.

Table 15 Development of toxicity reference values for livestock

Chemicals	No Observed Effect Level (mg/kg bw/d)	Scaling Factor	Toxicity Reference Value (mg/kg bw/d)
Antimony	0.35[U1]	0.16	0.06
Barium	63[U1]	0.16	10
Iron	1[U2]	0.16	0.2
Lithium	2.1[U2]	0.16	0.3
Strontium	190[U1]	0.16	30
Tin	60[U3]	0.16	10
Titanium	1000[W]	0.16	160
3-methylphenol 4-methylphenol	13.9[U4]	0.16	2
Phenol	70[N]	0.16	11
2,4,5-T	3[N]	0.16	0.5
2,4-D	1[N]	0.16	0.2
MCPA	1.1[N]	0.16	0.2
MCPP	1.1[N]	0.16	0.2
Triclopyr	0.5[A]	0.16	0.08
PBDE (Br1 to Br9)	0.29[N]	0.16	0.05
Deca PBDE	2.2[U1]	0.16	0.4

Notes:

U1 USEPA IRIS Database (USEPA IRIS) (original source used for RSL inputs)

U2 USEPA PPRTV Database (USEPA) (original source used for RSL inputs)

U3 USEPA HEAST Tables (USEPA) (original source used for RSL inputs)

U4 US ATSDR Toxicological Profile (ATSDR 2008) (original source used for RSL inputs)

N National Environment Protection (Assessment of Site Contamination) Measure Schedule B7 Appendices (NEPC 1999 amended 2013e)

A APVMA ADI List for Pesticides (APVMA 2019)

W WHO Environmental Health Criteria (EHC24). There is limited data on the toxicity of titanium as most studies have not found any effects. One study reported no effects in rats fed 100 g/kg food daily over 30 days. This converts to 5000 mg/kg bw/d. A value of 1000 mg/kg bw/d has been adopted for this assessment given the minimal information about the study (JECFA 2000; WHO 1982).

Once a toxicity reference value is available, the standard approach for calculating a livestock watering guideline can be applied. The approach is similar to that for drinking water.

It is noted that the equation used in the ANZECC guidelines for some contaminants replaces the body weight parameter used in the drinking water guidelines with daily food intake. This is for situations where the toxicity reference value available is one based on the level of the chemical of interest in the food that the stock are eating.

In this case, the toxicity reference value is on a per kg body weight basis so the body weight parameter (as per the drinking water guideline calculation) is appropriate.

$$Livestock\ Watering\ Guideline = \frac{Toxicity\ reference\ value\ x\ body\ weight\ x\ proportion\ from\ water}{daily\ water\ intake}$$

Where

Toxicity reference value	= Toxicity reference value as per **Table 15** (mg/kg bw/d)
Proportion from water	= 20% as per (ANZECC/ARMCANZ 2000)
Daily water intake	= 85 L/day (dairy); 60 L/day (beef); 11.5 L/day (sheep) as per (ANZECC/ARMCANZ 2000)
Body weight	= 500 kg as per NSW DPI

Table 16 Proposed livestock watering guidelines

Chemicals	Toxicity Reference Value (mg/kg bw/d)	Livestock Watering Guideline (mg/L)
Antimony	0.06	0.07
Barium	10	12
Iron	0.2	0.2
Lithium	0.3	0.4
Strontium	30	35
Tin	10	12
Titanium	160	190
3-methylphenol	2	2.4
4-methylphenol		
Phenol	11	13
2,4,5-T	0.5	0.6
2,4-D	0.2	0.2
MCPA	0.2	0.2
MCPP	0.2	0.2
Triclopyr	0.08	0.09
PBDE (Br1 to Br9)	0.05	0.06#
Deca PBDE	0.4	0.5#

Notes:

It is noted that the water solubility of these chemicals is well below these values, so these values are not particularly relevant as such concentrations cannot be reached.

4.3.4 Irrigation

The availability of toxicity values for terrestrial plants is quite limited. Further screening of parked chemicals in MWOO leachate for potential effects on plants has been undertaken using water quality guidelines for the protection of aquatic organisms which include data on algae and aquatic plants and using drinking water guidelines which are used to indicate water of suitable quality for uses around the home including irrigation of gardens.

This assessment is provided in **Section 4.4.4**.

4.4 Screening Assessment

4.4.1 Human Health

Solid MWOO

The concentrations reported in the solid MWOO or in the leachate have been compared to the relevant screening guidelines developed in **Section 4.3**. **Table 17** shows the screening assessment for these data in solid MWOO.

Table 17 Screening Assessment – MWOO (solid)

Chemicals (Parked Chemicals and Routine Monitoring Data)	Screening Guideline (mg/kg)$	Concentration (mg/kg)#	Concentration (mg/kg)@	Further Assessment (Y/N?)
Parked Chemicals				
Aluminium	60000	8455	NR	N
Iron	40000	17000	NR	N
Lithium	70	2.8	NR	N
Strontium	500	110	NR	N
Titanium	70000	120	NR	N
Acenaphthene	1000	0.36	1.1 (max)	N
Fluoranthene	2000	0.37	0.7	N
Fluorene	1000	0.35	0.5	N
Di-ethylhexyl adipate (DEHA)	20000	51	NR	N
Organotins (monobutyl, dibutyl and tributyltin)	20	0.058###	0.7	N
Brodifacoum$	0.0008	NR	10	**Y##**
Chlorpyrifos$	60	NR	10	N
Cypermethrin$	1000	NR	10	N
Dicamba	20	0.17	NR	N
Dichlofluanid$	80	NR	10	N
Emamectin benzoate$	2	NR	10	**Y##**
Fipronil	4	0.021	NR	N
Metalaxyl	4000	0.0045	NR	N
Permethrin$	3000	0.54	0.5^	N
Profenofos$	0.2	NR	10	**Y##**
Prometryn	100	0.089	NR	N
Simazine$	20	NR	10	N
Tebuconazole$	80	NR	10	N
Thiabendazole	6000	0.045	NR	N
Routine Monitoring Data				
Antimony	20	12	10	N
Arsenic	100	9.7	8	N
Beryllium	60	0.32	2	N

Chemicals (Parked Chemicals and Routine Monitoring Data)	Screening Guideline (mg/kg)$	Concentration (mg/kg)#	Concentration (mg/kg)@	Further Assessment (Y/N?)
Boron	4500	28	50	N
Cadmium	20	3.9	4	N
Chromium	100	63	54	N
Cobalt	100	6.1	7	N
Copper	6000	1200	320	N
Lead	300	340	340	**Y**
Manganese	3800	410	470	N
Mercury	40	0.62	0.7	N
Molybdenum	5	6.5	5	**Y**
Nickel	400	43	42	N
Selenium	200[N]	NR	5	N
Tin	47000[U]	36	55	N
Vanadium	130	17	14	N
Zinc	7400	730	750	N
Sum DDTs	240[N]	NR	0.1	N
Aldrin Dieldrin	6[N]	NR	0.2	N
Chlordane	50[N]	NR	0.2	N
Heptachlor	6[N]	NR	0.2	N
Hexachlorobenzene	10[N]	NR	0.2	N
Lindane	6	NR	0.2	N
Benzene hexachloride	400	NR	0.2	N
total PCBs	1[N]	NR	0.2	N
Acenaphthene	3600[U]	0.36	1.1 (max)	N
Naphthalene	130[U]	1.6	1.6	N
Acenaphthylene	3600[U]	NR	1.8 (max)	N
Fluorene	2400[U]	0.35	0.5	N
Phenanthrene	1800[U]	0.5	0.8	N
Anthracene	18000[U]	NR	0.5	N
Fluoranthene	2400[U]	0.37	0.7	N
Pyrene	1800[U]	0.39	0.6	N
Benzo[a]anthracene	See below	NR	0.5	See below
Chrysene		NR	0.5	
Benzo[b&k]fluoranthene		NR	0.7	
Benzo[a]pyrene		NR	6	
Indeno[123cd]pyrene		NR	1.9 (max)	
Benzo[ghi]perylene		NR	1.9 (max)	
Dibenz[ah]anthracene		NR	1.4 (max)	
Sum Carcinogenic PAHs (BaP equivalents)	3[N]	NR	7	**Y**
total PAHs	300[N]	2.5	4	N
Di-ethylhexyl phthalate	30	180	44	**Y**
Dibutyl phthalate	30	12	5	N
total phthalates (assumed as Di-ethylhexyl phthalate)	30	200	510	**Y**

Notes:

\# Results taken from Project 3 Table 6 (NSW OEH 2016)

@ Results from routine monitoring data (95th percentile)

$ Screening guidelines are those listed in Project 3 report (not labelled), calculated in **Section 10.3.1** or as per Site Contamination NEPM (labelled N) or USEPA RSLs (labelled U) (NEPC 1999 amended 2013d; USEPA 2019a)

$ Routine monitoring data for these pesticides indicate these chemicals are rarely detected or, if detected, are detected around the lower limits of reporting used. The 95th percentile data are driven by the use of a high limit of reporting (10 mg/kg) for some samples. For the rest of the data, the limit of reporting ranged between 0.01 and 0.5 mg/kg.

Brodifacoum, emamectin benzoate and profenofos were not detected at all or on only a few occasions over 8 years. As noted, the 95th percentile concentration is driven by the high limit of reporting used for some of the data. It is not considered that these chemicals need further detailed assessment based on the low number of measurable results and when detected the results were around the lowest limit of reporting used in any of the laboratories (0.01 mg/kg).

^ Permethrin results from the routine monitoring data reported a 95th percentile concentration of 10 when all data assessed including the non-detects where there was a high limit of reporting. When just the results that were above the relevant limit of reporting were assessed the 95th percentile was 0.5.

This screening assessment indicates that further assessment of lead, molybdenum, tin, carcinogenic PAHs and di-ethylhexyl phthalate is required based on people being directly exposed to MWOO without any dilution with soil. The previous screening assessment also compared against the concentration in MWOO without dilution.

To enable a more realistic assessment, consideration of how MWOO was applied has been used to adjust this screening assessment.

Cropping Land

For cropping land, MWOO was applied at a rate of 10 tonnes/hectare onto agricultural land and mixed into the top 10 cm of soil. Consequently, the concentration that could be present in cropping areas is based on the concentration in MWOO divided by 130 (based on application of 10 tonnes to one hectare and mixed it into 10 cm with a soil bulk density of 1300 kg/m^3).

Grazing Land

For grazing land, MWOO was applied at a rate of 10 tonnes/hectare and applied directly on the surface of the site or trampled into the top 2 cm of soil after livestock had grazed across the site. Consequently, the concentration that could be present in grazing areas can be based on the concentration in MWOO directly (as per the assessment already undertaken in **Table 18**) or divided by 26 (based on application of 10 tonnes to one hectare and mixed it into 2 cm with a soil bulk density of 1300 kg/m^3).

Where results are available from both the original assessment and the more recent routine monitoring data, the highest value has been adopted for this more detailed assessment.

Table 18 Detailed Assessment – MWOO (solid)

Chemicals (Parked Chemicals and Routine Monitoring Data)	Screening Guideline (mg/kg)	Concentration – Cropping Areas (mg/kg)	Concentration – Grazing Areas (mg/kg)	Further Assessment (Y/N?)
Lead	300	2.6	13	N
Molybdenum	5	0.05	0.3	N
Sum Carcinogenic PAHs (BaP equivalents)	3[N]	0.05	0.3	N
total phthalates (assumed as Di-ethylhexyl phthalate)	30	3.9	20	N

MWOO Leachate

Table 19 provides the screening of the concentrations measured in leachate against drinking water. This assumes no dilution occurs when leachate runs off into a surface water body. This is the approach adopted in the original screening assessment in the NSW EPA commissioned research program.

Table 19 Screening Assessment – MWOO (leachate) – Drinking

Parked Chemical	Screening Guideline (mg/L)$	Maximum Concentration (mg/L)#	Further Assessment (Y/N?)
Aluminium	3.5	16	**Y**
Cobalt	0.005	0.21	**Y**
Iron	2.5	23	**Y**
Lithium	0.007	0.08	**Y**
Strontium	2	2.9	**Y**
Tin	2	0.08	N
Titanium	2	0.49	N
Vanadium	0.02	0.06	**Y**
Zinc	1	14	**Y**
3-methylphenol	0.2	0.4	**Y**
4-methylphenol			
PBDEs (Br1-Br9)	0.0004	0.000047	N

Notes:

Results taken from Project 3 Table 7 (NSW OEH 2016)

$ screening guidelines are those determined in **Section 4.3.1**.

Assuming that no dilution of leachate occurs, this screening assessment indicates that further assessment of aluminium, cobalt, iron, lithium, strontium, vanadium, zinc and 3-methylphenol and 4-methylphenol is required. It is noted that these screening guidelines are those relevant if leachate was to be used as a drinking water source. If this water could be encountered only as recreational water (i.e. irrigation/swimming/boating etc), then a 10 fold factor can be applied to the screening guideline in line with the NHMRC Guidelines for Recreational Water Quality (NHMRC 2008).

Table 20 Screening Assessment – MWOO (leachate) – Recreational

Parked Chemical	Screening Guideline (mg/L)	Maximum Concentration (mg/L)#	Further Assessment (Y/N?)
Aluminium	35	16	N
Cobalt	0.05	0.21	**Y**
Iron	25	23	N
Lithium	0.07	0.08	**Y**
Strontium	20	2.9	N
Tin	20	0.08	N
Titanium	20	0.49	N
Vanadium	0.2	0.06	N
Zinc	10	14	**Y**
3-methylphenol	2	0.4	N
4-methylphenol			
PBDEs (Br1-Br9)	0.004	0.000047	N

Notes:

Results taken from Project 3 Table 7 (NSW OEH 2016)

$ screening guidelines are those determined in **Section 4.3.1** multiplied by 10 in line with recreational water guidelines (NHMRC 2008)

Using the recreational water quality scenario, cobalt, lithium and zinc remain above the guideline. It is noted that the methodology for determining such guidelines does assume that people recreate in the leachate without dilution regularly throughout their lives. However, people could be exposed only once or twice in their lives to significant amounts of leachate in a water body close to a treated area. The concentrations of these chemicals are between 1.5-4 times higher than the screening guideline. This is not sufficiently high to require any further assessment given that people cannot be exposed to water affected by leachate throughout their lives.

It is noted that in the column leachate experiments, fractions were collected over different time periods as follows

- F1 – 0-18 hours
- F2 – 18-35 hours
- F3 – 35-70 hours
- F4 – 70-163 hours

Concentrations for all contaminants in F1 and F2 were higher than those in F3 and F4. In most cases concentrations were close to limits of reporting by F3. This does indicate that leaching from the material into waters around a treated area will only be affected by the leachate for the first few rainfall events post application.

4.4.2 Ecological

The concentrations reported in the solid MWOO have been compared to the relevant screening guidelines developed in **Section 4.3.2** for ecological protection. **Table 21** shows the screening assessment for these data in solid MWOO.

Table 21 Screening Assessment – MWOO (solid) – ecological

Chemicals (parked and updated with Routine Monitoring Data)	Screening Guideline (mg/kg)^	95th Percentile Concentration (mg/kg)#	95th Percentile Concentration (mg/kg)@	Further Assessment (Y/N?)
Parked Chemicals				
Iron (essential micronutrient)	7.5	17000	NR	**Y**
Fluoranthene	50[C]	0.37	0.7	N
Fluorene		0.35	0.5	
Phenanthrene		0.5	0.8	
Pyrene		0.39	0.6	
Di-n-octyl phthalate	0.8	1.9	NR	**Y**
Organotins (monobutyl, dibutyl and tributyltin)	0.0003	0.058##	0.7	**Y**
Atrazine	0.01	1.5	NR	**Y**
Bifenthrin	8	0.47	NR	N
Endosulfan	0.004	0.7	NR	**Y**
Dicamba	0.002	0.17	NR	**Y**
Chlordane	0.02	0.35	NR	**Y**
Fipronil	0.02	0.021	NR	N
Permethrin$	4	0.54	NR	N
Prometryn	2	0.089	NR	N
2,4,5-T	0.02	0.18	NR	**Y**
Routine Monitoring Data				
Antimony	37	12	10	N
Arsenic	20	9.7	8	N

Chemicals (parked and updated with Routine Monitoring Data)	Screening Guideline (mg/kg)^	95th Percentile Concentration (mg/kg)#	95th Percentile Concentration (mg/kg)@	Further Assessment (Y/N?)
Beryllium	21	0.32	2	N
Boron	5.7	28	50	**Y**
Cadmium	0.9	3.9	4	**Y**
Chromium	75	63	54	N
Cobalt	10.9	6.1	7	N
Copper &	60	1200	320	**Y**
Lead	130	340	340	**Y**
Lithium	1.76	2.8	NR	**Y**
Manganese &	220	410	470	**Y**
Mercury	0.022	0.62	0.7	**Y**
Molybdenum	20.4	6.5	5	N
Nickel	10	43	42	**Y**
Selenium	1[C]	NR	5	N
Tin	50	36	55	**Y**
Titanium	60	120	NR	**Y**
Vanadium	6	17	14	**Y**
Zinc &	100	730	750	**Y**
Sum DDTs $	0.021[U1]	NR	0.1	N
Aldrin $ Dieldrin $	0.0049[U2]	ND	0.2	N
Chlordane $	0.02	NR	0.2	N
Heptachlor $	11	NR	0.2	N
Hexachlorobenzene $	2[C]	NR	0.2	N
Lindane $	2	NR	0.2	N
Benzene hexachloride $	0.8	NR	0.2	N
total PCBs		NR	0.2	N
Acenaphthene	50[C]	0.36	1.1 (max)	N
Naphthalene		1.6	1.6	
Acenaphthylene		NR	1.8 (max)	
Fluorene		0.35	0.5	
Phenanthrene		0.5	0.8	
Anthracene		NR	0.5	
Fluoranthene		0.37	0.7	
Pyrene		0.39	0.6	
Benzo[a]anthracene	20[C]	NR	0.5	N
Chrysene		NR	0.5	
Benzo[b&k]fluoranthene		NR	0.7	
Benzo[a]pyrene		NR	6	
Indeno[123cd]pyrene		NR	1.9 (max)	
Benzo[ghi]perylene		NR	1.9 (max)	
Dibenz[ah]anthracene		NR	1.4 (max)	
Di-ethylhexyl phthalate	13	180	44	**Y**
Dibutyl phthalate	0.05	12	5	**Y**
Total phthalates	13	200	510	**Y**

Notes:

#	Results taken from Project 3 Table 6 (NSW OEH 2016)
@	Results from routine monitoring data (95th percentile)
^	Screening guidelines are those listed in Project 3 report (not labelled), calculated in **Section 10.3.2** or from source as labelled
U1	USEPA EcoSSL DDT and metabolites (USEPA 2007a)
U2	USEPA EcoSSL dieldrin (USEPA 2007b)
C	CCME guidelines for residential land (non-human basis where available)
$	Routine monitoring data for these pesticides indicate these chemicals are rarely detected or, if detected, are detected around the lower limits of reporting used. The 95th percentile data are driven by the limits of reporting.

& updated guidelines for these metals as per discussion in **Section 9.2.2** in Interim HHERA (**Appendix B**)
sum of mono, di and tributyltin results

This screening assessment indicates that further evaluation of iron, di-n-octyl phthalate, organotins, atrazine, endosulfan, dicamba, chlordane, 2,4,5-T, boron, cadmium, copper, lead, lithium, manganese, mercury, nickel, tin, titanium, vanadium, zinc, di-ethylhexyl phthalate and di-butyl phthalate is required based on ecosystems being directly exposed to MWOO without any dilution in soil. The previous screening assessment also compared against the concentration in MWOO without dilution.

To enable a more realistic assessment, consideration of how MWOO was applied has been used to adjust this screening assessment.

Cropping Land

For cropping land, MWOO was applied at a rate of 10 tonnes/hectare onto agricultural land and mixed into the top 10 cm of soil. Consequently, the concentration that could be present in cropping areas is based on the concentration in MWOO divided by 130 (based on application of 10 tonnes to one hectare and mixed it into 10 cm with a soil bulk density of 1300 kg/m^3).

Grazing Land

For grazing land, MWOO was applied at a rate of 10 tonnes/hectare and applied directly on the surface of the site or trampled into the top 2 cm of soil after livestock had grazed across the site. Consequently, the concentration that could be present in grazing areas can be based on the concentration in MWOO directly (as per the assessment already undertaken in **Table 21**) or divided by 26 (based on application of 10 tonnes to one hectare and mixed it into 2 cm with a soil bulk density of 1300 kg/m^3). The concentrations determined when MWOO is mixed into the surface 2 cm is more relevant for ecological systems as the soil organisms are more likely to exposed to this material.

Where results are available from both the original assessment and the more recent routine monitoring data, the highest value has been adopted for this more detailed assessment.

Table 22 Screening Assessment – MWOO (solid) – ecological

Chemicals (parked and updated with Routine Monitoring Data)	Screening Guideline (mg/kg)%	Concentration – Cropping Areas (mg/kg)	Concentration – Grazing Areas (mg/kg)	Further Assessment (Y/N?)
Parked Chemicals				
Iron (essential micronutrient)	7.5	130	650	**Y**
Di-n-octyl phthalate	0.8	0.01	0.05	N
Organotins (monobutyl, dibutyl and tributyltin)	0.0003	0.005	0.03	N
Atrazine	0.01	0.01	0.05	**Y**
Endosulfan	0.004	0.005	0.03	**Y**
Dicamba	0.002	0.001	0.005	**Y**
Chlordane	0.02	0.003	0.02	N
2,4,5-T	0.02	0.001	0.005	N
Routine Monitoring Data				
Boron	5.7	0.4	2	N
Cadmium	0.9	0.03	0.2	N
Copper	60	9	45	N

Chemicals (parked and updated with Routine Monitoring Data)	Screening Guideline (mg/kg)%	Concentration – Cropping Areas (mg/kg)	Concentration – Grazing Areas (mg/kg)	Further Assessment (Y/N?)
Lead	130	3	15	N
Lithium	1.76	0.02	0.1	N
Manganese	220	4	20	N
Mercury	0.022	0.005	0.03	**Y**
Nickel	10	0.3	2	N
Tin	50	0.4	2	N
Titanium	60	0.9	5	N
Vanadium	6	0.1	0.5	N
Zinc	100	6	30	N
Di-ethylhexyl phthalate	13	1	5	N
Dibutyl phthalate	0.05	0.09	0.5	**Y**
Total phthalates	13	4	20	**Y**

This refined assessment indicates that further evaluation of iron, atrazine, endosulfan, dicamba, mercury, total phthalates and di butyl phthalate is required based on ecosystems being directly exposed to MWOO when dilution into the soil is considered.

Di-n-octyl phthalate, organotins, chlordane, 2,4,5-T, boron, cadmium, copper, lead, lithium, manganese, nickel, tin, titanium, vanadium, zinc reduce to levels below the screening guideline when mixed into either 2 cm or 10 cm of soil.

Further consideration of issues relating to these chemicals is provided below:

Actual detections

Some of the pesticides were detected infrequently. Some of the data included relatively high limits of reporting. The impact of these infrequent detections on understanding potential risks is discussed here:

- Atrazine was detected on one occasion in the data from one of the facilities assessed as part of the NSW EPA commissioned research program and on two occasions in the data for the other facility. The maximum measured concentration was 0.011 mg/kg at one facility (as per note at end of Table A2) and 0.11 mg/kg at the other facility, however, the 95th percentile used to screen was 1.5 mg/kg. If the adjustment for applying this material to cropping or grazing land is used with these maximum values then the concentration that could be in soil would be 0.0008 mg/kg for cropping areas and 0.004 mg/kg for grazing areas both of which are below the relevant screening guideline so the risk of impact is low.
- Endosulfan was detected on one occasion in the data from one of the facilities assessed as part of the NSW EPA commissioned research program and not at all in the data for the other facility. The only measured concentration was 0.065 mg/kg. If the adjustment for applying this material to cropping or grazing land is used then the maximum concentration that could be in soil would be 0.0005 mg/kg for cropping areas and 0.003 mg/kg for grazing areas both of which are at or below the relevant screening guideline so the risk of impact is low.

Grazing vs Cropping

For mercury, atrazine, endosulfan dicamba and total phthalates, the potential for ecological effects is low when MWOO is applied to cropping areas and mixed into the soil (i.e. top 10 cm of soil).

However, when MWOO material is applied to the surface of a site in grazing areas (and not mixed into the soil or only mixed into the top 2 cm), the levels of these chemicals are above screening guidelines.

It is noted that these guidelines have been calculated using a conservative approach based on concentrations that could be present in soil water (i.e. the levels that could dissolve into water within the ground from the solid material). It is likely that these chemicals will not readily dissolve into the soil water especially when placed on the surface where interaction with water will occur only during rain events where the MWOO will only be in contact with the rain water for a short period with runoff going across land as well as seeping into the ground. Such short exposure of the water to the MWOO is unlikely to allow much to dissolve. In periods of prolonged wet weather or in wetter parts of the state, the potential for risks to ecological systems may be higher. The potential for risks to ecological systems in such systems is likely to be low but cannot be ruled out given the limitations of current knowledge and methodologies.

No further discussion can be provided to adjust the assessment of di-ethylhexyl phthalate (as total phthalates) and di butyl phthalate so ecological risks from these chemicals cannot be ruled out.

This assessment has been undertaken using aquatic effects data converted into soil guidelines as recommended in the ASC NEPM when terrestrial ecotoxicology information is limited which is the case for many of the chemicals analysed in MWOO. This assessment has identified a range of chemicals that may pose an ecological risk including iron, atrazine, endosulfan, dicamba, mercury, di-ethylhexyl phthalate (as total phthalates) and di butyl phthalate. It is also noted that for some contaminants like copper and zinc, the concentrations present in MWOO were highly variable and the maximum concentrations were well above acceptable values but occurred in only one or two samples from the whole dataset. Using the 95th percentile concentration, risks from these contaminants were estimated to be acceptable. No further assessment is possible at this time.

4.4.3 Livestock Watering

The concentrations reported in MWOO leachate have been compared to the relevant screening guidelines developed in **Section 4.3.3**. **Table 23** shows the screening assessment.

Table 23 Screening Assessment – Livestock Watering

Chemicals	Concentration in Leachate (mg/L)	Livestock Watering Guideline (mg/L)	Further Assessment (Y/N?)
Antimony	0.05	0.08	N
Barium	0.21	13	N
Iron	23	0.3	**Y**
Lithium	0.08	0.4	N
Strontium	2.9	38	N
Tin	0.08	13	N
Titanium	0.49	200	N
3-methylphenol	0.4	2.5	N
4-methylphenol			
Phenol	2.3	14	N
2,4,5-T	0.001	0.6	N
2,4-D	0.037	0.3	N
MCPA	0.063	0.3	N
MCPP	0.01	0.3	N
Triclopyr	0.009	0.1	N

Chemicals	Concentration in Leachate (mg/L)	Livestock Watering Guideline (mg/L)	Further Assessment (Y/N?)
PBDE (Br1 to Br9)	0.00005	0.06	N
Deca PBDE	Not reported	0.5	N

The only chemical shown to be present in leachate above the proposed livestock watering guideline is iron.

These guidelines are based on consumption of the leachate as the sole source of water for the livestock. It is not likely that this will occur. Iron is an essential nutrient for livestock so there will be effects on the stock if they do not get enough iron as well as too much.

The availability of iron is also likely to be quite low as under environmental conditions iron is strongly incorporated into particles and so, while the "total iron" concentration in leachate may be quite high, it is likely that the iron is adsorbed to particles rather than dissolved. The potential for the iron to desorb from the particles and be taken up by the stock is expected to be quite small.

Given the limited likely exposure and these considerations, no further assessment of iron has been undertaken.

4.4.4 Irrigation

As discussed in **Section 4.3.4**, there are limited or no data to assess potential impacts on plants for many chemicals. This assessment has made use of water quality guidelines for ecological protection and drinking water guidelines to screen the results for MWOO leachate. **Table 24** shows this screening assessment.

Table 24 Screening Assessment – Irrigation

Chemical	Concentration in Leachate (mg/L)	Screening Guideline – Water Quality Guideline (mg/L)	Screening Guideline – Drinking Water Guideline (mg/L)	Further Assessment (Y/N?)
2,4,5-T	0.001	0.036[A]	0.2[U]	N
2,4-D	0.037	0.28[A]	0.03[a]	N
3-methylphenol	0.4	NA	0.9[a]	N
4-methylphenol				
Ammonia	520	0.9[A]	NR	**Y**
Barium	0.21	0.28[A]	2[a]	N
MCPA	0.063	0.0014[A]	0.04[a]	**Y**
MCPP	0.01			
PBDEs	0.047	NA	0.00035[ac]	**Y**
Phenol	2.3	0.32[A]	5.8[U]	**Y**
Strontium	2.9	NA	12[U]	N
Tin	0.08	0.1[A]	0.7[a]	N
Titanium	0.49	NA	3.5[ac]	N
Triclopyr	0.009	NA	0.02[a]	N

Risks to terrestrial plants during irrigation cannot be ruled out for ammonia, MCPA, MCPP, PBDEs and phenol. It is unlikely that MWOO leachate would be regularly used for irrigation at a particular location, so these guidelines are conservative. No further assessment is possible at this time.

Section 5. Exposure Assessment – Human Health – Soil – PBDEs

5.1 General

This section provides a short discussion on the potential receptors (human groups) and exposure pathways that are considered to be of significance in this assessment. In addition, where identified as of potential significance and warranting quantification in this assessment, the potential for exposure has been quantified using industry best practice and guidance available from (enHealth 2012a; NEPC 1999 amended 2013a; USEPA 1989, 2002, 2009b).

The assessment presented has addressed potential worst-case exposure to the key chemicals in soil and exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and therefore health risk.

The quantification of exposure has involved consideration of the following:

- Identification of relevant ***exposure parameters*** for each of the identified exposure pathways and receptors. The magnitude of the exposure is a function of a number of variables (termed exposure parameters), which describe the physical, and behavioural parameters relevant to the potentially exposed population. Exposure parameters which are considered representative have been selected. Where available, additional exposure data has been obtained from Australian sources (enHealth 2012a; NEPC 1999 amended 2013a); and
- Estimation of the ***chemical concentration*** in each medium relevant to the receptor groups and exposure pathways. This has involved the use of maximum concentrations reported in surface soil. Potential dust concentrations have been estimated on the basis of a particulate emission factor (that relates the concentration in air to that in soil) derived from guidance provided by the USEPA (USEPA 2002).

These approaches were described in the Interim HHERA. Descriptions have been included in this report as well to show how these calculations are undertaken and to update any parameter values that have been included.

5.2 Quantification of Exposure – PBDEs

5.2.1 Identified Receptors and Exposure Pathways

The targets of this assessment are the farmers/farm workers that may be exposed to land where these materials have been applied and consume produce grown at the farm. The general public are unlikely to be exposed to these materials.

The ASC NEPM low density residential scenario includes exposure to the soil while living at a property and doing routine garden maintenance, and where up to 10% of daily intake of fruit and vegetables may be derived from home grown produce.

For sites where these materials are applied to agricultural land it is possible that additional agricultural activities may occur including:

- Grazing of livestock (cattle/sheep)

- Cropping (wheat/oats/barley)
- Keeping poultry (for the purpose of producing eggs)
- Horticulture (fruit and vegetables – higher than expected in urban environments)

These agricultural activities are not included in the normal low density residential scenario assumed for the ASC NEPM so require separate evaluation.

It is noted that the Order permitting the use of MWOO specifically excluded using the waste in areas around a farm where vegetables might be grown or where chickens may be kept - *Definition in Resource Recovery Order – **broad acre agricultural use** means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.*

Uptake into these types of produce has been assessed to provide detailed information for NSW EPA should this have occurred at a site.

Table 25 Summary of Key Exposure Groups and Pathways

Receptor	Exposure Pathway/Mechanism
Farmers/farm workers	Incidental ingestion of surface soil and dust (tracked indoors) Dermal contact with surface soil and dust (tracked indoors) Inhalation of impacted dust generated from surface soil Ingestion of PBDEs in home grown produce at site (consumed on farm) Ingestion of PBDEs in eggs from poultry kept at the site (consumed on farm) Ingestion of PBDEs in milk from cattle kept at the site (consumed on farm) Ingestion of PBDEs in meat from livestock kept at the site (consumed on farm)

It is important to note that this assessment has focused on evaluating potential for on farm consumption of food stuffs by people living on a farm which has had the MWOO applied. The risk calculations provided do not address the commercial food supply.

5.2.2 Background information on PBDEs

PBDEs are chemicals that may be present in materials derived from AWT processes.

Polybrominated diphenyl ethers (PBDEs) are a group of compounds manufactured for their flame retardant properties. They consist of two phenyl groups bound to a single oxygen atom with the hydrogen atoms on the phenyl groups substituted with between one and ten bromine atoms. The group consists of 209 congeners, which differ in the number and location of substituted bromine atoms. The internationally accepted numbering system for PBDE congeners is the acronym ‘BDE’ followed by a number from 1 to 209 (NICNAS 2007).

PBDE are manufactured compounds, which have been widely used in industrial and consumer applications. A review of the compounds conducted by scientific and regulatory bodies has culminated in tetra- and penta-BDEs (components of technical grade penta-BDE (i.e. raw material used in manufacturing)) and hexa- and hepta-BDEs (components in technical grade octa-BDE (i.e. raw material used in manufacturing)) being listed as Persistent Organic Pollutants (POPs) under the Stockholm Convention in May 2009 (UNEP 2009). All production and use of these compounds has subsequently been banned, with the exception of recycling activities (UNEP 2009). PBDEs are not manufactured in Australia but were historically imported and used until 2005 (NICNAS 2007).

Their use in household products as additive flame retardants meant they could leach from articles like TVs, carpet or computers. As a result, they are present in municipal waste and can end up in MWOO. They are normally present within the small particles of plastics that remain in MWOO. Where these chemicals were used as additive flame retardants, they can leach from the small particles but once out of the plastic it is expected that these chemicals would sorb to the soil given their characteristics.

It is also noted that use of these chemicals is being phased out. NICNAS (industrial chemicals regulator) has prohibited importation of these chemicals and removed some of these chemicals from the list of chemicals that are legal to use in Australia https://www.nicnas.gov.au/chemical-information/factsheets/chemical-name/pbde-congeners-in-penta-and-octa). This is similar to steps taken in other countries. As a result, it is expected that the amount of PBDEs that may be present in household waste will be decreasing. It is also noted, however, that PBDEs are being replaced by other brominated chemicals which may have similar characteristics.

The WHO/FAO Joint Expert Committee on Food Additives assessed the presence of these chemicals (PBDEs) in food in 2006 (WHO 2006). Based on limited information, the committee estimated daily intakes for people ranging from 0.000001-0.000004 mg/kg bw/day across various global regions. Consumption of fish contributed most to intakes in Europe while meat and poultry contributed most in the US. As discussed in **Section 8**, the reference dose for these chemicals is estimated to be 0.0001 mg/kg bw/day, so it was determined that intake from food was a minor contribution.

The European Food Safety Agency has been investigating the presence of these contaminants in foods since then but have not published a final review at this time. More data is being sought from food producers and Country based food safety agencies in Europe (https://www.efsa.europa.eu/sites/default/files/wgs/chemical-contaminants/contambrflameretard.pdf and http://www.efsa.europa.eu/en/press/news/140311).

Food Standards Australia and New Zealand also undertook a survey of the presence of PBDEs in food. The study was released in 2007. The highest concentrations were reported for boiled eggs, grilled pork chops, bacon and cream. The estimated dietary intakes were 0.000001 to 0.0001 mg/kg bw/day (FSANZ 2007).

5.2.3 Exposure Concentrations

The calculation of exposure concentrations has been discussed in **Section 3.3.4**. The results to be used in this assessment are summarised in **Table 26**.

Table 26 Exposure Concentrations

Scenario	Mean Concentration (mg/kg)	Maximum Concentration (mg/kg)	95th Percentile Concentration (mg/kg)	Minimum Concentration (mg/kg)	Median Concentration (mg/kg)
PBDEs (Br1 to Br9)					
Cropping Land					
Interim HHERA	0.5	5.5	4	0.0003	--
Overall Dataset	0.1	5.5	0.07	0.0003	0.004
Grazing Land – no incorporation					

Scenario	Mean Concentration (mg/kg)	Maximum Concentration (mg/kg)	95th Percentile Concentration (mg/kg)	Minimum Concentration (mg/kg)	Median Concentration (mg/kg)
Interim HHERA	61	710	530	0.04	--
Overall Dataset	15	710	20	0.04	0.5
Grazing Land – trampled into the soil					
Interim HHERA	2.3	27	20	0.002	--
Overall Dataset	0.6	27	0.8	0.002	0.02
DecaBDE					
Cropping Land					
Interim HHERA	0.02	0.06	0.05	0.0004	--
Overall Dataset	0.02	0.1	0.07	0.0004	0.008
Grazing Land – no incorporation					
Interim HHERA	2.2	7.5	6.8	0.05	--
Overall Dataset	2	13	9	0.05	1
Grazing Land – trampled into the soil					
Interim HHERA	0.08	0.3	0.3	0.002	--
Overall Dataset	0.08	0.5	0.4	0.002	0.04

5.2.4 Ingestion and Dermal Contact with Treated Soil

Soil Ingestion

Ingestion of soil (direct incidental ingestion) is one of the key pathways of exposure relevant for the assessment of exposures.

As noted in Section 5.3.1.2 of Schedule B7 of the ASC NEPM, another pathway of exposure to soil is incidental ingestion of soil that is adhered to home grown produce (like carrots or potatoes). The UK Environment Agency has developed a methodology to estimate how much soil people are likely to consume in this way from home grown produce (i.e. indirect incidental ingestion). The approach found that 2-3 mg of soil is ingested via this pathway. The ingestion rate currently used in the calculations for the national health investigation levels is considered to be sufficient to cover direct and indirect incidental ingestion of soil.

The potential intake of PBDEs identified in surface soil via incidental ingestion (direct and indirect) has been undertaken using the following equation:

$$\text{Daily Chemical Intake}_{ls} = C_s \bullet \frac{IRs \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:
Cs = Concentration of treated soil (mg/kg), as per **Table 26**
IRs = Ingestion rate of soil (mg/day)
FI = Fraction of daily ingestion that is derived from contamination source (unitless), taken as 1

B = Bioavailability or absorption of chemical via ingestion (unitless), taken as 1
CF = Conversion factor of $1x10^{-6}$ to convert mg to kg
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via soil ingestion for a child or an adult are presented in **Table 27**. All calculations are presented in **Appendix F**.

Dermal Exposures

Dermal absorption of chemicals from soil depends on the area of skin in contact with soil, the duration of contact, how well sorbed the chemical is to the soil and the ability of the chemical to penetrate the skin.

The assessment of the potential dermal absorption of PBDEs has been generally undertaken using the approach presented by the USEPA. They define a simple approach to the evaluation of dermal absorption associated with soil contact (USEPA 1989, 2004). This is presented in the following equation:

$$\text{Daily Chemical Intake} = C_s \bullet \frac{SAs \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:
Cs = Concentration in soil (mg/kg), as per **Table 26**
SAs = Surface area of body exposed to soil per day (cm^2/day)
AF = Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil properties and area of body (mg/cm^2 per event)
ABSd = Dermal absorption fraction (unitless), refer to note below
CF = Conversion factor of $1x10^{-6}$ to convert mg to kg
EF = Exposure frequency (days/year)
ED = Exposure duration, taken to be 6 years for children and 29 years for adults
BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per ASC NEPM 1999
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via dermal absorption from soil ingestion for a child or an adult are presented in **Table 27**. All calculations are presented in **Appendix F**.

Table 27 Summary of Exposure Parameters Adopted –Ingestion and Dermal Contact with Soil

Exposure Parameter	Value adopted for Child (aged 0-5 years)	Value adopted for adults
Ingestion rate (soil)	100 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013e)	50 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013e)
Skin surface area	2 700 cm^2 based on the surface area for hands, legs, arms (NEPC 1999 amended 2013e)	6 300 cm^2 based on the surface area for hands, legs, arms (NEPC 1999 amended 2013e)
Soil to skin adherence factor	0.3 (USEPA 2004)	0.3 (USEPA 2004)
Fraction of day exposed	1 - assumes that the child remains in contact with the dirt on their skin for 24 hours (i.e. doesn't shower until next day)	1 - assumes that the adult remains in contact with the dirt on their skin for 24 hours (i.e. doesn't shower until next day)
Exposure frequency	365 days per year	365 days per year
Exposure duration	6 years as a young child	29 years as an adult assuming a total of 35 years residency at the same location

Exposure Parameter	Value adopted for Child (aged 0-5 years)	Value adopted for adults
		as a child and adult (NEPC 1999 amended 2013e)
Body weight	15 kg (NEPC 1999 amended 2013e)	70 kg (NEPC 1999 amended 2013e)
Bioavailability	100%	100%

Dermal absorption: For PBDEs, the ASC NEPM (2013) recommends a dermal absorption of 10% (NEPC 1999 amended 2013e).

Bioavailability: Bioavailability is an important factor for determining the amount of a chemical that is absorbed into the body. When a chemical is ingested, bioavailability is determined by the amount of the chemical that can be dissolved (from the soil matrix in this case) into the gastrointestinal fluids and absorbed across the gastrointestinal tract into the bloodstream. In addition, the relative bioavailability of the chemical under the exposure conditions (and media) compared with those under which the critical dose-response (toxicity) study was undertaken (typically dissolved in water or food) is important. Organisms, including humans, only respond to the fraction that is biologically available, therefore, the assumption of 100% bioavailability in this risk assessment would tend to overestimate risk. For PBDEs, limited information in available and it has been assumed that these chemicals will be 100% bioavailable from the MWOO mixed into soil. Given the log Kow for these chemicals is greater than 5, this is likely to be an overestimate of the amount of chemical that can be absorbed from the GI tract.

5.2.5 Inhalation of Impacted Dust

This pathway is considered where surface cover (grass or other vegetation) at a site may be limited.

For the purposes of this assessment, it has been assumed that there is potential for poor surface cover. Locations with poor surface cover can result in the generation of dust from wind or mechanical (such as landscaping, cultivation or mowing) disturbance. The potential concentration of PBDEs in dust that might be in air as a result of wind erosion and other typical site activities has been estimated using a Particulate Emission Factor (PEF).

A PEF is a ratio of the concentration of contaminants in soil (mg/kg) to the concentration of contaminants in air (mg/m^3). The concentration of particulates in air can be estimated using the surface soil concentrations listed in **Table 26** and the PEF. The PEF has been estimated using equations for outdoor workers provided in USEPA Guidance (USEPA 1996b, 2002).

$$PEF = \frac{\frac{Q}{C} * 3600}{0.036 * (1 - V) * \left(\frac{Um}{Ut}\right)^3 * F_x}$$

Where

PEF = particulate emission factor outdoors (mg/kg soil per mg/m^3 air)

Q/C = air dispersion factor which describes the dispersion of soil particles in the atmosphere of a theoretical outdoor box. The conservative default value assumed in the NEPM for application across Australia is 90.8 (g/m2/s per kg/m3). Site specific values can be calculated using Appendix D in the USEPA guidance (USEPA 2002) ($\frac{Q}{C} = A\ x\ \exp[\frac{(lnA_{site} - B)^2}{C}$) where A,B and C are constants based on air dispersion modelling for specific climate zones in the US. The values used are A=16.2302; B=18.7762 and C=216.108 which are the 90th percentile values for the 29 different meteorological zones modelled. The site specific value for A_{site} has been used.

V = the fraction of outdoor surface cover (0=bare soil) (50% vegetation cover has been assumed)

Um = mean annual windspeed at a height of 10 m (m/s) (mean annual 9am and 3pm windspeed from Scoresby Research Institute Met Station – 3.6 m/s – NEPM assumption based on a conservative value suitable across all of Australia for development of guidelines)

Ut = threshold wind speed at a height of 10 m which is required to generate dust from an erodible surface at a given site (USEPA default value used – 11.3 m/s – NEPM assumption based on an extremely conservative value suitable across all of Australia for development of guidelines)

Fx = empirical function based on the ratio of the mean and threshold windspeeds

$Fx = 0.18 * (8x^3 + 12x)\exp(-x^2)$ where x = 0.886 (Ut/Um)

This approach is considered suitable for the assessment of dust exposures by individuals in outdoor areas who could also be involved in moderate digging (including playing in outdoor soil by children and gardening) and other landscaping activities. This is also considered appropriate for the assessment of potential exposures in areas at any time when maintenance works are occurring or wind erosion has the potential to occur. Calculation of the PEF and associated contaminant concentrations in air is presented in **Appendix F**.

The quantification of inhalation exposures once concentrations in air have been established using the PEF approach, has been undertaken in accordance with guidance provided by USEPA (USEPA 2009b). This guidance does not require the calculation of a daily chemical intake, rather the approach requires calculation of an inhalation exposure concentration using the following equation:

$$\text{Inhalation Exposure Conc}_p = C_a \bullet \frac{ET \bullet DF \bullet CC \bullet FI \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

where:

Ca = Concentration of chemical in air (mg/m^3) (PEF x soil concentrations as per **Table 26**)

ET = Exposure time (hours/day) – assumed to be 24 hours per day

DF = Deposition fraction, fraction of inhaled dust retained in the respiratory tract (not exhaled), taken to be 75% (0.75) as per (enHealth 2012a; NEPC 1999 amended 2013e) (unitless)

CC = Cilliary clearance factor, fraction of the inspirable dust that is small enough to reach the pulmonary alveoli, taken to be 50% (or 0.5) as per (enHealth 2012a; NEPC 1999 amended 2013e) (unitless)

FI = Fraction inhaled from contaminated source (unitless) assumed to be 100%

EF = Exposure frequency (days/year), refer to **Table 27**

ED = Exposure duration, refer to **Table 27**

AT = Averaging time for threshold exposures, (=ED x 365 days x 24 hours)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days x 24 hours)

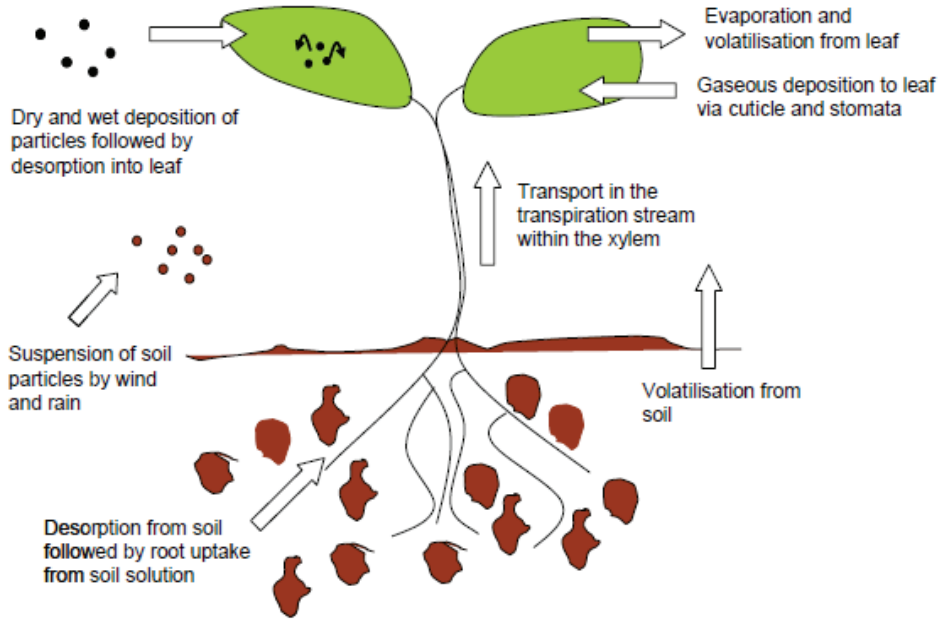
5.2.6 Ingestion of Contaminants present in Home Grown Vegetables

It is noted that the Resource Recovery Order and Exemption that set the framework for application of MWOO to agricultural land specifically prohibited application to land where root or tuber vegetables might be grown or where vegetables are grown close to the soil where they may come into contact with soil. *(Definition in Resource Recovery Order – **broad acre agricultural use** means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.)*

Consumption of these types of vegetables have been assessed here to provide information for management should farmers or farm workers have a vegetable patch at the farm in an area where MWOO has been applied. It is acknowledged that this is an unlikely scenario – a vegetable patch located in a field where these materials have been applied – as it is expected that such a patch is more likely to be close to the farm house.

The ASC NEPM has adopted the approach taken by the UK Environment Agency to calculate the uptake of chemicals in soil into plants (UK EA 2009). The Environment Agency in the UK undertook a review of models that are used to estimate uptake in plants from contaminated soil (UK EA 2009). The diagram below summarises all the different pathways by which contaminants can enter plants. For PBDEs present in soil due to the application of MWOO, the only pathway that is relevant is desorption from soil/MWOO into soil solution with root uptake from soil solution followed by transport throughout the rest of the plant via the xylem.

Figure 2-1: Principal pathways for plant uptake of organic chemicals



Schedule B7 Appendix A5 of the ASC NEPM (2013) provides a summary of the likelihood for PBDEs to be taken up by plants (NEPC 1999 amended 2013e).

As per Schedule B7, limited data is available on the potential for PBDEs to be taken up by plants from soil into edible fruit and vegetable crops.

ATSDR notes that PBDEs will be strongly adsorbed to soil, hence PBDEs present in soil-pore water will bind to soil organic matter. Because PBDEs adsorb strongly to soil, they will have very low mobility, and leaching of PBDEs from soil to groundwater will be insignificant which implies that there will be low uptake into plants (ATSDR 2017).

However, review of plant uptake of deca-PBDE (BDE-209) into plants from soil by Huang et al. (2010) suggests that deca-BDE is taken up and translocated within the plants assessed (ryegrass, alfalfa, pumpkin, squash, maize and radish). Nineteen lower brominated (di- to nona-) PBDEs were detected in the soil and plant samples and five hydroxylated congeners were detected in the plant samples, indicating debromination and hydroxylation of BDE-209 in the soil−plant system. Evidence of a relatively higher proportion of penta- through to di-BDE congeners in plant tissues than in the soil indicates that there is further debromination of PBDEs within plants or lower brominated PBDEs are more readily taken up by plants (Huang et al. 2010).

Other studies have evaluated uptake into maize and other crop species for a range of these chemicals (Yang et al. 2018; Zhao et al. 2012). Uptake into maize and sweet potatoes was reported in these studies.

The study in maize noted that uptake mainly occurred into the roots of the maize plants. There was translocation within the plant into stems and leaves and into the edible portion but the amount of PBDEs that transferred from the roots decreased the further from the roots they travelled through the plant. Also, this study used hydroponic techniques which means there was no soil in the experiment and there was a direct relationship between transpiration rate of water moving through the plant and concentration of PBDEs in the bottom stem of the plant. This is definitely a worst-case assessment of uptake as, if soil was present, partitioning between organic carbon and the water in the soil would limit how much was in the soil-water which would limit how much was taken up by the plant. This means that a transfer factor based on uptake into stems and leaves is likely to be an overestimate of uptake into the edible portion of the plant (seeds) (Zhao et al. 2012).

The more recent paper included a summary of uptake into a range of plant species (Yang et al. 2018). Factors for uptake into crop species ranged from 0.1-0.5 averaged for the sum of these congeners. Factors for uptake into a range of grass species ranged between 5 and 19 with most in the range 5-8. A value of 7 was chosen for as a reasonable upper end estimate for the Interim HHERA (Yang et al. 2018).

As discussed in **Section 3.5**, a further review of these results highlighted an issue with the value chosen. For this updated assessment, a value of 0.1 has been used.

Basis of Calculation

The ASC NEPM has adopted the approach taken by the UK Environment Agency to calculate the uptake of chemicals in soil into plants (UK EA 2009). This guidance document considered studies that are based on the uptake of these contaminants into green vegetables, root vegetables, tuber vegetables, herbaceous fruit, shrub fruit and tree fruit.

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

Fraction Home Grown (FHG)

It has been assumed, for the purposes of this assessment, that 35% of a person's intake of fruit and vegetables might come from produce grown at a site where MWOO has been applied. This is based on the following:

- A farm is more likely to grow one or two species in the fields where this material is applied so it is unlikely that 100% of a person's intake of fruit and vegetables could come from such a site every day of the year

- Common value applied at contaminated sites where significant amounts of home grown produce may be consumed (Cross & Taylor 1996)

This value has also been adopted for intake of wheat/oats.

Uptake Calculations

Interim HHERA

The ASC NEPM Schedule B7 Appendix B outlines the equations to develop plant uptake factors for each contaminant of interest (NEPC 1999 amended 2013e). Chemical specific plant uptake factors were calculated using the equations and defaults from the ASC NEPM Schedule B7 Appendix B (NEPC 1999 amended 2013e). The equations and defaults are outlined in **Appendix E** of this report. The calculations are included in **Appendix F**.

Calculation of the plant uptake factors has assumed a soil organic carbon content of 2% as detailed in Schedule B7 in the ASC NEPM (2013) – it is expected that horticultural or cropping land will be augmented with organic carbon to maximise yield (NEPC 1999 amended 2013e).

In this assessment, modelling has been undertaken to estimate concentrations that may be present in the vegetables, fruit or other crops that may be grown at sites where MWOO may have been applied to estimate exposure to PBDEs for people who might consume these foods.

Uptake Factors are calculated for different crops on the basis of the following equation:

$$UF = (kg/day) \quad (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit})$$

where:

CFy = plant uptake factors relevant for produce type (y), chemical specific value (mg/kg fresh weight produce to mg/kg dry weight soil), as per **Table 28**

Cy = Consumption rate of each produce type (y) (kg/day), as per **Table 28**

Table 28 Summary of Factors Adopted for Quantifying Plant Uptake (Interim HHERA)

	Produce Group			
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Consumption Rate – Children (kg/day)	0.055	0.017	0.028	0.18
Consumption Rate – Adults (kg/day)	0.15	0.047	0.060	0.14
Calculated Plant Uptake Factors for Key Chemicals (mg/kg fresh weight to mg/kg soil dry weight)				
Br1 to Br9	2.63E-03	2.30E-02	2.88E-01	2.42E-03
Deca BDE	2.84E-04	1.80E-03	1.59E-02	1.07E-04

Updated HHERA

An update to the approach for modelling uptake into plants was used for this HHERA. Older models for modelling uptake into roots and then for moving the chemicals from the roots to the above ground part of the plant are available (Briggs et al. 1982; Travis & Arms 1988). These older models were developed by USEPA.

The approach adopted in the Interim HHERA was difficult to apply for PBDEs due to the high log Kow for these chemicals. The older models appeared to work more effectively for these chemicals so this assessment has used these older models. The details of the approach are included in **Appendix E**. Calculations are presented in **Appendix F**.

In regard to production of fruit, vegetables or other crops, these chemical specific uptake factors and the estimated concentrations can be used to assess exposure using the following equations and assumptions:

$$DailyChemicalIntake_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs	= Concentration in soil (mg/kg), as per **Table 26**
UF	= Uptake factor relevant for the uptake from soil into different produce (kg/day) (Combined value)
FHG	= Fraction of all fruit and vegetable produce consumed that is home grown (unitless) – assumed to be 35% of diet
EF	= Exposure frequency (days/year), assumed to be 365 days per year
ED	= Exposure duration, 29 years for adults, 6 years for children
BW	= Body weight (kg), 70 kg for adults, 15 kg for children
AT	= Averaging time for threshold exposures, (=ED x 365 days)
AT(NT)	= Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix F**.

5.2.7 Ingestion of Contaminants present in Eggs

Given the persistent nature of PBDEs there is potential for their uptake from treated soil into eggs produced from hens kept on a site.

It is noted that the Order permitting the use of MWOO specifically excluded using the waste in places where chickens may be kept. Uptake into eggs has been assessed to provide detailed information for NSW EPA should this have occurred at a site *(Definition in Resource Recovery Order – **broad acre agricultural use** means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.)*

This exposure pathway has been assessed to inform future land management. It is acknowledged that it is an unlikely exposure scenario.

The Californian OEHHA (OEHHA 2012) provide chicken egg transfer factors for polychlorinated biphenyls and polychlorinated dibenzo-*p*-dioxins/furans. These chemicals are similar in structure to polybrominated diphenyl ethers. For this assessment, an uptake for the chicken to egg transfer factor of 10 mg/kg (in the egg) per mg/d (taken in by the chicken) has been used for the brominated BDEs (1-9) (based on the highest value from PCBs and dioxins) and a factor of 3 mg/kg (in the egg) per mg/d (taken in by the chicken) for decaBDE (based on octachlorinated dibenzo-*p*-dioxin).

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

In this HHERA, modelling has been undertaken to estimate concentrations that may be present in eggs. These concentrations have also been used to estimate uptake of PBDEs into people living at a site where MWOO may have been applied to soil where chickens are kept and where the eggs are consumed on farm.

The approach adopted for the quantification of uptake into eggs is in accordance with OEHHA (OEHHA 2012) which is based on a transfer factor and the potential intake of the contaminants by the hen. Calculations are presented in **Appendix F**. The approach adopted is presented below.

To calculate the concentration in eggs the following approach was followed:

$$C_{eggs} = (DailyIntake)_{hens} \bullet (TransferFactor)(mg/kgfreshweight)$$

where:

$$TransferFactor = \frac{\frac{mg}{kg} in\ eggs\ freshweight}{\frac{mg}{day} intake\ of chemicals\ by\ hens}(day/kg)$$

Transfer factors:

Br1 to Br9 = 10 d/kg (OEHHA 2012)
Deca BDE = 3 d/kg (OEHHA 2012)

And

$$Average\ Daily\ intake_{chickens} = C_{soil} * IR_{soil} * B * \frac{EF * ED}{AT}$$

where:

C_{soil} = Concentration of PBDEs in soil (mg/kg), (as per **Table 26**)
IR_{soil} = Ingestion rate of soil by hens (kg/day). The ingestion rate of soil by hens is not well studied. A value of 0.001 kg/day is recommended in (Travis & Hattemer-Frey 1991). A value of 0.01 kg/day is recommended in (OEHHA 2012). A value of 0.022 kg/day is recommended in (USEPA 2005). These values are primarily based on an intake of soil assumed to be 10% of the total diet. This assessment has used 0.01 kg/day as this value is from the most recently published reference.
B = Bioavailability of PBDEs via ingestion. Additionalwork in 2019 investigated the bioaccessibility of PBDEs in MWOO for cattle as an estimate of bioavailability (discussed in **Section 3.4.1**). This work confirmed that not all of the PBDEs were able to be taken into the body. While it is likely to be an overestimate, this assessment has still assumed that the PBDEs are 100% bioavailable to the chickens as the work from cattle is not directly transferable.
EF = Exposure frequency (days/year), assumed to be 365 days per year
ED = Exposure duration, taken to be 8 years
AT = Averaging time for threshold exposures, (=ED x 365 days)

The concentrations in eggs have been estimated using this approach and the spreadsheets showing these calculations are in **Appendix F**.

Table 29 Concentration in Eggs (mg/kg) (mean case)

Scenario	Exposure Concentration (mg/kg)	Daily Intake Chickens (mg/d)	Concentration in Eggs (mg/kg)
PBDEs (Br1 to Br9)			
Cropping Land			

Scenario	Exposure Concentration (mg/kg)	Daily Intake Chickens (mg/d)	Concentration in Eggs (mg/kg)
Interim HHERA	0.5	0.0025	0.03
Overall Dataset	0.1	0.001	0.01
DecaBDE			
Cropping Land			
Interim HHERA	0.02	0.0001	0.0003
Overall Dataset	0.02	0.0002	0.002

In regard to egg production for on farm consumption, exposure to PBDEs can be assessed for those living at the site using the egg concentrations and the consumption rate of eggs.

The most recent review of ingestion rates for eggs in Australia were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b). The 90% intake for people who reported consuming eggs on the day of the dietary survey ranges between 0.036 kg/day for children to 0.059 kg/day for adults. It is considered appropriate to use this estimate of high end consumption of eggs for on farm consumption. It is likely that all the eggs consumed by a household that keeps chickens would be from chickens kept at the site (FSANZ 2011).

The daily intake of PBDEs from the consumption of eggs was calculated as follows:

$$DailyChemicalIntake_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet B \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{eggs}	= concentration in eggs, calculated as outlined above (mg/kg fresh weight) (see **Table 29**)
IR_{eggs}	= ingestion rate of eggs (kg/day), taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b) of 0.036 kg/day for children 2-5 years and 0.059 kg/day for adults
FHG	= fraction of the daily diet that is derived from home grown source, taken to be 100% (or 1) for on farm consumption of eggs
B	= bioavailability – assumed to be 100%
EF	= Exposure frequency (days/year), assumed to be 365 days per year
ED	= Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013e)
BW	= Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013e)
AT	= Averaging time for threshold exposures, (=ED x 365 days)
AT(NT)	= Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix F**.

It should be noted that there are significant uncertainties in this modelling including:

- bioavailability/bioaccessibility of PBDEs for people consuming the eggs
- variability in transfer factors
- variability in the soil ingestion rate amongst individual animals.

5.2.8 Ingestion of Contaminants present in Milk

Given the persistent nature of these chemicals there is potential for their uptake from treated soil into milk.

The Californian OEHHA (OEHHA 2012) provides transfer factors for this type of chemical from soil (or feed) into milk from cattle. Transfer factors are listed in this guidance for polychlorinated biphenyls and polychlorinated dibenzo-*p*-dioxins/furans. These chemicals are similar in structure to polybrominated diphenyl ethers so they have been adopted for use in this assessment.

For the interim HHERA, a transfer factor for soil into milk of 0.04 mg/kg (in milk) per mg/kg bw/d (daily intake for cattle) could be used for PBDEs (Br1 to Br9) based on the highest value from PCBs and dioxins. For decaBDE, a transfer factor of 0.0006 mg/kg (in milk) per mg/kg bw/d (daily intake for cattle) based on octachlorinated dibenzo-*p*-dioxin could be used.

The additional work in 2019 by the OCSE Panel reviewed the transfer factors for cattle as discussed in **Section 3.4.4**. As a result, the transfer factors for uptake into milk have been adjusted for this assessment.

For this HHERA, a transfer factor for soil into milk of 0.01 mg/kg (in milk) per mg/kg bw/d (daily intake for cattle) has been used for the PBDEs (Br1 to Br9). For decaBDE, the transfer factor remains unchanged.

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

Given this limitation, exposure via milk has been modelled. Modelling has been undertaken to estimate concentrations that may be present in milk. These concentrations have also been used to estimate uptake of PBDEs into people living at the site who produce milk for on farm consumption.

The approach adopted for the quantification of uptake into milk is in accordance with OEHHA (OEHHA 2012) which is based on a transfer factor and the potential intake of the contaminants by cattle. Calculations are presented in **Appendix F**. The approach adopted is presented below.

To calculate the concentration in milk, the following approach was followed:

$$C_{milk} = (DailyIntake) \bullet (TransferFactor)(mg/kgfreshweight)$$

where:

$$TransferFactor = \frac{\frac{mg}{kg} in\ milk\ freshweight}{\frac{mg}{day} intake\ of chemicals\ by\ livestock} (day/kg)$$

Transfer factors:
Br1 to Br9 = 0.01 d/kg (as discussed in **Section 3.4.4)**
Deca BDE = 0.0006 d/kg (as discussed in **Section 3.4.4)**

And

$$Daily\ intake_{dairy\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT}$$

where:

C_{soil}	= Concentration of PBDEs in soil (mg/kg), (as per **Table 26**)
IR_{soil}	= Ingestion rate of soil by cattle (kg/day) as discussed in **Section 3.4.2** this value has been changed for this assessment, the value used is as per **Table 30**
IR_{fodder}	= ingestion rate of fodder (kg/day) as per **Table 30**
Transfer factor (soil to plant)	= 0.1 mg/kg (plant) / mg/kg (soil) PBDEs (Br1 to Br9 = 0.01 mg/kg (plant) / mg/kg (soil) DecaBDE as discussed in **Section 3.5**
B	= Bioavailability of PBDEs via ingestion of soil by the cattle. The interim HHERA assumed PBDEs were 100% bioavailable to the grazing animals. As noted in that report this was likely to be an overestimate. For this assessment, the bioaccessibility measurements discussed in **Section 3.4.1** provide an estimate of bioavailability that is more relevant for this material. In this case values of 12 and 30% for PBDEs (Br1 to Br9) and 4 and 15% for DecaBDE have been used in this HHERA.
EF	= Exposure frequency (days/year), assumed to be either 52 days per year or 183 days per year as discussed in **Section 3.4.3**
ED	= Exposure duration, taken to be 4 years
AT	= Averaging time for threshold exposures, (=ED x 365 days)

Table 30 Summary of Factors Relevant forDetermining Uptake into Grazing Animals that Produce Milk

Grazing Animal	Soil Ingestion (kg/day)	Body Weight (kg)	Fodder Ingestion (kg/day)
Cattle	0.5 (USEPA 2005)	500 (NSW DPI advice)	20 (ANZG 2018)

The concentrations in milk for the mean case for each scenario have been estimated using this approach and the spreadsheets showing these calculations are in **Appendix F**.

In regard to intake of milk on farm, exposure to PBDEs can be assessed for those living at the site using the concentrations in milk and the consumption rate for milk. The ingestion rates for milk were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b). The 90% intake for people who reported consuming milk on the day of the dietary survey ranges between 1.097 kg/day for children to 1.295 kg/day for adults. It might be possible that all the milk consumed on farm would be from cattle at the site, but this will depend on the amount of milk produced and the number of people consuming the milk.

The daily intake of PBDEs from the consumption of milk produced at the site was calculated as follows:

$$DailyChemicalIntake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet B \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{milk}	= concentration in milk, calculated as per **Table 31** (mg/kg fresh weight)
IR_{milk}	= ingestion rate of milk (kg/day), taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b) of 1.097 kg/day for children 2-5 years and 1.295 kg/day for adults
FHG	= fraction of the daily diet that is derived from home grown source, taken to be 100% (or 1) for on farm consumption
B	= bioavailability– assumed to be 100% for people as what is present in milk represented the bioavailable/bioaccessible fraction for the cattle and the data available for the cattle may not be directly transferable to people
EF	= Exposure frequency (days/year), assumed to be 365 days per year
ED	= Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013e)
BW	= Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013e)
AT	= Averaging time for threshold exposures, (=ED x 365 days)
AT(NT)	= Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix F**.

It should be noted that there are significant uncertainties in this modelling including:

- bioavailability/bioaccessibility of PBDEs for people consuming the milk
- variability in transfer factors
- variability in the soil ingestion rate amongst individual animals.

5.2.9 Ingestion of Contaminants present in Meat

Given the persistent nature of these chemicals there is potential that they will be taken up into meat produced if livestock kept at a site are used for on farm consumption.

The Californian OEHHA (OEHHA 2012) provides transfer factors for this type of chemical from soil (or feed) into meat from cattle. The transfer factors are for polychlorinated biphenyls and polychlorinated dibenzo-*p*-dioxins/furans. These chemicals are similar in structure to polybrominated diphenyl ethers so they have been adopted for use in this assessment.

For the Interim HHERA, an uptake for soil into meat transfer factor of 2 mg/kg (in meat) per mg/kg bw/d (taken in by cattle will be used for PBDEs (Br1 to Br9) (based on the highest value from PCBs and dioxins) and a factor of 0.02 mg/kg (in meat) per mg/kg bw/d (taken in by cattle) for deca BDE (based on octachlorinated dibenzo-*p*-dioxin) (OEHHA 2012).

The additional work in 2019 by the OCSE Panel reviewed the transfer factors for cattle as discussed in **Section 3.4.4**. As a result, the transfer factors for uptake into meat have been adjusted for this assessment.

For this HHERA, a transfer factor for soil into meat of 0.53 mg/kg (in meat) per mg/kg bw/d (daily intake for cattle) has been used for the PBDEs (Br1 to Br9). For decaBDE, the transfer factor remains unchanged.

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

Given this limitation, exposure via meat has been modelled. Modelling has been undertaken to estimate concentrations that may be present in meat. These concentrations have also been used to estimate uptake of PBDEs into people living at the site who produce meat for on farm consumption.

Using the approach outlined by OEHHA (OEHHA 2012, 2014) a concentration in meat for the various livestock can be calculated using the following equations.

To calculate the concentration in meat in grazing animals the following approach was followed:

$$C_{meat} = (DailyIntake)_{grazinganimal} \bullet (TransferFactor)(mg/kgfreshweight)$$

where

Transfer factors:
Br1 to Br9 = 0.53 d/kg (as discussed in **Section 3.4.4)**
Deca BDE = 0.02 d/kg (as discussed in **Section 3.4.4)**

And

$$Daily\ intake_{beef\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} *\ Transfer\ factor\ (soil\ to\ plant) *\ IR_{fodder})) * B * EF * ED}{AT}$$

where:

C_{soil}	= Concentration of PBDEs in soil (mg/kg), (as per **Table 26**)
IR_{soil}	= Ingestion rate of soil by cattle (kg/day), as discussed in **Section 3.4.2,** this value has been changed for this assessment, the value used is as per **Table 31**
IR_{fodder}	= ingestion rate of fodder (kg/day) as per **Table 31**
Transfer factor (soil to plant)	= 0.1 mg/kg (plant) / mg/kg (soil) PBDEs (Br1 to Br9 = 0.01 mg/kg (plant) / mg/kg (soil) DecaBDE as discussed in **Section 3.5**
B	= Bioavailability of PBDEs via ingestion of soil by the cattle. The interim HHERA assumed PBDEs were 100% bioavailable to the grazing animals. As noted in that report this was likely to be an overestimate. For this assessment, the bioaccessibility measurements discussed in **Section 3.4.1** provide an estimate of bioavailability that is more relevant for this material. In this case values of 12 and 30% for PBDEs (Br1 to Br9) and 4 and 15% for DecaBDE have been used in this HHERA.
EF	= Exposure frequency (days/year), assumed to be either 52 days per year or 183 days per year as discussed in **Section 3.4.3**
ED	= Exposure duration, taken to be 2 years
AT	= Averaging time for threshold exposures, (=ED x 365 days)

Table 31 Summary of Factors Relevant for Determining Uptake into Grazing Animals

Grazing Animal	Soil Ingestion (kg/day)	Body Weight (kg)	Fodder Ingestion (kg/day)
Cattle	0.5 (USEPA 2005)	500 (NSW DPI advice)	20 (ANZG 2018)

The concentrations in meat for the mean case for each scenario have been estimated using this approach and the spreadsheets showing these calculations are in **Appendix F**.

The estimated meat concentrations for sheep are lower than those for cattle. The rest of the assessment has focused on consumption of beef.

In regard to meat production for on farm consumption, exposure to PBDEs can be assessed for those living at the site using the concentrations in meat and the consumption rate for meat. The ingestion rates for meat were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b). The 90% intake for people who reported consuming meat on the day of the dietary survey ranges between 0.085 kg/day for children to 0.163 kg/day for adults.

Consumption will be assessed assuming 35% of meat consumed is from the farm.

The daily intake of PBDEs from the consumption of meat produced at the site was calculated as follows:

$$DailyChemicalIntake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet B \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{meat} = concentration in meat, calculated as per **Table 33** (mg/kg fresh weight)

IR_{meat} = ingestion rate of meat (kg/day) taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b) of 0.085 kg/day for children 2-5 years and 0.163 kg/day for adults

FHG = fraction of the daily diet that is derived from home grown source, taken to be 50, 75 and 100% for home produced meat

B =bioavailability – assumed to be 100% for people as what is present in meat represented the bioavailable/bioaccessible fraction for the cattle and the data available for the cattle may not be directly transferable to people

EF = Exposure frequency (days/year), assumed to be 365 days per year

ED = Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013e)

BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013e)

AT = Averaging time for threshold exposures, (=ED x 365 days)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix F**.

It should be noted that there are significant uncertainties in this modelling including:

- bioavailability/bioaccessibility of PBDEs for people consuming the meat
- variability in transfer factors
- variability in the soil ingestion rate amongst individual animals.

Section 6. Exposure Assessment – Human Health – Soil – Per and Polyfluoroalkyl Substances (PFAS)

6.1 General

This section provides a short discussion on the potential receptors (human groups) and exposure pathways that are considered to be of significance in this assessment. In addition, where identified as of potential significance and warranting quantification in this assessment, the potential for exposure has been quantified using industry best practice and guidance available from (enHealth 2012a; NEPC 1999 amended 2013a; USEPA 1989, 2002, 2009b).

The assessment presented has addressed potential worst-case exposure to the key chemicals in soil and exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and therefore health risk.

The quantification of exposure has involved consideration of the following:

- Identification of relevant ***exposure parameters*** for each of the identified exposure pathways and receptors. The magnitude of the exposure is a function of a number of variables (termed exposure parameters), which describe the physical, and behavioural parameters relevant to the potentially exposed population. Exposure parameters which are considered representative have been selected. Where available, additional exposure data has been obtained from Australian sources (enHealth 2012a; NEPC 1999 amended 2013a); and
- Estimation of the ***chemical concentration*** in each medium relevant to the receptor groups and exposure pathways. This has involved the use of maximum concentrations reported in surface soil. Potential dust concentrations have been estimated on the basis of a particulate emission factor (that relates the concentration in air to that in soil) derived from guidance provided by the USEPA (USEPA 2002).

6.2 Quantification of Exposure – PFAS

6.2.1 Identified Receptors and Exposure Pathways

The targets of this assessment are the farmers/farm workers that may be exposed to land where these materials have been applied and consume produce grown at the farm. The general public are unlikely to be exposed to these materials.

The ASC NEPM low density residential scenario includes exposure to the soil while living at a property and doing routine garden maintenance, and where up to 10% of daily intake of fruit and vegetables may be derived from home grown produce.

For sites where these materials are applied to agricultural land it is possible that additional agricultural activities may occur including:

- Grazing of livestock (cattle/sheep)
- Cropping (wheat/oats/barley)
- Keeping poultry (for the purpose of producing eggs)

- Horticulture (fruit and vegetables – higher than expected in urban environments)

These agricultural activities are not included in the normal low density residential scenario assumed for the ASC NEPM so require separate evaluation.

It is noted that the Order permitting the use of MWOO specifically excluded using the waste in areas around a farm where vegetables might be grown or where chickens may be kept - *Definition in Resource Recovery Order – **broad acre agricultural use** means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.*

Uptake into these types of produce has been assessed to provide detailed information for NSW EPA should this have occurred at a site.

Table 32 Summary of Key Exposure Groups and Pathways

Receptor	Exposure Pathway/Mechanism
Farmers/farm workers	Incidental ingestion of surface soil and dust (tracked indoors) Dermal contact with surface soil and dust (tracked indoors) (negligible for PFAS) Inhalation of impacted dust generated from surface soil (negligible for PFAS) Ingestion of PFAS in milk from cattle kept at the site (consumed on farm) Ingestion of PFAS in meat from livestock kept at the site (consumed on farm) Ingestion of PFAS in home grown fruit and vegetables at site (consumed on farm) Ingestion of PFAS in eggs from poultry kept at the site (consumed on farm)

It is important to note that this assessment has focused on evaluating potential for on farm consumption of food stuffs by people living on a farm which has had MWOO applied. The risk calculations provided do not address the commercial food supply.

The approach taken to assess potential exposure to PFAS is similar to that described in **Section 5** for assessing exposure to PBDEs.

6.2.2 Background information on PFAS

PFAS are a family of fluorine-containing compounds with unique properties to make materials stain- and stick-resistant. PFAS are often described as being “ubiquitous in the environment”. They have been widely used in man-made products such as paints, roof treatments, hardwood floor protectant, surface protection products (e.g. carpet and clothing treatments) and coatings for cardboard and packaging. Some PFAS are, or were also historically used in, fire-fighting foams (also known as aqueous film-forming foams; AFFF). PFAS are not found in the environment from natural sources, only from anthropogenic sources (ATSDR 2018).

These chemicals are reported in a range of household items so they may be present in municipal waste and, as a result, in MWOO.

6.2.3 2018 Targeted Study

A limited number of samples collected during the NSW EPA commissioned research program were assessed for the presence of the two main chemicals in this family – PFOS and PFOA. One sample from each facility was assessed. Neither sample reported a detection for these two chemicals.

In 2018 a targeted study for PFAS in MWOO was undertaken by NSW EPA. A range of PFAS were analysed in this work. The chemicals that were detected included perfluoropentanoic acid,

perfluorohexanoic acid, perfluoroheptanoic acid, perfluorooctanoic acid (PFOA), perfluorononanoic acid, perfluorodecanoic acid, perfluorobutanesulfonate, perfluorohexanesulfonate, perfluorooctanesulfonate (PFOS). In addition, 1 fluorotelomer and 3 sulfonamides were detected. These are precursor compounds – i.e. they can breakdown to PFOS or PFOA in the environment. The concentrations detected in this targeted study are listed in **Table 33**.

Table 33 Concentrations of PFAS in MWOO – NSW EPA Dataset

Chemical	Average (mg/kg)	Maximum (mg/kg)$	95th Percentile (mg/kg)	Minimum (mg/kg)
Perfluoropentanoic acid (PFPeA)@	0.003	0.0028	0.005	0.002
Perfluorohexanoic acid (PFHxA)@	0.005	0.026	0.009	0.001
Perfluoroheptanoic acid (PFHpA)@	0.003	0.0011	0.005	0.001
Perfluorooctanoic acid (PFOA)@	0.004	0.0039	0.005	0.001
Perfluorononanoic acid (PFNA)@	0.003	0.0012	0.005	0.001
Perfluorodecanoic acid (PFDA)@	0.003	0.0055	0.005	0.001
Perfluorododecanoic acid (PFDoDA)@	ND	ND	ND	ND
FOUEA@	0.003	0.0025	0.005	0.001
Perfluorobutanesulfonate (PFBS)#	0.004	0.025	0.006	0.001
Perfluorohexanesulfonate (PFHxS)#	0.003	0.0023	0.005	0.001
Perfluorooctanesulfonate (PFOS)#	0.004	0.0062	0.005	0.002
N-MeFOSAA#	0.003	0.0043	0.005	0.002
N-MeFOSE#	0.008	0.011	0.01	0.005
N-EtFOSE#	0.007	0.0051	0.01	0.005
8:2 diPAP	ND	ND	ND	ND
Total for PFOA	0.03	0.06	0.04	0.01
Total for PFOS	0.04	0.07	0.05	0.02

@ = chemicals summed and assessed as PFOA

= chemicals summed and assessed as PFOS

$ = maximum concentration is maximum measured concentration above the limit of reporting. The calculations of average and 95th percentile include the limit of reporting for samples with no detections.

Due to the lack of toxicological information for some of the listed PFAS, some of the individual PFAS shown in **Table 33** have been summed for assessment – N-MeFOSAA, N-MeFOSE, N-EtFOSE, PFBS, PFHxS and PFOS have been summed and compared to the reference dose for PFOS; PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA and FOUEA have been summed and compared to the reference dose for PFOA. This is expected to be a conservative approach as these other chemicals are likely to be less toxic than PFOS or PFOA.

6.2.4 2018/2019 Additional Data

The additional samples that were collected late in 2018/2019 (discussed previously in regard to PBDE levels) were also analysed for PFAS – a longer list of individual substances compared to the previous study. The same approach as listed above to combine the chemicals for assessment has been used to screen these data. **Table 34** lists the results for the minimum, maximum, average and 95th percentile concentrations from this dataset.

Table 34 Concentrations of PFAS in MWOO (OCSE Dataset)

Chemical	Average (mg/kg)	Maximum (mg/kg)	95th Percentile (mg/kg)	Minimum (mg/kg)
Perfluorobutanoic acid (PFBA)@	0.03	0.5	0.2	0.01
Perfluoropentanoic acid (PFPeA)@	0.005	0.0053	0.005	0.005
Perfluorohexanoic acid (PFHxA)@	0.008	0.035	0.03	0.005
Perfluoroheptanoic acid (PFHpA)@	ND	ND	ND	ND
Perfluorooctanoic acid (PFOA)@	0.005	0.0085	0.005	0.005
Perfluorononanoic acid (PFNA)@	ND	ND	ND	ND
Perfluorodecanoic acid (PFDA)@	0.005	0.0093	0.008	0.005
Perfluoroundecanoic acid (PFUDA)@	ND	ND	ND	ND
Perfluorododecanoic acid (PFDoDA)@	ND	ND	ND	ND
Perfluorotridecanoic acid (PFTrDA)@	ND	ND	ND	ND
Perfluorotetradecanoic acid (PFTeDA)@	ND	ND	ND	ND
Perfluorohexadecanoic acid (PFHxDA)@	ND	ND	ND	ND
PFODA@	ND	ND	ND	ND
FOUEA@	ND	ND	ND	ND
8:2diPAP@	0.01	0.019	0.018	0.01
Perfluorobutanesulfonate (PFBS)#	0.005	0.011	0.005	0.005
Perfluoropentanesulfonate (PFPeS)#	ND	ND	ND	ND
Perfluorohexanesulfonate (PFHxS)#	0.005	0.0053	0.005	0.005
Perfluoroheptanesulfonate (PFHpS)#	ND	ND	ND	ND
Perfluorooctanesulfonate (PFOS)#	0.006	0.01	0.009	0.005
Perfluorononanesulfonate (PFNS)#	ND	ND	ND	ND
Perfluorodecanesulfonate (PFDS)#	ND	ND	ND	ND
PFOSA#	ND	ND	ND	ND
N-MeFOSA#	ND	ND	ND	ND
N-EtFOSA#	ND	ND	ND	ND
N-MeFOSAA#	ND	ND	ND	ND
N-EtFOSAA#	ND	ND	ND	ND
N-MeFOSE#	ND	ND	ND	ND
N-EtFOSE#	ND	ND	ND	ND
4:2 FTS#	ND	ND	ND	ND
6:2 FTS#	ND	ND	ND	ND
8:2 FTS#	ND	ND	ND	ND
10:2 FTS#	ND	ND	ND	ND
Total for PFOA	0.12	0.64	0.3	0.1$
Total for PFOS	0.11	0.12	0.11	0.1$

@ = chemicals summed and assessed as PFOA

= chemicals summed and assessed as PFOS

$ = sum of all minimum values for each group – i.e. the limits of reporting for chemicals

Due to the lack of toxicological information for some of the listed PFAS, some of the individual PFAS shown in **Table 34** have been summed for assessment – N-MeFOSAA, N-MeFOSE, N-EtFOSE, PFBS, PFPeS, PFHpS, PFOS, PFHxS, PFNS, PFDS, PFOSA, N-MeFOSE, N-EtFOSE N-MeFOSA, N-EtFOSA, N-MeFOSAA, N-EtFOSAA, 4:2 FTS, 6:2 FTS, 8:2 FTS and 10:2 FTS have been summed and compared to the reference dose for PFOS; PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, PFHxDA, PFODA, 8:2-diPAP and FOUEA have been summed and compared to the reference dose for PFOA. This is expected to be a conservative approach as these other chemicals are likely to be less toxic than PFOS or PFOA.

Many of the individual PFAS were not detected in any samples. These included PFHpA, PFNA, PFUDA, PFDoDA, PFTrDA, PFTeDA, PFHxDA, PFODA, FOUEA, PFPeS, PFHpS, PFNS, PFDS, PFOSA, N-MeFOSE, N-EtFOSE N-MeFOSA, N-EtFOSA, N-MeFOSAA, N-EtFOSAA, 4:2 FTS, 6:2 FTS, 8:2 FTS and 10:2 FTS.

Some PFAS were detected on occasion (i.e. less than 30%) including PFPeA, PFOA, PFDA, PFBS, PFHxS and 8:2diPAP.

Only a small number of PFAS were detected more often (i.e. greater than 30% of the time) including PFOS, PFBA and PFHxA.

6.2.5 Exposure Concentrations

Concentrations for use in modelling exposure of PFAS to people and other organisms from MWOO have been calculated in a similar fashion to the approach taken for PBDEs discussed in **Sections 3.3.4** and **5.2.3**.

For cropping areas, an application rate of 10 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. This results in a concentration in soil 130 times lower than that reported for the original MWOO material. The cropping area concentrations are relevant for the assessment of exposure for ingestion of fruit, vegetables, crops and eggs as well as direct contact with soil.

For grazing land, it is assumed that livestock can be exposed to undiluted MWOO or MWOO that has been trampled into the top of the soil layer beneath the grass. It is noted that the regulation of MWOO required that livestock not be reintroduced to treated areas for at least 30 days after treatment.

Concentrations have been determined based on no dilution or where the material has been trampled into the top 2 cm of soil. For no dilution, the concentrations measured in MWOO are relevant. For the situation where the material has been trampled in it has been assumed that MWOO is applied at a rate of 10 tonnes/hectare, with a mixing depth of 2 cm and a soil bulk density of 1300 kg/m^3. This results in a concentration in soil 26 times lower than that reported for the original MWOO material.

These two sets of concentrations for grazing areas are relevant for the assessment of exposure for ingestion of meat and milk as well as direct contact with soil.

The exposure concentrations determined using this approach are listed in **Table 35**.

Table 35 Exposure Concentrations

Scenario	Average Concentration (mg/kg)	Maximum Concentration (mg/kg)	95th Percentile Concentration (mg/kg)	Minimum Concentration (mg/kg)	Median Concentration (mg/kg)
PFOS					
Cropping Land					
Interim HHERA	0.0003	0.0005	0.0004	0.0002	--
Overall Dataset	0.0008	0.001	0.0008	0.0006	0.0008
Grazing Land – no incorporation					
Interim HHERA	0.04	0.07	0.05	0.02	--
Overall Dataset	0.1	0.13	0.11	0.08	0.1
Grazing Land – trampled into the soil					

Scenario	Average Concentration (mg/kg)	Maximum Concentration (mg/kg)	95th Percentile Concentration (mg/kg)	Minimum Concentration (mg/kg)	Median Concentration (mg/kg)
Interim HHERA	0.002	0.003	0.002	0.0008	--
Overall Dataset	0.004	0.005	0.004	0.003	0.004
PFOA					
Cropping Land					
Interim HHERA	0.0002	0.0005	0.0003	0.00008	--
Overall Dataset	0.0009	0.005	0.002	0.0005	0.0008
Grazing Land – no incorporation					
Interim HHERA	0.03	0.06	0.04	0.01	--
Overall Dataset	0.12	0.64	0.3	0.06	0.1
Grazing Land – trampled into the soil					
Interim HHERA	0.001	0.002	0.002	0.0004	--
Overall Dataset	0.005	0.02	0.01	0.002	0.004

6.2.6 Ingestion and Dermal Contact with Treated Soil

Soil Ingestion

Ingestion of soil (direct incidental ingestion) is one of the key pathways of exposure relevant for the assessment of exposures.

As noted in Section 5.3.1.2 of Schedule B7 of the ASC NEPM, another pathway of exposure to soil is incidental ingestion of soil that is adhered to home grown produce (like carrots or potatoes). The UK Environment Agency has developed a methodology to estimate how much soil people are likely to consume in this way from home grown produce (i.e. indirect incidental ingestion). The approach found that 2-3 mg of soil is ingested via this pathway. The ingestion rate currently used in the calculations for the national health investigation levels is considered to be sufficient to cover direct and indirect incidental ingestion of soil.

The potential intake of PFAS identified in surface soil via incidental ingestion (direct and indirect) has been undertaken using the following equation:

$$\text{Daily Chemical Intake}_{is} = C_s \bullet \frac{IRs \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs = Concentration of treated soil (mg/kg), as per **Table 35**
IRs = Ingestion rate of soil (mg/day)
FI = Fraction of daily ingestion that is derived from contamination source (unitless), taken as 1
B = Bioavailability or absorption of chemical via ingestion (unitless), taken as 1
CF = Conversion factor of $1x10^{-6}$ to convert mg to kg
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via soil ingestion for a child or an adult are presented in **Table 36**. All calculations are presented in **Appendix G**.

Table 36 Summary of Exposure Parameters Adopted –Ingestion with Soil

Exposure Parameter	Value adopted for Child (aged 0-5 years)	Value adopted for adults
Ingestion rate (soil)	100 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013e)	50 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013e)
Exposure frequency	365 days per year	365 days per year
Exposure duration	6 years as a young child	29 years as an adult assuming a total of 35 years residency at the same location as a child and adult (NEPC 1999 amended 2013e)
Body weight	15 kg (NEPC 1999 amended 2013e)	70 kg (NEPC 1999 amended 2013e)
Bioavailability	100%	100%

Bioavailability: Bioavailability is an important factor for determining the amount of a chemical that is absorbed into the body as has been discussed in **Section 3.4.1**. Given the water solubility of PFAS, these chemicals are always assumed to be 100% bioavailable.

Dermal Exposures

Dermal absorption of chemicals from soil depends on the area of skin in contact with soil, the duration of contact, how well sorbed the chemical is to the soil and the ability of the chemical to penetrate the skin.

The assessment of the potential dermal absorption of PFAS would normally be undertaken using the general approach presented by the USEPA. They define a simple approach to the evaluation of dermal absorption associated with soil contact (USEPA 1989, 2004). This is presented in the following equation:

$$\text{Daily Chemical Intake} = C_s \bullet \frac{SAs \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs = Concentration in soil (mg/kg), as per **Table 35**
SAs = Surface area of body exposed to soil per day (cm^2/day)
AF = Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil properties and area of body (mg/cm^2 per event)
ABSd = Dermal absorption fraction (unitless), refer to note below
CF = Conversion factor of $1x10^{-6}$ to convert mg to kg
EF = Exposure frequency (days/year)
ED = Exposure duration, taken to be 6 years for children and 29 years for adults
BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per ASC NEPM 1999
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

Dermal absorption: For PFAS, limited information is available in regard to dermal absorption, but it is expected to be extremely limited given that these chemicals are ions at relevant pH. Ionised chemicals do not move through the skin easily.

6.2.7 Inhalation of Impacted Dust

This pathway is considered where surface cover (grass or other vegetation) at a site may be limited.

For the purposes of this assessment, it has been assumed that there is potential for poor surface cover. Locations with poor surface cover can result in the generation of dust from wind or mechanical (such as landscaping, cultivation or mowing) disturbance. The potential concentration of

PFAS in dust that might be in air as a result of wind erosion and other typical site activities has been estimated using a Particulate Emission Factor (PEF).

A PEF is a ratio of the concentration of contaminants in soil (mg/kg) to the concentration of contaminants in air (mg/m^3). The concentration of particulates in air can be estimated using the surface soil concentrations listed in **Table 35** and the PEF. The PEF has been estimated using equations for outdoor workers provided in USEPA Guidance (USEPA 1996b, 2002).

$$PEF = \frac{\frac{Q}{C} * 3600}{0.036 * (1 - V) * \left(\frac{Um}{Ut}\right)^3 * F_x}$$

Where

PEF = particulate emission factor outdoors (mg/kg soil per mg/m^3 air)

Q/C = air dispersion factor which describes the dispersion of soil particles in the atmosphere of a theoretical outdoor box. The conservative default value assumed in the NEPM for application across Australia is 90.8 (g/m2/s per kg/m3). Site specific values can be calculated using Appendix D in the USEPA guidance (USEPA 2002) ($\frac{Q}{C} = A\ x\ \exp[\frac{(lnA_{site} - B)^2}{C}$) where A,B and C are constants based on air dispersion modelling for specific climate zones in the US. The values used are A=16.2302; B=18.7762 and C=216.108 which are the 90th percentile values for the 29 different meteorological zones modelled. The site specific value for A_{site} has been used.

V = the fraction of outdoor surface cover (0=bare soil) (50% vegetation cover has been assumed)

Um = mean annual windspeed at a height of 10 m (m/s) (mean annual 9am and 3pm windspeed from Scoresby Research Institute Met Station – 3.6 m/s – NEPM assumption based on a conservative value suitable across all of Australia for development of guidelines)

Ut = threshold wind speed at a height of 10 m which is required to generate dust from an erodible surface at a given site (USEPA default value used – 11.3 m/s – NEPM assumption based on an extremely conservative value suitable across all of Australia for development of guidelines)

Fx = empirical function based on the ratio of the mean and threshold windspeeds

$Fx = 0.18 * (8x^3 + 12x)\exp(-x^2)$ where x = 0.886 (Ut/Um)

This approach is considered suitable for the assessment of dust exposures by individuals in outdoor areas who could also be involved in moderate digging (including playing in outdoor soil by children and gardening) and other landscaping activities. This is also considered appropriate for the assessment of potential exposures in areas at any time when maintenance works are occurring or wind erosion has the potential to occur. Calculation of the PEF and associated contaminant concentrations in air is presented in **Appendix G**.

The quantification of inhalation exposures once concentrations in air have been established using the PEF approach, has been undertaken in accordance with guidance provided by USEPA (USEPA 2009b). This guidance does not require the calculation of a daily chemical intake, rather the approach requires calculation of an inhalation exposure concentration using the following equation:

$$\text{Inhalation Exposure Conc}_p = C_a \bullet \frac{ET \bullet DF \bullet CC \bullet FI \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

where:

Ca = Concentration of chemical in air (mg/m^3) (PEF x soil concentrations as per **Table 35**)

ET = Exposure time (hours/day) – assumed to be 24 hours per day

DF = Deposition fraction, fraction of inhaled dust retained in the respiratory tract (not exhaled), taken to be 75% (0.75) as per (enHealth 2012a; NEPC 1999 amended 2013e) (unitless)

CC = Cilliary clearance factor, fraction of the inspirable dust that is small enough to reach the pulmonary alveoli, taken to be 50% (or 0.5) as per (enHealth 2012a; NEPC 1999 amended 2013e) (unitless)
FI = Fraction inhaled from contaminated source (unitless) assumed to be 100%
EF = Exposure frequency (days/year), refer to **Table 38**
ED = Exposure duration, refer to **Table 38**
AT = Averaging time for threshold exposures, (=ED x 365 days x 24 hours)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days x 24 hours)

6.2.8 Transfer Factors

A similar approach to that adopted for PBDEs has been used to assess potential for uptake of PFAS into home grown produce.

The transfer factors for PFOS and PFOA have been taken from a number of documents including previous assessments by enRiskS and the National Environmental Management Plan for PFAS (HEPA 2018). The transfer factors for PFOS and PFOA are listed in **Table 37**.

Table 37 Transfer Factors for PFOS and PFOA

Produce Type	PFOS	PFOA
Green Vegetables	2.2 mg/kg plant dw/mg/kg soil dw	1.5 mg/kg plant dw/mg/kg soil dw
Root Vegetables	0.05 mg/kg plant ww/mg/kd soil dw	0.05 mg/kg plant ww/mg/kd soil dw
Tuber Vegetables	0.04 mg/kg plant ww/mg/kd soil dw	0.1 mg/kg plant ww/mg/kd soil dw
Tree Fruit (incl blueberries)	0.07 mg/kg plant dw/mg/kg soil dw	0.03 mg/kg plant dw/mg/kg soil dw
Wheat/Oats/Barley	0.5 mg/kg plant ww/ mg/kg soil dw	3.2 mg/kg plant ww/ mg/kg soil dw
Eggs	37.7 mg/kg (egg) ww/ mg/kg bw/d	14.6 mg/kg (egg) ww/ mg/kg bw/d
Milk	8.5 mg/L (milk) ww/ mg/kg bw/d	0.04 mg/L (milk) ww/ mg/kg bw/d
Meat	41 mg/kg (meat) ww/ mg/kg bw/d	0.3 mg/kg (meat) ww/ mg/kg bw/d

6.2.9 Ingestion of Contaminants present in Home Grown Vegetables

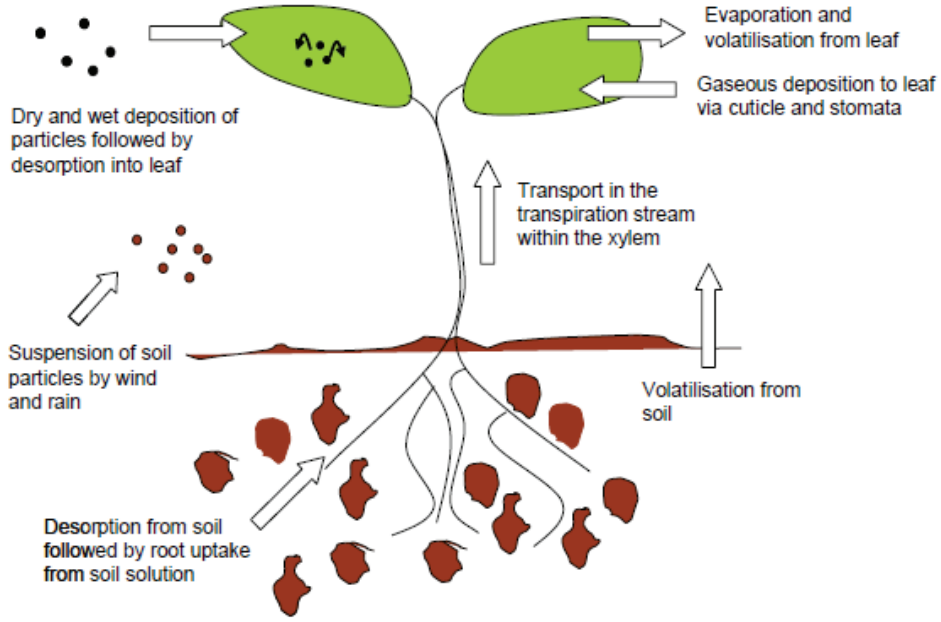
It is noted that the Resource Recovery Order and Exemption that set the framework for application of MWOO to agricultural land specifically prohibited application to land where root or tuber vegetables might be grown or where vegetables are grown close to the soil where they may come into contact with soil. *(Definition in Resource Recovery Order – **broad acre agricultural use** means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.)*

Consumption of these types of vegetables have been assessed here to provide information for management should farmers or farm workers have a vegetable patch at the farm in an area where MWOO has been applied. It is acknowledged that this is an unlikely scenario – a vegetable patch located in a field where these materials have been applied – as it is expected that such a patch is more likely to be close to the farm house.

The Environment Agency in the UK has undertaken a review of models that are used to estimate uptake in plants from contaminated soil (UK EA 2009). The diagram below summarises all the different pathways by which contaminants can enter plants. For PFAS present in soil due to the application of MWOO, the relevant pathway is desorption from soil/MWOO into soil solution with root uptake from soil solution followed by transport throughout the rest of the plant via the xylem.

However, PFAS are highly water soluble so they are much more likely than the PBDEs discussed above to be taken up into the plants.

2-1: Principal pathways for plant uptake of organic chemicals



Basis of Calculation

The ASC NEPM has adopted the approach taken by the UK Environment Agency to calculate the uptake of chemicals in soil into plants (UK EA 2009). This guidance document considered studies that are based on the uptake of these contaminants into green vegetables, root vegetables, tuber vegetables, herbaceous fruit, shrub fruit and tree fruit.

FSANZ has developed screening trigger values for PFAS in fruit and vegetables. These values are provided in **Section 7.2** (FSANZ 2017a).

Fraction Home Grown (FHG)

As was proposed for the assessment of exposure to PBDEs, it has been assumed, for the purposes of this assessment, that 35% of a person's intake of fruit and vegetables might come from produce grown at a site where MWOO has been applied for PFAS exposure. This is based on the following:

- A farm is more likely to grow one or two species in the fields where this material is applied so it is unlikely that 100% of a person's intake of fruit and vegetables could come from such a site every day of the year
- Common value applied at contaminated sites where significant amounts of home grown produce may be consumed (Cross & Taylor 1996).

This value has also been adopted for intake of wheat/oats.

Uptake Calculations

The ASC NEPM Schedule B7 Appendix B outlines the equations to develop plant uptake factors for each contaminant of interest (NEPC 1999 amended 2013e). Chemical specific plant uptake factors were calculated using the equations and defaults from the ASC NEPM Schedule B7 Appendix B (NEPC 1999 amended 2013e). The equations and defaults are outlined in **Appendix E** of this report. The calculations are included in **Appendix G**.

In this assessment, modelling has been undertaken to estimate concentrations that may be present in the vegetables, fruit or other crops that may be grown at sites where MWOO may have been applied to estimate exposure to PFAS for people who might consume these foods.

Uptake Factors are calculated for different crops on the basis of the following equation:

$$UF\ (kg/day) \quad (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit})$$

where:

CFy = plant uptake factors relevant for produce type (y), chemical specific value (mg/kg fresh weight produce to mg/kg dry weight soil), as per **Table 38**

Cy = Consumption rate of each produce type (y) (kg/day), as per **Table 39** (NEPC 1999 amended 2013e)

Table 38 Transfer Factors for PFOS and PFOA

Produce Type	PFOS	PFOA
Green Vegetables	2.2 mg/kg plant dw/mg/kg soil dw	1.5 mg/kg plant dw/mg/kg soil dw
Root Vegetables	0.05 mg/kg plant ww/mg/kd soil dw	0.05 mg/kg plant ww/mg/kd soil dw
Tuber Vegetables	0.04 mg/kg plant ww/mg/kd soil dw	0.1 mg/kg plant ww/mg/kd soil dw
Tree Fruit	0.07 mg/kg plant dw/mg/kg soil dw	0.03 mg/kg plant dw/mg/kg soil dw
Wheat/Oats/Barley	0.5 mg/kg plant ww/ mg/kg soil dw	3.2 mg/kg plant ww/ mg/kg soil dw

Table 39 Summary of Factors Adopted for Quantifying Plant Uptake

	Produce Group			
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Consumption Rate – Children (kg/day)	0.055	0.017	0.028	0.18
Consumption Rate – Adults (kg/day)	0.15	0.047	0.060	0.14

Table 40 Concentration in Produce (mg/kg) (mean case)

Scenario	Exposure Concentration (mg/kg)	Concentration in Produce (mg/kg)
PFOS – Cropping Land		
Green Vegetables		
Interim HHERA	0.0003	0.0001
Overall Dataset	0.0008	0.0003
Root Vegetables		
Interim HHERA	0.0003	0.00002
Overall Dataset	0.0008	0.00004
Tuber Vegetables		
Interim HHERA	0.0003	0.00001
Overall Dataset	0.0008	0.00003
Tree Fruit		

Scenario	Exposure Concentration (mg/kg)	Concentration in Produce (mg/kg)
Interim HHERA	0.0003	0.000003
Overall Dataset	0.0008	0.000008
Wheat		
Interim HHERA	0.0003	0.00002
Overall Dataset	0.0008	0.00006
PFOA		
Green Vegetables		
Interim HHERA	0.0002	0.00005
Overall Dataset	0.0009	0.0002
Root Vegetables		
Interim HHERA	0.0002	0.00001
Overall Dataset	0.0009	0.00005
Tuber Vegetables		
Interim HHERA	0.0002	0.00002
Overall Dataset	0.0009	0.00009
Tree Fruit		
Interim HHERA	0.0002	0.000001
Overall Dataset	0.0009	0.000004
Wheat		
Interim HHERA	0.0002	0.0001
Overall Dataset	0.0009	0.0004

In regard to production of fruit, vegetables or other crops, these chemical specific uptake factors and the estimated concentrations can be used to assess exposure using the following equations and assumptions:

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs = Concentration in soil (mg/kg), as per **Table 35**
UF = Uptake factor relevant for the uptake from soil into different produce (kg/day)
FHG = Fraction of all fruit and vegetable produce consumed that is home grown (unitless) – assumed to be 35% of diet
EF = Exposure frequency (days/year), assumed to be 365 days per year
ED = Exposure duration, 29 years for adults, 6 years for children
BW = Body weight (kg), 70 kg for adults, 15 kg for children
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

6.2.10 Ingestion of Contaminants present in Eggs

Given the persistent nature of PFAS there is potential for their uptake from treated soil into eggs produced from hens kept on a site.

It is noted that the Order permitting the use of MWOO specifically excluded using the waste in places where chickens may be kept. Uptake into eggs has been assessed to provide detailed information for NSW EPA should this have occurred at a site *(Definition in Resource Recovery Order – **broad acre agricultural use** means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.)*

This exposure pathway has been assessed to inform future land management. It is acknowledged that it is an unlikely exposure scenario.

FSANZ has developed screening trigger values for PFAS in eggs. These values are provided in **Section 7.2** (FSANZ 2017a).

In this HHERA, modelling has been undertaken to estimate concentrations that may be present in eggs. These concentrations have also been used to estimate uptake of PFAS into people living at a site where MWOO may have been applied to soil where chickens are kept and where the eggs are consumed on farm.

The approach adopted for the quantification of uptake into eggs is in accordance with the PFAS National Environmental Management Plan (HEPA 2018). It is based on a transfer factor and the potential intake of the contaminants by the hen. Calculations are presented in **Appendix G**. The approach adopted is presented below.

To calculate the concentration in eggs the following approach was followed:

$$C_{eggs} = (DailyIntake)_{hens} \bullet (TransferFactor)(mg/kgfreshweight)$$

where:

Transfer factors are provided in **Table 37** in **Section 6.2.8**. For eggs, these transfer factors are based on a large study undertaken in Australia in 2017 (AECOM 2017).

$$Average\ Daily\ intake_{chickens} = C_{soil} * IR_{soil} * B * \frac{EF * ED}{BW * AT}$$

where:

C_{soil} = Concentration of PFOS or PFOA in soil (mg/kg), (as per **Table 35**)
IR_{soil} = Ingestion rate of soil by hens (kg/day). The ingestion rate of soil by hens is not well studied. A value of 0.001 kg/day is recommended in (Travis & Hattemer-Frey 1991). A value of 0.01 kg/day is recommended in (OEHHA 2012). A value of 0.022 kg/day is recommended in (USEPA 2005). These values are primarily based on an intake of soil assumed to be 10% of the total diet. This assessment has used 0.01 kg/day as this value is from the most recently published reference.
B = Bioavailability of PFAS via ingestion - assumed to be 100% bioavailable
EF = Exposure frequency (days/year), assumed to be 365 days per year
ED = Exposure duration, taken to be 8 years
BW = Body weight (kg), taken to be 2 kg
AT = Averaging time for threshold exposures, (=ED x 365 days)

Table 41 Concentration in Eggs (mg/kg) (mean case)

Scenario	Exposure Concentration (mg/kg)	Daily Intake Chickens (mg/kg bw/d)	Concentration in Eggs (mg/kg)
PFOS			
Cropping Land			
Interim HHERA	0.0003	0.000002	0.00006
Overall Dataset	0.0008	0.000004	0.0002
PFOA			
Cropping Land			

Scenario	Exposure Concentration (mg/kg)	Daily Intake Chickens (mg/kg bw/d)	Concentration in Eggs (mg/kg)
Interim HHERA	0.0002	0.000001	0.00002
Overall Dataset	0.0009	0.000005	0.00008

In regard to egg production for on farm consumption, exposure to PFAS can be assessed for those living at the site using the egg concentrations and the consumption rate of eggs.

The most recent review of ingestion rates for eggs in Australia were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b). The 90% intake for people who reported consuming eggs on the day of the dietary survey ranges between 0.036 kg/day for children to 0.059 kg/day for adults. It is considered appropriate to use this estimate of high end consumption of eggs for on farm consumption. It is likely that all the eggs consumed by a household that keeps chickens would be from chickens kept at the site (FSANZ 2011).

The daily intake of PFAS from the consumption of eggs was calculated as follows:

$$DailyChemicalIntake_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{eggs} = concentration in eggs, calculated as outlined above (mg/kg fresh weight) (see **Table 41**)

IR_{eggs} = ingestion rate of eggs (kg/day), taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b) of 0.036 kg/day for children 2-5 years and 0.059 kg/day for adults

FHG = fraction of the daily diet that is derived from home grown source, taken to be 100% (or 1) for on farm consumption of eggs

EF = Exposure frequency (days/year), assumed to be 365 days per year

ED = Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013e)

BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013e)

AT = Averaging time for threshold exposures, (=ED x 365 days)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix G**.

6.2.11 Ingestion of Contaminants present in Milk

Given the persistent nature and bioaccumulative potential of PFAS there is potential for their uptake from treated soil into milk produced from cattle kept on a site.

FSANZ has developed screening trigger values for PFAS in milk. These values are provided in **Section 7.2** (FSANZ 2017a).

In this HHERA, modelling has been undertaken to estimate concentrations that may be present in milk. These concentrations have also been used to estimate uptake of PFAS into people living at a site where MWOO may have been applied to soil where dairy cattle may graze and where milk is consumed on farm.

The approach adopted for the quantification of uptake into milk is in accordance with the PFAS National Environmental Management Plan (HEPA 2018). It is based on a transfer factor and the

potential intake of the contaminants by the cattle. Calculations are presented in **Appendix G**. The approach adopted is presented below.

To calculate the concentration in milk, the following approach was followed:

$$C_{milk} = (DailyIntake) \bullet (TransferFactor)(mg/kgfreshweight)$$

where:

Transfer factors:
PFOS = 8.5 mg/kg (milk) / mg/kg bw-d (intake of cattle) (**Table 37**)
PFOA = 0.04 mg/kg (milk) / mg/kg bw-d (intake of cattle) (**Table 37**)

And

$$Daily\ intake_{dairy\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} *\ Transfer\ factor\ (soil\ to\ plant) *\ IR_{fodder})) * B * EF * ED}{BW * AT}$$

where:

Csoil	= Concentration of PFAS in soil (mg/kg), (as per **Table 35**)
IRsoil	= Ingestion rate of soil by cattle (kg/day) as discussed in **Section 3.4.2**, this value has been changed for this assessment, the value used is as per **Table 42**
IRfodder	= ingestion rate of fodder (kg/day) as per **Table 42**
Transfer factor (soil to plant)	= 0.5 mg/kg (plant) / mg/kg (soil) PFOS = 3.2 mg/kg (plant) / mg/kg (soil) PFOA
B	= Bioavailability of PFAS via ingestion - assumed to be 100% bioavailable
EF	= Exposure frequency (days/year), assumed to be either 52 days per year or 183 days per year as discussed in Section 3.4.3
ED	= Exposure duration, taken to be 4 years
BW	= Body weight (kg), taken to be 500 kg (advice from NSW DPI)
AT	= Averaging time for threshold exposures, (=ED x 365 days)

Table 42 Summary of Factors Relevant for Determining Uptake into Grazing Animals that Produce Milk

Grazing Animal	Soil Ingestion (kg/day)	Body Weight (kg)	Fodder Ingestion (kg/day)
Cattle	0.5 (USEPA 2005)	500 (NSW DPI advice)	20 (ANZG 2018)

The concentrations in milk for the mean case for each scenario have been estimated using this approach and the spreadsheets showing these calculations are in **Appendix G**.

Table 43 Concentration in Milk (mg/kg) (mean case)

Scenario	Exposure Concentration (mg/kg)	Daily Intake Cattle (mg/kg bw/d)	Concentration in Milk (mg/kg)
PFOS			
Grazing Land – no incorporation			
Interim HHERA	0.04	0.0002	0.001
Overall Dataset	0.11	0.0004	0.003
Grazing Land – trampled into the soil			
Interim HHERA	0.002	0.000008	0.00007
Overall Dataset	0.004	0.00002	0.0001
PFOA			
Grazing Land – no incorporation			
Interim HHERA	0.03	0.0006	0.00002
Overall Dataset	0.12	0.002	0.0001
Grazing Land – trampled into the soil			
Interim HHERA	0.001	0.00002	0.0000008
Overall Dataset	0.005	0.0001	0.000004

In regard to intake of milk on farm, exposure to PFAS can be assessed for those living at the site using the concentrations in milk and the consumption rate for milk. The ingestion rates for milk were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b). The 90% intake for people who reported consuming milk on the day of the dietary survey ranges between 1.097 kg/day for children to 1.295 kg/day for adults. It might be possible that all the milk consumed on farm would be from cattle at the site, but this will depend on the amount of milk produced and the number of people consuming the milk.

The daily intake of PFAS from the consumption of milk produced at the site was calculated as follows:

$$DailyChemicalIntake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \text{ (mg/kg/day)}$$

where:

C_{milk} = concentration in milk, calculated as per **Table 43** (mg/kg fresh weight)

IR_{milk} = ingestion rate of milk (kg/day), taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b) of 1.097 kg/day for children 2-5 years and 1.295 kg/day for adults

FHG = fraction of the daily diet that is derived from home grown source, taken to be 100% (or 1) for on farm consumption

EF = Exposure frequency (days/year), assumed to be 365 days per year

ED = Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013e)

BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013e)

AT = Averaging time for threshold exposures, (=ED x 365 days)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix G**.

6.2.12 Ingestion of Contaminants present in Meat

Given the persistent nature and bioaccumulative potential of PFAS there is potential that they will be taken up into meat produced if livestock kept at a site are used for on farm consumption.

FSANZ has developed screening trigger values for PFAS in meat. These values are provided in **Section 7.2** (FSANZ 2017a).

In this HHERA, modelling has been undertaken to estimate concentrations that may be present in meat. These concentrations have also been used to estimate uptake of PFAS into people living at a site where MWOO may have been applied to soil where beef cattle may graze and where meat is consumed on farm.

The approach adopted for the quantification of uptake into milk is in accordance with the PFAS National Environmental Management Plan (HEPA 2018). It is based on a transfer factor and the potential intake of the contaminants by the cattle. Calculations are presented in **Appendix G**. The approach adopted is presented below.

To calculate the concentration in meat in grazing animals the following approach was followed:

$$C_{meat} = (DailyIntake)_{grazinganimal} \bullet (TransferFactor)(mg/kgfreshweight)$$

where:

Transfer factors:
PFOS = 41 mg/kg (meat) / mg/kg bw-d (intake of cattle) (**Table 37**)
PFOA = 0.3 mg/kg (meat) / mg/kg bw-d (intake of cattle) (**Table 37**)

$$Daily\ intake_{grazing\ animal} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} *\ Transfer\ factor\ (soil\ to\ plant) *\ IR_{fodder})) * B * EF * ED}{BW * AT}$$

where:

C_{soil}	= Concentration of PFAS in soil (mg/kg), (as per **Table 35**)
IR_{soil}	= Ingestion rate of soil by cattle (kg/day), as discussed in **Section 3.4.2,** this value has been changed for this assessment, the value used is as per **Table 44**
IR_{fodder}	= ingestion rate of fodder (kg/day) as per **Table 44**
Transfer factor (soil to plant)	= 0.5 mg/kg (plant) / mg/kg (soil) PFOS = 3.2 mg/kg (plant) / mg/kg (soil) PFOA
B	= Bioavailability of PFAS via ingestion - assumed to be 100% bioavailable
EF	= Exposure frequency (days/year), assumed to be either 52 days per year or 183 days per year as discussed in **Section 3.4.3**
ED	= Exposure duration, taken to be 2 years
BW	= Body weight (kg), taken to be 500 kg (advice from NSW DPI)
AT	= Averaging time for threshold exposures, (=ED x 365 days)

Table 44 Summary of Factors Relevant for Determining Uptake into Grazing Animals that Produce Meat

Grazing Animal	Soil Ingestion (kg/day)	Body Weight (kg)	Fodder Ingestion (kg/day)
Cattle	0.5 (USEPA 2005)	500 (NSW DPI advice)	20 (ANZG 2018)

Table 45 Concentration in Meat (mg/kg) (mean case)

Scenario	Exposure Concentration (mg/kg)	Daily Intake Cattle (mg/kg bw/d)	Concentration in Meat (mg/kg)
PFOS			
Grazing Land – no incorporation			
Interim HHERA Dataset	0.04	0.0002	0.007
Overall Dataset	0.11	0.0003	0.01
Grazing Land – trampled into the soil			
Interim HHERA Dataset	0.002	0.000008	0.0003
Overall Dataset	0.004	0.00001	0.0004
PFOA			
Grazing Land – no incorporation			
Interim HHERA Dataset	0.03	0.0006	0.0002
Overall Dataset	0.12	0.002	0.0005
Grazing Land – trampled into the soil			
Interim HHERA Dataset	0.001	0.00002	0.000006
Overall Dataset	0.005	0.00006	0.00002

In regard to meat production for on farm consumption, exposure to PFAS can be assessed for those living at the site using the concentrations in meat and the consumption rate for meat. The ingestion rates for meat were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b). The 90% intake for people who reported consuming meat on the day of the dietary survey ranges between 0.085 kg/day for children to 0.163 kg/day for adults.

Consumption will be assessed assuming 35% of meat consumed is from the farm.

The daily intake of PFAS from the consumption of meat produced at the site was calculated as follows:

$$DailyChemicalIntake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{milk} = concentration in meat, calculated as per **Table 45** (mg/kg fresh weight)

IR_{milk} = ingestion rate of meat (kg/day) taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017b) of 0.085 kg/day for children 2-5 years and 0.163 kg/day for adults

FHG = fraction of the daily diet that is derived from home grown source, taken to be 35% for home produced meat

EF = Exposure frequency (days/year), assumed to be 365 days per year

ED = Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013e)

BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013e)

AT = Averaging time for threshold exposures, (=ED x 365 days)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 8** and they are detailed in **Appendix G**.

Section 7. Toxicity Profile – Human Health

7.1 Polybrominated Diphenyl Ether Flame Retardants (Br1 to Br9)

7.1.1 General

This review was taken from Appendix A5, Schedule B7 of the ASC NEPM with updates where appropriate from the ATSDR (ATSDR 2017; NEPC 1999 amended 2013e).

Polybrominated diphenyl ethers (PBDE) are a group of compounds manufactured for their flame retardant properties. They consist of a two phenyl groups bound to a single oxygen atom with the hydrogen atoms on the phenyl groups substituted with between one and ten bromine atoms. The group consists of 209 structurally similar compounds or 'congeners' which differ in the number and location of substituted bromine. The internationally accepted numbering system for PBDE congeners is the acronym 'BDE' followed by a number from 1 to 209 (NEPC 1999 amended 2013e; NICNAS 2007).

Several comprehensive reviews of PBDEs in the environment and toxicity to humans are available (ATSDR 2017; NEPC 1999 amended 2013e; NICNAS 2007; UNEP 2009). The following provides a summary of the key aspects of these compounds that are relevant to this assessment.

The literature to date indicates that the toxicity and environmental fate of PBDEs with a lower number of substituted bromine atoms (penta-BDE to hexa-BDE) is different to the fully brominated BDE (deca-BDE or BDE-209). Lower brominated BDEs have been demonstrated to be more toxic in animal studies, have a higher bioavailability and are more readily transported in the environment. As a result, the ATSDR has recommended separating deca-BDE from 'lower brominated BDEs' (ATSDR 2017).

For the purpose of this assessment 'lower brominated BDEs' are considered to be BDEs containing between one and nine substituted bromines.

PBDE are manufactured compounds, which have been widely used in industrial, and consumer applications. A review of the compounds conducted by scientific and regulatory bodies have culminated in tetra- and penta-BDEs (components of technical penta-BDE) and hexa- and hepta-BDEs (components in technical octa-BDE) being listed as a Persistent Organic Pollutants (POP) under the Stockholm Convention in May 2009. All production and use of these compounds have subsequently been banned with the exception of recycling activities.

PBDEs have not been manufactured in Australia but were historically imported and used until 2005. Importation of products pre-treated with PBDEs is expected to decrease following the ban. Technical grade penta-BDE (i.e. raw material used in manufacturing) was mainly used in polyurethane foams (such as in furnishings) whereas technical grade octa-BDE and deca-BDE (i.e. raw materials used in manufacturing) were mainly used in hard plastics (such as for electrical equipment). The articles treated with PBDEs usually have long lives and as such, articles containing PBDEs are still expected to be in use. Deca-BDE was declared a priority existing chemical in Australia and is currently being assessed as to its environment and human health risks (ATSDR 2017; NEPC 1999 amended 2013e; NICNAS 2007; UNEP 2009).

7.1.2 Significance of Exposure Pathways

Oral Bioavailability

Insufficient data is available to adequately define the bioavailability of lower BDEs hence a default approach of assuming 100% oral bioavailability has been adopted (ATSDR 2017; NEPC 1999 amended 2013e).

Dermal absorption

Insufficient data is available on the dermal absorption of lower BDEs from soil. Hence the default values of 0.1 (10%) suggested by USEPA for semi-volatile organic compounds has been adopted (USEPA 2004).

It is noted that the EU estimated a dermal absorption value of 1% as a maximum for deca-BDE based on assumptions associated with the lipophillic nature of the compound and analogies to PCBs (EU 2003). However, it was noted that dermal absorption may also be associated with accumulation in the stratum corneum which may behave as a storage site resulting in a low systemic release over time (ATSDR 2017; NEPC 1999 amended 2013e).

Inhalation of Dust

Lower BDEs are not considered sufficiently volatile to be of significance and inhalation exposures associated with dust particulates outdoors and indoors are expected to be of less significance than ingestion of soil. While likely to be negligible, potential inhalation exposures associated with dust have been considered (NEPC 1999 amended 2013e).

Plant Uptake:

Limited data are available on the potential for lower BDEs to be taken up by plants from soil into edible fruit and vegetable crops. ATSDR notes that PBDEs will be strongly adsorbed to soil; hence, PBDEs present in soil-pore water will bind to soil organic matter. Because PBDEs adsorb strongly to soil, they will have very low mobility and leaching of PBDEs from soil to groundwater will be insignificant (ATSDR 2017).

Review of plant uptake of deca-PBDE (BDE-209) into plants from soil by Huang et al. (2010) suggests that deca-BDE is taken up and translocated within the plants assessed (ryegrass, alfalfa, pumpkin, squash, maize and radish). Nineteen lower brominated (di- to nona-) PBDEs were detected in the soil and plant samples and five hydroxylated congeners were detected in the plant samples, indicating debromination and hydroxylation of BDE-209 in the soil−plant system. Evidence of a relatively higher proportion of penta- through di-BDE congeners in plant tissues than in the soil indicates that there is further debromination of PBDEs within plants or low brominated PBDEs are more readily taken up by plants (Huang et al. 2010).

Other studies have evaluated uptake into maize and other crop species for a range of these chemicals (Yang et al. 2018; Zhao et al. 2012). Uptake into maize and sweet potatoes was reported in these studies. In addition, the more recent paper included a summary of uptake into a range of plant species.

On the basis of the available information, the potential for the uptake of lower BDEs into home-grown produce has been considered. This has been undertaken on the basis of the equations presented in **Appendix E** with the following parameters and plant uptake factors estimated.

Table 46 Parameters for assessment uptake into plants

Parameter	Value	Reference/Comment
Parameters		
Koc	1698000 (cm^3/g)	Refer to note below*
log Kow	6.84	(RAIS) for pentaBDE (BDE-99)
Diffusivity in water	$5.32x10^{-6}$ (cm^2/s)	Estimated as per (Guan et al. 2009)
Calculated Plant Uptake Factors (mg/kg produce fresh weight per mg/kg soil)		
Green vegetables	0.00026	calculated
Root vegetables	0.0038	calculated
Tuber vegetables	0.079	calculated
Tree fruit	0.00096	calculated

* The estimation of potential plant uptake of BDE is sensitive to the value of Koc adopted. The data would normally be derived from RAIS (2010) for consistency; however, the data provided is only for penta-BDE with data from no other lower BDEs presented for comparison. Data presented in ATSDR (2001) suggests log Koc ranges from 2.89-5.1 for penta-BDE and from 5.92-6.22 for octa-BDE. Review by Guan et al. (2009) provides log Koc values for the lower BDEs (BDE-28 to BDE-208) that range from 5.73 to 6.49. Due to the range of values provided for the lower BDEs, the average of values presented by Guan et al. (2009), log Koc = 6.23 has been adopted.

Intakes from Other Sources – Background:

Background intakes were evaluated by NICNAS on the basis of PBDE levels in blood rather than as an intake (NICNAS 2007). The presence of PBDEs in blood lipids indicates exposure by the general population; however, the data does not determine the major source of exposure.

Data available from FSANZ suggests that dietary sources are likely to be low, therefore, house dust may be the major source of exposure, however, there is little correlation between exposure levels and house construction/contents. FSANZ notes a review by the US where dietary exposures did not explain the current body burden and exposures to house dust were estimated to account for 82% of the total intake (FSANZ 2007).

Based on information presented in the available reviews the following can be noted with respect to background intakes of PBDEs:

- A range of dietary intakes have been determined by FSANZ for all age groups. Estimated 95th percentile dietary intakes from FSANZ for a child aged 2-5 years ranged from 7 ng/kg/day (lower bound) to 389 ng/kg/day (upper bound). These intakes are consistent with data reported from other countries including Canada and the US and corresponded with a margin of exposure (MOE) of 300 or greater where a threshold of 0.1 mg/kg/day was considered. The MOE was greater for all other age groups considered in the study (FSANZ 2007).
- PBDE in dust reported in indoor air in Australian buildings ranged from 0.5 to 179 pg/m^3 for homes and 15 to 487 pg/m^3 for offices. Dust concentrations ranged from 87 ng/g to 3070 ng/g. PBDEs were detected in 9 out of 10 surface wipe samples. No estimation of intake associated with measured levels in air and dust were presented. The study size was limited

and showed dust levels similar to or lower than those conducted overseas in Canada and the US (Toms et al. 2006).

- Upper bound total intakes of PBDEs from all sources (ambient and indoor air, dietary and dust) in Canada have been estimated to be approximately 0.95 µg/kg/day for children aged 0.5 to 4 years. Higher intakes (2.6 µg/kg/day) are noted for breastfed infants. Recent review of total intakes from food, dust and air of PBDEs in the US range from 1.2 ng/kg/day for adults to 307 ng/kg/day for infants (Health Canada 2006; Schecter, A et al. 2008).
- Based on the Australian data noted above, intakes by young children may range from 0.007 to 0.5 µg/kg/day. The higher value is half that estimated by Health Canada, both of which exceed the recommended oral toxicity reference value (TRV) (FSANZ 2007; Health Canada 2006).
- On the basis of the above, total intakes (and those reported from Australia) vary and may comprise a significant proportion of the recommended threshold value. Hence, consideration of 80% of the recommended TRV as background intake is considered appropriate.

7.1.3 Identification of Toxicity Reference Values

Effects:

PBDEs have been shown to cause impacts on the developing nervous, immune, endocrine and reproductive systems as well as the liver. In addition, some effects (limited evidence) have been identified in the male and female reproductive systems and in the adult nervous and immune systems (ATSDR 2017).

Classification:

The International Agency for Research on Cancer (IARC 1999) has classified technical deca-BDE as Group 3: not classifiable. No classification is available for other BDEs (IARC 1999).

It is noted that the USEPA has a classification for deca-BDE where it is classified as "*suggestive evidence of carcinogenic potential*" (USEPA 2008a). The USEPA has classified technical penta-BDE and technical octa-BDE as Group D: not classifiable (USEPA 2008a, 2008c).

Review of Available Values/Information

Review of PBDEs, in particular penta-BDE and octa-BDE, by NICNAS indicated there is insufficient information of the carcinogenic potential of these PBDEs and that the overall conclusion relating to penta-BDE is that it is not genotoxic (NICNAS 2007). Further review of octa-BDE, PBDE mixtures and penta-BDE suggest that PBDE mixtures and individual congeners are not genotoxic (WHO 2006). On the basis of the available information, it is considered appropriate that a threshold dose-response approach be adopted for PBDEs (ATSDR 2017; NEPC 1999 amended 2013e).

The following are available for the lower BDEs from Level 1 Australian and International sources

Table 47 Toxicity Reference Values

Source	Value	Basis/Comments
Australian		
ADWG (NHMRC 2011 updated 2018)	No evaluation available	

Source	Value	Basis/Comments
NICNAS (NICNAS 2007)	No TRV established	Based on review of PBDEs and available studies, the highest toxicity was associated with penta-BDE associated with neurodevelopmental effects in pups and dams where the LOAELs were 0.8 mg/kg/day in pups and 0.06 mg/kg/day in dams.
FSANZ (FSANZ 2007)	No TRV established	Review of dietary intakes considered a margin of exposure (MOE) approach where a threshold value of 0.1 mg/kg/day was considered acceptable based on review by JECFA.
International		
JECFA (WHO 2006)	No TRV established	Due to the complexity of PBDEs and the lack of adequate data, provisional reference doses have not been derived for PBDEs. Limited data suggests that for more toxic PBDE congeners, adverse effects would be unlikely to occur in rodents at doses less than approximately 0.1 mg/kg/day.
WHO DWG	No evaluation available	
Health Canada (Health Canada 2006)	No TRV established	A threshold value of 0.8 mg/kg/day was identified for penta-BDE based on neurobehavioural effects in neonatal mice, considered the critical effects and appropriate for undertaking a MOE approach to the assessment of risk.
ATSDR (ATSDR 2017)	No chronic duration MRLs derived	No chronic duration MRLs have been derived for lower brominated BDEs due to insufficient data. An intermediate duration oral MRL of 0.000003 mg/kg/day has been derived on the basis of a LOAEL of 0.001 mg/kg/day associated with 34% reduction in serum testosterone in rats exposed to tetra-BDE (BDE47). An intermediate duration inhalation MRL of 0.006 mg/m^3 has been derived based on a NOAEL of 1.1 mg/m^3 for thyroid effects in rats exposed to commercial octa-BDE mixture.
USEPA (USEPA 2008a, 2008c, 2008b, 2008d; USEPA IRIS)	RfD = 0.0001 mg/kg/day for penta-BDE (BDE-99)	RfD established for BDE-99 (penta-BDE) on the basis of a benchmark dose approach and a $BMDL_{1SD}$ of 0.29 mg/kg/day associated with neurobehavioral effects in mice and an uncertainty factor of 3000.
	RfD = 0.0002 mg/kg/day for hexa-BDE (BDE-153)	Hexa-BDE RfD established for BDE-153 on the basis of a NOAEL of 0.45 mg/kg/day associated with neurobehavioral effects in mice and an uncertainty factor of 3000.
	RfD = 0.0001 mg/kg/day for tetra-BDE (BDE-47)	Tetra-BDE RfD established for BDE-47 on the basis of a benchmark dose approach and a $BMDL_{1SD}$ of 0.35 mg/kg/day associated with neurobehavioral effects in mice and an uncertainty factor of 3000.
	RfD = 0.003 mg/kg/day for octa-BDE	Octa-BDE RfD (established in 1986) for octa-BDE based on a NOAEL of 2.51 mg/kg/day associated with liver effects in rats and an uncertainty factor of 1000.
	RfD = 0.007 mg/kg/day for deca-BDE	Note the USEPA review established an RfD = 0.007 mg/kg/day for deca-BDE (BDE-209) based on a NOAEL of 2.22 mg/kg/day associated with neurobehavioral effects in mice and application of a 300 fold uncertainty factor. This evaluation indicates that deca-BDE is less toxic than the lower BDEs.

Limited quantitative data is available for the characterisation of chronic exposures to lower BDEs. The more recent evaluations by the USEPA (IRIS) for individual congeners BDE-99, BDE-153 and BDE-47 have considered threshold values (BMDLs or NOAELs) that are consistent with those identified in reviews by NICNAS (2007), JECFA (2006) and Health Canada (2006) that are associated with the more sensitive endpoint of neurobehavioral/developmental effects. These endpoints are more sensitive than those considered by ATSDR in the derivation of intermediate duration MRLs and considered in older reviews by the USEPA for penta-BDE and octa-BDE. The uncertainty factor applied by the USEPA to the individual congeners of 3000, includes an additional 10 fold factor to address database deficiencies.

There is no evaluation of a chronic threshold value that would be applicable to all lower BDEs as a group, hence application of the USEPA values requires an assumption that the congeners studied are an appropriate indicator for total lower BDEs. This is likely to be conservative; however, no more detailed evaluations are available. The individual congener studies by the USEPA are noted by

NICNAS to be those within technical grade penta-BDE (i.e. raw material used in manufacturing) that are of most importance in biomonitoring and environmental sampling.

The lower RfD of 0.0001 mg/kg/day derived by the USEPA for BDE-99 and BDE-47 is recommended for use for the lower BDEs. As noted in most other reviews, the available database is poor and limited with respect to identification of a threshold associated with chronic exposures to the group of congeners. Hence, the use of this threshold TRV will require update in the future when the results of future studies become available.

No dermal or inhalation specific chronic studies or data are available. For the presence of lower BDEs in soil, it is considered appropriate to consider use of the available threshold value for all pathways of exposures.

7.1.4 Recommendation

On the basis of the discussion above, the following toxicity reference values (TRVs) have been adopted for this assessment in line with ASC NEPM guidance **(ATSDR 2017; NEPC 1999 amended 2013e)**:

Recommendation for Lower BDEs
Oral TRV (TRV_O) = 0.0001 mg/kg/day (USEPA (USEPA 2008c, 2008b) for BDE-99 and BDE-47) for all pathways of exposure
Dermal absorption factor (DAF) = 0.1 (or 10%) (USEPA 2004)
Background intakes from other sources (as % of TRV):
BI_O = 80% for oral and dermal intakes
BIi = 80% for inhalation
Uptake in home grown produce considered

Recommendation for DecaBDE
Oral TRV (TRV_O) = 0.007 mg/kg/day (USEPA 2008a) for all pathways of exposure
Dermal absorption factor (DAF) = 0.01 (or 1%) (EU 2003)
Background intakes from other sources (as % of TRV):
BI_O = 80% for oral and dermal intakes
BIi = 80% for inhalation
Uptake in home grown produce considered

7.2 PFAS Compounds

7.2.1 General

As PFAS compounds are widely distributed throughout the environment, can be highly persistent in the body, and present in many products and foods, FSANZ (FSANZ 2017d) has provided the most current evaluation of PFAS toxicity, for the purpose of establishing Australian guidelines for these compounds in produce to protect human health. The FSANZ review specifically addressed PFOS, PFOA and PFHxS.

7.2.2 PFOS and PFOA

The following provides a general summary of health effects that have been associated with PFOS and PFOA (Rumsby et al. 2009):

- Although the acute toxicity of PFAS is moderate, their persistence in the body (half-lives for PFOA of up to 8.7 years have been determined in retired production workers) has led to increasing concerns over long-term effects. The toxicity of PFOS and PFOA is not clearly understood at present. Different animal species appear to have different sensitivities to these compounds, which makes interpretation of experiments difficult (e.g. Rhesus monkeys are more sensitive to PFOS than rats, while mice are the least sensitive). The species variability may be due to the different handling of these compounds in the body;
- At present, it is unclear whether PFOS and PFOA act by the same mechanisms, and high and low doses may differ in their toxic effects. High-dose studies on animals have indicated that cancer, developmental delays, endocrine disruption, immunotoxicity and neonatal mortality are potential toxic endpoints; and
- Recent research has also suggested that receptor binding may be an important general mechanism. PFOS and PFOA both bind to peroxisomal proliferator-activated receptors. Activation of such receptors may alter fatty acid metabolism and play a role in cancer, foetal growth, hormone and immune function.

The toxicity of PFAS to humans can be inferred from animal toxicity studies as well as occupational exposure studies. The occupational exposure studies consider workers who handle or make PFAS, where the exposure levels are high. These studies have been undertaken in the US and Belgium, and have evaluated a range of health effects based on blood serum levels of PFAS in workers. These studies have identified some associations between altered cholesterol, triglyceride and high-density lipoprotein production (for PFOS > 6 mg/L in serum) and PFAS exposure. Review of these studies (ToxConsult 2014) identified that a no effect level of 2 mg/L (in serum) can be established for adult workers.

In general, observations from toxicological studies undertaken in animals with PFOS and PFOA include irritation of eyes, skin and nose; loss of appetite, reductions in body-weight and weight gain, changes in the liver (including increases in liver weight [characterised by increased centrilobular hepatocellular hypertrophy]), mild-to-moderate peroxisome proliferation in rats, increased incidence of hepatocellular adenomas in rats (non-genotoxic), and hypo-cholesterolemia (ATSDR 2018). Effects identified appear to be related to a threshold body burden and often are observed with a steep dose–response (i.e. after the threshold the potential for adverse effects increases rapidly with increasing exposure level) (ToxConsult 2014).

Data from epidemiological studies with occupationally exposed workers at 3M manufacturing facilities (Alabama, USA and Belgium), communities exposed to contaminated drinking water (USA) and general populations (USA, UK and Scandinavia) are also available. It is noted that concentrations of PFAS in occupationally exposed workers are 100 to 1,000-fold higher than those in the general populations. Despite this, epidemiology studies have generally failed to draw conclusive links between exposure to PFOS or PFOA and adverse health effects. Associations between exposure and the following health effects have been suggested:

- Changes in serum lipid levels e.g. increase total cholesterol levels;
- Changes in serum liver enzymes levels;
- Kidney disease;
- Effects on fertility, pregnancy, lactation, and birth outcomes;
- Effects on thyroid and immune function;

- Endocrine effects (e.g. elevated thyroxine levels and increased risk of thyroid disease, *diabetes mellitus* and early onset menopause);
- Cardiovascular disease; and
- Cancer.

Overall, the evidence for adverse effects in humans following exposure is inconsistent from the epidemiological studies. In addition, the biological significance of some of the observed effects has been questioned (i.e. just because an effect is observed it does not mean it is, or will lead to, an adverse effect) and there is the potential that observed effects may be due to confounding factors e.g. exposure to other contaminants or diet.

7.2.3 Characterising toxicity for PFOS, PFHxS and PFOA

Consistent with reviews by other authorities (EFSA 2008; enHealth 2016; USEPA 2016a, 2016b), FSANZ has determined reference doses (TDI) for PFOS and PFOA on the basis of data derived from animal studies, that show exposure to these compounds can cause liver toxicity and tumours and reproductive and developmental effects.

Reference doses are defined by the USEPA as *"an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a no observed adverse effect level (NOAEL), lowest observed adverse effect level (LOAEL), or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used."*
https://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do;jsessionid=rnSwRmjfz-doqnih5EI_z4Wv__YSPyTwZACoG9fyu8miDTBFObHI!-412884133?details=&vocabName=IRIS%20Glossary&filterTerm=Reference%20Dose&checkedAcronym=false&checkedTerm=false&hasDefinitions=false&filterTerm=Reference%20Dose&filterMatchCriteria=Contains

The available epidemiological studies have not provided sufficient evidence of a link between exposure to PFOS and PFHxS and any cancer type in human beings. Although associations between PFOA and some human cancers have been suggested from some epidemiological studies, results have often been contradictory, and a causal relationship cannot be established with reasonable confidence.

In relation to PFHxS, FSANZ determined there was insufficient information to establish a reference dose for PFHxS. In the absence of a reference dose (or data sufficient to calculate one), FSANZ agreed with enHealth (enHealth 2016) that using the reference dose for PFOS was likely to be conservative and protective of public health. This means that PFHxS and PFOS should be summed for the purposes of exposure assessment and risk characterisation.

The reference doses adopted by FSANZ for the assessment PFOS + PFHxS and PFOA are provided in **Section 7.2.4**. This section also includes the background intakes adopted for the HHERA, which are based on the review presented by ToxConsult (ToxConsult 2016).

7.2.4 Recommendation

On the basis of the discussion above, the following toxicity reference values (TRVs) have been adopted:

Recommendation for PFOS+PFHxS
Oral TRV (TRV_O) = 0.02 µg/kg/day (FSANZ 2017c) for all pathways of exposure
Dermal absorption factor (DAF) = negligible
Background intakes from other sources (as % of TRV):
BI_O = 10% for oral, dermal and inhalation intakes
Uptake in all types of home grown produce considered

Recommendation for PFOA
Oral TRV (TRV_O) = 0.16 µg/kg/day (FSANZ 2017c) for all pathways of exposure
Dermal absorption factor (DAF) = negligible
Background intakes from other sources (as % of TRV):
BI_O = 0.5% for oral, dermal and inhalation intakes (i.e. negligible) (FSANZ 2017c)
Assessment has assumed same background for PFOA as for PFOS+PFHxS.
Uptake in all types of home grown produce considered

7.2.5 Other PFAS Compounds

In relation to other PFAS compounds, limited data is available to evaluate the toxicity of many of these individual compounds. Review of comparative toxicity for PFAS compounds (Borg et.al. 2013), relevant to liver and reproductive effects, indicates that most of these are 10 to 100 times less toxic than PFOS and PFOA.

Due to the lack of toxicological information for some of the listed PFAS, some of the individual PFAS have been summed for assessment as discussed in **Sections 6.2.3** and **6.2.4**. The following chemicals have been summed and compared to the reference dose for PFOS - N-MeFOSAA, N-MeFOSE, N-EtFOSE, PFBS, PFPeS, PFHpS, PFOS, PFHxS, PFNS, PFDS, PFOSA, N-MeFOSE, N-EtFOSE N-MeFOSA, N-EtFOSA, N-MeFOSAA, N-EtFOSAA, 4:2 FTS, 6:2 FTS, 8:2 FTS and 10:2 FTS. The following chemicals have been summed and compared to the reference dose for PFOA - PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, PFHxDA, PFODA, 8:2-diPAP and FOUEA.

7.2.6 FSANZ Trigger Levels for Different Food Types

In addition to these overarching toxicity reference values, other types of screening criteria have been developed for use in contaminated land investigations involving PFAS chemicals. These screening criteria are listed in **Table 48** and the food based criteria were developed by FSANZ (FSANZ 2017b).

Table 48 Screening Criteria for PFAS

Criteria Type	Screening Criteria	
	PFOS + PFHxS	PFOA
Finfish (mg/kg) [1]	0.0052	0.041
Fish liver (mg/kg) [1]	0.28	2.24
Crustaceans/Molluscs (mg/kg) [1]	0.065	0.52
Meat (mg/kg) [1]	0.0035	0.028
Milk (mg/kg) [1]	0.0004	0.0028
Honey (mg/kg) [1]	0.033	0.264
Offal (mg/kg) [1]	0.096	0.765
Eggs (mg/kg) [1]	0.011	0.085
Fruit (mg/kg) [1]	0.0006	0.0051
Vegetables (mg/kg)[1]	0.0011	0.0088

Notes:

1 FSANZ Dietary Assessment (FSANZ 2017b)

Section 8. Risk Characterisation

8.1 Quantitative Assessment of Risk

8.1.1 Approach

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure and toxicity assessment to provide a quantitative evaluation of risk. Risk is characterised separately for threshold and non-threshold carcinogenic effects as outlined in the following:

Threshold Risk

The quantification of potential exposure and risks to human health associated with the presence of key chemicals in surface soil at the site has been undertaken by comparing the estimated intake (or exposure concentration) with the threshold values adopted that represent an intake (or concentration) that is likely to be without effect, with consideration for background intakes. The calculated ratio is termed a Risk or Hazard Index (RI/HI), which is the sum of all ratios (termed Risk or Hazard Quotients [RQ/HQ]) over all relevant pathways of exposure. These are calculated using the following equations:

$$Risk/HazardQuotient[RQ/HQ](oral\ or\ dermal) = \frac{Daily\ Chemical\ Intake}{(TRV - Background)}$$

$$Risk/HazardQuotient[RQ/HQ](inhalation) = \frac{Exposure\ Concentration\ in\ Air}{(TRV - Background)}$$

$$Risk/Hazard\ Index(RI/HI) = \sum_{All\ pathways} RQ/HQ$$

The interpretation of an acceptable RI/HI needs to recognise an inherent degree of conservatism that is built in to the establishment of appropriate guideline (threshold) values (using many uncertainty factors) and the exposure assessment. Hence, in reviewing and interpreting the calculated HI the following is noted:

- A RI/HI less than or equal to a value of 1 (where intake or exposure is less than or equal to the threshold) represents no cause for concern (as per risk assessment industry practice, supported by protocols outlined in ASC NEPM (1999) and US EPA guidance); and
- A RI/HI greater than 1 requires further consideration within the context of the assessment undertaken, particularly with respect to the level of conservatism in the assumptions adopted for the quantification of exposure and the level of uncertainty within the toxicity (threshold) values adopted.

Non-Threshold Risk

The key chemicals present at the site are chemicals that act via threshold modes of action. As a result, no chemicals need to be assessed for non-threshold risks.

8.1.2 Calculated Risks – PBDEs – UPDATE

The following tables present the threshold RQs for each pathway assessed. The values presented in the tables (and all other risk calculations) are rounded to 1 or 2 significant figures reflecting the level of certainty inherent in risk calculations. Detailed calculations are presented in **Appendix F.**

Additional calculations are provided in **Appendix F** for the minimum, maximum and 95th percentile concentrations measured in MWOO.

DIRECT CONTACT WITH SOIL/MWOO

These calculations have been undertaken to be similar to those undertaken in the Interim HHERA, so they have used:

- Updated understanding of concentrations of these chemicals in MWOO using all the available data
- All other assumptions as per Interim HHERA

Cropping Land (Incorporated into the Soil) Overall Dataset

Table 49 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.03
- Adults	0.004
Dermal contact with PBDEs in soil	
- Young children	0.03
- Adults	0.01
Inhalation of PBDEs in dust	
- Young children	0.00000005
- Adults	0.00000005
Below Reference Dose	**≤1**

Grazing Land (Not incorporated into the Soil) Overall Dataset

Table 50 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	5
- Adults	0.5
Dermal contact with PBDEs in soil	
- Young children	4
- Adults	2
Inhalation of PBDEs in dust	
- Young children	0.000007
- Adults	0.000007
Below Reference Dose	**≤1**

Grazing Land (Trampled into the Soil) Overall Dataset

Table 51 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.2
- Adults	0.02
Dermal contact with PBDEs in soil	
- Young children	0.2
- Adults	0.08
Inhalation of PBDEs in dust	
- Young children	0.0000003
- Adults	0.0000003
Below Reference Dose	**≤1**

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present results in the following:

- Scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied directly to the ground surface is estimated to be higher than the reference dose for PBDEs until it is trampled in

It is noted that these calculations have listed the results for the mean concentrations.

INGESTION OF HOME-GROWN PRODUCE

Cropping Land (Incorporated into the Soil) Overall Dataset

This scenario is relevant for fruits and vegetables, wheat or eggs where produce is grown on land where MWOO was mixed into the top 10 cm of soil. These calculations have been undertaken to be similar to those undertaken in the Interim HHERA, so they have used:

- Updated understanding of concentrations of these chemicals in MWOO using all the available data
- Updates outlined in **Section 3.5** where incorrect values had been used previously (transfer factor into fodder/wheat)

The calculations have not used the updated parameter values recommended in the additional research from 2019 as discussed in **Section 3.4** as these apply to the grazing cattle scenarios only. Grazing locations are those where the MWOO materials have been applied to the surface of the land rather than incorporated into the soil for cropping land.

It is noted that the Resource Recovery Order and Exemption that set the framework for application of MWOO to agricultural land specifically prohibited application to land where root or tuber vegetables might be grown or where vegetables are grown close to the soil where they may come into contact with soil. *(Definition in Resource Recovery Order – **broad acre agricultural use** means*

application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.)

Consumption of fruits, vegetables or eggs have been assessed here to provide information for management should farmers or farm workers have a vegetable patch at the farm in an area where MWOO has been applied.

However, it is noted that the use of land treated with MWOO is an unlikely scenario – a vegetable patch or chicken coop are located in a field where these materials have been applied. It is expected that it is more likely that these would be close to the farm house.

Table 52 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in home grown fruit and vegetables refined calculation (35% contribution to diet)	
- Young children	3
- Adults	2
Ingestion of PBDEs in wheat/oats/barley/fodder (35% contribution to diet)	
- Young children	0.4
- Adults	0.2
Ingestion of PBDEs in chicken eggs from a site (100% contribution to diet)	
- Young children	1
- Adults	0.4
Below Reference Dose	**≤1**

Based on the risk estimates for ingestion of home grown produce where MWOO was incorporated into the soil**,** the potential for PBDEs to be present results in the following:

- Where people may consume home grown fruit and vegetables on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) exposure is estimated to be higher than the reference dose for PBDEs
- Where people may consume home grown wheat/oats on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) exposure is estimated to be lower than the reference dose for PBDEs
- Where people may consume home grown eggs on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) exposure is estimated to be equal to the reference dose for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

Grazing Land (Not incorporated into the Soil or Trampled into the Soil) Overall Dataset

Only the scenarios for home grown meat and milk have been updated for this scenario. These calculations have used:

- updated understanding of concentrations of these chemicals in MWOO using all the available data
- updated parameter values recommended in the additional research from 2019 as discussed in **Section 3.4**

- updated parameter values etc as outlined in **Section 3.5**.

Table 53 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled In
6 months on treated pasture – higher bioaccessibility value		
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)		
- Young children	66	2.5
- Adults	17	0.6
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)		
- Young children	95	3.6
- Adults	39	1.5
6 months on treated pasture – lower bioaccessibility value		
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)		
- Young children	26	1
- Adults	7	0.3
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)		
- Young children	38	1.5
- Adults	16	0.6
52 days on treated pasture – higher bioaccessibility value		
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)		
- Young children	19	0.7
- Adults	5	0.2
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)		
- Young children	27	1
- Adults	11	0.4
52 days on treated pasture – lower bioaccessibility value		
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)		
- Young children	7.5	0.3
- Adults	2	0.07
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)		
- Young children	11	0.4
- Adults	4	0.2
Below Reference Dose	**≤1**	

It is noted that the regulation governing the application of MWOO to agricultural land requires that livestock not be permitted to graze on the land for the first month after it is applied. Once livestock begins to graze on the treated land they will trample the material into the top 2 cm of soil and so are likely to mix the MWOO into the soil over weeks to months.

Based on the risk estimates for ingestion of home-grown produce where MWOO was not incorporated into the soil or when it was trampled into the top 2 cm soil, the potential for PBDEs to be present results in the following:

- There was likely to be a peak uptake of PBDEs into livestock when, after the one month exclusion period, they began to graze on land where MWOO was applied. This results in scenarios where people who consume home grown milk or meat on a regular basis produced from grazing land where MWOO has been applied directly to the ground surface are estimated to be exposed to levels higher than the reference doses for PBDEs
- Once the MWOO has been trampled and/or weathered into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce but remain above the reference dose for PBDEs where cattle graze in a paddock for up to 6 months of a year.
- Once the MWOO has been trampled and/or weathered into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce to levels equal to or below the reference dose for PBDEs where cattle graze in a paddock for 52 days per year.

It is noted that these calculations have listed the results for the mean concentrations.

8.1.3 Calculated Risks – PFAS – UPDATE

The following tables present the threshold RQs for each pathway assessed. The values presented are rounded to 1 or 2 significant figures reflecting the level of certainty inherent in risk calculations. Detailed calculations are presented in **Appendix G.**

Cropping Land (Incorporated into the Soil) Overall Dataset

All types of home-grown produce are relevant for this scenario. These calculations have been undertaken to be similar to those undertaken in the interim HHERA, so they have used:

- Updated understanding of concentrations of these chemicals in MWOO using all available data
- Update outlined in **Section 3.5** – a pathway for uptake had not been included (uptake via fodder for calculations for grazing cattle)
- As discussed in **Section 6.2**, all measured chemicals similar to PFOS have been summed and the total concentration assessed as PFOS and all measured chemicals similar to PFOA have been summed and the total concentration assessed as PFOA

Table 54 Summary of Risk Estimates (Incorporated into Soil – PFOS mean) (Overall Dataset)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOS in soil - Young children - Adults	 0.0003 0.00004
Dermal contact with PFOS in soil - Young children - Adults	Dermal absorption is very low for this chemical, so risk is negligible

Receptor/Exposure Pathway	Threshold Risk
Inhalation of PFOS in dust	
- Young children	Negligible
- Adults	Negligible
Ingestion of PFOS in home grown fruit and vegetables (35% contribution to diet)	
- Young children	0.02
- Adults	0.01
Ingestion of PFOS in wheat/oats/barley (35% contribution to diet)	
- Young children	0.003
- Adults	0.004
Ingestion of PFOS in chicken eggs from a site (100% contribution to diet)	
- Young children	0.02
- Adults	0.007
Below Reference Dose	**≤1**

Table 55 Summary of Risk Estimates (Incorporated into Soil – PFOA mean) (Overall Dataset)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOA in soil	
- Young children	0.00004
- Adults	0.00002
Dermal contact with PFOA in soil	
- Young children - Adults	Dermal absorption is very low for this chemical, so risk is negligible
Inhalation of PFOA in dust	
- Young children	Negligible
- Adults	Negligible
Ingestion of PFOA in home grown fruit and vegetables (35% contribution to diet)	
- Young children	0.002
- Adults	0.001
Ingestion of PFOA in wheat/oats/barley (35% contribution to diet)	
- Young children	0.003
- Adults	0.004
Ingestion of PFOA in chicken eggs from a site (100% contribution to diet)	
- Young children	0.001
- Adults	0.0005
Below Reference Dose	**≤1**

Based on these risk estimates, the potential for PFAS to be present where MWOO was incorporated into the soil, results in the following conclusions:

- All scenarios where people may come into contact with soil and/or consume any type of produce on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference doses for PFAS

Grazing Land (Not incorporated into the Soil or Trampled into the Soil) Overall Dataset

Only the scenarios for direct contact and home grown meat/milk have been updated for this scenario. These calculations have used:

- Updated understanding of concentrations of these chemicals in MWOO using all available data
- Updated parameter values recommended in the additional research from 2019 as discussed in **Section 3.4** (where relevant)
- Updated parameter values etc as outlined in **Section 3.5** (where relevant)
- As discussed in **Section 6.2**, all measured chemicals similar to PFOS have been summed and the total concentration assessed as PFOS and all measured chemicals similar to PFOA have been summed and the total concentration assessed as PFOA

Table 56 Summary of Risk Estimates (PFOS mean) (Overall Dataset – Cattle present on treated area 183 days per year)

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled
Ingestion of PFOS in soil		
- Young children	0.04	0.001
- Adults	0.004	0.0002
Dermal contact with PFOS in soil		
- Young children	Dermal absorption is very low for these chemicals, so risk is negligible	
- Adults		
Inhalation of PFOS in dust		
- Young children	Negligible	
- Adults	Negligible	
Ingestion of PFOS in milk from a site (100% contribution to diet)		
- Young children	7	0.3
- Adults	2	0.07
Ingestion of PFOS in meat at a site (35% contribution to diet)		
- Young children	0.9	0.04
- Adults	0.4	0.01
Below Reference Dose	**≤1**	

Table 57 Summary of Risk Estimates (PFOA mean) (Overall Dataset – Cattle present on treated area 183 days per year)

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled
Ingestion of PFOA in soil		
- Young children	0.006	0.0002
- Adults	0.0006	0.00002
Dermal contact with PFOA in soil		
- Young children	Dermal absorption is very low for these chemicals, so risk is negligible	
- Adults		
Inhalation of PFOA in dust		
- Young children	Negligible	

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled
- Adults	Negligible	
Ingestion of PFOA in milk from a site (100% contribution to diet)		
- Young children	0.02	0.001
- Adults	0.006	0.0003
Ingestion of PFOA in meat at a site (35% contribution to diet)		
- Young children	0.005	0.0002
- Adults	0.002	0.00009
Below Reference Dose	**≤1**	

Table 58 Summary of Risk Estimates (PFOS mean) (Overall Dataset - – Cattle present on treated area 52 days per year))

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled
Ingestion of PFOS in soil		
- Young children	0.04	0.001
- Adults	0.004	0.0002
Dermal contact with PFOS in soil		
- Young children	Dermal absorption is very low for these chemicals, so risk is negligible	
- Adults		
Inhalation of PFOS in dust		
- Young children	Negligible	
- Adults	Negligible	
Ingestion of PFOS in milk from a site (100% contribution to diet)		
- Young children	2	0.08
- Adults	0.5	0.02
Ingestion of PFOS in meat at a site (35% contribution to diet)		
- Young children	0.3	0.01
- Adults	0.1	0.004
Below Reference Dose	**≤1**	

Table 59 Summary of Risk Estimates (PFOA mean) (Overall Dataset – Cattle present on treated area 52 days per year))

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled
Ingestion of PFOA in soil		
- Young children	0.006	0.0002
- Adults	0.0006	0.00002
Dermal contact with PFOA in soil		
- Young children	Dermal absorption is very low for these chemicals, so risk is negligible	
- Adults		
Inhalation of PFOA in dust		
- Young children	Negligible	

Receptor/Exposure Pathway	Threshold Risk No Incorporation	Threshold Risk Trampled
- Adults	Negligible	
Ingestion of PFOA in milk from a site (100% contribution to diet)		
- Young children	0.007	0.0003
- Adults	0.002	0.00007
Ingestion of PFOA in meat at a site (35% contribution to diet)		
- Young children	0.001	0.00006
- Adults	0.0006	0.00002
Below Reference Dose	**≤1**	

It is noted that the regulation governing the application of MWOO to agricultural land requires that livestock not be permitted to graze on the land for the first month after it is applied. Once livestock begins to graze on the treated land they will trample the material into the top 2 cm of soil and so are likely to mix the MWOO into the soil over weeks to months.

Based on these risk estimates, the potential for PFAS to be present in surface soil after application of MWOO directly to the ground surface or after it has been trampled and mixed with the top 2 cm of soil, results in the following conclusions:

- Scenarios where people may come into direct contact with soil on a regular basis from land where MWOO has not been incorporated into the soil or has been trampled into the top 2 cm of soil indicate exposure will be below the reference doses for PFAS
- There was likely to be a peak uptake of PFAS (i.e. PFOS related chemicals and PFOA related chemicals) into livestock when MWOO was initially applied such that scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied directly to the ground surface will be exposed above the reference doses for PFAS
- Scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been trampled into the top 2 cm indicate exposure will be below the reference doses for PFAS

It is noted that these calculations have listed the results for the mean concentrations.

8.2 Uncertainties

Uncertainty in any assessment refers to a lack of knowledge (that could be better refined through the collection of additional data or conduct of additional studies) and is an important aspect of the risk assessment process. An assessment of uncertainty is a qualitative process relating to the selection and rejection of specific data, estimates or scenarios within the risk assessment. In general, to compensate for uncertainty, conservative assumptions are often made that result in an overestimate rather than an underestimate of risk.

In general, the uncertainties and limitations of the risk assessment can be classified into the following categories, where uncertainties relevant to each have been addressed within the report (as noted):

- Sampling and analysis

- the NSW EPA commissioned research program generated chemical characterisation of MWOO – given the potentially highly variable nature of these materials the available data is limited but adequate for this assessment
- Additional data from new samples and from routine monitoring data have been considered which assists in addressing this uncertainty

- Toxicological assessment
  - In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals. Uncertainties (such as those arising from interspecies differences in chemical absorption, metabolism, excretion and toxic response or due to short term testing or due to less relevant exposure routes) are all considered when extrapolating from animal data to people using assessment factors. These are factors that are applied to a no observed effect level determined in a laboratory animal experiment (usually the most sensitive level relevant for people from the overall animal dataset) to generate a reference dose or tolerable daily intake. Overall the toxicological data presented are considered to be current and adequate for the assessment of risks to human health associated with the potential exposure to the key chemicals identified in this assessment.
- Exposure assessment
  - The quantification of exposure has adopted a number of conservative assumptions as recommended by the (NEPC 1999 amended 2013a). Many of the parameters adopted for RME are considered to be an overestimate of actual exposures.
    The values adopted for the purpose of quantifying exposure are point values that are derived from a wide range of physiological or behavioural values that are better defined using a distribution. It is overly complex to present the assessment based on distributions hence the point values identified provide a reasonable approximation of the RME. The overall approach, however, is expected to result in an overestimate of actual exposure.
    While not quantified in this assessment, potential exposure and chemical intake for older children is usually considered to be more in line with adults and generally lower than that for young children so does not need to be considered separately. In addition, exposure and intake during short-duration activities such as construction and general gardening activities will be lower than those calculated here for young children.

A number of approaches and assumptions have been adopted that are expected to result in an overestimate of risk. However, in relation to the assessment presented, the following assumptions are likely to be conservative:

- People live at the site for 29 years as adults and 6 years as young children
- People come into contact with soil every day of the year
- PBDEs are assumed to be up to 30% bioaccessible to cattle in the UPDATED assessment
- PBDEs are assumed to be 100% bioaccessible for uptake into chickens or crops/vegetables

- PFAS are assumed to be 100% bioavailable/bioaccessible for all aspects of the assessment
- Home grown produce (crops) accumulates PBDEs and PFAS
- 100% of the eggs or milk people consume all year round are produced from land treated with MWOO (even though chickens were not supposed to be kept on land treated with MWOO)
- People consume 35% of their daily intake of fruit and vegetables (even though fruit/vegetables were not supposed to be kept on land treated with MWOO) or meat all year round from produce from land treated with MWOO.

Section 9. Conclusions

Environmental Risk Sciences Pty Ltd has prepared an updated assessment of the human health and ecological risks posed by application of mixed waste organic outputs (MWOO) generated at Alternative Waste Treatment facilities to agricultural land.

Mixed waste from red-lid garbage bins is processed at Alternative Waste Treatment (AWT) facilities to produce mixed waste organic outputs (MWOO). These materials have been permitted for application to land (agriculture, forestry and mine rehabilitation) under a resource recovery order and exemption issued by NSW EPA. When the use of these materials commenced there was limited information available. In addition to regulating their use, NSW EPA commissioned a research program which was undertaken between 2011 and 2017.

The risk assessment process involves estimating concentrations of chemicals that may be in the MWOO that could be present in the environment after the material is applied to land. Once the concentrations in the environment that people or organisms may be exposed to have been estimated, they are compared with toxicity reference values to determine risk. If the concentrations people might be exposed to are higher than the toxicity reference values risks are higher than preferred. If concentrations are lower then the risks are low and acceptable.

Toxicity reference values are values that Australian or international health authorities have determined should be protective of heath. Determining toxicity reference values involves reviewing the scientific literature to find the lowest dose that caused no effects. This dose is then divided by a number of uncertainty factors depending on how much and what type of data is available, so these toxicity reference values are much smaller than any of the doses used in studies where no effects were seen.

Calculating how much people or organisms may be exposed to involves making a number of assumptions about how people might be exposed. If the site specific situation where this material might be applied is well understood then these assumptions can be tailored to what might actually occur. When a more generic calculation is required, as is the case here due to the number of sites where this material may have been applied, the assumptions need to be more worst case to ensure risks are not underestimated for the wide range of potential exposures at the various sites.

An Interim HHERA was prepared in October 2018 (provided in **Appendix B**) which highlighted some potential risks. In October 2018, the resource recovery order and exemption were revoked.

Additional work was undertaken in late 2018 and 2019 to allow the assessment to be refined. These investigations included further sampling and analysis of MWOO for PBDEs and PFAS, bioaccessibility measurements for PBDEs, review of a range of exposure assumptions used in the calculations. In addition, this update has also reviewed the chemicals that were previously parked in the NSW EPA commissioned research program due to a lack of guidelines.

9.1 Parked Chemicals and Routine Monitoring Data

In regard to human health, all the parked chemicals have assessed. In addition, routine monitoring data have been assessed. In regard to human health, there were no chemicals that were present above relevant guidelines in either MWOO that has not been mixed into soil or when a more refined assessment was undertaken.

In regard to ecological health, an assessment has been undertaken using aquatic effects data converted into soil guidelines as recommended in the ASC NEPM when terrestrial ecotoxicology information is limited which is the case for many of the chemicals analysed in MWOO. This assessment has identified a range of chemicals that may pose an ecological risk including iron, atrazine, endosulfan, dicamba, mercury, di-ethylhexyl phthalate (as total phthalates) and di butyl phthalate. It is also noted that for some contaminants like copper and zinc, the concentrations present in MWOO were highly variable. The maximum concentrations were well above acceptable values but occurred in only one or two samples from the whole dataset. Using the 95th percentile concentration, risks from these contaminants were estimated to be acceptable. No further assessment is possible at this time.

In regard to livestock watering using water affected by leachate from MWOO, all chemicals were present at concentrations well below screening guidelines for livestock health.

In regard to using water affected by leachate from MWOO for irrigation, most chemicals were present at concentrations well below screening guidelines for irrigation except for ammonia, MCPA, MCPP, PBDEs and phenol. However, it is unlikely that water affected by MWOO leachate would be regularly used for irrigation at a particular location, so these guidelines are conservative. No further assessment is possible at this time.

9.2 PBDEs

The key assumptions that have been used in this assessment include:

- People live at a site for 29 years as adults and 6 years as children and the PBDE chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- People eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO (even though chickens were not permitted to be kept on land treated with MWOO)
- People drink 100% of the milk they consume each year from dairy cows kept at the site on land that has been treated with the MWOO
- People eat 35% of the meat they consume each year from cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of fruit, vegetables or wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO (even though vegetables were not permitted to be grown on land treated with MWOO)
- The PBDEs found in the MWOO are up to 30% available to be taken up by livestock
    - PBDEs (Br1 to Br9) – 12% *(based on the upper end of the values for samples containing more than 1 mg/kg PBDEs (Br1 to Br9))*
    - PBDEs (Br1 to Br9) – 30% *(based on the upper end of the values for samples containing less than 1 mg/kg PBDEs (Br1 to Br9))*
    - DecaBDE – 4% *(based on the upper end of the values for samples containing more than 2 mg/kg DecaBDE)*
    - DecaBDE – 15% *(based on the upper end of the values for samples containing less than 2 mg/kg DecaBDE)*
- Background intake of PBDEs from household articles (like TVs, furniture, computers etc) takes up 80% of the allowable amount (as per the toxicity reference value) of these

chemicals so the risk estimates here are based on comparing the concentrations people might be exposed to with 20% of the reference dose determined by health authorities
- Cattle ingest 0.5 kg soil per day.
- Cattle are present in a paddock treated with MWOO for either 183 days per year (i.e. 6 months of the year) or 52 days per year (i.e. 14% of the year) to provide more realistic estimates of exposure.
- Transfer factors of 0.53 for uptake into meat and 0.01 for uptake into milk have been assumed for PBDEs (Br1 to Br9).

Direct Contact

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present results in the following:

- Almost all scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied directly to the ground surface is estimated to be higher than the reference dose for PBDEs until it is trampled in

Home Grown Produce

Cropping Land (i.e. incorporated into the soil)

Based on the updated risk estimates for ingestion of home grown produce where MWOO was incorporated into the soil**,** the potential for PBDEs to be present results in the following:

- Where people may consume home grown fruit and vegetables on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) indicate exposure is estimated to be higher than the reference dose for PBDEs
- Where people may consume home grown wheat/oats on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) indicate exposure is estimated to be lower than the reference dose for PBDEs
- Where people may consume home grown eggs on a regular basis produced on land where MWOO has been incorporated into the soil (top 10 cm) indicate exposure is estimated to be equal to the reference dose for PBDEs

Grazing Land (i.e. not incorporated into the soil)

It is noted that the regulation governing the application of MWOO to agricultural land requires that livestock not be permitted to graze on the land for the first month after it is applied. Once livestock begins to graze on the treated land, they will trample the material into the top 2 cm of soil and so are likely to mix the MWOO into the soil over weeks to months.

Based on the risk estimates for ingestion of home-grown produce where MWOO was not incorporated into the soil when it was initially applied or when it was trampled into the top 2 cm of soil, the potential for PBDEs to be present results in the following:

- There was likely to be a peak uptake of PBDEs into livestock when, after the one month exclusion period, they began to graze on land where MWOO was applied. This results in scenarios where people who consume home grown milk or meat on a regular basis

produced from grazing land where MWOO has been applied directly to the ground surface are estimated to be exposed to levels higher than the reference doses for PBDEs

- Once the MWOO has been trampled into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce but remain above the reference dose for PBDEs where cattle graze in a paddock for up to 6 months of a year.
- Once the MWOO has been trampled into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce to levels equal to or below the reference dose for PBDEs where cattle graze in a paddock for 52 days per year.

9.3 PFAS

The key assumptions that have been used in this assessment include:

- People live at a site for 29 years as adults and 6 years as children and the PFAS chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- People eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO (even though chickens were not permitted to be kept on land treated with MWOO)
- People drink 100% of the milk they consume each year from dairy cows kept at the site on land that has been treated with the MWOO
- People eat 35% of the meat they consume each year from cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of fruit, vegetables or wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO (even though vegetables were not permitted to be grown on land treated with MWOO)
- PFAS found in the MWOO are 100% available to be taken up by livestock
- Background intake of PFAS has been determined to be 10% of the reference dose determined by health authorities

Cropping Land (i.e. incorporated into the soil)

Based on these risk estimates, the potential for PFAS to be present where MWOO was incorporated into the soil, results in the following conclusions:

- All scenarios where people may come into contact with soil and/or consume any type of produce on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference doses for PFAS

Grazing Land (i.e. not incorporated into the soil or trampled into top 2 cm of soil)

It is noted that the regulation governing the application of MWOO to agricultural land requires that livestock not be permitted to graze on the land for the first month after it is applied. Once livestock begins to graze on the treated land, they will trample the material into the top 2 cm of soil and so are likely to mix the MWOO into the soil over weeks to months.

Based on the risk estimates for direct contact and ingestion of home-grown produce where MWOO was not incorporated into the soil when it was initially applied or when it was trampled into the top 2 cm of soil, the potential for PFAS to be present results in the following conclusions:

- Scenarios where people may come into direct contact with soil on a regular basis from land where MWOO has not been incorporated into the soil or has been trampled into the top 2 cm of soil indicate exposure will be below the reference doses for PFAS
- There was likely to be a peak uptake of PFAS (i.e. PFOS related chemicals and PFOA related chemicals) into livestock when, after the one month exclusion period, they began to graze on land where MWOO was applied. This results in scenarios where people who consume home grown milk or meat on a regular basis produced from grazing land where MWOO has been applied directly to the ground surface are estimated to be exposed to levels higher than the reference doses for PFAS
- Once the MWOO has been trampled into the top 2 cm over subsequent weeks to months, exposure levels using the above scenario (where people consume home grown milk or meat on a regular basis produced on land where MWOO was initially directly applied) reduce to be below the reference doses for PFAS

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Appendix A Resource Recovery Order and Exemption

Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014

The organic outputs derived from mixed waste order 2014

Introduction

This order, issued by the Environment Protection Authority (EPA) under clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014 (Waste Regulation), imposes the requirements that must be met by suppliers of organic outputs derived from mixed waste (organic outputs) to which the 'organic outputs derived from mixed waste exemption 2014' applies. The requirements in this order apply in relation to the supply of organic outputs applied to land as a soil amendment.

1. Waste to which this order applies

1.1. This order applies to organic outputs. In this order, organic outputs means the pasteurised and biologically stabilised organic outputs produced from the mechanical biological treatment of mixed waste.

2. Persons to whom this order applies

2.1. The requirements in this order apply, as relevant, to any person who supplies organic outputs that has been generated, processed or recovered by the person.

2.2. This order does not apply to the supply of organic outputs to a consumer for land application at premises for which the consumer holds a licence under the POEO Act that authorises the carrying out of the scheduled activities on the premises of clause 39 'waste disposal (application to land) or clause 40 'waste disposal' (thermal treatment) of Schedule 1 of the POEO Act.

3. Duration

3.1. This order commences on 24 November 2014 and is valid until revoked by the EPA by notice published in the Government Gazette.

4. Processor requirements

The EPA imposes the following requirements on any processor who supplies organic outputs.

General conditions

4.1. On or before supplying organic outputs, the processor must:

4.1.1. ensure that the organic outputs do not contain contaminants that will degrade land or present a risk of harm to human health or to the environment.

4.1.2. ensure that the organic outputs do not contain sharp pieces of glass, metal or plastic of a size, shape (e.g. glass shards), or type that might cause damage or injury to humans, animals, plants or soil.

4.1.3. ensure that the organic outputs do not contain any asbestos.

4.1.4. ensure that it provides effective pre-sorting mechanisms to remove lead-acid batteries and other sortable lead containing wastes.

4.1.5. ensure that all practicable measures have been taken to remove (i) glass, metal and rigid plastics, and (ii) light, flexible or film plastics, so that they are not present at unacceptable levels (including for particle sizes less than 2 mm and 5 mm respectively) in the organic outputs.

Sampling requirements

4.2. On or before supplying organic outputs, the processor must:

4.2.1. Prepare a written sampling plan which includes a description of sample preparation and storage procedures for the organic outputs.

4.2.2. Undertake sampling and testing of the organic outputs as required under clause 4.2.3. The sampling must be carried out in accordance with the written sampling plan. Testing must be within 25 working days from the date of sampling.

4.2.3. Undertake characterisation sampling of the organic outputs by collecting 20 composite samples of the waste and testing each sample for the chemical and other attributes listed in Column 1 of Table 1. Each composite sample must be taken from a batch, truckload or stockpile that has not been previously sampled for the purposes of characterisation. A maximum of 2 composite samples may be collected per month. Characterisation must be conducted for the organic outputs generated and processed during the 1-year period following the commencement of the process. Note: Routine sampling requirements will be determined on review of the results of characterisation testing.

Chemical and other material requirements

4.3. The absolute maximum concentration or other value of that attribute in any organic outputs supplied under this order must not exceed the absolute maximum concentration or other value listed in Column 2 of Table 1. Note that while limits are not included for attributes 16 – 20 in Table 1, these must be tested in each sample and records kept of results.

The processor must not supply organic outputs to any person if, in relation to any of the chemical and other attributes of the organic outputs, the concentration or other value of that attribute of any sample collected and tested as part of the characterisation of the organic outputs exceeds the absolute maximum concentration or other value listed in Column 2 of Table 1.

Table 1

Column 1	Column 2
Chemicals and other attributes	**Absolute maximum concentration** (dry weight in mg/kg unless otherwise specified)
1. Mercury	4
2. Cadmium	3
3. Lead	420 for mine sites 250 for plantation forestry use, non-contact agricultural use and broad acre agricultural use [1,2]
4. Arsenic	20
5. Chromium (total)	100
6. Copper	375
7. Nickel	60
8. Selenium	5
9. Zinc	700
10. DDT/DDD/DDE	0.5
11. Other pesticides [3]	2
12. Polychlorinated Biphenyls (PCBs)	ND[4]
13. Glass, metal and rigid plastics > 2 mm	2.5% for mine sites (as % dry matter on weight/weight basis)[1]
	0.5% for plantation forestry use, non-contact agricultural use and broad acre agricultural use (as % dry matter on weight/weight basis)[1]
14. Plastics – light flexible film > 5 mm	0.1% for mine sites (as % dry matter on weight/weight basis)[1]
	0.2% for plantation forestry use, non-contact agricultural use and broad acre agricultural use (as % dry matter on weight/weight basis)[1]
15. Maximum particle size	16 mm (particle size)
16.	N/A
17. Total Polycyclic Aromatic Hydrocarbons (PAHs)[6]	N/A
18. Phthalates[7]	N/A
19. Pesticides (non-scheduled)[8]	N/A
20. Monobutyltin	N/A

Notes and Definitions for Table 1

1. Future contaminant levels will be set after considering the outcomes of research and trials that are to be conducted as well as the other considerations outlined in the notes to this Order.

2. The effectiveness of mechanisms implemented by each facility in clause 4.1.4 in reducing the levels of lead present in the organic outputs will be evaluated. The maximum lead concentration may be amended following this review.
3. **Other pesticides** mean Aldrin, Dieldrin, Chlordane, Heptachlor, Hexachlorobenzene (HCB), Lindane and Benzene Hexachloride (BHC).
4. No detected individual PCB Aroclor at a limit of detection of 0.2 mg PCB Aroclor/kg.
5. **Other metals** mean antimony, beryllium, boron, cobalt, manganese, molybdenum, tin, and vanadium.
6. **PAHs** means the following 16 USEPA priority pollutant polycyclic aromatic hydrocarbons (with CAS registry numbers): Acenaphthene (83-32-9), Chrysene (21[illegible]-9), Acenaphthylene (208-96-8), Dibenzo(a,h)anthracene (53-70-3), Anthracene (120-[illegible]), Fluoranthene (206-44-0), Benzo(a)anthracene (56-55-3), Fluorene (86-[illegible]), Benzo(a)pyrene (50-32-8), Indeno(1,2,3-cd)pyrene (193-39-5), Benzo(b)fluoranthene (205-99-2), Naphthalene (91-20-3), Benzo(ghi)perylene (191-24-2), Phenanthrene (85-01-8), Benzo(k)fluoranthene (207-08-9), and Pyrene (129-00-0).
7. **Phthalates** means (with CAS registry numbers): Di-2-ethylhexylphthalate (DEHP) (117-81-7) and Dibutylphthalate (DBP) (84-74-2).
8. **Pesticides (non-scheduled)** means the following pesticides, herbicides, fungicides and insecticides (with CAS registry numbers): Brodifacoum (56073-10-0), Chlorpyrifos (2921-88-2), Cypermethrin (52315-07-8), Dichlofluanid (1085-98-9), Emamectin benzoate (137515-75-4 & 155569-91-8), Permethrin (52645-53-1), Phoxim (4114-08-7), Simazine (122-34-9), and Tebuconazole (107534-96-3).

Test methods

4.5. The processor must ensure that any testing of samples required by this order is undertaken by analytical laboratories accredited by the National Association of Testing Authorities, Australia or equivalent.

4.6. The processor must ensure that the chemicals and other attributes (listed in Column 1 of Table 1) in the organic outputs supplied are tested in accordance with the test methods specified below or other equivalent analytical methods. Where an equivalent analytical method is used the detection limit must be equal to or less than that nominated for the given method below.

4.6.1. Test method for measuring the mercury concentration:

4.6.1.1. Analysis using USEPA SW-846 Method 7471B Mercury in solid or semisolid waste (manual cold-vapor technique), or an equivalent analytical method with a detection limit < 20% of the stated absolute maximum concentration in Table 1, Column 2.

4.6.1.2. Results must be reported as mg/kg dry weight.

4.6.2. Test methods for measuring metals 2 – 9 and 16:

4.6.2.1. Sample preparation by digestion - USEPA SW-846 Method 3050B acid digestion of sediments, sludges, soils, and oils, or using an equivalent digestion method.

4.6.2.2. Analysis using USEPA SW-846 Method 6010C Inductively coupled plasma - atomic emission spectrometry, or an equivalent analytical method with a detection limit < 10% of the stated absolute maximum concentration in Table 1, Column 2.

4.6.2.3. Results must be reported as mg/kg dry weight.

4.6.3. Test method for measuring 10, 11, 17 and 18:

4.6.3.1. Analysis using USEPA SW-846 Method 8270D Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), or equivalent.

4.6.3.2. Results must be reported as mg/kg dry weight.

4.6.4. Test method for measuring PCBs:

4.6.4.1. Analysis using USEPA SW-846 Method 8082A Polychlorinated Biphenyls (PCBs) By Gas Chromatography (GC), or equivalent.

4.6.4.2. Measure the following PCBs: Aroclor 1016 (CAS Registry No. 12674-11-2), Aroclor 1221 (CAS Registry No. 11104-28-2), Aroclor 1232 (CAS Registry No. 11141-16-5), Aroclor 1242 (CAS Registry No. 53469-21-9), Aroclor 1248 (CAS Registry No. 12672-29-6), Aroclor 1254 (CAS Registry No. 11097-69-1), Aroclor 1260 (CAS Registry No. 11096-82-5).

4.6.4.3. Results must be reported as mg/kg dry weight.

4.6.5. Test method for measuring physical contaminants (13 and 14):

4.6.5.1. Analysis using Australian Standard AS4454-2003 Composts, soil conditioners and mulches, "Appendix H - Method For Determination Of Moisture Content And Level Of Visible Contamination".

4.6.5.2. Results must be reported as % contamination on a dry mass basis.

4.6.6. Test method for measuring maximum particle size:

4.6.6.1. Analysis using Australian Standard AS4454-2003 Composts, soil conditioners and mulches, "Appendix F – Method For Determination Of Particle Size Grading".

4.6.6.2. Results must be reported as % by mass retained on a sieve with 16 mm apertures.

4.6.6.3. The entire sample must pass through the sieve.

4.6.7. Test method for measuring pesticides (non-scheduled):

4.6.7.1. Analysis using USEPA SW-846 Method 8270D Semivolatile Organic Compounds By Gas Chromatography/Mass Spectrometry (GC/MS) for all pesticides (non-scheduled) or equivalent, except for the following:

(a) Analysis of Dichlofluanid – AOAC method 2007.01 Pesticide Residues in Foods by GC/MS.

(b) Emamectin benzoate – acceptable analytical methods for the determination of emamectin benzoate include high-performance liquid chromatography (HPLC) with fluorescence detection.

(c) Brodifacoum – acceptable analytical methods for the determination of brodifacoum include high-performance liquid chromatography (HPLC) with fluorescence detection such as AOAC International 18th Edition, Method 983.11 and *Journal of Chromatography A*, 1985, Volume 321, Pages 255-272.

4.6.7.2. Results must be reported as mg/kg dry weight.

4.6.8. Test method for measuring monobutyltin:

4.6.8.1. Analysis using International Organization for Standardization ISO/DIS 23161.2:2007 Selected organotin compounds – Soil quality by Gas-chromatographic method (GC), or equivalent.

4.6.8.2. Results must be reported as mg/kg dry weight.

Notification

4.7. On or before each transaction, the processor must obtain a written statement of compliance in accordance with clauses 7.18 of 'the organic outputs derived from mixed waste exemption 2014'.

4.8. On or before each transaction, the processor must provide the following to each person to whom the processor supplies the organic outputs:

- a written statement of compliance certifying that all the requirements set out in this order have been met;
- a copy of the organic outputs exemption, or a link to the EPA website where the organic outputs exemption can be found; and
- a copy of the organic outputs order, or a link to the EPA website where the organic outputs order can be found.

Record keeping and reporting

4.9. The processor must keep a written record of the following for a period of six years:

- the sampling plan required to be prepared under clause 4.2.1;
- all characterisation sampling results in relation to organic outputs supplied;
- the quantity of any organic outputs supplied;
- the name and address of each person to whom the processor supplied the organic outputs;
- the location(s) where the organic outputs are applied, including the address and paddock or plot identification;
- the rate(s) at which the organic outputs are applied to the land at each location as defined above; and
- the date(s) on which the organic outputs are applied to the land at each location as defined above.

4.10. The processor must provide, on request, the most recent characterisation results for organic outputs that are supplied to any consumer of the organic outputs.

4.11. The processor must notify the EPA within seven days of becoming aware that it has not complied with any requirement in clause 4.1 to 4.6.

5. Definitions

In this order:

animal waste means dead animals and animal parts and any mixture of dead animals and animal parts.

AOAC International 18th Edition means Dr. William Horwitz and Dr. George Latimer, Jr. Editors. "Official Methods of Analysis of AOAC International", 18th Edition Revision 2 (2007), AOAC INTERNATIONAL, Gaithersburg, MD, USA.

application or apply to land means applying to land by:

- spraying, spreading or depositing on the land; or
- ploughing, injecting or mixing into the land; or

- filling, raising, reclaiming or contouring the land.

biological stabilisation means a process whereby mixed waste undergoes a process of managed biological transformation for a period of not less than a total of 6 weeks of composting and curing, or until an equivalent level of biological stability can be demonstrated. Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

biologically stabilised means the mixed waste that has undergone biological stabilisation.

broad acre agricultural use means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are grown below the surface of the land.

composite sample means a sample that combines five discrete sub-samples of equal size into a single sample for the purpose of analysis.

consumer means a person who applies, or intends to apply, organic outputs to land.

food waste means waste from the manufacture, preparation, sale or consumption of food but does not include grease trap waste.

garden waste means waste that consists of plant material, grass, leaves, plants, loppings, tree trunks, tree stumps and similar materials and includes any mixture of those materials.

manure means faecal matter generated by animals other than humans and includes any mixture of animal faecal matter and biodegradable animal bedding such as straw or sawdust.

mine site means land disturbed by mining on which rehabilitation is being carried out by or on behalf of:

(a) the holder of an authority under the *Mining Act 1992* pursuant to an approved rehabilitation plan

(b) the State of NSW.

mixed waste means:

(a) residual household waste that contains putrescible organics and/or

(b) waste from litter bins that are collected by or on behalf of local councils.

It may only be mixed with any one or more of the following:

(i) waste collected from commercial premises by or on behalf of councils as part of a kerbside household waste collection service,

(ii) commercial waste sourced from restaurants, clubs, pubs, hotels, motels, resorts, offices, schools and shopping centres that is similar in composition to household waste (but may include a higher proportion of food waste),

(iii) manure,

(iv) food waste,

(v) animal waste,

(vi) grit or screenings from sewage treatment systems that have been dewatered so that the grit or screenings do not contain free liquids,

(vii) up to 20% source separated household garden and food waste.

It must not contain any other waste. For example, it must not contain:

(a) any special waste, hazardous waste, restricted solid waste or liquid waste as defined in clause 49 of Schedule 1 to the Act; or

(b) any source separated recyclable household waste other than those set out in (vii) above.

N/A means not applicable.

non-contact agricultural use means application to land where the land is used for the growing of fruit or nut trees or vines but not where fallen produce is or may be collected off the ground. It does not include application to land where the land is used for grazing or for any other cropping purpose.

pasteurisation means a process to significantly reduce the numbers of plant and animal pathogens and plant propagules. Pasteurisation requires that the entire mass of organic material be subjected to either of the following:

(a) Appropriate turning of outer material to the inside of the windrow so that the whole mass is subjected to a minimum of 3 turns in total, internal temperature reaching a minimum of 55°C for 3 consecutive days before each turn. Where materials with a higher risk of containing pathogens are present, including but not limited to manure and food waste, the core temperature of the material mass should be maintained at 55°C or higher for 15 days or longer, and during this period the windrow should be turned a minimum of 5 times.

(b) An alternative process that guarantees the same pathogen reduction, and the reduction of plant propagules as in (a). Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

pasteurised means that the mixed waste that has been subject to a process of pasteurisation.

pathogen means a living organism that could be harmful to humans, animals, plants or other living organisms.

plantation forestry use means application to an area of land on which the predominant number of trees or shrubs forming, or expected to form, the canopy are trees or shrubs that have been planted (whether by sowing seed or otherwise) for the purpose of timber production.

processor means a person who processes, mixes, blends, or otherwise incorporates organic outputs into a material in its final form for supply to a consumer.

source separated recyclable household waste means household waste from kerbside waste collection services that has been separated for the purpose of recycling.

transaction means:

- in the case of a one-off supply, the supply of a batch, truckload or stockpile of organic outputs that is not repeated,
- in the case where the supplier has an arrangement with the recipient for more than one supply of organic outputs the first supply of organic outputs as required under the arrangement.

Manager Waste Strategy and Innovation

Environment Protection Authority

(by delegation)

Notes

The EPA may amend or revoke this order at any time. It is the responsibility of each of the generator and processor to ensure it complies with all relevant requirements of the most current order. The current version of this order will be available on www.epa.nsw.gov.au

In gazetting or otherwise issuing this order, the EPA is not in any way endorsing the supply or use of this substance or guaranteeing that the substance will confer benefit.

The conditions set out in this order are designed to minimise the risk of harm to the environment, human health or agriculture, although neither this order nor the accompanying exemption guarantee that the environment, human health or agriculture will not be harmed.

Any person or entity which supplies organic outputs should assess whether the material is fit for the purpose the material is proposed to be used for, and whether this use may cause harm. The supplier may need to seek expert engineering or technical advice.

Regardless of any exemption or order provided by the EPA, the person who causes or permits the application of the substance to land must ensure that action is lawful and consistent with any other legislative requirements including, if applicable, any development consent(s) for managing operational odour(s).

The supply of organic outputs remains subject to other relevant environmental regulations in the POEO Act and Waste Regulation. For example, a person who pollutes land (s. 142A) or water (s. 120) or causes air pollution through the emission of odours (s. 126), or does not meet the special requirements for asbestos waste (Part 7 of the Waste Regulation) regardless of this order, is guilty of an offence and subject to prosecution.

This order does not alter the requirements of any other relevant legislation that must be met in supplying this material, including for example, the need to prepare a Safety Data Sheet.

Failure to comply with the conditions of this order constitutes an offence under clause 93 of the Waste Regulation.

Research program

The goal of the Resource Recovery Order and Resource Recovery Exemption for organic outputs is to facilitate the resource recovery of fit for purpose organic outputs by minimising the risks of physical and chemical contaminants.

Trials and research will be conducted to examine the environmental and human health impacts of contaminants in the organic outputs.

The EPA intends to extend the RRE for agricultural uses following a review of the results of the research and trials. The nature of the extended RRE for broad acre agricultural use, non-contact agricultural use and plantation forestry use will be determined taking into account:

- trials that are to be conducted in collaboration with the processors of mixed waste,
- the goal of the exemption,
- the environmental, agricultural and human health impacts of the use of organic outputs,
- the technological capabilities of AWT facilities including the adequacy of pre-sorting processes, and
- community acceptance of the use of organic outputs.

Resource Recovery Exemption under Part 9 Clauses 91 and 92 of the Protection of the Environment Operations (Waste) Regulation 2014

The organic outputs[1] derived from mixed waste exemption 2014

Introduction

This exemption:

- is issued by the Environment Protection Authority (EPA) under clauses 91 and 92 of the Protection of the Environment Operations (Waste) Regulation 2014 (Waste Regulation); and
- exempts a consumer of organic outputs derived from mixed waste (organic outputs) from certain requirements under the *Protection of the Environment Operations Act 1997* (POEO Act) and the Waste Regulation in relation to the application of that waste to land, provided the consumer complies with the conditions of this exemption.

This exemption should be read in conjunction with 'the organic outputs derived from mixed waste order 2014'.

1. Waste to which this exemption applies

1.1 This exemption applies to organic outputs that are, or are intended to be, applied to land as a soil amendment.

1.2 Organic outputs are fine pasteurised and biologically stabilised organic outputs produced from mechanical biological treatment of mixed waste.

2. Persons to whom this exemption applies

This exemption applies to any person who applies, or intends to apply, the organic outputs to land as set out in 1.1.

3. Duration

3.1 This exemption commences on 24 November 2014 and is valid until revoked by the EPA by notice published in the Government Gazette.

[1]These organic outputs are not the same as the source segregated outputs that are covered by the exemptions for compost, pasteurised garden organics, or raw mulch.

4. Premises to which this exemption applies

4.1 This exemption applies to the premises at which the consumer's actual or intended application of organic outputs is carried out.

5. Revocation

5.1 'The organic outputs derived from mixed waste exemption 2014' which commenced on 6 June 2014 is revoked from 24 November 2014.

6. Exemption

6.1 Subject to the conditions of this exemption, the EPA exempts each consumer from the following provisions of the POEO Act and the Waste Regulation in relation to the consumer's actual or intended application of organic outputs to land as a soil amendment at the premises:

- section 48 of the POEO Act in respect of the scheduled activity described in clauses 39 and 42 of Schedule 1 of the POEO Act;
- Part 4 of the Waste Regulation;
- section 88 of the POEO Act; and
- clause 109 and 110 of the Waste Regulation.

6.2 The exemption does not apply in circumstances where organic outputs are received at the premises for which the consumer holds a licence under the POEO Act that authorises the carrying out of the scheduled activities on the premises under clause 39 'waste disposal (application to land)' or clause 40 'waste disposal (thermal treatment)' of Schedule 1 of the POEO Act.

7. Conditions of exemption

The exemption is subject to the following conditions:

General conditions

7.1 At the time organic outputs are received at the premises, the material must meet all chemical and other material requirements for organic outputs which are required on or before the supply of organic outputs under 'the organic outputs order 2014'.

7.2 The organic outputs can only be applied to land as a soil amendment for:

7.2.1 soil improvement or site rehabilitation at mine sites, or

7.2.2 plantation forestry use, or

7.2.3 non-contact agricultural use, or

7.2.4 broad acre agricultural use.

7.3 The organic outputs must not be used:

7.3.1 in urban landscaping,

7.3.2 at public contact sites,

7.3.3 on or in home lawns and gardens,

7.3.4 in potting mix, or

7.3.5 in turf production.

7.4 The consumer must ensure that no windblown litter leaves the premises as a result of the application to land of organic outputs.

7.5 All organic outputs applied to land must be evenly applied across the designated land application area at the application rate prescribed for that land use in clauses 7.6, 7.7 and 7.8.

7.6 For mine sites, no more than 140 tonnes/hectare (dry weight) of organic outputs may be applied in total to a given location.

7.7 For plantation forestry use and for non-contact agricultural use, no more than 50 tonnes/hectare (dry weight) of organic outputs may be applied in total to a given location.

7.8 For broad acre agricultural use, no more than 10 tonnes/hectare (dry weight) of organic outputs may be applied in total to a given location.

7.9 Organic outputs must not be applied to:

7.9.1 land with a slope in excess of 18% (10^0), unless used for mine rehabilitation where all practicable measures have been taken to control stability and prevent runoff, or

7.9.2 soil having a pH of less than 5.0* when measured in a 1:5 soil:water extract, or

7.9.3 land that is within the buffer zone for the protected areas specified in Table 1.

7.10 Animals must not be allowed to graze the land for 30 days after the application of organic outputs to land.

7.11. Lactating and new born animals must not be allowed to graze the land for 90 days after the application of organic outputs to land.

7.12. Crops must not be harvested for 30 days after the application of organic outputs to land.

Table 1 Buffer zones for protected areas

Column 1	Column 2	Column 3	Column 4
Protected Area	**Minimum width of Buffer Zones (m)**		
	Flat (< 3% or 2° slope)	**Downslope (> 3% or 2° slope)**	**Upslope**
Surface waters	50	100	5
Drinking water bores	250	250	250
Other bores	50	50	50

* Where organic outputs are proposed for land application on soils (such as mine sites) where the pH is less than 5.0, a specific exemption may be considered where low concentrations of metals can be achieved.

Sampling requirements

7.13. Prior to receiving and land applying any organic outputs, where the application will result in greater than 10 tonnes/hectare (dry weight) total organic outputs in or on the land, the consumer must sample the soil to which the organic outputs are to be applied by taking the following samples at a depth of 0 to 15 centimetres:

7.13.1. For plantation forestry use and non-contact agricultural use:

(i) For land equal to, or less than 10 hectares - 2 composite samples, and

(ii) For land greater than 10 hectares - 1 composite sample per 10 ha.

7.13.2. For mine site rehabilitation:

(i) For land equal to, or less than, 20 hectares - 2 composite samples, and

(ii) For land greater than 20 hectares - 1 composite sample per 20 ha.

7.14. The soil where the organic outputs have been applied to land must be re-sampled and re-tested as set out in clause 7.13 prior to receiving or applying any additional organic outputs to the land.

Chemical and other material requirements

7.15. Prior to receiving and land applying the organic outputs where the application will result in greater than 10 tonnes/hectare (dry weight) total organic outputs, the consumer must ensure that:

7.15.1. each of the composite samples referred to in section 7.13 are tested for the contaminants listed in Column 1 of Table 2.

7.15.2. the contaminant concentrations prior to application of organic outputs to the land do not exceed the maximum levels specified for those contaminants for the relevant land use in either Column 2 or Column 3 of Table 2.

Table 2 Maximum allowable soil contaminant concentrations[1] prior to organic outputs application to land

Column 1	Column 2	Column 3
Contaminant	**Mine sites** **Maximum allowable soil contaminant concentration** (dry weight of soil in mg/kg, unless otherwise specified)	**Plantation forestry use, non-contact agricultural use and broad acre agricultural use land** **Maximum allowable soil contaminant concentration** (dry weight of soil in mg/kg, unless otherwise specified)
1. Mercury	4	1
2. Arsenic	20	20
3. Cadmium	5	1
4. Chromium (total)	250	100
5. Copper	375	100
6. Lead	150	150
7. Nickel	125	60
8. Selenium	8	5
9. Zinc	700	200

10. DDT/DDD/DDE	0.5	0.5
11. Aldrin	0.2	0.02
12. Dieldrin	0.2	0.02
13. Chlordane	0.2	0.02
14. Heptachlor	0.2	0.02
15. Hexachlorobenzene (HCB)	0.2	0.02
16. Lindane	0.2	0.02
17. Benzene hexachloride (BHC)	0.2	0.02
18.Polychlorinated Biphenyls (PCBs)	0.3	ND[2]

Notes and Definitions for the purposes of Table 2:

1. Maximum allowable soil contaminant concentrations are mean concentration values based on the sampling requirements set out in Section 7.13.
2. No detected PCBs at a limit of detection of 0.[illegible] mg PCB/kg soil. Organic output must not be applied to land where any individual PCB Aroclor has been detected at a limit of detection of 0.1 mg PCB/kg.

Test methods

7.16. The consumer must ensure that any testing of samples required by this exemption is undertaken by analytical laboratories accredited by the National Association of Testing Authorities (NATA), or equivalent.

7.17. The consumer must ensure that the contaminants (listed in Column 1 of Table 2) in the soil are tested in accordance with the test methods specified below or other equivalent analytical methods. Where an equivalent analytical method is used the detection limit must be equal to or less than that nominated for the given method below.

7.17.1. Test method for measuring the mercury concentration:

7.17.1.1. Analysis using USEPA SW-846 Method 7471B Mercury in solid or semisolid waste (manual cold-vapor technique), or an equivalent analytical method with a detection limit < 20% of the applicable stated maximum allowable concentration in Table 2, Columns 2 and 3.

7.17.1.2. Results must be reported as mg/kg dry weight.

7.17.2. Test methods for measuring metals 2 – 9:

7.17.2.1. For sample preparation by digestion - USEPA SW-846 Method 3050B acid digestion of sediments, sludges, soils, and oils, or using an equivalent digestion method.

7.17.2.2. Analysis using USEPA SW-846 Method 6010C Inductively coupled plasma - atomic emission spectrometry, or an equivalent analytical method with a detection limit < 10% of the applicable stated maximum allowable concentration in Table 2, Columns 2 and 3.

7.17.2.3. Results must be reported as mg/kg dry weight.

7.17.3. Test method for measuring 10 – 18 in Table 2:

7.17.3.1. Analysis using USEPA SW-846 Method 8270D Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), or equivalent.

7.17.3.2. Results must be reported as mg/kg dry weight.

Notification

7.18. On or before each transaction, the consumer must provide a written statement of compliance to each generator or supplier that the consumer has engaged to supply the organic outputs, certifying that:

- all the sampling and testing requirements set out in clause 7.13 – 7.17 of this exemption have been met; and
- none of those test results show that existing contaminant concentrations in the soil exceed any of the maximum allowable soil contaminant concentrations in Table 2.

Record keeping and reporting

7.19 The consumer must keep a written record of the following for a period of six years for each delivery of organic outputs received:

- the quantity of the organic outputs received;
- the name and address of the supplier of organic outputs received;
- the location(s) where the organic outputs are applied including the address and paddock or property identification;
- the rate(s) at which the organic outputs are applied to the land at each location as defined above;
- the date(s) upon which the organic outputs are applied to the land at each location as defined above; and
- for land application sites other than mine sites, where the consumer is not the owner of the land on which the organic outputs are applied, the consumer must obtain a statement of consent from the owner of the land that the owner has received a copy of the exemption and accepts the application on the land.

7.20 The consumer must make any records required to be kept under this exemption available to authorised officers of the EPA on request.

7.21 The consumer must ensure that any application of organic outputs to land must occur within a reasonable period of time after its receipt.

Definitions

In this exemption:

animal waste means dead animals and animal parts and any mixture of dead animals and animal parts.

application or apply to land means applying to land by:

- spraying, spreading or depositing on the land; or
- ploughing, injecting or mixing into the land; or
- filling, raising, reclaiming or contouring the land.

biological stabilisation means a process whereby mixed waste undergoes a process of managed biological transformation for a period of not less than a total of 6 weeks of composting and curing, or until an equivalent level of biological stability can be demonstrated. Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

biologically stabilised means the mixed waste that has undergone biological stabilisation.

broad acre agricultural use means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.

composite sample means a sample that combines five discrete sub-samples of equal size into a single sample for the purpose of analysis.

consumer means a person who applies, or intends to apply, organic outputs to land.

food waste means waste from the manufacture, preparation, sale or consumption of food but does not include grease trap waste.

garden waste means waste that consists of branches, grass, leaves, plants, loppings, tree trunks, tree stumps and similar materials and includes any mixture of those materials.

manure means faecal matter generated by any animal other than humans and includes any mixture of animal faecal matter and biodegradable animal bedding such as straw or sawdust.

mine site means land disturbed by mining on which rehabilitation is being carried out by or on behalf of:

(a) the holder of an authority under the *Act 1992* pursuant to an approved rehabilitation plan, or

(b) the State of NSW.

mixed waste means:

(a) residual household waste that contains putrescible organics and/or

(b) waste from litter bins that are collected by or on behalf of local councils.

It may only be mixed with any one or more of the following:

(i) waste collected from commercial premises by or on behalf of councils as part of its kerbside household waste collection service,

(ii) waste sourced from restaurants, clubs, pubs, hotels, motels, resorts, offices, schools and shopping centres that is similar in composition to household waste (but may include a higher proportion of food waste),

(iii) manure,

(iv) food waste,

(v) animal waste,

(vi) grit or screenings from sewage treatment systems that have been dewatered so that the grit or screenings do not contain free liquids, or

(vii) up to 20% source separated household garden and food waste.

It must not contain any other waste. For example, it must not contain:

(a) any special waste, hazardous waste, restricted solid waste or liquid waste as defined in clause 49 of Schedule 1 to the Act; or

(b) any source separated recyclable household waste other than those set out in (vii) above.

non-contact agricultural use means application to land where the land is used for the growing of fruit or nut trees or vines but not where fallen produce is or may be collected off the ground. It does not include application to land where the land is used for grazing or for any other cropping purpose.

pasteurisation means a process to significantly reduce the numbers of plant and animal pathogens and plant propagules. Pasteurisation requires that the entire of organic material be subjected to either of the following:

(a) Appropriate turning of outer material to the inside of the windrow so that the whole mass is subjected to a minimum of 3 turns with the internal temperature reaching a minimum of 55°C for 3 consecutive days before each turn. Where materials with a higher risk of containing pathogens are present, including not limited to manure and food waste, the core temperature of the material mass should be maintained at 55°C or higher for 15 days or longer, and during this period the windrow should be turned a minimum of 5 times.

(b) An alternative process that guarantees the same level of pathogen reduction, and the reduction of plant propagules as in (a). Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

pasteurised means that the mixed waste that has been subject to a process of pasteurisation.

pathogen means a living organism that could be harmful to humans, animals, plants or other living organisms.

plantation forestry use means application to an area of land on which the predominant number of trees or shrubs forming, or expected to form, the canopy are trees or shrubs that have been planted (whether by sowing seed or otherwise) for the purpose of timber production.

processor means a person who processes, mixes, blends, or otherwise incorporates organic outputs into a material in its final form for supply to a consumer.

public contact site means land with a high potential for contact by the public, including public parks, fields, cemeteries, plant nurseries and golf courses.

source separated recyclable household waste means household waste from kerbside waste collection services that has been separated for the purpose of recycling.

transaction means:

- in the case of a one-off supply, the supply of a batch, truckload or stockpile of organic outputs that is not repeated,
- in the case where the supplier has an arrangement with the recipient for more than one supply of organic outputs the first supply of organic outputs as required under the arrangement.

Manager Waste Strategy and Innovation

Environment Protection Authority

(by delegation)

Notes

The EPA may amend or revoke this exemption at any time. It is the responsibility of the consumer to ensure they comply with all relevant requirements of the most current exemption. The current version of this exemption will be available on www.epa.nsw.gov.au.

In gazetting or otherwise issuing this exemption, the EPA is not in any way endorsing the use of this substance or guaranteeing that the substance will confer bene

The conditions set out in this exemption are designed to minimise the risk of pot harm to the environment, human health or agriculture, although neither this exe nor the accompanying order guarantee that the environment, human ealth o agriculture will not be harmed.

The consumer should assess whether or not the organic outputs is fit for th urpose the material is proposed to be used for, and whether this use may ause ha The consumer may need to seek expert advice from a certified prof sional il scie (http://www.cpss.com.au/index.php/locate-a-cpss/cpss-register)

Regardless of any exemption provided by the EPA, the person who c ses o ermits the application of the substance to land must ensure hat the ion is la ul and consistent with any other legislative req ments cluding, pplic le, any development consent(s) for managing operati n the te(s).

The receipt of organic outputs remains subje t relevant environmental regulations in the POEO Act and the Waste Regula . For exa le, a person who pollutes land (s. 142A) or water (s. 120), c s air p tion through the emission of odours (s. 126), or does not meet e spec equir nts for asbestos waste (Part 7 of the Waste Regulation), reg dless of ha g an exemption, is guilty of an offence and subject to prosecution.

This exemption does not alter th requi ments of y other relevant legislation that must be met in utilising this mat al, inc example, the need to prepare a Safety Data Sheet (SDS).

Failure to comply with the ditions f this exemption constitutes an offence under clause 91 of the Waste Regulati

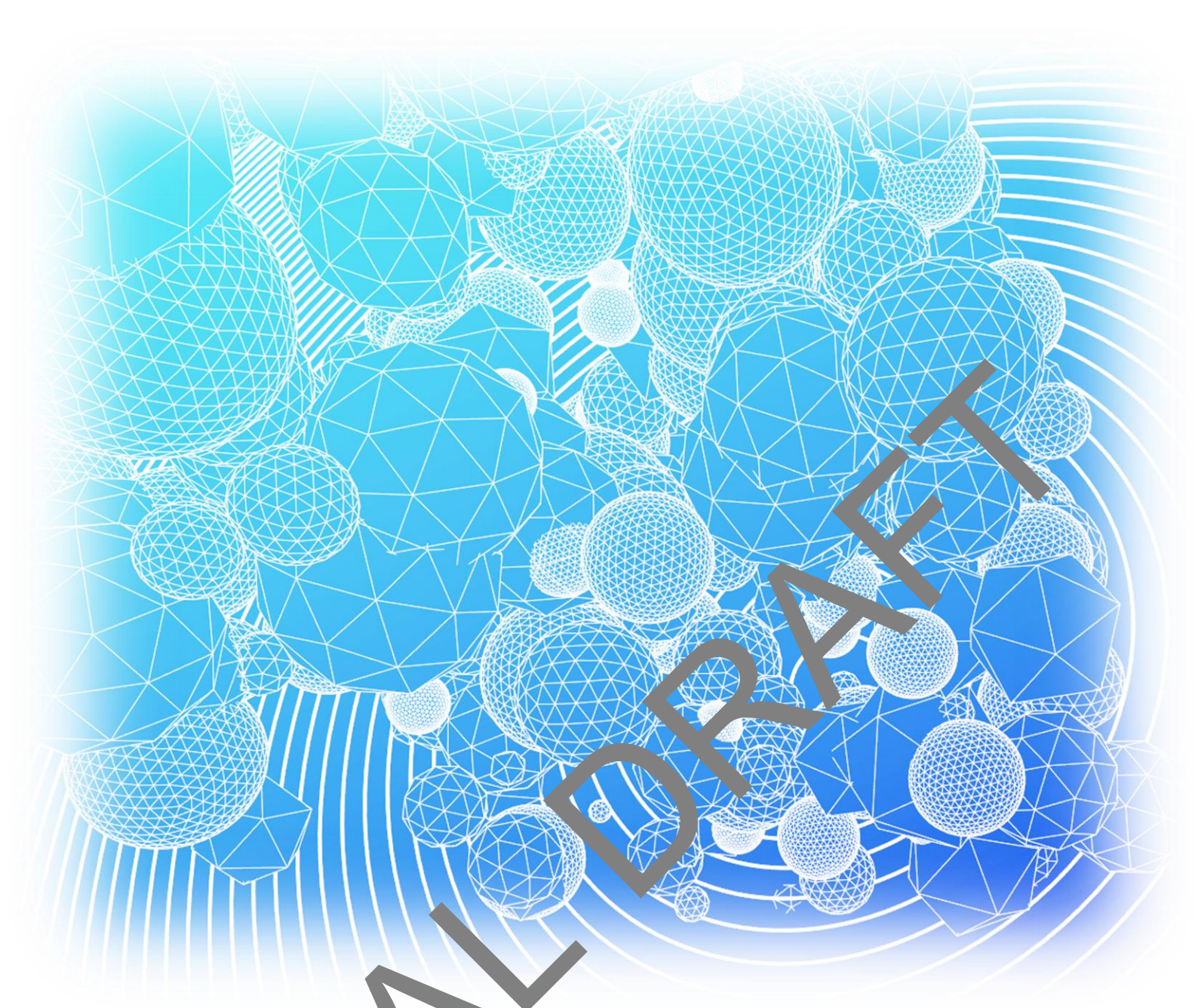
Additional infor ation

Application a the m imum rates allowed in this exemption can add physical c minants lan as follo s:

Glass etal and rigid plastics > 2	3.5 tonnes per hectare for mine sites
	0.75 tonnes per hectare for plantation forestry use and non-contact agricultural use
	0.15 tonnes per hectare for broad acre agricultural use
Pla – light, flexible or film > 5 m	0.35 tonnes per hectare for mine sites
	0.1 tonnes per hectare for plantation forestry use and non-contact agricultural use
	0.02 tonnes per hectare for broad acre agricultural use

Physical contaminants may also be present in substantial quantities below 2 mm (for glass, metal and rigid plastics) and 5 mm (for Plastics – light, flexible or film).

Appendix B Interim HHERA (October 2018)



FINAL DRAFT

Human Health and Ecological Risk Assessment, Application of Alternative Waste Technologies Materials to Agricultural Land

Prepared for: NSW EPA

19 October 2018

Document History and Status

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Limitations

Environmental Risk Sciences has prepared this report for the use of NSW EPA in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

It is prepared in accordance with the scope of work and for the purpose outlined in the Section 1 of this report.

The methodology adopted and sources of information used are outlined in this report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information provided was false.

This report was prepared in October 2018 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Appendices

Appendix A Resource Recovery Order and Exemption
Appendix B Plant Uptake Factor Equations
Appendix C Risk Calculations

Glossary of Terms

ADI	Acceptable Daily Intake
ANZECC	Australia and New Zealand Environment and Conservation Council
AT	Averaging Time
BGL	Below Ground Level
BTEX	Benzene, toluene, ethylbenzene and total xylenes
BW	Body Weight
CF	Unit Conversion Factor
CoPC	Chemicals of Potential Concern
ED	Exposure Duration
EF	Exposure Frequency
EPA	Environment Protection Authority
ET	Exposure Time
HHRA	Human Health Risk Assessment
HI	Hazard Index
HIL	Health Investigation Level
HQ	Hazard Quotient
HSL	Health Screening Level
LOR	Limit of Reporting
NEPM	National Environment Prote ion Meas
NHMRC	National Health and Medica Research C ncil
PAH	Polycyclic aromatic hydrocarb
RfC	Reference Concentration
RfD	Reference Dose
RME	Reasonable m ximum exposure
SA	Surface area
TC	Tolera Concentra n
TDI	Tolerab Dai take
TDS	Total Dis ol d Solids
US EPA	U ed Sta es Environmental Protection Agency
VOC	Volat Org nic Compound
WHO	lth Organisation

Executive Summary

Environmental Risk Sciences Pty Ltd has undertaken an assessment of the human health and ecological risks posed by application of mixed waste organic outputs (MWOO) materials generated at Alternative Waste Treatment facilities to agricultural land.

Mixed waste from red-lid garbage bins is processed at Alternative Waste Treatment (AWT) facilities to produce mixed waste organic outputs (MWOO). These materials have been permitted for application to land (agriculture, forestry and mine rehabilitation) under a resource recovery order and exemption issued by NSW EPA. When the use of these materials commenced there was limited information available. In addition to regulating their use, NSW EPA commissioned a research program which was undertaken between 2011 and 2017.

The risk assessment process involves estimating concentrations of chemicals that may be in the MWOO that could be present in the environment after the material is applied to land. Once the concentrations in the environment that people or organisms may be exposed to have been estimated they are compared with toxicity reference values to determine risk. If the concentrations people might be exposed to are higher than the toxicity reference values risks are higher than preferred. If concentrations are lower then the risks are low and acceptable.

Toxicity reference values are that Australian or international health authorities have determined should be protective of heath. Determining toxicity reference values involves reviewing the scientific literature to find the lowest dose that caused no effects. This dose is then divided by a number of uncertainty factors depending on how much and what type of data is available so these toxicity reference values are much smaller than any of the doses used in studies where no effects were seen.

Calculating how much people or organisms may be exposed to involves making a number of assumptions about how people might be exposed. If the site specific situation where this material might be applied is well understood then these assumptions can be tailored to what might actually occur. When a more generic calculation is required, as is the case here due to the number of sites where this material may have been applied, the assumptions need to be more-worst case to ensure risks are not underestimated for the wide range of potential exposures at the various sites.

This assessment is a more worst-case type of assessment. The key assumptions that have been made include:

- People live at a site for 29 years as adults and 6 years as children and the PBDE chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- People eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO
- People drink 100% of the milk they consume each year from dairy cows kept at the site on land that has been treated with the MWOO
- People eat 50, 75 or 100% of the meat they consume each year from cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of fruit, vegetables or wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO

- The PBDEs found in the MWOO are 100% available to be taken up (this is unlikely due to the nature of these chemicals which means they are likely to be strongly absorbed into the soil and MWOO materials)
- Background intake of PBDEs from household articles (like TVs, furniture, computers etc) takes up 80% of the allowable amount (as per the toxicity reference value) of these chemicals so the risk estimates here are based on comparing the concentrations people might be exposed to with 20% of the allowable amount recommended by health authorities

This risk assessment has used the results of the NSW EPA research program.

This assessment has not evaluated the potential risk to the commercial food supply for food types grown at sites where these materials have been applied. Given the large number of farms that supply such food types into the commercial food supply, it is not possible that a person, who does not live on one of these farms, would consume food from such a site on a daily basis.

Based on the assessment presented in this report, the potential for PBDEs to be present in surface soil after application of treated waste materials results in the following:

- Risks for people who come into contact with soil where these materials have been applied are low and acceptable (i.e. exposure via ingestion of soil, dermal contact with soil and inhalation of dust)
- Risks for people who consume any type of produce on a regular basis (i.e. all year round based on the assumptions listed above) from land where these materials have been applied are not acceptable and such exposure should be avoided.

Based on the assessment presented in this report, the potential for PFAS to be present in surface soil after application of treated waste materials results in the following:

- Risks for people who come into contact with soil and/or consume any type of produce on a regular basis (i.e. all year round based on the assumptions listed above) from land where these materials have been applied where these materials have been applied are low and acceptable

Based on the assessment presented in this report, the potential for various chemicals to be present in groundwater or surface water after leaching from the treated waste materials results in the following:

- Risks for people who come into contact with such surface or groundwaters are low and acceptable

This assessment could be further refined to allow a more realistic/site-specific consideration of the risks if more information was available about actual measured concentrations of PBDEs in soil at sites where these materials have been applied.

It is expected that ecological risks at sites where these materials have been applied will be relatively low for both soil and surface/groundwater and are unlikely to need management.

It is expected that risks for water that may be impacted by leaching or runoff from soil treated with these materials, where that water is used for agricultural purposes, will be relatively low and do not need management.

Section 1. Introduction

1.1 Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned by NSW EPA to assess the human health and ecological risks posed by application to agricultural land of mixed waste organic outputs (MWOO) materials generated at Alternative Waste Treatment facilities.

Some mixed waste from red-lid garbage bins is processed at Alternative Waste Treatment (AWT) facilities to produce mixed waste organic outputs (MWOO). These materials have been permitted for application to land (agriculture, forestry and mine rehabilitation) under a resource recovery order and exemption issued by NSW EPA. The most recent versions of these instruments were issued in 2014. The order and exemption are included in full in **Appendix A**.

When the use of these materials commenced there was limited information available about them. In addition to regulating their use, NSW EPA commissioned a research program which was undertaken between 2011 and 2017.

The information available from the research program has been used for this assessment to determine potential risks from the use of this product over the last decade.

1.2 Objectives

The overall objective of this assessment is to use worst case modelling to quantify the risk to human health and the environment resulting from land application of MWOO to agricultural land. The assessment is to focus on chemicals that may be present in MWOO that were classified as high or very high priority in a hazard assessment undertaken by NSW OEH.

Specifically, the assessment is to address the following questions:

- What is the risk to human health and the environment from past applications to land of MWOO in agriculture in NSW? (Agriculture includes broadacre cropping, grazing animals (sheep, cattle), fruit trees (blueberries), tea trees, sugar cane) The key focus areas to be covered are the risks of:
  - Uptake into edible crops (wheat, oats, barley), fruit (blueberries) and then human consumption of those crops;
  - Uptake into grazing animals (cattle and sheep) via direct ingestion of soil and ingestion of pasture and then human consumption of animal products (meat, milk) from those animals;
  - Direct exposure to humans from contact with soil (via direct ingestion, inhalation or dermal pathways).
- What is the risk that surface or ground water bodies may be contaminated by past and/or future applications to land of MWOO?
- Is there a risk to human health or the environmental from PFAS found in MWOO?
- If risks are identified above, how long will the risk remain?

It is important to note that for this assessment has focused on evaluating potential for on farm consumption of food stuffs by people living on a farm which has had the treated waste materials applied. The risk calculations provided do not address the commercial food supply.

The chemicals identified by NSW OEH that need to be considered in this assessment for the solid MWOO materials include:

Human Health

- PBDEs (Polybrominated diphenyl ethers)

Ecological

- Aluminium
- Copper
- Manganese
- Zinc
- Phenol
- Bis-2-ethylhexyl adipate
- Bis-2-ethylhexyl phthalate
- Bisphenol A
- Penta brominated diphenyl ether
- Electrical conductivity/salinity

The chemicals identified by NSW OEH that need to be considered in this assessment for leachate from solid MWOO materials include:

Human Health

- Antimony
- Arsenic
- Cadmium
- Lead
- Nickel

Ecological

- Aluminium
- Barium
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Mercury
- Nickel
- Tin
- Zinc
- Sulfate
- Sulfide
- MCPA
- Ammonia
- Nitrate

- Phosphorus
- Electrical conductivity/salinity

Agricultural uses – Livestock watering

- Copper

Agricultural Uses – Irrigation

- Copper
- Iron
- Manganese
- Molybdenum
- Nickel
- Dicamba
- Phosphorus
- Electrical conductivity/salinity

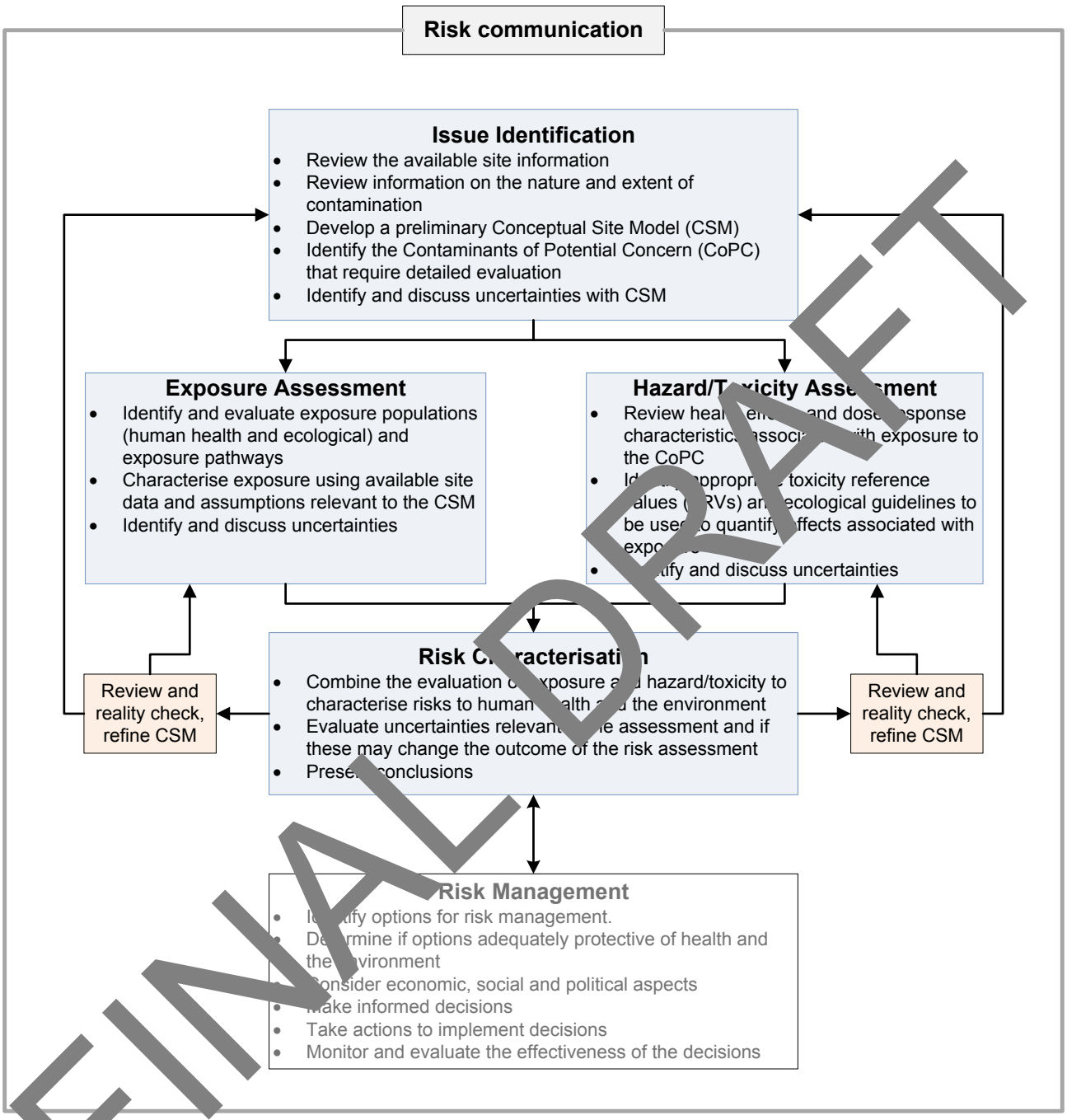
1.3 Methodology and Scope of Works

The approach taken for the quantitative assessment of human health risks is in accordance with guidelines/protocols endorsed by Australian regulators, including:

- enHealth (2012a) Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a)
- enHealth (2012b) Australian Exposure Factor Guide (enHealth 2012b)
- ASC NEPM (2013) National Environmental Protection Measure – Assessment of Site Contamination including:
    - Schedule B1 Investigation Levels for Soil and Groundwater (NEPC 1999 amended 2013e)
    - Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013d)
    - Schedule B5 Guideline on Ecological Risk Assessment (NEPC 1999 amended 2013a)
    - Schedule B6 Guideline on Risk Based Assessment of Groundwater Contamination (NEPC 1999 amended 2013b, 2013)
    - Schedule B7 Guideline on Health-Based Investigation Levels (NEPC 1999 amended 2013c)
    - Toolbox Note – Key principles for the remediation and management of contaminated sites
- Technical guidance in relation to the assessment of vapour risks (CRC CARE 2011, 2013; Davis et al. 2009).
- ANZECC Guidelines on Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000)

The above documents are supplemented by protocols and guidelines developed by international agencies such as the USEPA (USEPA 1989, 1991, 2002, 2004, 2009) as required.

The overall approach to health risk assessment recommended by the enHealth national risk assessment guidance document is outlined in the following **Figure** (enHealth 2012a).



Following this guidance, the assessment has been undertaken to include the following:

- Background information (**Section 2**);
- Exposure Assessment for Human Health (Solid MWOO) (**Section 3**);
- Exposure Assessment for Human Health (Leachate from MWOO) (**Section 4**);
- Identification of relevant toxicological information and data for the key chemicals (**Section 5**);

- Quantification and characterisation of the risks to human health and consideration of the uncertainties in the assessment of risk (**Section 6**);
- Characterisation of ecological risks (**Section 7**);
- Conclusions (**Section 8**).

Section 2. Background

2.1 Presence of chemicals and exposure to chemicals in everyday life

The fundamental building blocks for the entire planet are chemical substances. Whether it is the water we drink, the air we breathe, the food we eat, the ground we walk on, the houses we live in, the things we have inside our houses or workplaces or what we are made of, everything is made of chemicals.

Some chemical substances are essential for life (humans, animals or plants) – like water, oxygen and nutrients. Other chemical substances are naturally occurring but they can kill us – like spider and snake venoms or well-known poisons like arsenic or mercury. The same applies to the chemical substances we make – some are quite benign and some are quite toxic.

A range of chemical substances are used to manufacture things we use every day like food, clothes, computers, kitchen appliances, cars, houses, roads, trains, planes, hair dyes, beauty products, toothpaste, shampoo, flea rinse for our pets and many other things. Some of these chemicals can end up in domestic rubbish and, therefore, in municipal waste used to generate the treated waste materials being discussed in this assessment.

2.2 Hazard vs Risk

Governments have established a range of legal requirements about how chemicals are approved for use, handling, transport and disposal as well as what to do in emergency situations so that chemicals are managed well. Such requirements include consideration of the characteristics of the chemical substances, how much will be used, how they might be released into the environment and a range of other matters.

The potential for a chemical to have effects on people, plants or animals is assessed using toxicity tests. Such tests expose relevant organisms or parts of organisms to a chemical and determine at what concentration damage appears to occur.

Interpretation of such tests is not straightforward because there is variability in the normal functioning of the processes inside cells and within organs and whole organisms. Also, some effects seen in these tests can be due to stress caused by the experiment rather than any impact of a chemical. Detailed understanding of the normal functioning of organisms and effects that may be stress related is required by those using the data from such tests.

Toxicity tests provide information on the hazard posed by chemical – the amount of a chemical that would cause a noticeable effect. Hazard is one of the characteristics of a chemical used in some parts of chemicals management. Hazard is used by the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) which is a single internationally agreed system of classifying and labelling chemicals, particularly in regard to occupational use, emergency management and transport. The GHS has been put together under the auspices of the UN.

Environmental protection and other aspects of chemicals management are more usually based on a measure of risk rather than hazard. Risk combines a consideration of hazard and the potential for exposure. This means a chemical can be extremely hazardous but will pose a low or negligible risk if exposure to people or ecological systems cannot occur (e.g. if it is used only within a reaction

vessel at a particular manufacturing facility). This also means a less hazardous chemical can pose a more elevated risk if exposure is widespread and/or high.

Consequently, assessing the potential risk posed by a chemical and the need for management actions requires detailed consideration of a complex range of factors. Assessing risk is what has been undertaken in this report.

2.3 Environmental Fate of Chemicals

Assessing risk requires detailed consideration of how much of a chemical can reach a place where people or ecosystems can be exposed.

This includes consideration of where and how a chemical is used along with whether or not it can escape into the environment and then what happens to the chemical when it is released into the environment.

Issues for consideration of exposure in relation to the fate of a chemical in the environment include:

- Will the chemical end up in soil, water, air, sediments or in organisms
- Is the chemical persistent
- Is the chemical bioaccumulative
- Can the chemical be broken down by chemical processes (hydrolysis, photolysis)
- Can the chemical be broken down by microbial processes (aerobic/anaerobic)
- Does the chemical leach to groundwater
- Is the chemical volatile
- What mix of chemicals is present in the environment and does that change the fate of a particular chemical

As noted in the Commonwealth risk assessment manuals for industrial chemicals and agricultural chemicals, an exposure assessment needs to:

- Estimate how much will be released into the environment
- Consider the environmental fate of the chemical (mobility, degradation, drift, accumulation, form, persistence etc)
- Determine how much of the chemical will end up in environmental compartments where people or organisms can be exposed (e.g. soil, water, air etc) (EPHC 2009a, 2009b).

2.4 What are organic outputs derived from mixed waste?

Mixed waste from residual household and commercial collections, as well as kerbside-collected waste from council managed litter bins, is processed at Alternative Waste Treatment (AWT) facilities to produce “mixed waste organic outputs” (MWOO). Sometimes known as AWT outputs, this waste can also contain manure, food waste, animal waste, grit or screenings from sewage treatment systems, and up to 20 % source separated household garden and food waste (NSW EPA 2018).

Processing typically involves two distinct stages:

(i) mechanical sorting and separation to concentrate the biodegradable fraction by removing plastic, metal, and other large miscellaneous items such as car batteries and gas bottles, and

(ii) biological stabilisation akin to composting (NSW EPA 2018).

In short, MWOO are the contents of the red top garbage bin processed into a “compost-like” material. Important differences between compost and MWOO are the numerous chemical contaminants. These include heavy metals as well as organic contaminants such as phthalates, phenols and pesticides present in MWOO. MWOO also contains plastic, glass and metal, collectively called physical contaminants. Inputs to the waste stream such as pet litter and nappies mean that human pathogens that survive the composting process may also be present (NSW EPA 2018).

2.5 How are MWOO used internationally?

Mechanical Biological Treatment (MBT) of waste, or AWT, frequently appears in national strategies for the diversion of organic waste from landfill. While there is some variation in the terminology and definitions of municipal solid waste “compost” across jurisdictions, the following summary is relevant to the NSW situation (NSW EPA 2018).

Land application of “Compost-Like Outputs” is currently not allowed in agriculture (or on land that may become agricultural in the future) in the United Kingdom due to concerns about the mixed waste stream and the physical and chemical contaminants it contains. Some allowance is made for use on brownfield sites (previously developed, and subsequently vacant, derelict or contaminated) having poor soil quality and low nutrient content, if an ecological benefit can be demonstrated. It has also been suggested for use to grow coppice crops as a renewable biomass source (NSW EPA 2018).

Germany uses the MBT process as a pre-treatment for the waste to stabilise the biodegradable fraction prior to landfilling and does not allow the use of the outputs on land. Germany also sends outputs for incineration. Austria sends MBT outputs to landfill (NSW EPA 2018).

In Italy the focus is on using the outputs as refuse derived fuel with some land application occurring in restricted applications. Concerns surround the accumulation of metals in soil and the high salt content of the outputs (NSW EPA 2018).

France, Spain, Portugal, Turkey and Poland allow some land application, largely due to lower carbon contents of soil in Southern Europe. Portugal had plans to phase out land spreading by 2016, however this has not been confirmed. There is a move away from producing MBT outputs for use as soil amendments due to economic uncertainties about markets. Compost standards in different European countries vary however none include mixed waste sources. Public perception of the risk to human health from application of waste and public confidence are also issues requiring careful consideration (NSW EPA 2018).

2.6 NSW EPA Research Program

The first MWOO produced and land applied in NSW pre-dated the development of a regulatory framework in NSW. This material was originally believed to be able to comply with the Australian Standard for Compost, Soil Conditioners and Mulches, AS4454. AS4454 is not designed for MWOO and is a voluntary market-based standard for compost made from source separated garden waste, manure and food waste. Once production of MWOO had commenced, it was evident that it could not meet the conditions of AS4454, predominantly due to the amount of physical contaminants it contained (NSW EPA 2018).

The NSW EPA (EPA) was concerned that the waste contained large concentrations of numerous known and unknown chemicals, and that it contained very large concentrations of physical contaminants with unknown environmental effects. The physical contaminants were visible and there was concern about the community perception. Also, other jurisdictions internationally were using similar facilities to stabilise organic waste prior to landfill and were not land applying it due to environmental concerns (NSW EPA 2018).

In 2010, the EPA issued a Resource Recovery Exemption (RRE) for the land application of MWOO containing conditions limiting application rate in four different land uses: broad acre agriculture, non-contact agriculture, plantation forestry and mine site rehabilitation. The RRE included testing of both the waste and soil at the land application site for a range of chemical and physical contaminants. This was updated in 2011 with the EPA making a commitment to conduct research to fill some of the knowledge gaps and provide an evidence base for further decision making and review of the RRE. $2.66 million was allocated through the Environmental Trust for research investigating the benefits and risks of land applying MWOO in NSW (NSW EPA 2018).

The research program was undertaken and included:

- Project 1 was split into 5 sub-projects all dealing with different aspects of physical contaminants.
- Project 2 was a large-scale field trial conducted over 3 cropping seasons examining the benefits and risks of MWOO in plant-based agriculture.
- Project 3 investigated the chemical characteristics of MWOO, its leachate, the ecotoxicity of that leachate, and a hazard assessment to identify chemicals of concern.
- Project 4 expanded the experimental program to 10 different soil types found in NSW (NSW EPA 2018).

Reports detailing the findings of these projects have been used in preparation of this HHERA.

As noted in **Section 1.2**, the following chemicals have been identified for further assessment.

The chemicals identified by NSW OEH that need to be considered in this assessment for the solid MWOO materials include:

Human Health

- PBDEs (Polybrominated diphenyl ethers)

Ecological

- Aluminium
- Copper
- Manganese
- Zinc
- Phenol
- Bis-2-ethylhexyl adipate
- Bis-2-ethylhexyl phthalate
- Bisphenol A
- Penta brominated diphenyl ether
- Electrical conductivity/salinity

The chemicals identified by NSW OEH that need to be considered in this assessment for leachate from solid MWOO materials include:

Human Health

- Antimony
- Arsenic
- Cadmium
- Lead
- Nickel

Ecological

- Aluminium
- Barium
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Mercury
- Nickel
- Tin
- Zinc
- Sulfate
- Sulfide
- MCPA
- Ammonia
- Nitrate
- Phosphorus
- Electrical conductivity/salinity

Agricultural uses – Livestock watering

- Copper

Agricultural Uses – Irrigation

- Copper
- Iron
- Manganese
- Molybdenum
- Nickel
- Dicamba
- Phosphorus
- Electrical conductivity/salinity

Section 3. Exposure Assessment – Human Health – Soil

3.1 General

This section provides a short discussion on the potential receptors (human groups) and exposure pathways that are considered to be of significance in this assessment. In addition, where identified as of potential significance and warranting quantification in this assessment, the potential for exposure has been quantified using industry best practice and guidance available from (enHealth 2012a; NEPC 1999 amended 2013d; USEPA 1989, 2002, 2009).

The assessment presented has addressed potential worst-case exposure to the key chemicals in soil and exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and therefore health risk.

The quantification of exposure has involved consideration of the following:

- Identification of relevant ***exposure parameters*** for each of the identified exposure pathways and receptors. The magnitude of the exposure is a function of a number of variables (termed exposure parameters), which describe the physical, and behavioural parameters relevant to the potentially exposed population. Exposure parameters which are considered representative have been selected. Where available, additional exposure data has been obtained from Australian sources (enHealth 2012a; NEPC 1999 amended 2013d); and
- Estimation of the ***chemical concentration*** in each medium relevant to the receptor groups and exposure pathways. This has involved the use of maximum concentrations reported in surface soil. Potential dust concentrations have been estimated on the basis of a particulate emission factor (that relates the concentration in air to that in soil) derived from guidance provided by the USEPA (USEPA 2002).

3.2 Quantification of Exposure – PBDEs

3.2.1 Identified Receptors and Exposure Pathways

The targets of this assessment are the farmers/farm workers that may be exposed to land where these materials have been applied and consume produce grown at the farm. The general public

The ASC NEPM low density residential scenario includes exposure to the soil while living at a property and doing routine garden maintenance, and where up to 10% of daily intake of fruit and vegetables may be derived from home grown produce.

For sites where these materials are applied to agricultural land it is possible that additional agricultural activities may occur including:

- Grazing of livestock (cattle/sheep)
- Cropping (wheat/oats/barley)
- Keeping poultry (for the purpose of producing eggs)
- Horticulture (blueberries)

These agricultural activities are not included in the normal low density residential scenario assumed for the ASC NEPM so require separate evaluation.

Table 1 Summary of Key Exposure Groups and Pathways

Receptor	Exposure Pathway/Mechanism
Farmers/farm workers	■ Incidental ingestion in surface soil and dust (tracked indoors) ■ Dermal contact with surface soil and dust (tracked indoors) ■ Inhalation of impacted dust generated surface soil ■ Ingestion of PBDEs in home grown produce at site (consumed on farm) ■ Ingestion of PBDEs in eggs from poultry kept at the site (consumed on farm) ■ Ingestion of PBDEs in milk from cows kept at the site (consumed on farm) ■ Ingestion of PBDEs in meat from livestock kept at the site (consumed on farm)

It is important to note that for this assessment has focused on evaluating potential for on farm consumption of food stuffs by people living on a farm which has had the treated waste materials applied. The risk calculations provided do not address the commercial food supply.

It is also noted that these treated waste materials can be applied to land used for broad acre agricultural. The definition for broad acre agricultural use means application to land where the land is used for agriculture. It does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.

Risks have been estimated for a range of produce types including some of those listed above as not being permitted uses where these materials are applied – eggs and vegetables, in particular. This is to provide information for management.

3.2.2 Background information on PBDEs

PBDEs are chemicals that may be present in materials derived from AWT processes.

Polybrominated diphenyl ethers (PBDEs) are a group of compounds manufactured for their flame retardant properties. They consist of two phenyl groups bound to a single oxygen atom with the hydrogen atoms on the phenyl groups substituted with between one and ten bromine atoms. The group consists of 209 congeners, which differ in the number and location of substituted bromine atoms. The internationally accepted numbering system for PBDE congeners is the acronym ‘BDE’ followed by a number from 1 to 209 (NICNAS 2007).

PBDE are manufactured compounds, which have been widely used in industrial and consumer applications. A review of the compounds conducted by scientific and regulatory bodies has culminated in tetra- and penta-BDEs (components of technical penta-BDE) and hexa- and hepta-BDEs (components in technical octa-BDE) being listed as a Persistent Organic Pollutants (POPs) under the Stockholm Convention in May 2009 (UNEP 2009). All production and use of these compounds has subsequently been banned, with the exception of recycling activities (UNEP 2009). PBDEs are not manufactured in Australia but were historically imported and used until 2005 (NICNAS 2007).

Their use in household products as additive flame retardants meant they could leach from articles like TVs, carpet or computers. As a result, they are present in municipal waste and can end up in MWOO.

It is expected that these chemicals would be well sorbed to the soil given their characteristics.

It is also noted that use of these chemicals is being phased out. NICNAS (industrial chemicals regulator) has prohibited importation of these chemicals and removed some of these chemicals from the list of chemicals that are legal to use in Australia https://www.nicnas.gov.au/chemical-information/factsheets/chemical-name/pbde-congeners-in-penta-and-octa). This is similar to steps taken in other countries. As a result, it is expected that the amount of these chemicals that may be present in household waste will be decreasing.

The WHO/FAO Joint Expert Committee on Food Additives assessed the presence of these chemicals (PBDEs) in food in 2006 (WHO 2006). Based on limited information, the committee estimated daily intakes for people ranging from 0.000001-0.000004 mg/kgbw/day across various global regions. Consumption of fish contributed most to intakes in Europe while meat and poultry contributed most in the US. As discussed in **Section 5**, the tolerable daily intake for these chemicals is estimated to be 0.0001 mg/kg bw/day so it was determined that intake from food was a minor contribution.

The European Food Safety Agency has been investigating the presence of these contaminants in foods since then but have not published a final review at this time. More data is being sought from food producers and Country based food safety agencies in Europe (https://www.efsa.europa.eu/sites/default/files/wgs/chemical-contaminants/contambrflameretard.pdf and http://www.efsa.europa.eu/en/press/news/140311).

Food Standards Australia and New Zealand also undertook a survey of the presence of PBDEs in food. The study was released in 2007. The highest concentrations were reported for boiled eggs, grilled pork chops, bacon and cream. The estimated dietary intakes were 0.000001 to 0.0001 mg/kg bw/day (FSANZ 2007).

3.2.3 Soil Concentrations

The research program for MWOO measured PBDEs in 12 samples – 6 each from 2 facilities over a number of years. The concentrations in AWT ranged from 0.1 to more than 700 mg/kg. Half the samples had concentrations between 0.1 and 1 mg/kg. Another 5 of the samples of MWOO had concentrations ranging from 4 to 15 mg/kg. Only one sample had a concentration above 700 mg/kg (NSW OEH 2016).

Using this limited information available on the concentrations of PBDEs in MWOO and the application rate of this material to agricultural lands, concentrations in soil after 1 application have been determined. An application rate of 10 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. The following concentrations have been considered in the assessment for agricultural land:

- Mean – 0.5 mg/kg
- Maximum – 5.5 mg/kg
- Minimum – 0.0008 mg/kg

Using this limited information available on the concentrations of PBDEs in MWOO and the application rate of this material for mine rehabilitation, concentrations in soil after 1 application have been determined. An application rate of 140 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. The following concentrations have been considered in the assessment for grazing on rehabilitated mining land:

- Mean – 6.8 mg/kg
- Maximum – 75 mg/kg
- Minimum – 0.01 mg/kg

Using this limited information available on the concentration of deca BDE in MWOO and the application rate of this material to agricultural lands, concentrations in soil after 1 application have been determined. An application rate of 10 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. The following concentrations have been considered in the assessment for agricultural land:

- Mean – 0.02 mg/kg
- Maximum – 0.06 mg/kg
- Minimum – 0.0004 mg/kg

Using this limited information available on the concentration of deca BDE in MWOO and the application rate of this material for mine rehabilitation, concentrations in soil after 1 application have been determined. An application rate of 140 tonnes/hectare, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been assumed. The following concentrations have been considered in the assessment for grazing on rehabilitated mining land:

- Mean – 0.2 mg/kg
- Maximum – 0.8 mg/kg
- Minimum – 0.006 mg/kg

In regard to the use for mine rehabilitation only cattle grazing has been assessed as it is possible that such areas may have livestock grazing at some time in the future. For such sites, cropping, horticulture or production of eggs is unlikely and so these pathways have not been assessed.

It is also noted that an application rate of 50 tonnes per hectare is permissible for non-contact agriculture uses such as blueberries or grapes. Concentrations in soil for this rate are discussed in **Section 3.2.5**.

3.2.4 Ingestion and Dermal Contact with Impacted Soil

Soil Ingestion

Ingestion of soil (direct incidental ingestion) is one of the key pathways of exposure relevant for the assessment of exposures.

As noted in Section 5.3.1.2 of Schedule B7 of the ASC NEPM, another pathway of exposure to soil is incidental ingestion of soil that is adhered to home grown produce (like carrots or potatoes). The UK Environment Agency has developed a methodology to estimate how much soil people are likely to consume in this way from home grown produce (i.e. indirect incidental ingestion). The approach found that 2-3 mg of soil is ingested via this pathway. The ingestion rate currently used in the calculations for the national health investigation levels is considered to be sufficient to cover direct and indirect incidental ingestion of soil.

The potential intake of PBDEs identified in surface soil via incidental ingestion (direct and indirect) has been undertaken using the following equation:

$$\text{Daily Chemical Intake}_{ls} = C_s \bullet \frac{IRs \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs = Concentration of impacted soil (mg/kg), as per **Section 3.2.3**
IRs = Ingestion rate of soil (mg/day)
FI = Fraction of daily ingestion that is derived from contamination source (unitless), taken as 1
B = Bioavailability or absorption of chemical via ingestion (unitless), taken as 1
CF = Conversion factor of $1x10^{-6}$ to convert mg to kg
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via soil ingestion for a child or an adult are presented in **Table 8**. All calculations are presented in **Appendix C**.

Dermal Exposures

Dermal absorption of chemicals from soil depends on the area of skin in contact with soil, the duration of contact, how well sorbed the chemical is to the soil and the ability of the chemical to penetrate the skin.

The assessment of the potential dermal absorption of PBDEs has been generally undertaken using the approach presented by the USEPA. They define a simple approach to the evaluation of dermal absorption associated with soil contact (USEPA 1989, 2004). This is presented in the following equation:

$$\text{Daily Chemical Intake} = C_s \bullet \frac{SAs \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

where:

Cs = Concentration in soil (mg/kg), as per **Section 3.2.3**
SAs = Surface area of body exposed to soil per day (cm^2/day)
AF = Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil properties and area of body (mg/cm^2 per event)
ABSd = Dermal absorption fraction (unitless), refer to note below
CF = Conversion factor of $1x10^{-6}$ to convert mg to kg
EF = Exposure frequency (days/year)
ED = Exposure duration, taken to be 6 years for children and 29 years for adults
BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per ASC NEPM 1999
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via dermal absorption from soil ingestion for a child or an adult are presented in **Table 2**. All calculations are presented in **Appendix C**.

Table 2 Summary of Exposure Parameters Adopted –Ingestion and Dermal Contact with Soil

Exposure Parameter	Value adopted for Child (aged 0-5 years)	Value adopted for adults
Ingestion rate (soil)	100 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013c)	50 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013c)
Skin surface area	2 700 cm^2 based on the surface area for hands, legs, arms (NEPC 1999 amended 2013c)	6 300 cm^2 based on the surface area for hands, legs, arms (NEPC 1999 amended 2013c)
Soil to skin adherence factor	0.3 (USEPA 2004)	0.3 (USEPA 2004)

Exposure Parameter	Value adopted for Child (aged 0-5 years)	Value adopted for adults
Fraction of day exposed	1 - assumes that the child remains in contact with the dirt on their skin for 24 hours (i.e. doesn't shower until next day)	1 - assumes that the adult remains in contact with the dirt on their skin for 24 hours (i.e. doesn't shower until next day)
Exposure frequency	365 days per year	365 days per year
Exposure duration	6 years as a young child	29 years as an adult assuming a total of 35 years residency at the same location as a child and adult (NEPC 1999 amended 2013c)
Body weight	15 kg (NEPC 1999 amended 2013c)	70 kg (NEPC 1999 amended 2013c)
Bioavailability	100%	100%

Dermal absorption: For PBDEs, the ASC NEPM (2013) recommends a dermal absorption of 10% (NEPC 1999 amended 2013c).

Bioavailability: Bioavailability is an important factor for determining the amount of a chemical that is absorbed into the body. When a chemical is ingested, bioavailability is determined by the amount of the chemical that can be dissolved (from the soil matrix in this case) into the gastrointestinal fluids and absorbed across the gastrointestinal tract into the bloodstream. In addition, the relative bioavailability of the chemical under the exposure conditions (and media) compared with those under which the critical dose-response (toxicity) study was undertaken (typically dissolved in water or food) is important. Organisms, including humans, only respond to the fraction that is biologically available, therefore, the assumption of 100% bioavailability in this risk assessment would tend to overestimate risk. For PBDEs, limited information in available and it has been assumed that these chemicals will be 100% bioavailable from the treated waste material mixed into soil. Given the log Kow for these chemicals is greater than 5, this is likely to be an overestimate of the amount of chemical that can be absorbed from the GI tract.

3.2.5 Inhalation of Impacted Dust

This pathway is considered where surface cover (grass or other vegetation) at a site may be limited. For most locations where this material has been applied to agricultural soils, it is unlikely that there will be no or limited surface cover.

However, for the purposes of this assessment it has been assumed that there is potential for poor surface cover. Locations with poor surface cover can result in the generation of dust from wind or mechanical (such as landscaping and mowing) disturbance. The potential concentration of PBDEs in dust that might be in air as a result of wind erosion and other typical site activities has been estimated using a Particulate Emission Factor (PEF).

A PEF is a ratio of the concentration of contaminants in soil (mg/kg) to the concentration of contaminants in air (mg/m^3). The concentration of particulates in air can be estimated using the surface soil concentrations listed in **Section 3.2.2**. The PEF has been estimated using equations for outdoor workers provided in USEPA Guidance (USEPA 1996, 2002).

$$PEF = \frac{\frac{Q}{C} * 3600}{0.036 * (1 - V) * \left(\frac{Um}{Ut}\right)^3 * F_x}$$

Where
PEF = particulate emission factor outdoors (mg/kg soil per mg/m^3 air)

Q/C = air dispersion factor which describes the dispersion of soil particles in the atmosphere of a theoretical outdoor box. The conservative default value assumed in the NEPM for application across Australia is 90.8 (g/m2/s per kg/m3). Site specific values can be calculated using Appendix D in the USEPA guidance (USEPA 2002) ($\frac{Q}{C} = A\ x\ \exp[\frac{(lnA_{site}-B)^2}{C}$) where A,B and C are constants based on air dispersion modelling for specific climate zones in the US. The values used are A=16.2302; B=18.7762 and C=216.108 which are the 90th percentile values for the 29 different meteorological zones modelled. The site specific value for A_{site} has been used.

V = the fraction of outdoor surface cover (0=bare soil) (50% vegetation cover has been assumed)

Um = mean annual windspeed at a height of 10 m (m/s) (mean annual 9am and 3pm windspeed from Scoresby Research Institute Met Station – 3.6 m/s – NEPM assumption based on a conservative value suitable across all of Australia for development of guidelines)

Ut = threshold wind speed at a height of 10 m which is required to generate dust from an erodible surface at a given site (USEPA default value used – 11.3 m/s – NEPM assumption based on an extremely conservative value suitable across all of Australia for development of guidelines)

Fx = empirical function based on the ratio of the mean and threshold windspeeds

$Fx = 0.18 * (8x^3 + 12x)\exp(-x^2)$ where x = 0.886 (Ut/Um)

This approach is considered suitable for the assessment of dust exposures by individuals in outdoor areas who could also be involved in moderate digging (including playing in outdoor soil by children and gardening) and other landscaping activities. This is also considered appropriate for the assessment of potential exposures in areas at any time when maintenance works are occurring or wind erosion has the potential to occur. Calculation of the PEF and associated contaminant concentrations in air is presented in **Appendix C**.

The quantification of inhalation exposures once concentrations in air have been established using the PEF approach, has been undertaken in accordance with guidance provided by USEPA (USEPA 2009). This guidance does not require the calculation of a daily chemical intake, rather the approach requires calculation of an inhalation exposure concentration using the following equation:

$$\text{InhalationExposureConc}_p = C_a \bullet \frac{ET \bullet DF \bullet CC \bullet FI \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

where:

Ca = Concentration of chemical in air (mg/m^3) (PEF x soil concentrations as per **Section 3.2.3**)

ET = Exposure time (hours/day) – assumed to be 24 hours per day

DF = Deposition fraction, fraction of inhaled dust retained in the respiratory tract (not exhaled), taken to be 75% (0.75) as per (enHealth 2012a; NEPC 1999 amended 2013c) (unitless)

CC = Cilliary clearance factor, fraction of the inspirable dust that is small enough to reach the pulmonary alveoli, taken to be 50% (or 0.5) as per (enHealth 2012a; NEPC 1999 amended 2013c) (unitless)

FI = Fraction inhaled from contaminated source (unitless) assumed to be 100%

EF = Exposure frequency (days/year), refer to **Table 8**

ED = Exposure duration, refer to **Table 8**

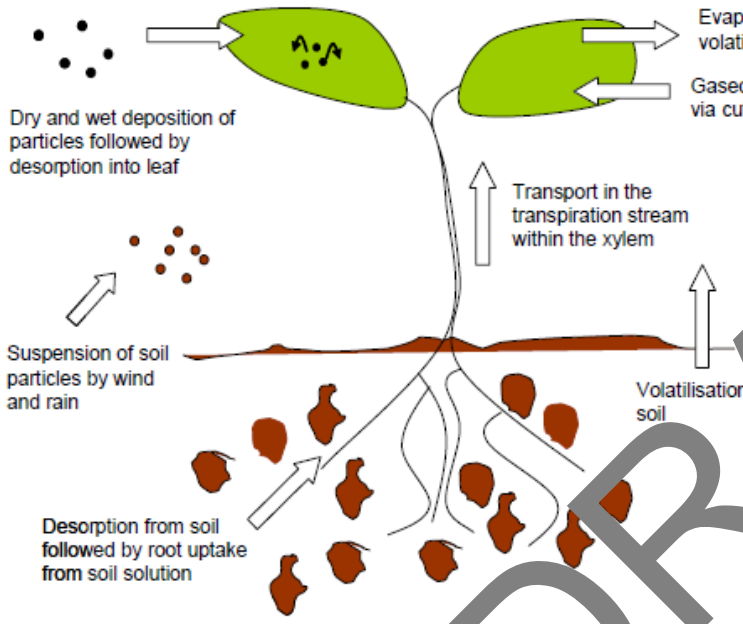
AT = Averaging time for threshold exposures, (=ED x 365 days x 24 hours)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days x 24 hours)

3.2.6 Ingestion of Contaminants from Home Grown Vegetables

The Environment Agency in the UK has undertaken a review of models that are used to estimate uptake in plants from contaminated soil (UK EA 2009). The diagram below summarises all the different pathways by which contaminants can enter plants. For PBDEs in soil the only pathway that is relevant is desorption from soil into soil solution with root uptake from soil solution followed by transport throughout the rest of the plant via the xylem.

2-1: Principal pathways for plant uptake of organic chemicals



Schedule B7 Appendix A5 of the ASC NEPM (2013) provides a summary of the likelihood for PBDEs to be taken up by plants (NEPC 1999 amended 2013c).

As per Schedule B7, limited data is available on the potential for BDEs to be taken up by plants from soil into edible fruit and vegetable crops. ATSDR notes that PBDEs will be strongly adsorbed to soil, hence PBDEs present in soil-pore water will bind to soil organic matter. Because PBDEs adsorb strongly to soil, they will have very low mobility, and leaching of PBDEs from soil to groundwater will be insignificant (ATSDR 2017).

Review of plant uptake of deca-PBDE (BDE-209) into plants from soil by Huang et al. (2010) suggests that deca-BDE is taken up and translocated within the plants assessed (ryegrass, alfalfa, pumpkin, squash, maize and radish). Nineteen lower brominated (di- to nona-) PBDEs were detected in the soil and plant samples and five hydroxylated congeners were detected in the plant samples, indicating debromination and hydroxylation of BDE-209 in the soil−plant system. Evidence of a relatively higher proportion of penta- through to di-BDE congeners in plant tissues than in the soil indicates that there is further debromination of PBDEs within plants or lower brominated PBDEs are more readily taken up by plants (Huang et al. 2010).

Other studies have evaluated uptake into maize and other crop species for a range of these chemicals (Yang et al. 2018; Zhao et al. 2012). Uptake into maize and sweet potatoes was reported in these studies.

In addition, the more recent paper included a summary of uptake into a range of plant species. Factors for uptake into crop species ranged from 0.1-0.5 averaged for the sum of these congeners. Factors for uptake into a range of grass species ranged between 5 and 19 with most in the range 5-

8. A value of 7 was chosen for this assessment as a reasonable upper end estimate (Yang et al. 2018).

The study in maize noted that uptake mainly occurred into the roots of the maize plants. There was translocation within the plant into stems and leaves and into the edible portion but the amount of PBDEs that transferred from the roots decreased the further from the roots they travelled through the plant. Also, this study used hydroponic techniques which means there was no soil in the experiment and there was a direct relationship between transpiration rate of water moving through the plant and concentration of PBDEs in the bottom stem of the plant. This is definitely a worst-case assessment of uptake as, if soil was present, partitioning between organic carbon and the water in the soil would limit how much was in the soil-water which would limit how much was taken up by the plant. This means that a transfer factor based on uptake into stems and leaves is likely to be an overestimate of uptake into the edible portion of the plant (seeds) (Zhao et al. 2012).

Basis of Calculation

The ASC NEPM has adopted the approach taken by the UK Environment Agency to calculate the uptake of chemicals in soil into plants (UK EA 2009). This guidance document considered studies that are based on the uptake of these contaminants into green vegetables, root vegetables, tuber vegetables, herbaceous fruit, shrub fruit and tree fruit.

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

It is noted that the Resource Recovery Order and Exemption that set the framework for application of these treated waste materials to agricultural land specifically prohibit application to land where root or tuber vegetables might be grown or vegetables that are grown close to the soil which may come into contact with soil. Consumption of these types of vegetables have been assessed here to provide information for management should farmers or farm workers have a vegetable patch at the farm in an area where these treated waste materials have been applied. It is potentially unlikely that an on farm vegetable patch will be located in a field where these materials have been applied as such a patch is more likely to be close to the farm house.

Fraction Home Grown (FHG)

It has been assumed for the purposes of this assessment, that 35% of a person's intake of fruit and vegetables might come from produce grown at a site where this treated waste material has been applied. This is based on the following:

- A farm is more likely to grow one or two species in the fields where this material is applied so it is unlikely that 100% of a person's intake of fruit and vegetables could come from such a site every day of the year

- Common value being applied at contaminated sites where significant amounts of home grown produce may be consumed

The ASC NEPM Schedule B7 Appendix B outlines the equations to develop plant uptake factors for each contaminant of interest (NEPC 1999 amended 2013c). Chemical specific plant uptake factors were calculated using the equations and defaults from the ASC NEPM Schedule B7 Appendix B (NEPC 1999 amended 2013c). The equations and defaults are outlined in **Appendix B** of this report. The calculations are included in **Appendix C**.

Calculation of the plant uptake factors has assumed a soil organic carbon content of 2% as detailed in Schedule B7 in the ASC NEPM (2013) – it is expected that horticultural or cropping land will be augmented with organic carbon to maximise yield (NEPC 1999 amended 2013c).

In this assessment, modelling has been undertaken to estimate concentrations that may be present in the vegetables, fruit or other crops that may be grown at sites where treated waste material may have been applied to estimate exposure to PBDEs for people who might consume these foods.

Uptake Factors are calculated for different crops on the basis of the following equation:

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit})$$

where:

CFy = plant uptake factors relevant for produce type (y), chemical specific value (mg/kg fresh with produce to mg/kg dry weight soil), as per **Table 3**

Cy = Consumption rate of each produce type (y) (kg/day), as per **Table 3**

Table 3 Summary of Factors Adopted for Quantifying Plant Uptake

	Produce Group			
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Consumption Rate – Children (kg/day)	0.055	0.017	0.028	0.18
Consumption Rate – Adults (kg/day)	0.15	0.047	0.060	0.14
Calculated Plant Uptake Factors for Key Chemicals (mg/kg fresh weight to mg/kg soil dry weight)				
Br1 to Br9	2.63E-03	2.30E-02	2.88E-01	2.42E-03
Deca BDE	2.84E-04	1.80E-03	1.59E-02	1.07E-04

Table 4 Estimated Concentrations in Fruit/Vegetables (mg/kg fresh weight) (Mean Case)

	Produce Group (mg/kg fw)			
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Br1 to Br9	0.001	0.01	0.1	0.001
Deca BDE	0.000006	0.00004	0.0003	0.0000002

The concentrations modelled in vegetables range from 0.0002 to 0.02 mg/kg for the lower BDEs and 0.001 to 0.00002 for deca BDE. For fruit, the modelling estimates concentrations around 0.0002 mg/kg for the lower BDEs and 0.000006 mg/kg for deca BDE may be present.

Given that people eat these different types of vegetables in different amounts, an additional calculation is undertaken to show the amount or dose of these chemicals that would come from each produce group each day. This is shown in **Table 5**. The calculations involve multiplying the concentration in each type of produce by the amount of each type of produce people consume each day.

Table 5 Estimated Dose/Uptake from Fruit/Vegetables (mg/day) (Mean Case)

	Produce Group (mg/day)			
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Children				
Br1 to Br9	0.00006	0.0002	0.003	0.0002
Deca BDE	0.0000003	0.0000007	0.00008	0.00000004
Adult				
Br1 to Br9	0.0002	0.0005	0.006	0.0001
Deca BDE	0.0000009	0.000002	0.00002	0.00000003

As can be seen from these calculations, tuber vegetables like potatoes contribute the highest amount to a person's intake of PBDEs from consuming fruit and vegetables in soil treated with MWOO. It will depend on how such vegetables are prepared as to how much remains when cooked and eaten. Peeling the potatoes is quite likely to remove some or most of the PBDEs, for example, as this is the layer where they are most likely to have accumulated.

Blueberry cultivation is classed as non-contact agriculture, so a higher application rate may be used – up to 50 tonnes/hectare. At this application rate, the mean case soil concentration is 0.4 mg/kg instead of 0.08 mg/kg for the lower BDEs. Using this higher application rate for these calculations provides the results as outlined in **Table 6**.

Table 6 Quantifying Plant Uptake for Blueberries

Chemical	Uptake Factor for Tree Fruit (mg/kg fresh weight to mg/kg soil dry weight)	Soil Concentration	Concentration in Tree Fruit (mg/kg fw)
Br1 to Br9	2.42E-03	2.5	0.006
Deca BDE	1.07E-04	0.1	0.00001

In addition, these treated waste materials may be applied to land where crops like wheat, oats or barley are produced. Transfer factors (equivalent to the plant uptake factors used above) were listed in the study undertaken by Yang et al. (Yang et al. 2018). The study investigated uptake into sweet potatoes but Table 2 in the paper refers to bioconcentration factors (transfer factors) for a range of plants including a number of grasses which are more relevant for use in considering uptake into wheat, oats or barley. A transfer factor of 7 (mg/kg fresh weight to mg/kg soil dry weight) was adopted for use in this assessment. Using this transfer factor for these calculations provides the results as outlined in **Table 7**.

Table 7 Quantifying Plant Uptake for Wheat, Oats, Barley

Chemical	Transfer Factor (mg/kg fresh weight to mg/kg soil dry weight)	Soil Concentration	Concentration in Wheat, Oats or Barley (mg/kg fw)
Br1 to Br9	7	0.5	3.5
Deca BDE	7	0.06	0.4

In regard to production of fruit, vegetables or other crops, these chemical specific uptake factors and the estimated concentrations can be used to assess exposure using the following equations and assumptions:

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

where:

Cs = Concentration in soil (mg/kg), as per **Section 3.2.3**
UF = Uptake factor relevant for the uptake from soil into different produce (kg/day)
FHG = Fraction of all fruit and vegetable produce consumed that is home grown (unitless) – assumed to be 35% of diet
EF = Exposure frequency (days/year), assumed to be 365 days per year
ED = Exposure duration, 29 years for adults, 6 years for children
BW = Body weight (kg), 70 kg for adults, 15 kg for children
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

3.2.7 Ingestion of Contaminants from Eggs

Given the persistent nature of PBDEs there is potential for their uptake from impacted soil into eggs produced from hens kept on a site.

The Californian OEHHA (OEHHA 2012) provide chicken egg transfer factors for polychlorinated biphenyls and polychlorinated dibenzo-p-dioxins/furans. These chemicals are similar in structure to polybrominated diphenyl ethers. For this assessment, an uptake for the chicken to egg transfer

factor of 10 mg/kg (in the egg) per mg/d (taken in by the chicken) will be used for the brominated BDEs (1-9) (based on the highest value from PCBs and dioxins) and a factor of 3 mg/kg (in the egg) per mg/d (taken in by the chicken) for deca BDE (based on octachlorinated dibenzo-p-dioxin).

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

In this assessment, modelling has been undertaken to estimate concentrations that may be present in eggs. These concentrations have also been used to estimate uptake of PBDEs into people living at a site where AWT may have been applied to soil where chickens are kept and where the eggs are consumed on farm.

The approach adopted for the quantification of uptake into eggs is in accordance with OEHHA (OEHHA 2012) which is based on a transfer factor and the potential intake of the contaminants by the hen. Calculations are presented in **Appendix C**. The approach adopted is presented below.

To calculate the concentration in eggs the following approach was followed:

$$C_{eggs} = (DailyIntake)_{hens} \bullet (TransferFactor) \qquad (mg/kg\,freshweight)$$

where:

$$Transfer\ \ Factor = \frac{mg/kg\ in\ \ eggs\ \ fresh\,weight}{mg/day\,\text{int}\ ake\,of\ chemicals\,by\,hens} \qquad (day/kg)$$

Transfer factors:

Br1 to Br9 = 10 d/kg
Deca BDE = 3 d/kg

$$(DailyIntake)_{hens} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

Csoil = Concentration of PBDEs in soil (mg/kg)
IRsoil = Ingestion rate of soil by hens (kg/day). The ingestion rate of soil by hens is not well studied. OEHHA (OEHHA 2012) indicates that the amount of soil ingested is limited and comprises 2% of the daily feed intake. For poultry in the wild, or more free-range, a higher estimate of 9% has been determined for wild turkeys (Beyer et al. 1994). To provide a conservative estimate of potential soil intake by hens in the backyard, a value of 10% of daily feed has been adopted. The amount of feed ingested by hens each day has been taken to be 0.12 kg/day (OEHHA 2012) Hence the amount of soil ingested each day has been taken to be 0.012 kg/day for egg-laying hens.
B = Bioaccessibility of via ingestion. It is assumed PBDEs are 100% bioaccessible to the chickens which is likely to be an overestimate

Table 8 Estimated Concentrations in Eggs (mg/kg)

Livestock	Daily intake (livestock) (mg/d)	Transfer Factor	Concentration in egg (mg/kg)
PBDEs (Br1 to Br9 – minimum)	0.0001	10	0.001
PBDEs (Br1 to Br9 – mean)	0.006	10	0.01
PBDEs (Br1 to Br9 – maximum)	0.07	10	0.7
DecaBDE (minimum)	0.000005	3	0.00002
DecaBDE (mean)	0.0002	3	0.0006
DecaBDE (maximum)	0.0007	3	0.002

In regard to egg production for on farm consumption, exposure to PBDEs can be assessed for those living at the site using the egg concentrations and the consumption rate of eggs. The ingestion rates for eggs were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017c). The 90% intake for people who reported consuming eggs on the day of the dietary survey ranges between 0.036 kg/day for children to 0.059 kg/day for adults. It is considered appropriate to use this estimate of high end consumption of eggs for on farm consumption. It is likely that all the eggs consumed by a household that keeps chickens would be from chickens kept at the site (FSANZ 2011).

The daily intake of PBDEs from the consumption of eggs was calculated as follows:

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{eggs} = concentration in eggs, calculated as outlined above (mg/kg fresh weight)

IR_{eggs} = ingestion rate of eggs (kg/day), taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017c) of 0.036 kg/day for children 2-5 years and 0.059 kg/day for adults

FHG = fraction of the daily diet that is derived from home grown source, taken to be 100% (or 1) for on farm consumption of eggs

EF = Exposure frequency (days/year), assumed to be 365 days per year

ED = Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013c)

BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013c)

AT = Averaging time for threshold exposures, (=ED x 365 days)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 5** and detailed in **Appendix C**.

It should be noted that there are significant uncertainties in this modelling including:

- bioavailability/bioaccessibility of PBDEs
- variability in transfer factors
- variability in the soil ingestion rate amongst individual animals.

3.2.8 Ingestion of Contaminants in Milk

Given the persistent nature of these chemicals there is potential for their uptake from impacted soil into milk.

The Californian OEHHA (OEHHA 2012) provides transfer factors for this type of chemical from soil (or feed) into cow's milk. The transfer factors are for polychlorinated biphenyls and polychlorinated dibenzo-p-dioxins/furans. These chemicals are similar in structure to polybrominated diphenyl ethers. For this assessment, an uptake for soil into milk transfer factor of 0.04 mg/kg (in milk) per mg/d (taken in by the cow) will be used for the brominated BDEs (1-9) (based on the highest value from PCBs and dioxins) and a factor of 0.0006 mg/kg (in milk) per mg/d (taken in by the cow) for deca BDE (based on octachlorinated dibenzo-p-dioxin).

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

In this assessment, modelling has been undertaken to estimate concentrations that may be present in milk. These concentrations have also been used to estimate uptake of PBDEs into people living at the site who produce milk for on farm consumption.

The approach adopted for the quantification of uptake into milk is in accordance with OEHHA (OEHHA 2012) which is based on a transfer factor and the potential intake of the contaminants by the cow. Calculations are presented in **Appendix C**. The approach adopted is presented below.

To calculate the concentration in milk, the following approach was followed:

$$C_{milk} = (DailyIntake) \bullet (TransferFactor)(mg/kgfreshweight)$$

where:

$$Transfer\ Factor = \frac{mg/kg\ in\ milk\ \ fresh\ weight}{mg/day\ int\ akeof\ chemicals\ by\ livestock} \qquad (day/kg)$$

Transfer factors:

Br1 to Br9	= 0.04 d/kg
Deca BDE	= 0.0006 d/kg

and

$$(Daily\ Intake)_{goat} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

Csoil = Concentration of PBDEs in soil (mg/kg), (minimum, mean and maximum values as per **Section 3.2.2**)
IRsoil = Ingestion rate of soil by cows (kg/day) as per **Table 12**

Table 9 Summary of Factors Relevant for Determining Uptake into Grazing Animals that Produce Milk

Grazing Animal	Soil Ingestion (kg/day)	Body Weight (kg)
Cattle	2.4	450

B = Bioaccessibility of via ingestion. It is assumed PBDEs are 100% bioaccessible to the grazing animals which is likely to be an overestimate given that the chemicals are likely to be well sorbed to the soil (i.e. 1 in the calculation).

Table 10 Estimated Concentrations in Milk (mg/kg)

Livestock	Daily intake (livestock) (mg/d)	Transfer Factor	Concentration in milk (mg/kg)
PBDEs (Br1 to Br9 – minimum)	0.02	0.04	0.0008
PBDEs (Br1 to Br9 – mean)	1.2	0.04	0.05
PBDEs (Br1 to Br9 – maximum)	13	0.04	0.5
DecaBDE (minimum)	0.001	0.0006	0.0000006
DecaBDE (mean)	0.05	0.0006	0.00003
DecaBDE (maximum)	0.1	0.0006	0.00006

In regard to milk production for domestic purposes, exposure to PBDEs can be assessed for those living at the site using the concentrations in milk and the consumption rate for milk. The ingestion rates for milk were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017c). The 90% intake for people who reported consuming milk on the day of the dietary survey ranges between 1.097 kg/day for children to 1.295 kg/day for adults. It might be possible that all the milk consumed on farm would be from the cows at the site but this will depend on the amount of milk produced and the number of people consuming the milk.

The daily intake of PBDEs from the consumption of milk produced at the site was calculated as follows:

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{milk} = concentration in milk, calculated as outlined above (mg/kg fresh weight)

IR_{milk} = ingestion rate of milk (kg/day), taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017c) of 1.097 kg/day for children 2-5 years and 1.295 kg/day for adults

FHG = fraction of the daily diet that is derived from home grown source, taken to be 100% (or 1) for on farm consumption

EF = Exposure frequency (days/year), assumed to be 365 days per year

ED = Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013c)

BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013c)

AT = Averaging time for threshold exposures, (=ED x 365 days)

AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 5** and detailed in **Appendix C**.

It should be noted that there are significant uncertainties in this modelling including:

- bioavailability/bioaccessibility of PBDEs
- variability in transfer factors

- variability in the soil ingestion rate amongst individual animals.

3.2.9 Ingestion of Contaminants in Meat

Given the persistent nature of these chemicals there is potential that they will be taken up into meat produced if livestock kept at a site are used for on farm consumption.

The Californian OEHHA (OEHHA 2012) provides transfer factors for this type of chemical from soil (or feed) into cow's meat. The transfer factors are for polychlorinated biphenyls and polychlorinated dibenzo-p-dioxins/furans. These chemicals are similar in structure to polybrominated diphenyl ethers. For this assessment, an uptake for soil into milk transfer factor of 2 mg/kg (in meat) per mg/d (taken in by the cow) will be used for the brominated BDEs (1-9) (based on the highest value from PCBs and dioxins) and a factor of 0.02 mg/kg (in meat) per mg/d (taken in by the cow) for deca BDE (based on octachlorinated dibenzo-p-dioxin) (OEHHA 2012).

Along with the transfer factors, an estimate of the soil ingestion rate for grazing animals is needed to estimate the concentration of these chemicals that might accumulate into meat. OEHHA reports that cattle consume soil at a rate of 5% of their food intake (Table 5.4 (OEHHA 2014)). The American Petroleum Institute also provides guidance on assessing uptake of chemicals from soil into livestock (API 2004). The API notes that grazing animals consume soil at a rate of 18 to 30% of food intake.

FSANZ and the Commonwealth Department of Agriculture provide maximum residue limits (MRL) for pesticides in agricultural products. The APVMA (Australian Pesticides and Veterinary Medicines Authority) determines such residue limits based on a chemical product's chemistry, metabolism, analytical methodology and residue trial data. The APVMA MRLs apply to foods produced in Australia (DoA 2014; FSANZ 2014, 2015).

Such limits have not been developed for PBDEs. The UN Committee that looks at contaminants in foods evaluated PBDEs in 2005 – JECFA (Joint FAO/WHO Expert Committee on Food Additives) (WHO 2006). The main finding of this assessment was that information was limited.

In this assessment, modelling has been undertaken to estimate concentrations that may be present in meat. These concentrations have also been used to estimate uptake of into people living at the site who produce meat for on farm consumption.

Using the approach outlined by OEHHA (OEHHA 2012, 2014) a concentration in meat for the various livestock can be calculated using the following equations.

To calculate the concentration in meat in grazing animals the following approach was followed:

$$C_{meat} = (Daily\ Intake)_{grazinganimal} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

where:

$$Transfer\ \ Factor = \frac{mg/kg\ in\ \ meat\ \ fresh\ weight}{mg/day\ \text{int}\ ake\ of\ \ chemicals\ by\ grazinganimals} \qquad (day/kg)$$

Transfer factors:

Br1 to Br9	= 2 d/kg
Deca BDE	= 0.02 d/kg

$$(Daily\ Intake)_{grazinganimals} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

Csoil = Concentration of PBDEs in soil (mg/kg), (minimum, mean and maximum values as per **Section 3.2.2**)

IRsoil = Ingestion rate of soil by grazing animals (kg/day). **Table 14** provides a soil ingestion rate and body weight for cattle. While the amount of soil consumed by livestock is related to their size (and as such the larger amount of chemical in the larger amount of soil ingested would be distributed through more muscle tissue) the transfer factor is based on accumulation of the chemical into muscle tissue for the relevant animal so this is taken into account.

B = Bioaccessibility of via ingestion. It is assumed PBDEs are 100% bioaccessible to the grazing animals which is likely to be an overestimate given that the chemicals are likely to be well sorbed to the soil (i.e. 1 in the calculation).

Table 11 Summary of Factors Relevant for Determining Uptake into Grazing Animals

Grazing Animal	Soil Ingestion (kg/day)	Body Weight (kg)
Cattle	2.4	540
Sheep	0.6	57

Notes:
The values for soil ingestion rates have been taken from (API 2004) – a guidance document for determining screening guidelines for petroleum hydrocarbons for a range of livestock. The body weight for sheep has also been taken from this document. The body weight for cattle has been adopted from ANZECC/ARMCANZ 2000 Volume 3

Table 12 Estimated Concentrations in Meat (mg/kg)

Livestock	Daily intake (livestock) (mg/d)	Transfer Factor	Concentration in meat (mg/kg)
Cattle			
PBDEs (Br1 to Br9 – minimum)	0.02	2	0.04
PBDEs (Br1 to Br9 – mean)	1.2	2	2.4
PBDEs (Br1 to Br9 – maximum)	13	2	26
DecaBDE (minimum)	0.001	0.02	0.00002
DecaBDE (mean)	0.05	0.02	0.001
DecaBDE (maximum)	0.1	0.02	0.002
Sheep			
PBDEs (Br1 to Br9 – minimum)	0.005	2	0.01
PBDEs (Br1 to Br9 – mean)	0.3	2	0.6
PBDEs (Br1 to Br9 – maximum)	3.3	2	6.6
DecaBDE (minimum)	0.0002	0.02	0.000004
DecaBDE (mean)	0.01	0.02	0.0002
DecaBDE (maximum)	0.04	0.02	0.0008

The estimated meat concentrations for sheep are lower than those for cattle. The rest of the assessment has focused on consumption of beef.

In regard to meat production for on farm consumption, exposure to PBDEs can be assessed for those living at the site using the concentrations in meat and the consumption rate for meat. The ingestion rates for meat were reported in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017c). The 90% intake for people who reported consuming milk on the day of the dietary survey ranges between 0.085 kg/day for children to 0.163 kg/day for adults.

A range of potential levels of consumption will be assessed including a one off meal, 50%, 75% and 100% of meat consumed being from the farm for on farm consumption.

The daily intake of PBDEs from the consumption of meat produced at the site using the various levels of consumption was calculated as follows:

$$Daily\ Chemical\ Intake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

where:

C_{milk}	= concentration in meat, calculated as outlined above (mg/kg fresh weight)
IR_{milk}	= ingestion rate of meat (kg/day) taken to be equal to the P90 value for consumers as presented in the dietary assessment for PFAS chemicals undertaken by FSANZ in 2017 (FSANZ 2017c) of 0.085 kg/day for children 2-5 years and 0.163 kg/day for adults
FHG	= fraction of the daily diet that is derived from home grown source, taken to be 50, 75 and 100% for home produced meat
EF	= Exposure frequency (days/year), assumed to be 365 days per year
ED	= Exposure duration, taken to be 6 years for children and 29 years for adults as per (NEPC 1999 amended 2013c)
BW	= Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per (NEPC 1999 amended 2013c)
AT	= Averaging time for threshold exposures, (=ED x 365 days)
AT(NT)	= Averaging time for non-threshold exposures (=70 years x 365 days)

The results from these calculations are discussed in **Section 5** and detailed in **Appendix C**.

It should be noted that there are significant uncertainties in this modelling including:

- bioavailability/bioaccessibility of PBDEs
- variability in transfer factors
- variability in the soil ingestion rate amongst individual animals.

3.3 Quantification of Exposure – Per and Polyfluoroalkyl Substances (PFAS)

PFAS are a family of fluorine-containing compounds with unique properties to make materials stain- and stick-resistant. PFAS are often described as being “ubiquitous in the environment”. They have been widely used in man-made products such as paints, roof treatments, hardwood floor protectant, surface protection products (e.g. carpet and clothing treatments) and coatings for cardboard and packaging. Some PFAS are, or were also historically used in, fire-fighting foams (also known as aqueous film-forming foams; AFFF). PFAS are not found in the environment from natural sources, only from anthropogenic sources (ATSDR 2018).

These chemicals are reported in a range of household items so they may be present in municipal waste and, as a result, in this treated waste material.

A limited number of samples collected during the NSW OEH study were assessed for the presence of the two main chemicals in this family – PFOS and PFOA. One sample from each facility was assessed. Neither sample reported a detection for these two chemicals.

In 2018 a targeted study for PFAS in MWOO was undertaken. A range of PFAS were analysed in this work. The chemicals that were detected included perfluoropentanoic acid, perfluorohexanoic acid, perfluoroheptanoic acid, perfluorooctanoic acid (PFOA), perfluorononanoic acid, perfluorodecanoic acid, perfluorobutanesulfonate, perfluorohexanesulfonate, perfluorooctanesulfonate (PFOS). In addition, 1 fluorotelomer and 3 sulfonamides were detected. These are precursor compounds – i.e. they can breakdown to PFOS or PFOA in the environment. The concentrations detected in this targeted study are listed in **Table 13**.

Table 13 Concentrations of PFAS in MWOO

Chemical	Average (mg/kg)	Maximum (mg/kg)
Perfluoropentanoic acid (PFPeA)@	0.002	0.0028
Perfluorohexanoic acid (PFHxA)@	0.005	0.026
Perfluoroheptanoic acid (PFHpA)@	0.001	0.0011
Perfluorooctanoic acid (PFOA)@	0.003	0.004
Perfluorononanoic acid (PFNA)@	0.001	0.0012
Perfluorodecanoic acid (PFDA)@	0.003	0.006
Perfluorobutanesulfonate (PFBS)#	0.004	0.025
Perfluorohexanesulfonate (PFHxS)#	0.0014	0.0023
Perfluorooctanesulfonate (PFOS)#	0.004	0.006
FOUEA@	0.001	0.003
N-MeFOSAA#	0.003	0.004
N-MeFOSE#	0.006	0.011
N-EtFOSE#	0.005	0.005

@ = chemicals summed and assessed as PFOA

= chemicals summed and assessed as PFOS

Due to the lack of toxicological information for some of the listed PFAS some of the individual PFAS have been summed for assessment as shown in **Table 13** – N-MeFOSAA, N-MeFOSE, N-EtFOSE, PFBS, PFHxS and PFOS have been summed and compared to the tolerable intake for PFOS; PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA and FOUEA have been summed and compared to the tolerable intake for PFOA.

3.3.1 Soil Concentrations

Application of 10 tonnes/hectare of treated waste materials to land, a mixing depth of 10 cm and a soil bulk density of 1300 kg/m^3 have been used to calculate soil concentrations.

From **Table 13**, the concentration summed and assumed to be similar to PFOS is 0.023 mg/kg (average) and 0.05 mg/kg (maximum). For PFOA, the average summed concentration is 0.02 mg/kg and for the maximum case the summed concentration is 0.04 mg/kg.

The estimated average concentration in soil for PFOS when MWOO has been applied to agricultural land is 0.0002 mg/kg. The estimated maximum concentration in soil for PFOS is 0.0004 mg/kg. The estimated average concentration in soil for PFOA is 0.0002 mg/kg. The estimated maximum concentration in soil for PFOA is 0.0003 mg/kg.

3.3.2 Intakes

The same approach as adopted in **Section 3.2** for PBDEs has been used to assess potential for exposures.

The daily intake of PFOS and PFOA have been calculated for contact with soil and ingestion of affected food in the same way as for PBDEs. The transfer factors for uptake from soil into the various food types are the only values that are changed from the evaluation for PBDEs. The transfer factors for PFOS and PFOA are listed in **Table 14**. These transfer factors have been taken from a number of documents including previous assessments by enRiskS and NSW OEH guidance on screening guidelines (NSW OEH 2017).

Table 14 Transfer Factors for PFOS and PFOA

Produce Type	PFOS	PFOA
Green Vegetables	2.2 mg/kg plant dw/mg/kg soil dw	1.5 mg/kg plant dw/mg/kg soil dw
Root Vegetables	0.05 mg/kg plant ww/mg/kd soil dw	0.05 mg/kg plant ww/mg/kd soil dw
Tuber Vegetables	0.04 mg/kg plant ww/mg/kd soil dw	0.1 mg/kg plant ww/mg/kd soil dw
Tree Fruit (incl blueberries)	0.07 mg/kg plant dw/mg/kg soil dw	0.03 mg/kg plant dw/mg/kg soil dw
Wheat/Oats/Barley	0.5 mg/kg ww/ mg/kg soil	3.2 mg/kg ww/ mg/kg soil
Eggs	37.7 mg/kg (egg) ww/ mg/kg bw/d	14.6 mg/kg (egg) ww/ mg/kg bw/d
Milk	8.5 mg/L (milk) ww/ mg/kg bw/d	0.04 mg/L (milk) ww/ mg/kg bw/d
Meat	41 mg/kg (meat) ww/ mg/kg bw/d	0.3 mg/kg (meat) ww/ mg/kg bw/d

Table 15 Produce Concentrations for PFOS

Produce Type	Soil Concentration (mg/kg)	Transfer Factor	Concentration in Produce (mg/kg ww)
Average			
Green Vegetables	0.0002	2.2 mg/kg plant dw/mg/kg soil dw	0.00007
Root Vegetables	0.0002	0.05 mg/kg plant ww/mg/kg soil dw	0.00001
Tuber Vegetables	0.0002	0.04 mg/kg plant ww/mg/kg soil dw	0.000008
Tree Fruit (incl blueberries)	0.0002	0.07 mg/kg plant dw/mg/kg soil dw	0.000002
Wheat/Oats/Barley	0.0002	0.5 mg/kg ww/ mg/kg soil	0.0001
Eggs	0.0002	37.7 mg/kg (egg) ww/ mg/kg bw/d	0.00005
Milk	0.0002	8.5 mg/L (milk) ww/ mg/kg bw/d	0.00001
Meat	0.0002	41 mg/kg (meat) ww/ mg/kg bw/d	0.00002
Maximum			
Green Vegetables	0.0004	2.2 mg/kg plant dw/mg/kg soil dw	0.0001
Root Vegetables	0.0004	0.05 mg/kg plant ww/mg/kg soil dw	0.00002
Tuber Vegetables	0.0004	0.04 mg/kg plant ww/mg/kg soil dw	0.00002
Tree Fruit (incl blueberries)	0.0004	0.07 mg/kg plant dw/mg/kg soil dw	0.000004
Wheat/Oats/Barley	0.0004	0.5 mg/kg ww/ mg/kg soil	0.0002
Eggs	0.0004	37.7 mg/kg (egg) ww/ mg/kg bw/d	0.0001
Milk	0.0004	8.5 mg/L (milk) ww/ mg/kg bw/d	0.00002
Meat	0.0004	41 mg/kg (meat) ww/ mg/kg bw/d	0.00004

Assumptions
Chickens consume 0.012 kg soil/day and weigh 2.1 kg
Cows consume 2.4 kg soil/day and weigh 800 kg for beef cattle and 400 kg for dairy cattle
Milk has density of 1.03
Plants consist of 15% dry matter to allow conversion from dw to ww.

Table 16 Produce Concentrations for PFOA

Produce Type	Soil Concentration (mg/kg)	Transfer Factor	Concentration in Produce (mg/kg ww)
Average			
Green Vegetables	0.0002	1.5 mg/kg plant dw/mg/kg soil dw	0.00005
Root Vegetables	0.0002	0.05 mg/kg plant ww/mg/kd soil dw	0.00001
Tuber Vegetables	0.0002	0.1 mg/kg plant ww/mg/kd soil dw	0.00002
Tree Fruit (incl blueberries)	0.0002	0.03 mg/kg plant dw/mg/kg soil dw	0.000001
Wheat/Oats/Barley	0.0002	3.2 mg/kg ww/ mg/kg soil	0.0008
Eggs	0.0002	14.6 mg/kg (egg) ww/ mg/kg bw/d	0.00002
Milk	0.0002	0.04 mg/L (milk) ww/ mg/kg bw/d	0.00000005
Meat	0.0002	0.3 mg/kg (meat) ww/ mg/kg bw/d	0.0000002
Maximum			
Green Vegetables	0.0003	1.5 mg/kg plant dw/mg/kg soil dw	0.00008
Root Vegetables	0.0003	0.05 mg/kg plant ww/mg/kd soil dw	0.00002
Tuber Vegetables	0.0003	0.1 mg/kg plant ww/mg/kd soil dw	0.00003
Tree Fruit (incl blueberries)	0.0003	0.03 mg/kg plant dw/mg/kg soil dw	0.000002
Wheat/Oats/Barley	0.0003	3.2 mg/kg ww/ mg/kg soil	0.001
Eggs	0.0003	14.6 mg/kg (egg) ww/ mg/kg bw/d	0.00003
Milk	0.0003	0.04 mg/L (milk) ww/ mg/kg bw/d	0.00000008
Meat	0.0003	0.3 mg/kg (meat) ww/ mg/kg bw/d	0.0000003

Assumptions
Chickens consume 0.012 kg soil/day and weigh 2.1 kg
Cows consume 2.4 kg soil/day and weigh 800 kg for beef cattle and 400 kg for dairy cattle
Milk has density of 1.03
Plants consist of 15% dry matter to allow conversion from dw to ww.

These concentrations have been used to estimate uptake into people consuming this produce on farm. The calculations are provided in **Appendix C**.

Section 4. Exposure Assessment – Human Health – Leachate

4.1 General

This section provides a short discussion on the potential receptors (human groups) and exposure pathways that are considered to be of significance in this assessment. In addition, where identified as of potential significance and warranting quantification in this assessment, the potential for exposure has been quantified using industry best practice and guidance available from (enHealth 2012a; NEPC 1999 amended 2013d; USEPA 1989, 2002, 2009).

The assessment presented has addressed potential worst-case exposure to the key chemicals in soil and exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and therefore health risk.

The quantification of exposure has involved consideration of the following:

- Identification of relevant ***exposure parameters*** for each of the identified exposure pathways and receptors. The magnitude of the exposure is a function of a number of variables (termed exposure parameters), which describe the physical, and behavioural parameters relevant to the potentially exposed population. Exposure parameters which are considered representative have been selected. Where available, additional exposure data has been obtained from Australian sources (enHealth 2012a; NEPC 1999 amended 2013d); and
- Estimation of the ***chemical concentration*** in each medium relevant to the receptor groups and exposure pathways. This has involved the use of maximum concentrations reported in surface soil. Potential dust concentrations have been estimated on the basis of a particulate emission factor (that relates the concentration in air to that in soil) derived from guidance provided by the USEPA (USEPA 2002).

4.2 Leachate Concentrations

The NSW OEH study investigated the potential for leaching from MWOO in two ways (NSW OEH 2016).

Batch extractions were undertaken using the USEPA 1311 method (i.e. TCLP). This involved a 1:20 mix of treated waste materials and water which was then shaken continuously for 18 hours.

Column leaching was also undertaken using the German Standard Method – leaching of solid material. Approximately 300 g of material was packed into a glass column. The material was allowed to saturate and then equilibrate for 2 hours. The columns were then leached continuously for 7 days. The leachate from this work was divided into 4 fractions depending on the time of collection. The F1 fraction was the leachate collected over the first 18 hours.

The hazard assessment undertaken using this data identified the following chemicals as needing further evaluation – antimony, arsenic, cadmium, lead and nickel – in regard to leaching.

The results for the leaching investigations are provided in **Table 17**.

Table 17 Leachate Concentrations (mg/L) (NSW OEH 2016)

Method	Antimony	Arsenic	Cadmium	Lead	Nickel
Column Leaching – Maximum Concentrations					
Fraction 1	0.05	0.11	0.04	0.4	2.6
Fraction 2	0.01	0.05	<0.01	0.28	0.61
Fraction 3	<0.01	0.03	<0.01	0.08	0.2
Fraction 4	<0.01	<0.03	<0.01	<0.02	0.07
Batch Extraction – Maximum Concentrations					
Batch	0.02	<0.03	<0.01	0.1	0.

It is noted that neither method took into account the amount of treated waste material that might be applied to a site but rather looked at what would leach from just the treated material. So these concentrations are a worst case evaluation of what might leach from the materials.

It is noted that if the material is applied at a rate of 10 tonnes/hectare then there is a dilution of approximately 100 fold when this material is mixed with the soil. This assessment has been undertaken assuming the treated waste materials are 100% of the solid material which could leach to groundwater or cause runoff that might affect a nearby water body. In fact, the treated waste materials form 1% of the solid material from which leachate can be generated.

4.3 Quantification of Exposure – Groundwater

The investigation of these treated waste materials that was undertaken by the NSW OEH included the use of a standard method for leaching potential to determine what chemicals present in the materials that might leach due to rain or irrigation. The standard method was USEPA 1311 – the toxicity leaching procedure. The leaching fluid used was water only. The use of acidic leachate was checked in the first round of assessments and found not to be significantly different to water so water only was used for the rest of the assessment (NSW OEH 2016).

The OEH hazard assessment undertaken in 2016 screened the concentrations reported in the leachates against drinking water. This means the screening was on the basis of people potentially drinking these leachates as the only source of drinking water. This is a conservative but appropriate approach to identify which chemicals need further assessment (NSW OEH 2016).

Further assessment of potential exposure is being undertaken in this assessment based on a more realistic exposure scenario. The chemicals that were reported to be above the relevant drinking water guideline in the leachate were a range of metals including antimony, arsenic, cadmium, lead and nickel.

When these treated waste materials are present in soil at a site, chemicals present can leach out of the materials during rain or irrigation. Leachate can move downward through the soil profile and mix into groundwater or it can run off the surface soil into a surface water body like a dam or creek. In both cases, the leachate is diluted before it reaches an area where people might extract water for domestic uses (or other uses).

A generic assessment for mixing leachate into groundwater can be undertaken using the default dilution factor recommended by the USEPA (Gradient 2013; USEPA 1996). The default dilution factor is 20. It is based on chemicals leaching from soil, then mixing in the water moving through the

soil profile, then mixing with the water already in the groundwater. Using this dilution factor and the data collected in the OEH investigation allows a further assessment of the potential risks for extracted groundwater where leachate mixes with groundwater.

Table 18 Assessment of Leachate when mixed with Groundwater

Chemical	Maximum Concentration (mg/L)	Estimated Groundwater Concentration (mg/L)	Mean Concentration (mg/L)	Estimated Groundwater Concentration (mg/L)	Drinking Water Guideline (mg/L)
Antimony	0.05	0.003	0.01	0.0005	0.003
Arsenic	0.11	0.006	0.08	0.004	0.01
Cadmium	0.04	0.002	0.02	0.001	0.002
Lead	0.4	0.02	0.1	0.005	0.01
Nickel	2.6	0.1	0.28	0.01	0.02

Using this more realistic assessment, antimony, arsenic and cadmium are no longer above the drinking water guideline for the maximum or mean concentrations reported in the OEH data. Lead and nickel are below the drinking water guideline for the mean case but still slightly above for the maximum case.

Further assessment can be undertaken by using recreational water guidelines rather than drinking water guidelines. Recreational water guidelines are designed to be protective for recreational use of water like swimming or boating. In most situations, it is unlikely that groundwater will be the sole source of water used on farm for all potable uses. The recreational water guidelines are based on the toxicity information used to determine the drinking water guidelines but assume people consume 200 mL of water per day rather than 2 L per day. The recreational water guidelines still assume a person is exposed every day for their lifetime and that only 10% of the tolerable intake recommended for a chemical can result from exposure to water so for situations where groundwater may be used occasionally for potable purposes at a site, the recreational water guidelines are a conservative tool for assessment.

Table 19 Further Assessment of Leachate when mixed with Groundwater

Chemical	Maximum Concentration (mg/L)	Estimated Groundwater Concentration (mg/L)	Mean Concentration (mg/L)	Estimated Groundwater Concentration (mg/L)	Recreational Water Guideline (mg/L)
Lead	0.4	0.02	0.1	0.005	0.1
Nickel	2.6	0.1	0.28	0.01	0.2

This further assessment shows that when leachate is mixed into groundwater on a site where these treated waste materials were applied, the risks due to leachate from the materials mixing into groundwater are low.

4.4 Quantification of Exposure – Runoff

Assessing chemical concentrations in runoff is not commonly undertaken for assessments like this one, however, the APVMA has a methodology for assessing potential runoff of pesticides to surface water bodies. This methodology has been adopted for this assessment.

The APVMA runoff scenario assumes a 100 mm rainfall event over a farm. It is assumed that 20% of this water runs off the paddock where a pesticide has been applied to a surface water body nearby (https://apvma.gov.au/node/805). It is also assumed that 10% of the applied pesticide get washed off the paddock in this runoff. The runoff mixes in a standard pond – 1 hectare pond which is 15 cm deep.

Using these assumptions for this scenario, results in the following considerations:

- 200 m^3 of water runs off a 1 hectare paddock
- Concentrations of each chemical measured in leachate are present in these 200 m^3 at 10% of the measured leachate concentration
- 200 m^3 runoff mixes into 1500 m^3 water already in pond

Using these considerations allows a more realistic calculation of risks from potential runoff of leachate as shown in **Table 20**.

Table 20 Assessment of Leachate when mixed with Surface Water

Chemical	Maximum Concentration (mg/L)	Estimated Surface Water Concentration (mg/L)#	Mean Concentration (mg/L)	Estimated Surface Water Concentration (mg/L)#	Drinking Water Guideline (mg/L)
Antimony	0.05	0.0006	0.01	0.0001	0.003
Arsenic	0.11	0.001	0.08	0.0009	0.01
Cadmium	0.04	0.0005	0.02	0.0002	0.002
Lead	0.4	0.005	0.1	0.001	0.01
Nickel	2.6	0.03	0.28	0.003	0.02

= (concentration x 0.1) x 200/1700

Using this more realistic assessment, almost all of these metals/metalloids are no longer above the drinking water guideline for the maximum or mean concentrations reported in the OEH data. Nickel remains just above the drinking water guideline for the maximum case but the estimated concentration is still within the measurement error for the analysis, so it is not sufficiently different from the drinking water guideline to be of concern. It is noted that the estimated concentration in surface water is well below the recreational water guideline. It is considered that these chemicals pose a low risk to human health when considered in these more realistic scenarios.

Section 5. Toxicity Profile – Human Health

5.1 Polybrominated Diphenyl Ether Flame Retardants (Br1 to Br9)

5.1.1 General

Polybrominated diphenyl ethers (PBDE) are a group of compounds manufactured for their flame retardant properties. They consist of a two phenyl groups bound to a single oxygen atom with the hydrogen atoms on the phenyl groups substituted with between one and ten bromine atoms. The group consists of 209 structurally similar compounds or 'congeners' which differ in the number and location of substituted bromine. The internationally accepted numbering system for PBDE congeners is the acronym 'BDE' followed by a number from one to 209 (NICNAS 2007).

Several comprehensive reviews of PBDEs in the environment and toxicity to humans are available (ATSDR 2017; NICNAS 2007; UNEP 2009). The following provides a summary of the key aspects of these compounds that are relevant to this assessment.

The literature to date indicates that the toxicity and environmental fate of PBDEs with a lower number of substituted bromine atoms (penta-BDE to hexa-BDE) is different to the fully brominated BDE (deca-BDE or BDE-209). Lower brominated BDEs have been demonstrated to be more toxic in animal studies, have a higher bioavailability and are more readily transported in the environment. As a result, the ATSDR has recommended separating deca-BDE from 'lower brominated BDEs' (ATSDR 2017).

For the purpose of this assessment 'lower brominated BDEs' are considered to be BDEs containing between one and nine substituted bromines.

PBDE are manufactured compounds, which have been widely used in industrial, and consumer applications. A review of the compounds conducted by scientific and regulatory bodies have culminated in tetra- and penta-BDEs (components of technical penta-BDE) and hexa- and hepta-BDEs (components in technical octa-BDE) being listed as a Persistent Organic Pollutants (POP) under the Stockholm Convention in May 2009. All production and use of these compounds have subsequently been banned with the exception of recycling activities. PBDEs are not manufactured in Australia but were historically imported and used until 2005. Importation of products pre-treated with PBDEs is expected to decrease following the recent ban. Technical penta-BDE was mainly used in polyurethane foams (such as in furnishings) whereas technical octa-BDE and deca-BDE were mainly used in hard plastics (such as for electrical equipment). The articles treated with PBDEs usually have long lives and as such, articles containing PBDEs are still expected to be in use. Deca-BDE was declared a priority existing chemical in Australia and is currently being assessed as to its environment and human health risks (ATSDR 2017; NICNAS 2007; UNEP 2009).

5.1.2 Significance of Exposure Pathways

Oral Bioavailability

Insufficient data is available to adequately define the bioavailability of lower BDEs hence a default approach of assuming 100% oral bioavailability has been adopted.

Dermal absorption:

Insufficient data is available on the dermal absorption of lower BDEs from soil. Hence the default values of 0.1 (10%) suggested by USEPA for semi-volatile organic compounds has been adopted (USEPA 2004).

It is noted that the EU estimated a dermal absorption value of 1% as a maximum for deca-BDE based on assumptions associated with the lipophillic nature of the compound and analogies to PCBs (EU 2003). However, it is also noted in this review that dermal absorption may also be associated with accumulation in the stratum corneum which may behave as a storage site resulting in a low systemic release over time.

Inhalation of Dust:

Lower BDEs are not considered sufficiently volatile to be of significance and inhalation exposures associated with dust particulates outdoors and indoors are expected to be of less significance than ingestion of soil. While likely to be negligible, potential inhalation exposures associated with dust have been considered.

Plant Uptake:

Limited data are available on the potential for lower BDEs to be taken up by plants from soil into edible fruit and vegetable crops. ATSDR notes that PBDEs will be strongly adsorbed to soil; hence, PBDEs present in soil-pore water will bind to soil organic matter. Because PBDEs adsorb strongly to soil, they will have very low mobility and leaching of PBDEs from soil to groundwater will be insignificant (ATSDR 2017).

Review of plant uptake of deca-PBDE (BDE-209) into plants from soil by Huang et al. (2010) suggests that deca-BDE is taken up and translocated within the plants assessed (ryegrass, alfalfa, pumpkin, squash, maize and radish). Nineteen lower brominated (di- to nona-) PBDEs were detected in the soil and plant samples and five hydroxylated congeners were detected in the plant samples, indicating debromination and hydroxylation of BDE-209 in the soil−plant system. Evidence of a relatively higher proportion of penta- through di-BDE congeners in plant tissues than in the soil indicates that there is further debromination of PBDEs within plants or low brominated PBDEs are more readily taken up by plants (Huang et al. 2010).

Other studies have evaluated uptake into maize and other crop species for a range of these chemicals (Yang et al. 2018; Zhao et al. 2012). Uptake into maize and sweet potatoes was reported in these studies. In addition, the more recent paper included a summary of uptake into a range of plant species.

On the basis of the available information the potential for the uptake of lower BDEs into home-grown produce has been considered. This has been undertaken on the basis of the equations presented in **Appendix B** with the following parameters and plant uptake factors estimated

Table 21 Parameters for assessment uptake into plants

Parameter	Value	Reference/Comment
Parameters		

Parameter	Value	Reference/Comment
Koc	1698000 (cm^3/g)	Refer to note below*
log Kow	6.84	(RAIS) for pentaBDE (BDE-99)
Diffusivity in water	$5.32x10^{-6}$ (cm^2/s)	Estimated as per (Guan et al. 2009)
Calculated Plant Uptake Factors (mg/kg produce fresh weight per mg/kg soil)		
Green vegetables	0.00026	calculated
Root vegetables	0.0038	calculated
Tuber vegetables	0.079	calculated
Tree fruit	0.00096	calculated

* The estimation of potential plant uptake of BDE is sensitive to the value of Koc adopted. The data would normally be derived from RAIS (2010) for consistency; however, the data provided is only for penta-BDE with data from no other lower BDEs presented for comparison. Data presented in ATSDR (2001) suggests log Koc ranges from 2.89-5.1 for penta-BDE and from 5.92-6.22 for octa-BDE. Review by Guan et al. (2009) provides log Koc values for the lower BDEs (BDE-28 to BDE-208) that range from 5.73 to 6.49. Due to the range of values provided for the lower BDEs, the average of values presented by Guan et al. (2009), log Koc = 6.23 has been adopted.

Intakes from Other Sources – Background:

Background intakes were evaluated by NICNAS on the basis of PBDE levels in blood rather than as an intake (NICNAS 2007). The presence of PBDEs in blood lipids indicates exposure by the general population; however, the data does not determine the major source of exposure.

Data available from FSANZ suggests that dietary sources are likely to be low, therefore, house dust may be the major source of exposure, however, there is little correlation between exposure levels and house construction/contents. FSANZ notes a review by the US where dietary exposures did not explain the current body burden and exposures to house dust were estimated to account for 82% of the total intake (FSANZ 2007).

Based on information presented in the available reviews the following can be noted with respect to background intakes of PBDEs:

- A range of dietary intakes have been determined by FSANZ for all age groups. Estimated 95th percentile dietary intakes from FSANZ for a child aged 2-5 years ranged from 7 ng/kg/day (lower bound) to 389 ng/kg/day (upper bound). These intakes are consistent with data reported from other countries including Canada and the US and corresponded with a margin of exposure (MOE) of 300 or greater where a threshold of 0.1 mg/kg/day was considered. The MOE was greater for all other age groups considered in the study (FSANZ 2007).
- PBDE in dust reported in indoor air in Australian buildings ranged from 0.5 to 179 pg/m^3 for homes and 15 to 487 pg/m^3 for offices. Dust concentrations ranged from 87 ng/g to 3070 ng/g. PBCEs were detected in 9 out of 10 surface wipe samples. No estimation of intake associated with measured levels in air and dust were presented. The study size was limited and showed dust levels similar to or lower than those conducted overseas in Canada and the US (Toms et al. 2006).
- Upper bound total intakes of PBDEs from all sources (ambient and indoor air, dietary and dust) in Canada have been estimated to be approximately 0.95 µg/kg/day for children aged 0.5 to 4 years. Higher intakes (2.6 µg/kg/day) are noted for breastfed infants. Recent review of total intakes from food, dust and air of PBDEs in the US range from 1.2 ng/kg/day for adults to 307 ng/kg/day for infants (Health Canada 2006; Schecter et al. 2008).

- Based on the Australian data noted above, intakes by young children may range from 0.007 to 0.5 µg/kg/day. The higher value is half that estimated by Health Canada, both of which exceed the recommended oral TRV (FSANZ 2007; Health Canada 2006).
- On the basis of the above, total intakes (and those reported from Australia) vary and may comprise a significant proportion of the recommended threshold value. Hence, consideration of 80% of the recommended TRV as background intake is considered appropriate.

5.1.3 Identification of Toxicity Reference Values

Classification:

The International Agency for Research on Cancer (IARC 1999) has classified technical deca-BDE as Group 3: not classifiable. No classification is available for other BDEs (IARC 1999).

It is noted that the USEPA has a classification for deca-BDE where it is classified as "*suggestive evidence of carcinogenic potential*" (USEPA 2008c). The USEPA has classified technical penta-BDE and technical octa-BDE as Group D: not classifiable (USEPA 2008c, 2008b).

Review of Available Values/Information

Review of PBDEs, in particular penta-BDE and octa-BDE by NICNAS indicated there are insufficient information of the carcinogenic potential of these PBDEs and that the overall conclusion relating to penta-BDE is that it is not genotoxic (NICNAS 2007). Further review of octa-BDE, PBDE mixtures and penta-BDE suggest that PBDE mixtures and individual congeners are not genotoxic (WHO 2006). On the basis of the available information, it is considered appropriate that a threshold dose-response approach be adopted for PBDEs.

The following are available for the lower BDEs from Level 1 Australian and International sources

Table 22 Toxicity Reference Values

Source	Value	Basis/Comments
Australian		
ADWG (NHMRC 2011 updated 2018)	No evaluation available	
NICNAS (NICNAS 2007)	No ADI/TDI established	Based on review of PBDEs and available studies the highest toxicity was associated with penta-BDE associated with neurodevelopmental effects in pups and dams where the LOAELs were 0.8 mg/kg/day in pups and 0.06 mg/kg/day in dams.
FSANZ (FSANZ 2007)	No ADI/TDI established	Review of dietary intakes considered a margin of exposure (MOE) approach where a threshold value of 0.1 mg/kg/day was considered based on review by JECFA.
International		
JECFA (WHO 2006)	No ADI/TDI established	Due to the complexity of PBDEs and the lack of adequate data a provisional maximum tolerable daily intake or provisional tolerable weekly intake has not been derived for PBDEs. Limited data suggests that for more toxic PBDE congeners adverse effects would be unlikely to occur in rodents at doses less than approximately 0.1 mg/kg/day.
WHO DWG	No evaluation available	
Health Canada (Health Canada 2006)	No ADI/TDI established	A threshold value of 0.8 mg/kg/day was identified for penta-BDE based on neurobehavioural effects in neonatal mice, considered the critical effects and appropriate for undertaking a MOE approach to the assessment of risk.
ATSDR (ATSDR 2017)	No chronic duration MRLs derived	No chronic duration MRLs have been derived for lower brominated BDEs due to insufficient data. An intermediate duration oral MRL of 0.000003 mg/kg/day has been derived on the basis of a LOAEL of 0.001 mg/kg/day associated with 34% reduction in serum testosterone in rats exposed to tetra-BDE (BDE47).

Source	Value	Basis/Comments
		An intermediate duration inhalation MRL of 0.006 mg/m^3 has been derived based on a NOAEL of 1.1 mg/m^3 for thyroid effects in rats exposed to commercial octa-BDE mixture.
USEPA (USEPA 2008c, 2008b, 2008d, 2008a; USEPA IRIS)	RfD = 0.0001 mg/kg/day for penta-BDE (BDE-99) RfD = 0.0002 mg/kg/day for hexa-BDE (BDE-153) RfD = 0.0001 mg/kg/day for tetra-BDE (BDE-47) RfD = 0.003 mg/kg/day for octa-BDE RfD = 0.007 mg/kg/day for deca-BDE	RfD established for BDE-99 (penta-BDE) on the basis of a benchmark dose approach and a $BMDL_{1SD}$ of 0.29 mg/kg/day associated with neurobehavioral effects in mice and an uncertainty factor of 3000. Hexa-BDE RfD established for BDE-153 on the basis of a NOAEL of 0.45 mg/kg/day associated with neurobehavioral effects in mice and an uncertainty factor of 3000. Tetra-BDE RfD established for BDE-47 on the basis of a benchmark dose approach and a $BMDL_{1SD}$ of 0.35 mg/kg/day associated with neurobehavioral effects in mice and an uncertainty factor of 3000. Octa-BDE RfD (established in 1986) for octa-BDE based on a NOAEL of 2.51 mg/kg/day associated with liver effects in rats and an uncertainty factor of 1000. Note the USEPA review established an RfD = 0.007 mg/kg/day for deca-BDE (BDE-209) based on a NOAEL of 2.22 mg/kg/day associated with neurobehavioral effects in mice and application of a 300 fold uncertainty factor. This evaluation indicates that deca-BDE is less toxic than the lower BDEs.

Limited quantitative data is available for the characterisation of chronic exposures to lower BDEs. The more recent evaluations by the US EPA (IRIS) for individual congeners BDE-99, BDE-153 and BDE-47 have considered threshold values (BMDLs or NOAELs) that are consistent with those identified in reviews by NICNAS (2007), JECFA (2006) and Health Canada (2006) that are associated with the more sensitive endpoint of neurobehavioral/developmental effects. These endpoints are more sensitive than those considered by ATSDR in the derivation of intermediate duration MRLs and considered in older reviews by the US EPA for penta-BDE and octa-BDE. The uncertainty factor applied by the USEPA to the individual congeners considered, 3000, includes an additional 10 fold factor to address database deficiencies.

There is no evaluation of a chronic threshold value that would be applicable to all lower BDEs as a group, hence application of the USEPA values requires an assumption that the congeners studied are an appropriate indicator for total lower BDEs. This is likely to be conservative; however, no more detailed evaluations are available. The individual congener studies by the USEPA are noted by NICNAS to be those within commercial penta-BDE that are of most importance in biomonitoring and environmental sampling.

The lower RfD of 0.0001 mg/kg/day derived by the USEPA for BDE-99 and BDE-47, similar to that derived for BDE-153 is recommended for use for the lower BDEs. As noted in most other reviews the available database is poor and limited with respect to identification of a threshold associated with chronic exposures to the group of congeners. Hence, the use of this threshold TRV required further review and update the future and further studies are undertaken.

No dermal or inhalation specific chronic studies or data are available. For the presence of lower BDEs in soil, it is considered appropriate to consider use of the available threshold value for all pathways of exposures.

5.1.4 Recommendation

On the basis of the discussion above the following toxicity reference values (TRVs) have been adopted:

Recommendation for Lower BDEs

Oral TRV (TRV_O) = 0.0001 mg/kg/day (USEPA (USEPA 2008b, 2008d) for BDE-99 and BDE-47) for all pathways of exposure
Dermal absorption factor (DAF) = 0.1 (or 10%) (USEPA 2004)
Intakes allowable from soil (as % of TRV) = 20%
Background intakes from other sources (as % of TRV):
BI_O = 80% for oral and dermal intakes
BIi = 80% for inhalation
Uptake in home grown produce considered

Recommendation for Deca BDE

Oral TRV (TRV_O) = 0.007 mg/kg/day (USEPA 2008c) for all pathways of exposure
Dermal absorption factor (DAF) = 0.01 (or 1%) (EU 2003)
Intakes allowable from soil (as % of TRV) = 20%
Background intakes from other sources (as % of TRV):
BI_O = 80% for oral and dermal intakes
BIi = 80% for inhalation

5.2 PFAS Compounds

5.2.1 General

As PFAS compounds are widely distributed throughout the environment, can be highly persistent in the body, and present in many products and foods, FSANZ (FSANZ 2017b) has provided the most current evaluation of PFAS toxicity, for the purpose of establishing Australian guidelines for these compounds in produce to protect human health. The FSANZ review specifically addressed PFOS, PFOA and PFHxS.

5.2.2 PFOS and PFOA

The following provides a general summary of health effects that have been associated with PFOS and PFOA (Rumsby et al. 2009):

- Although the acute toxicity of PFAS is moderate, their persistence in the body (half-lives for PFOA of up to 8.7 years have been determined in retired production workers) has led to increasing concerns over long-term effects. The toxicity of PFOS and PFOA is not clearly understood at present. Different animal species appear to have different sensitivities to these compounds, which makes interpretation of experiments difficult (e.g. Rhesus monkeys are more sensitive to PFOS than rats, while mice are the least sensitive). The species variability may be due to the different handling of these compounds in the body;
- At present, it is unclear whether PFOS and PFOA act by the same mechanisms, and high and low doses may differ in their toxic effects. High-dose studies on animals have indicated that cancer, developmental delays, endocrine disruption, immunotoxicity and neonatal mortality are potential toxic endpoints; and
- Recent research has also suggested that receptor binding may be an important general mechanism. PFOS and PFOA both bind to peroxisomal proliferator-activated receptors.

Activation of such receptors may alter fatty acid metabolism and play a role in cancer, foetal growth, hormone and immune function.

The toxicity of PFAS to humans can be inferred from animal toxicity studies as well as occupational exposure studies. The occupational exposure studies consider workers who handle or make PFAS, where the exposure levels are high. These studies have been undertaken in the US and Belgium, and have evaluated a range of health effects based on blood serum levels of PFAS in workers. These studies have identified some associations between altered cholesterol, triglyceride and high-density lipoprotein production (for PFOS > 6 mg/L in serum) and PFAS exposure. Review of these studies (ToxConsult 2014) identified that a no effect level of 2 mg/L (in serum) can be established for adult workers.

In general, observations from toxicological studies undertaken in animals with PFOS and PFOA include irritation of eyes, skin and nose; loss of appetite, reductions in body-weight and weight gain, changes in the liver (including increases in liver weight [characterised by increased centrilobular hepatocellular hypertrophy]), mild-to-moderate peroxisome proliferation in rats, increased incidence of hepatocellular adenomas in rats (non-genotoxic), and hypo-cholesterolemia (ATSDR 2018). Effects identified appear to be related to a threshold body burden and often are observed with a steep dose–response (i.e. after the threshold the potential for adverse effects increases rapidly with increasing exposure level) (ToxConsult 2014).

Data from epidemiological studies with occupationally exposed workers at 3M manufacturing facilities (Alabama, USA and Belgium), communities exposed to contaminated drinking water (USA) and general populations (USA, UK and Scandinavia) are also available. It is noted that concentrations of PFAS in occupationally exposed workers are 100 to 1,000-fold higher than those in the general populations. Despite this, epidemiology studies have generally failed to draw conclusive links between exposure to PFOS or PFOA and adverse health effects. Associations between exposure and the following health effects have been suggested:

- Changes in serum lipid levels e.g. increase total cholesterol levels;
- Changes in serum liver enzymes levels;
- Kidney disease;
- Effects on fertility, pregnancy, lactation, and birth outcomes;
- Effects on thyroid and immune function;
- Endocrine effects (e.g. elevated thyroxine levels and increased risk of thyroid disease, diabetes mellitus and early onset menopause);
- Cardiovascular disease; and
- Cancer.

Overall, the evidence for adverse effects in humans following exposure is inconsistent from the epidemiological studies. In addition, the biological significance of some of the observed effects has been questioned (i.e. just because an effect is observed it does not mean it is, or will lead to, an adverse effect) and there is the potential that observed effects may be due to confounding factors e.g. exposure to other contaminants or diet.

5.2.3 Characterising toxicity for PFOS, PFHxS and PFOA

Consistent with reviews by other authorities (EFSA 2008; enHealth 2016; USEPA 2016a, 2016b), FSANZ has determined tolerable daily intakes (TDI) for PFOS and PFOA on the basis of data

derived from animal studies, that show exposure to these compounds can cause liver toxicity and tumours and reproductive and developmental effects. The available epidemiological studies have not provided sufficient evidence of a link between exposure to PFOS and PFHxS and any cancer type in human beings. Although associations between PFOA and some human cancers have been suggested from some epidemiological studies, results have often been contradictory, and a causal relationship cannot be established with reasonable confidence.

In relation to PFHxS, FSANZ determined there was insufficient information to establish a TDI for PFHxS. In the absence of a TDI, FSANZ agrees with enHealth (enHealth 2016) that using the TDI for PFOS is likely to be conservative and protective of public health. This means that PFHxS and PFOS should be summed for the purposes of exposure assessment and risk characterisation. The TDIs adopted by FSANZ for the assessment PFOS + PFHxS and PFOA are summarised in **Table 23**. This table also includes the background intakes adopted for the HHERA, which are based on the review presented by ToxConsult (ToxConsult 2016).

Table 23 Toxicity Reference Values

PFAS Compound	TDI	Adopted Background intake	Reference
PFOS + PFHxS	0.02 µg/kg/day	0.0014 µg/kg/day (7% of the TDI)	(FSANZ 2017a)
PFOA	0.16 µg/kg/day	0.00078 µg/kg/day (negligible)	(FSANZ 2017a)

Notes:
Refer to **Appendix E** for further information

5.2.4 Other PFAS Compounds

In relation to other PFAS compounds, limited data is available to evaluate the toxicity of many of these individual compounds. Review of comparative toxicity for PFAS compounds (Borg et.al. 2013), relevant to liver and reproductive effects, indicates that most of these are 10 to 100 times less toxic than PFOS and PFOA.

Due to the lack of toxicological information for some of the listed PFAS in this assessment some of the individual PFAS have been summed for assessment as discussed in **Section 3.3**. For this assessment N-MeFOSAA, N-MeFOSE, N-EtFOSE, PFBS, PFHxS and PFOS have been summed and compared to the tolerable intake for PFOS and PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA and FOUEA have been summed and compared to the tolerable intake for PFOA.

Section 6. Risk Characterisation

6.1 Quantitative Assessment of Risk

6.1.1 Approach

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure and toxicity assessment to provide a quantitative evaluation of risk. Risk is characterised separately for threshold and non-threshold carcinogenic effects as outlined in the following:

Threshold Risk

The quantification of potential exposure and risks to human health associated with the presence of key chemicals in surface soil at the site has been undertaken by comparing the estimated intake (or exposure concentration) with the threshold values adopted that represent a tolerable intake (or concentration), with consideration for background intakes. The calculated ratio is termed a Risk or Hazard Index (RI/HI), which is the sum of all ratios (termed Risk or Hazard Quotients [RQ/HQ]) over all relevant pathways of exposure. These are calculated using the following equations:

$$Risk\ /\ Hazard\ \ Quotient\,[RQ\ /\ HQ](oral\ or\ dermal) = \frac{Daily\ \ Chemical\ \ Intake}{(ADI, TDI, RfD - Background)}$$

$$Risk\ /\ Hazard\ \ Quotient\,[RQ\ /\ HQ](inhalation) = \frac{Exposure Concentration\ in\ Air}{(TC, RfC - Background)\ or\ TWA}$$

$$Risk\ /\ Hazard\ \ Index\,(RI\ /\ HI) = \sum_{All\ pathways} RQ\ /\ HQ$$

The interpretation of an acceptable RI/HI needs to recognise an inherent degree of conservatism that is built in to the establishment of appropriate guideline (threshold) values (using many uncertainty factors) and the exposure assessment. Hence, in reviewing and interpreting the calculated HI the following is noted:

- A RI/HI less than or equal to a value of 1 (where intake or exposure is less than or equal to the threshold) represents no cause for concern (as per risk assessment industry practice, supported by protocols outlined in ASC NEPM (1999) and US EPA guidance); and
- A RI/HI greater than 1 requires further consideration within the context of the assessment undertaken, particularly with respect to the level of conservatism in the assumptions adopted for the quantification of exposure and the level of uncertainty within the toxicity (threshold) values adopted.

Non-Threshold Risk

The key chemicals present at the site are chemicals that act via threshold modes of action. As a result, no chemicals need to be assessed for non-threshold risks.

6.1.2 Calculated Risks – PBDEs

Tables 24, 25 and **26** presents the threshold RQs for each pathway assessed. The values presented in **Tables 24, 25** and **26** (and all other risk calculations) are rounded to 1 or 2 significant figures reflecting the level of certainty inherent in risk calculations. Detailed calculations are presented in **Appendix C.**

This assessment has not evaluated the potential risk to the commercial food supply for food types grown at sites where these materials have been applied. Given the large number of farms that supply such food types into the commercial food supply, it is not possible that a person, who does not live on one of these farms, would consume food from such a site on a daily basis.

This assessment has evaluated worst case exposures. The calculations have assumed:

- Treated waste materials have been applied to a site at the maximum application rate permitted for that land use
- People living at the site come into contact with soil where the materials have been applied every day of the year
- People consume 35% of the fruit and vegetables they eat over a year from the fruit and vegetables they grow on a farm
- People consume 100% of eggs they consume over a year from chickens that are kept at a farm and these people are high end consumers of eggs
- People consume 100% of the milk they consume over a year from dairy cows kept at a farm and that these people are high end consumers of milk
- People consume 100%, 75% or 50% of the meat they consume over a year from beef cattle kept at a farm and that these people are high end consumers of meat

These risk quotients are based on regular exposure to agricultural produce grown in land where the treated waste materials are applied. It is not likely that a person living on one of these farms would grow all types of produce discussed in this assessment. Farms usually involve either cropping, horticulture or grazing but not all of these types of practice. Some farms include cropping and grazing but these activities are conducted in different areas of the property.

Keeping chickens and a home vegetable garden are more likely to be located close to the farm house rather than in the paddocks where these materials would be applied. Also, the regulatory requirements for the use of these materials mean that these materials are not permitted for application to land where chickens are kept or where vegetables are grown for commercial purposes.

It is also noted that the available data for the concentrations of these chemicals in the treated materials is limited and quite skewed. It is quite possible that using the mean concentration in these calculations may be an overestimate of risk as the mean concentration is skewed by the single high concentration that was found in one sample. Additional calculations are provided in **Appendix C** for the minimum and maximum concentrations measured in these treated waste materials.

Table 24 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE) - Young children - Adults	0.2 0.02
Dermal contact with PBDEs in soil - Young children - Adults	0. 0.07
Inhalation of PBDEs in dust - Young children - Adults	0.000008 .0000008
Ingestion of PBDEs in home grown fruit and vegetables as per HIL-A calculations with higher intake fraction (35% instead of 10% from farm) - Young children - Adults	 270 84
Ingestion of PBDEs in wheat/oats/barley - Young children - Adults	 150 83
Ingestion of PBDEs in chicken eggs from a site - Young children - Adults	 7 2.5
Ingestion of PBDEs in milk produced at a site - Young children - Adults	 170 44
Acceptable Risk	**≤1**

Table 25 Summary of Risk – Consumption of Meat (mean)

Receptor/Exposure Pathway	Proportion Consumed	Threshold Risk
Beef (10 tonnes/hectare – agricultural land)		
Young Children	50% of diet	340
	75% of diet	510
	100% of diet	680
Adults	50% of diet	140
	75% of diet	210
	100% of diet	279
Beef (140 tonnes/hectare – mine site rehabilitation)		
Young Children	50% of diet	4600
	75% of diet	6900
	100% of diet	9200
Adults	50% of diet	1900
	75% of diet	2850
	100% of diet	3800
Acceptable Risk		**≤1**

Table 26 Summary of Risk Estimates (mean – additional application rates)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in home grown fruit and vegetables at higher application rate – non-contact agriculture (blueberries/grapes) (50 tonnes per hectare)	
- Young children	328
- Adults	55
Ingestion of PBDEs in milk produced at a rehabilitated mine site should grazing for dairy cows occur in future (140 tonnes per hectare)	
- Young children	2390
- Adults	604
Acceptable Risk	**≤1**

Based on the risk estimates in **Tables 24, 25** and **26,** the potential for PBDEs to be present in surface soil after application of treated waste materials results in the following:

- Risks for people who come into contact with soil where these materials have been applied are low and acceptable (exposure via ingestion of soil, dermal contact with soil and inhalation of dust)
- Risks for people who consume any type of produce on a regular basis from land where these materials have been applied are not acceptable and such exposure should be avoided.

It is noted that these calculations have used the mean concentration reported from the research program (NSW OEH 2016) which was skewed high by the presence of one sample that had a very high concentration.

6.1.3 Calculated Risks – PFAS

Tables 27 and **28** present the threshold RQs for each pathway assessed. The values presented in **Tables 27** and **28** (and all other risk calculations) are rounded to 1 or 2 significant figures reflecting the level of certainty inherent in risk calculations. Detailed calculations are presented in **Appendix C.**

Table 27 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOS in soil	
- Young children	0.00007
- Adults	0.000007
Dermal contact with PFOS in soil	
- Young children	Dermal absorption is very low for this chemical so risk is negligible
- Adults	
Inhalation of PFOS in dust	
- Young children	Negligible
- Adults	Negligible
Ingestion of PFOS in home grown fruit and vegetables (35% instead of 10% from farm)	
- Young children	0.006
- Adults	

Receptor/Exposure Pathway	Threshold Risk
	0.003
Ingestion of PFOS in wheat/oats/barley	
- Young children	0.01
- Adults	0.008
Ingestion of PFOS in chicken eggs from a site	
- Young children	0.0
- Adults	
Ingestion of PFOS in milk from a site	
- Young children	0.04
- Adults	0.01
Ingestion of PFOS in meat at a site (35% consumption)	
- Young children	0.002
- Adults	0.001
Acceptable Risk	**≤1**

Table 28 Summary of Risk Estimates (mean)

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOA in soil	
- Young children	0.00007
- Adults	0.000007
Dermal contact with PFOA in soil	
- Young children - Adults	Dermal absorption is very low for this chemical so risk is negligible
Inhalation of PFOA in dust	
- Young children	Negligible
- Adults	Negligible
Ingestion of PFOA in home grown fruit and vegetables (35% instead of 10% from farm)	
- Young children	0.0006
- Adults	0.0003
Ingestion of PFOA in wheat/oats/barley	
- Young children	0.01
- Adults	0.008
Ingestion of PFOA in chicken eggs from a site	
- Young children	0.0003
- Adults	0.0001
Ingestion of PFOA in milk from a site	
- Young children	$2x10^{-5}$
- Adults	$6x10^{-6}$
Ingestion of PFOA in meat at a site (35% consumption)	
- Young children	$3x10^{-6}$
- Adults	$1x10^{-6}$
Acceptable Risk	**≤1**

Based on the risk estimates in **Tables 27** and **28,** the potential for PFAS to be present in surface soil after application of treated waste materials results in the following:

- Risks for people who come into contact with soil and/or consume any type of produce on a regular basis from land where these materials have been applied where these materials have been applied are low and acceptable

6.2 Uncertainties

Uncertainty in any assessment refers to a lack of knowledge (that could be better refined through the collection of additional data or conduct of additional studies) and is an important aspect of the risk assessment process. An assessment of uncertainty is a qualitative process relating to the selection and rejection of specific data, estimates or scenarios within the risk assessment. In general, to compensate for uncertainty, conservative assumptions are often made that result in an overestimate rather than an underestimate of risk.

In general, the uncertainties and limitations of the risk assessment can be classified into the following categories, where uncertainties relevant to each have been addressed within the report (as noted):

- Sampling and analysis
  - the NSW EPA research program generated chemical characterisation of the treated waste materials – given the potentially highly variable nature of these materials the available data is limited but adequate for this assessment
- Toxicological assessment
  - In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals, although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response. There may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the necessity to extrapolate results of short-term or subchronic animal studies to humans exposed over a lifetime has inherent uncertainty.
    With respect to the assessment of key chemicals identified in this assessment, the approach for evaluating risks to mixtures of chemicals assumes dose additivity and does not account for potential synergism, antagonism or differences in target organ specificity and mechanism of action. In general, the additive approach has the effect of overestimating the risks. However, it is noted that the assessment of a range of petroleum related compounds presented in this report have similar toxicological endpoints (rather than the parent compound itself). For these compounds the consideration of cumulative exposure on the basis of additivity is considered appropriate.
    Overall the toxicological data presented are considered to be current and adequate for the assessment of risks to human health associated with the potential exposure to the key chemicals identified in groundwater that may move off the site
- Exposure assessment

- The quantification of exposure has adopted a number of conservative assumptions as recommended by the (NEPC 1999 amended 2013d). Many of the parameters adopted for RME are considered to be an overestimate of actual exposures.
  The values adopted for the purpose of quantifying exposure are point values that are derived from a wide range of physiological or behavioural values that are better defined using a distribution. It is overly complex to present the assessment based on distributions hence the point values identified provide a reasonable approximation of the RME. The overall approach, however, is expected to result in an overestimate of actual exposure.
  While not quantified in this assessment, potential exposure and chemical intake by older children and adults will be lower than considered for young children. In addition, exposure and intake during short-duration activities such as construction and general gardening activities will be lower than those calculated here for young children.

A number of approaches and assumptions have been adopted that are expected to result in an overestimate of risk. However, in relation to the assessment presented, the following assumptions are likely to be conservative:

- People live at the site for 29 years as adults and 6 years as young children
- People come into contact with soil every day
- PBDEs are assumed to be 100% bioavailable/bioaccessible for both the human health and ecological aspects of the assessment
- Home grown produce (crops) accumulates PBDEs and PFAS
- 100% of the eggs or milk people consume are produced at this site
- People consume 35% of their daily intake of fruit and vegetables all year round and for up to 35 years from produce grown at this site in land where these materials are applied

Section 7. Ecological Risks

An assessment of ecological risk using the approach adopted by NSW OEH with the methodologies to determine more realistic media concentrations used in **Sections 3** and **4** for the assessment of human health. The criteria adopted by NSW OEH in their hazard assessment are still appropriate for use here. The hazard assessment involved using chemical concentrations in the treated waste material and in undiluted leachate. This approach is useful for screening out chemicals that are unlikely to ever be at concentrations that might pose a risk. Such an assessment, however, can be refined by using more realistic media concentrations (NSW OEH 2016).

The assessment has been undertaken with consideration of the following Australian and international guidance documents:

- National Environmental Protection (Assessment of Site Contamination) Measure, Schedule B5 – Ecological Risk Assessment (NEPC 1999 amended 2013a);
- Australia and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ 2000); and
- USEPA Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) (USEPA 2007a).

The general framework to assess and manage ecological risks is a process that incorporates the following:

- Problem Identification – identify the potential problems that contamination may pose.
- Exposure Assessment – measure or quantify the contamination that may be present at the site.
- Effects Assessment – determine the types of effects that the contamination may cause and the concentrations at which such effects may occur.
- Risk Characterisation – compare the estimated exposure with the concentrations at which effects may occur to determine if the contamination may pose a risk.
- Risk Management – consider the level of risk posed in order to design a remediation and/or management strategy that will effectively reduce the risk to an acceptable level.

7.1 Problem Identification

The treated waste materials are applied to land as soil conditioner. They are assumed to be mixed into the top 10 cm of soil. As already outlined in other reports from the NSW EPA research program, a range of chemical and physical contaminants are present in these wastes as would be expected for material derived from municipal waste.

Just the presence of a range of chemicals in the treated waste materials does not indicate that risks to ecosystems are likely or definite, it depends on the concentrations of these chemicals in soil once the materials are mixed with soil. Consequently, the assessment needs to determine the concentration that might be present in soil at a farm when these materials are applied.

It is also important to consider the types of ecosystem relevant at the types of sites where this material has been applied. When applied to agricultural land, the land needs to remain suitable for soil organisms and plants to allow cropping or grazing to continue to occur. When applied for mine rehabilitation, the land has already been significantly altered due to mining. The land must be

suitable for soil organisms and plants after the rehabilitation has been completed to ensure retention of capping material (if present) and to minimise erosion. In addition, occasional visits by transitory wildlife will also be important to consider.

7.2 Exposure Assessment

7.2.1 Soil Concentrations

The chemicals identified by NSW OEH as needing additional evaluation in the treated waste materials include:

- Aluminium
- Copper
- Manganese
- Zinc
- Phenol
- Bis-2-ethylhexyl adipate
- Bis-2-ethylhexyl phthalate
- Bisphenol A
- Penta brominated diphenyl ether
- Electrical conductivity/salinity

As discussed in **Section 3.2.2**, these materials are applied at 10 tonnes per hectare to agricultural land, 50 tonnes per hectare for non-contact agricultural uses and 140 tonnes per hectare for mine rehabilitation. Using these application rates, a soil bulk density of 1300 kg/m^3 and a mixing depth of 10 cm, concentrations of these chemicals can be determined. The concentrations are listed in **Table 29**. The 95th percentile concentrations in the waste materials have been used for these calculations.

Table 29 Concentrations in Soil (mg/kg)

Chemical/Parameter	Concentration - MWOO	Concentration – Agricultural	Concentration – Non-contact Ag	Concentration – Mine Rehabilitation
Aluminium	8455	65	325	910
Copper	1200	9	46	129
Manganese	410	3	16	44
Zinc	730	6	28	79
Phenol	60	0.5	2	6
Bis-2-ethylhexyl adipate	51	0.4	2	5
Bis-2-ethylhexyl phthalate	180	1.4	7	19
Bisphenol A	53	0.5	2.5	7
Penta brominated diphenyl ether	116	0.9	4.5	12
Electrical conductivity/salinity (dS/cm)	14	0.1	0.5	1.5

7.2.2 Screening Assessment – Soil

Agricultural

These concentrations that could be present in soil at a farm have been compared to the screening guidelines from the NSW OEH hazard assessment.

Table 30 Screening Assessment for Agricultural Land Uses

Key Chemicals	Concentration - Ag (mg/kg)	Concentration – Non-contact Ag (mg/kg)	Screening Criteria (mg/kg)
Aluminium	65	325	50[S]
Copper	9	46	20[N]
Manganese	3	16	3.4[EU]
Zinc	6	28	25[N]
Phenol	0.5	2	0.13[EU]
Bis-2-ethylhexyl adipate	0.4	2	0.9[EU]
Bis-2-ethylhexyl phthalate	1.4	7	13[EU]
Bisphenol A	0.5	2.5	3.7[EU]
Penta brominated diphenyl ether	0.9	4.5	0.4[EU]
Electrical conductivity/salinity (dS/cm)	0.1	0.5	2[C]

Notes:
Shaded cells show estimated concentrations in soil in excess of screening guideline
EU = PNEC values from European Chemicals Agency Dossiers
C = CCME Guidelines (Soil)
N = ASC NEPM ESL (urban residential/public open space) – Added Contaminant Limit – pH 4.5, CEC 5
S = NOAA SQuiRT Tables (https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf)

These refined exposure estimates show that risks are low and acceptable for conductivity, bisphenol A and bis-2-ethylhexyl phthalate (DEHP) for all types of application for agricultural uses. The risks for copper, manganese, zinc and bis-2-ethylhexyl adipate (DEHA) are low and acceptable for application at 10 tonnes per hectare but not at 50 tonnes per hectare.

It is noted that some of the screening guidelines chosen by NSW OEH are at or below background levels in soil making them difficult to use in this assessment and extremely conservative. Further consideration is provided below:

- **Aluminium** – background levels of aluminium in soil are high – it is a component of clay and is present in soil at around 5% (i.e. 50000 mg/kg). Aluminium might be present in a more leachable form in the treated waste materials, but it is still likely to be readily sorbed into soil from leachate making it less available for soil organisms and plants. Also, while the SQuiRT table lists a value of 50 mg/kg for a screening guideline for aluminium, the source document for this value actually lists a value of 600 mg/kg as a screening guideline based on impacts to soil microbes. If this value is used instead of 50 mg/kg then both agricultural uses are within the acceptable levels (Efroymson et al. 1997)
- **Copper** – the NSW OEH hazard assessment adopted a NOEC/EC10 values from the NEPM ecotoxicological assessment of copper in soil. While the ecotoxicological assessment of copper prepared for the NEPM included consideration of the data on the basis of NOEC/EC10, LOEC/EC30 and EC50 to show the range of values and the different ways to use the data, the guidelines developed as EILs were based on LOEC/EC30 given that soil ecotoxicological tests are usually evaluated on the basis that a 20% change or greater is needed to demonstrate effects that are sufficiently different from control treatments to show effects from the chemical being tested. If the copper screening guideline is changed to the LOEC/EC30 value from the NEPM for the soil characteristics listed in the NSW OEH hazard assessment, the screening guideline becomes 60 mg/kg for soil. The

concentrations listed above are lower than this value and so copper added to soil due to the application of these waste materials does not pose an unacceptable risk. It is also important to note that copper is an essential micronutrient for plants and soil organisms (NEPC 1999 amended 2013a).

- **Manganese** – background levels of manganese in soil are high and manganese is an essential micronutrient. It is noted that the EU dossier from which this screening guideline was adopted includes the following information:
    - *No experimental data on terrestrial toxicity exist. The data are not required as the hazard assessment performed during the chemical safety assessment concludes that the substance is not classified and is of no immediate concern to the environment. PNEC soil is calculated by the equilibrium partitioning method. It should also be noted that this value is considerably lower than the background concentration of manganese in European environments (428.6 mg/kg in soil; "Probabilistic Distribution of Manganese in European Surface Water, Sediment and Soil and Derivation of Predicted Environmental Concentrations (PEC)", Parametrix, 2009 and supported by GEMAS data) and hence has little relevance for assessment of any potential risk from Mn https://echa.europa.eu/registration-dossier/-/registered-dossier/15553/6/1*
    - It is also noted that the SQuiRT table indicates that background levels of manganese are around 300 mg/kg (https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf)
    - The USEPA have issued an interim ecological soil screening level for use in assessments. The guidelines are for the protection of plants – 220 mg/kg; for the protection of soil invertebrates – 450 mg/kg; for the protection of avian and mammalian wildlife – >4000 mg/kg (USEPA 2007b)

  It is recommended that a guideline of 220 mg/kg be adopted for this assessment. Risks are low and acceptable using this benchmark.

- **Zinc** – the NSW OEH hazard assessment adopted a NOEC/EC10 values from the NEPM ecotoxicological assessment of copper in soil. While the ecotoxicological assessment of copper prepared for the NEPM included consideration of the data on the basis of NOEC/EC10, LOEC/EC30 and EC50 to show the range of values and the different ways to use the data, the guidelines developed as EILs were based on LOEC/EC30 given that soil ecotoxicological tests are usually evaluated on the basis that a 20% change or greater is needed to demonstrate effects that are sufficiently different from control treatments to show effects from the chemical being tested. If the zinc screening guideline is changed to the LOEC/EC30 value from the NEPM for the soil characteristics listed in the NSW OEH hazard assessment, the screening guideline becomes 100 mg/kg for soil. The concentrations listed above are lower than this value and so copper added to soil due to the application of these waste materials does not pose an unacceptable risk (NEPC 1999 amended 2013a).

- **Phenol** – the EU Chemicals Agency dossier indicates a screening guideline of 0.13 mg/kg. This is based on a single study on earthworms with an uncertainty factor of 1000 – i.e. the LC50 was 136 mg/kg and the guideline was based on this value divided by 1000 (https://echa.europa.eu/registration-dossier/-/registered-dossier/15508/6/1). Other agencies have also assessed phenol and developed guidelines. These include:

- SQuiRT tables as used for aluminium – screening guideline for protection of invertebrates – 30 mg/kg; for protection of plants – 70 mg/kg; and for protection of mammals – 120 mg/kg (https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf)
- Canadian Ecological Guidelines – soil quality guideline for ecosystems in agricultural or residential/parkland land is 20 mg/kg (http://ceqg-rcqe.ccme.ca/download/en/277/)

It is recommended that the Canadian guideline is used for this assessment given the limited data considered by the EU. If so risks are acceptable for these land uses.

- **Bis-2-ethylhexyl adipate** – the EU Chemicals Agency dossier indicates a screening guideline of 0.9 mg/kg. This is based on a single study on earthworms with an uncertainty factor of 1000 – i.e. the LC50 was 865 mg/kg and the guideline was based on this value divided by 1000 (https://echa.europa.eu/registration-dossier/-/registered-dossier/15293/6/1). There are no other agencies that have developed relevant guidelines for this chemical.
- **Penta brominated diphenyl ether (BDE99)** – the EU undertook a risk assessment for BDE99 in 2001. The risk assessment included a summary of terrestrial ecotoxicity data. A range of data were available and the most sensitive species was used (a plant study) with an uncertainty factor of 50. The recommended screening guideline was, therefore, 0.4 mg/kg as per the NSW OEH hazard assessment. No other agencies have derived soil guidelines for ecosystem protection for this chemical so no adjustment can be made to the value used in the hazard assessment.

In addition to these amended guidelines, it is also appropriate to consider the use of the mean concentration in soil rather than the 95th percentile concentration given how this material is produced and how it is applied to sites. The soil concentrations using the mean values in the waste materials are listed in **Table 31**.

Table 31 Concentrations in Soil (mg/kg)

Chemical/Parameter	Concentration - MWOO	Concentration – Agricultural	Concentration – Non-contact Ag	Concentration – Mine Rehabilitation
Aluminium	6100	47	235	660
Copper	473	4	18	51
Manganese	285	2	11	31
Zinc	565	4	22	61
Phenol	27	0.2	1	3
Bis-2-ethylhexyl adipate	17	0.1	0.7	2
Bis-2-ethylhexyl phthalate	125	1	5	13
Bisphenol A	26	0.2	1	3
Penta brominated diphenyl ether	60	0.4	2	6
Electrical conductivity/salinity (dS/cm)	8.4	0.06	0.3	0.9

Using these updated screening guidelines and estimated soil concentrations, the screening assessment has been updated as shown in **Table 32**.

Table 32 Updated Screening Assessment for Agricultural Land Uses

Key Chemicals	Concentration - Ag (mg/kg)	Concentration – Non-contact Ag (mg/kg)	Screening Criteria (mg/kg)
Aluminium	47	235	600[ORNL]
Copper	4	18	60[N]
Manganese	2	11	220[U]
Zinc	4	22	100[N]
Phenol	0.2	1	20[C]
Bis-2-ethylhexyl adipate	0.1	0.7	0.9[EU]
Bis-2-ethylhexyl phthalate	1	5	13[EU]
Bisphenol A	0.2	1	3.7[EU]
Penta brominated diphenyl ether	0.4	2	0.4[EU]
Electrical conductivity/salinity (dS/cm)	0.06	0.3	2[C]

Notes:
Shaded cells show estimated concentrations in soil in excess of screening guideline
EU = PNEC values from European Chemicals Agency Dossiers
C = CCME Guidelines (Soil)
N = ASC NEPM ESL (urban residential/public open space) – Added Contaminant Limit – pH 4.5, CEC 5
S = NOAA SQuiRT Tables (https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf)
U = USEPA EcoSSL (https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents)

The ecological risks that might exist at an agricultural site where these treated waste materials have been applied are considered low and acceptable for all of these contaminants except BDE99 at the higher application rate for non-contact agriculture, given this more detailed assessment.

As part of the NSW EPA research program, pot trials have been undertaken with these materials by DPI (DPI 2017). Some initial/short term effects on earthworms were noted at high application rates (>20 tonnes per hectare) which may have been due to increased salinity. Otherwise no significant impacts on the soil or plants were noted. The report did note that a beneficial effect due to increased nutrients in the treated soil was also not obvious, even though this is the purpose of applying the treated waste materials to agricultural land.

Mine Rehabilitation

If the material is applied at an application rate of 140 tonnes per hectare as is permissible for mine rehabilitation, the screening assessment is as provided in **Table 33**.

Table 33 Updated Screening Assessment for Mine Rehabilitation

Key Chemicals	Concentration – Mine Rehabilitation (mg/kg)	Screening Criteria (mg/kg)
Aluminium	660	600[ORNL]
Copper	51	60[N]
Manganese	31	220[U]
Zinc	61	100[N]
Phenol	3	20[C]
Bis-2-ethylhexyl adipate	2	0.9[EU]
Bis-2-ethylhexyl phthalate	13	13[EU]
Bisphenol A	3	3.7[EU]
Penta brominated diphenyl ether	6	0.4[EU]

Key Chemicals	Concentration – Mine Rehabilitation (mg/kg)	Screening Criteria (mg/kg)
Electrical conductivity/salinity (dS/cm)	0.9	2[C]

Notes:
Shaded cells show estimated concentrations in soil in excess of screening guideline
[EU] = PNEC values from European Chemicals Agency Dossiers
[C] = CCME Guidelines (Soil)
[N] = ASC NEPM ESL (urban residential/public open space) – Added Contaminant Limit – pH 4.5, CEC 5
[S] = NOAA SQuiRT Tables (https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf)
[U] = USEPA EcoSSL (https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents)

Elevated levels are noted for aluminium, bis-2-ethylhexyl adipate and penta brominated diphenyl ether (BDE99).

Aluminium readily sorbs into soil, so it is unlikely that aluminium will be available to soil organisms or plants for very long after the materials have been applied. So, no further consideration is required.

Bis-2-ethylhexyl adipate is readily biodegradable in accordance with OECD criteria. This means more than 60% of this chemical present in soil will breakdown in 28 days or less. This means that it will not be present in the soil for very long after the treated waste materials have been applied. So, no further consideration is required.

7.2.3 Screening Assessment – Leachate/Ecosystem Protection

The chemicals identified by NSW OEH as needing additional evaluation in the treated waste materials include:

- Aluminium
- Barium
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Mercury
- Nickel
- Tin
- Zinc
- Sulfate
- Sulfide
- MCPA
- Ammonia
- Nitrate
- Phosphorus
- Electrical conductivity/salinity

As discussed in **Section 4**, evaluating the potential risks to ecosystems from leaching or runoff of leachate from a site where these materials have been applied requires some adjustment of the concentrations for mixing the leachate with groundwater or mixing the leachate that might runoff a site during a rain event in a local water body.

It is noted that neither method for generating leachate took into account the amount of treated waste material that might be applied to a site but rather looked at what would leach from just the treated material. So, the concentrations measured in the leachate are a worst case evaluation of what might leach from the materials. The material is applied at a rate of 10 tonnes/hectare which is a dilution of approximately 100 fold of treated waste materials in the soil. This would be expected to result in a 100 fold dilution of what might be in leachate/runoff from such a site.

The concentrations in groundwater or surface water, calculated as per **Section 4**, are listed in **Table 34**. The average concentrations in the leachate have been used for these calculations given the nature of these measurements.

Table 34 Concentrations in Groundwater/Surface Water (mg/L)

Chemical/Parameter	Concentration – MWOO	Concentration – Groundwater	Concentration – Surface Water
Aluminium	2.8	0.14	0.03
Barium	0.06	0.003	0.0007
Cadmium	0.01	0.0005	0.0001
Chromium	0.07	0.004	0.0008
Cobalt	0.03	0.002	0.0003
Copper	0.8	0.04	0.009
Iron	4.2	0.2	0.05
Lead	0.1	0.005	0.001
Mercury	0.0003	0.00002	0.000004
Nickel	0.4	0.02	0.005
Tin	0.03	0.002	0.0004
Zinc	2.4	0.1	0.03
Sulfate	170	8.5	2
Sulfide	0.2	0.01	0.002
MCPA	0.02	0.001	0.0002
Ammonia	93	4.7	1.1
Nitrate	2.1	0.1	0.025
Phosphorus	5.1	0.3	0.06
Electrical conductivity/salinity (µS/cm)	3200	160	37

These concentrations that could be present in groundwater or surface water at a farm have been compared to the screening guidelines from the NSW OEH hazard assessment.

Table 35 Screening Assessment for Ecosystem Protection/Water

Key Chemicals	Concentration – Groundwater (mg/L)	Concentration – Surface Water (mg/L)	Screening Criteria (mg/L)
Aluminium	0.14	0.03	0.055[A]
Barium	0.003	0.0007	0.4[A]
Cadmium	0.0005	0.0001	0.0002[A]
Chromium	0.004	0.0008	0.001[A]
Cobalt	0.0015	0.0003	0.0014[A]
Copper	0.04	0.009	0.0014[A]
Iron	0.2	0.05	0.3[A]
Lead	0.005	0.001	0.0034[A]
Mercury	0.00002	0.000004	0.00006[A]

Key Chemicals	Concentration – Groundwater (mg/L)	Concentration – Surface Water (mg/L)	Screening Criteria (mg/L)
Nickel	0.02	0.005	0.011[A]
Tin	0.002	0.0004	0.003[A]
Zinc	0.1	0.03	0.008[A]
Sulfate	8.5	2	50[A]
Sulfide	0.01	0.002	0.001[A]
MCPA	0.001	0.0002	0.0014[A]
Ammonia	4.7	1.1	0.9[A]
Nitrate	0.1	0.025	0.7[A]
Phosphorus	0.3	0.06	na[A]
Electrical conductivity/salinity (µS/cm)	160	37	na[A]

Notes:
Shaded cells show estimated concentrations in excess of screening guideline
[A] = ANZECC/ARMCANZ (2000) Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters – Volume 1/2

This screening guidelines indicate that it might be possible for impacts on ecosystems to occur due to leachate or runoff from land where these treated waste materials have been applied. These potential risks need to be put into context:

- There are many sources of these chemicals to water in the environment not just these treated waste materials
- The leachate testing was undertaken on the solid material applied to land alone not this material mixed with soil as occurs on a farm when these materials are applied
- There is likely at least a 100 fold dilution when these materials are applied at 10 tonnes per hectare
- Applying these materials to soil is likely to reduce the leaching of the chemicals on farm as the chemicals in the treated waste materials sorb onto soil, this will increase the dilution of any leachate from the values determined in the research program
- Worst case assumptions have been made about dilution of leachate in groundwater or runoff; realistic values are likely to result in larger dilution but it is not possible to determine more realistic assumptions relevant for a range of sites

Consequently, it is not expected that risks to ecosystems are large enough to be of concern.

7.2.4 Screening Assessment – Leachate/Agricultural Uses

The chemicals identified by NSW OEH as needing additional evaluation for agricultural uses of water that may contain leachate include:

Livestock watering

- Copper

Irrigation

- Copper
- Iron
- Manganese

- Molybdenum
- Nickel
- Dicamba
- Phosphorus
- Electrical conductivity/salinity

As discussed in **Section 4**, evaluating the potential risks to agricultural uses of water that may be affected by leaching or runoff of leachate from a site where these materials have been applied requires some adjustment of the concentrations for mixing the leachate with groundwater or mixing the leachate that might runoff a site during a rain event in a local water body.

It is noted that neither method for generating leachate took into account the amount of treated waste material that might be applied to a site but rather looked at what would leach from just the treated material. So, the concentrations measured in the leachate are a worst case evaluation of what might leach from the materials. The material is applied at a rate of 10 tonnes/hectare which is a dilution of approximately 100 fold of treated waste materials in the soil. This would be expected to result in a 100 fold dilution of what might be in leachate/runoff from such a site.

The concentrations in groundwater or surface water, calculated as per **Section 4**, are listed in **Table 36**. The average concentrations in the leachate have been used for these calculations given the nature of these measurements.

Table 36 Concentrations in Groundwater/Surface Water (mg/L)

Chemical/Parameter	Concentration – MWOO	Concentration – Groundwater	Concentration – Surface Water
Livestock Watering			
Copper	0.8	0.04	0.009
Irrigation			
Copper	0.8	0.04	0.009
Iron	4.2	0.2	0.05
Manganese	1.2	0.06	0.01
Molybdenum	0.04	0.002	0.0005
Nickel	0.4	0.02	0.005
Dicamba	0.004	0.0002	0.00005
Phosphorus	5.1	0.3	0.06
Electrical conductivity/salinity (µS/cm)	3200	160	37

These concentrations that could be present in groundwater or surface water at a farm that could be used for irrigation or livestock water have been compared to the screening guidelines from the NSW OEH hazard assessment.

Table 37 Screening Assessment for Agricultural Uses/Water

Key Chemicals	Concentration – Groundwater (mg/L)	Concentration – Surface Water (mg/L)	Screening Criteria – Irrigation (mg/L)	Screening Criteria – Livestock (mg/L)
Livestock Watering				
Copper	0.04	0.009	na	0.4[A]
Irrigation				
Copper	0.04	0.009	0.2[A]	na

Key Chemicals	Concentration – Groundwater (mg/L)	Concentration – Surface Water (mg/L)	Screening Criteria – Irrigation (mg/L)	Screening Criteria – Livestock (mg/L)
Iron	0.2	0.05	0.2[A]	na
Manganese	0.06	0.01	0.2[A]	na
Molybdenum	0.002	0.0005	0.01[A]	na
Nickel	0.02	0.005	0.2[A]	na
Dicamba	0.0002	0.00005	0.000006[C]	na
Phosphorus	0.3	0.06	0.8[A]	na
Electrical conductivity/salinity (µS/cm)	160	37	650[A#]	na

Notes:

Shaded cells show estimated concentrations in excess of screening guideline

[A] = ANZECC/ARMCANZ (2000) Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters – Volume 3

[C] = CCME Guidelines (Irrigation Water)

= value listed in the NSW OEH hazard assessment was 0.65 dS/m which is not the same units as reported for the measured data – this value has been adjusted to the correct units for comparison in this assessment

This screening guidelines indicate that it is unlikely that groundwater or surface water that may contain some leachate from these treated waste materials will pose a risk if it is used for irrigation or livestock watering. The levels of dicamba appear high enough to pose a risk if affected water is used for irrigation but it is noted that this is mostly due to the low screening guideline and the elevated limit of reporting used in the investigation, so it also is unlikely that this chemical poses a risk.

7.3 Uncertainties

Uncertainty in any assessment refers to a lack of knowledge (that could be better refined through the collection of additional data or conduct of additional studies) and is an important aspect of the risk assessment process. An assessment of uncertainty is a qualitative process relating to the selection and rejection of specific data, estimates or scenarios within the risk assessment. In general, to compensate for uncertainty, conservative assumptions are often made that result in an overestimate rather than an underestimate of risk.

Assumptions used in this ecological risk assessment have been adopted to ensure estimated environmental concentrations in water or soil are conservative estimates of likely environmental concentrations for sites where these materials have been applied – at 10 tonnes per hectare or 140 tonnes per hectare.

Section 8. Conclusions

Environmental Risk Sciences Pty Ltd has undertaken an assessment of the human health and ecological risks posed by application of mixed waste organic outputs (MWOO) materials generated at Alternative Waste Treatment facilities to agricultural land.

Mixed waste from red-lid garbage bins is processed at Alternative Waste Treatment (AWT) facilities to produce mixed waste organic outputs (MWOO). These materials have been permitted for application to land (agriculture, forestry and mine rehabilitation) under a resource recovery order and exemption issued by NSW EPA. When the use of these materials commenced there was limited information available. In addition to regulating their use, NSW EPA commissioned a research program which was undertaken between 2011 and 2017.

The risk assessment process involves estimating concentrations of chemicals that may be in the MWOO that could be present in the environment after the material is applied to land. Once the concentrations in the environment that people or organisms may be exposed to have been estimated they are compared with toxicity reference values to determine risk. If the concentrations people might be exposed to are higher than the toxicity reference values risks are higher than preferred. If concentrations are lower then the risks are low and acceptable.

Toxicity reference values are that Australian or international health authorities have determined should be protective of heath. Determining toxicity reference values involves reviewing the scientific literature to find the lowest dose that caused no effects. This dose is then divided by a number of uncertainty factors depending on how much and what type of data is available so these toxicity reference values are much smaller than any of the doses used in studies where no effects were seen.

Calculating how much people or organisms may be exposed to involves making a number of assumptions about how people might be exposed. If the site specific situation where this material might be applied is well understood then these assumptions can be tailored to what might actually occur. When a more generic calculation is required, as is the case here due to the number of sites where this material may have been applied, the assumptions need to be more-worst case to ensure risks are not underestimated for the wide range of potential exposures at the various sites.

This assessment is a more worst-case type of assessment. The key assumptions that have been made include:

- People live at a site for 29 years as adults and 6 years as children and the PBDE chemicals are assumed to be present in the soil for all of that time without breaking down
- People come into direct contact with the treated soil every day of the year
- People eat 100% of the eggs they consume each year from chickens kept at the site on land that has been treated with the MWOO
- People drink 100% of the milk they consume each year from dairy cows kept at the site on land that has been treated with the MWOO
- People eat 50, 75 or 100% of the meat they consume each year from cattle kept at the site on land that has been treated with the MWOO
- People eat 35% of fruit, vegetables or wheat/oats/barley they consume each year from plants grown in the land that has been treated with MWOO

- The PBDEs found in the MWOO are 100% available to be taken up (this is unlikely due to the nature of these chemicals which means they are likely to be strongly absorbed into the soil and MWOO materials)
- Background intake of PBDEs from household articles (like TVs, furniture, computers etc) takes up 80% of the allowable amount (as per the toxicity reference value) of these chemicals so the risk estimates here are based on comparing the concentrations people might be exposed to with 20% of the allowable amount recommended by health authorities

This risk assessment has used the results of the NSW EPA research program.

This assessment has not evaluated the potential risk to the commercial food supply for food types grown at sites where these materials have been applied. Given the large number of farms that supply such food types into the commercial food supply, it is not possible that a person, who does not live on one of these farms, would consume food from such a site on a daily basis.

Based on the assessment presented in this report, the potential for PBDEs to be present in surface soil after application of treated waste materials results in the following:

- Risks for people who come into contact with soil where these materials have been applied are low and acceptable (i.e. exposure via ingestion of soil, dermal contact with soil and inhalation of dust)
- Risks for people who consume any type of produce on a regular basis (i.e. all year round based on the assumptions listed above) from land where these materials have been applied are not acceptable and such exposure should be avoided.

Based on the assessment presented in this report, the potential for PFAS to be present in surface soil after application of treated waste materials results in the following:

- Risks for people who come into contact with soil and/or consume any type of produce on a regular basis (i.e. all year round based on the assumptions listed above) from land where these materials have been applied where these materials have been applied are low and acceptable

Based on the assessment presented in this report, the potential for various chemicals to be present in groundwater or surface water after leaching from the treated waste materials results in the following:

- Risks for people who come into contact with such surface or groundwaters are low and acceptable

This assessment could be further refined to allow a more realistic/site-specific consideration of the risks if more information was available about actual measured concentrations of PBDEs in soil at sites where these materials have been applied.

It is expected that ecological risks at sites where these materials have been applied will be relatively low for both soil and surface/groundwater and are unlikely to need management.

It is expected that risks for water that may be impacted by leaching or runoff from soil treated with these materials, where that water is used for agricultural purposes, will be relatively low and do not need management.

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Appendix A Resource Recovery Order and Exemption

Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014

The organic outputs derived from mixed waste order 2014

Introduction

This order, issued by the Environment Protection Authority (EPA) under clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014 (Waste Regulation), imposes the requirements that must be met by suppliers of organic outputs derived from mixed waste (organic outputs) to which the 'organic outputs derived from mixed waste exemption 2014' applies. The requirements in this order apply in relation to the supply of organic outputs for application to land as a soil amendment.

1. Waste to which this order applies

1.1. This order applies to organic outputs. In this order, organic outputs means the pasteurised and biologically stabilised organic outputs produced from the mechanical biological treatment of mixed waste.

2. Persons to whom this order applies

2.1. The requirements in this order apply, as relevant, to any person who supplies organic outputs, that has been generated, processed or recovered by the person.

2.2. This order does not apply to the supply of organic outputs to a consumer for land application at a premises for which the consumer holds a licence under the POEO Act that authorises the carrying out of the scheduled activities on the premises under clause 39 'waste disposal (application to land) or clause 40 'waste disposal' (thermal treatment) of Schedule 1 of the POEO Act.

3. Duration

3.1. This order commences on 24 November 2014 and is valid until revoked by the EPA by notice published in the Government Gazette.

4. Processor requirements

The EPA imposes the following requirements on any processor who supplies organic outputs.

General conditions

4.1. On or before supplying organic outputs, the processor must:

4.1.1. ensure that the organic outputs do not contain contaminants that will degrade land or present a risk of harm to human health or to the environment.

4.1.2. ensure that the organic outputs do not contain sharp pieces of glass, metal or plastic of a size, shape (e.g. glass shards), or type that might cause damage or injury to humans, animals, plants or soil.

4.1.3. ensure that the organic outputs do not contain any asbestos.

4.1.4. ensure that it provides effective pre-sorting mechanisms to remove lead-acid batteries and other sortable lead containing wastes.

4.1.5. ensure that all practicable measures have been taken to remove (i) glass, metal and rigid plastics, and (ii) light, flexible or film plastics, so that they are not present at unacceptable levels (including in particle sizes less than 2 mm and 5 mm respectively) in the organic outputs.

Sampling requirements

4.2. On or before supplying organic outputs, the processor must:

4.2.1. Prepare a written sampling plan which includes a description of sample preparation and storage procedures for the organic outputs.

4.2.2. Undertake sampling and testing of the organic outputs as required under clause 4.2.3. The sampling must be carried out in accordance with the written sampling plan. Testing must occur within 25 working days from the date of sampling.

4.2.3. Undertake characterisation sampling of the organic outputs by collecting 20 composite samples of the waste and testing each sample for the chemicals and other attributes listed in Column 1 of Table 1. Each composite sample must be taken from a batch, truckload or stockpile that has not been previously sampled for the purposes of characterisation. A maximum of 2 composite samples may be collected per month. Characterisation must be conducted for the organic outputs generated and processed during the 1-year period following the commencement of the process. Note: Routine sampling requirements will be determined on review of the results of characterisation testing.

Chemical and other material requirements

4.3. The absolute maximum concentration or other value of that attribute in any organic outputs supplied under this order must not exceed the absolute maximum concentration or other value listed in Column 2 of Table 1. Note that while limits are not included for attributes 16 – 20 in Table 1, these must be tested in each sample and records kept of results.

4.4. The processor must not supply organic outputs to any person if, in relation to any of the chemical and other attributes of the organic outputs, the concentration or other value of that attribute of any sample collected and tested as part of the characterisation of the organic outputs exceeds the absolute maximum concentration or other value listed in Column 2 of Table 1.

Table 1

Column 1	Column 2
Chemicals and other attributes	**Absolute maximum concentration** (dry weight in mg/kg unless otherwise specified)
1. Mercury	4
2. Cadmium	3
3. Lead	420 for mine sites 250 for plantation forestry use, non-contact agricultural use and broad acre agricultural use [1,2]
4. Arsenic	20
5. Chromium (total)	100
6. Copper	375
7. Nickel	60
8. Selenium	5
9. Zinc	700
10. DDT/DDD/DDE	0.5
11. Other pesticides [3]	0.2
12. Polychlorinated Biphenyls (PCBs)	ND[4]
13. Glass, metal and rigid plastics > 2 mm	2.5% for mine sites (as % dry matter on weight/weight basis)[1]
	1.5% for plantation forestry use, non-contact agricultural use and broad acre agricultural use (as % dry matter on weight/weight basis)[1]
14. Plastics – light, flexible or film > 5 mm	0.25% for mine sites (as % dry matter on weight/weight basis)[1]
	0.2% for plantation forestry use, non-contact agricultural use and broad acre agricultural use (as % dry matter on weight/weight basis)[1]
15. Maximum particle size	16 mm (particle size)
16. Other metals[5]	N/A
17. Total Polycyclic Aromatic Hydrocarbons (PAHs)[6]	N/A
18. Phthalates[7]	N/A
19. Pesticides (non-scheduled)[8]	N/A
20. Monobutyltin	N/A

Notes and Definitions for Table 1

1. Future contaminant levels will be set after considering the outcomes of research and trials that are to be conducted as well as the other considerations outlined in the notes to this Order.

2. The effectiveness of mechanisms implemented by each facility in clause 4.1.4 in reducing the levels of lead present in the organic outputs will be evaluated. The maximum lead concentration may be amended following this review.
3. **Other pesticides** mean Aldrin, Dieldrin, Chlordane, Heptachlor, Hexachlorobenzene (HCB), Lindane and Benzene Hexachloride (BHC).
4. No detected individual PCB Aroclor at a limit of detection of 0.2 mg PCB Aroclor/kg.
5. **Other metals** mean antimony, beryllium, boron, cobalt, manganese, molybdenum, tin, and vanadium.
6. **PAHs** means the following 16 USEPA priority pollutant polycyclic aromatic hydrocarbons (with CAS registry numbers): Acenaphthene (83-32-9), Chrysene (218-01-9), Acenaphthylene (208-96-8), Dibenzo(a,h)anthracene (53-70-3), Anthracene (120-12-7), Fluoranthene (206-44-0), Benzo(a)anthracene (56-55-3), Fluorene (86-73-7), Benzo(a)pyrene (50-32-8), Indeno(1,2,3-cd)pyrene (193-39-5), Benzo(b)fluoranthene (205-99-2), Naphthalene (91-20-3), Benzo(ghi)perylene (191-24-2), Phenanthrene (85-01-8), Benzo(k)fluoranthene (207-08-9), and Pyrene (129-00-0).
7. **Phthalates** means (with CAS registry numbers): Di-2-ethylhexylphthalate (DEHP) (117-81-7) and Dibutylphthalate (DBP) (84-74-2).
8. **Pesticides (non-scheduled)** means the following pesticides, herbicides, fungicides and insecticides (with CAS registry numbers): Brodifacoum (56073-10-0), Chlorpyrifos (2921-88-2), Cypermethrin (52315-07-8), Dichlofluanid (1085-98-9), Emamectin benzoate (137515-75-4 & 155569-91-8), Permethrin (52645-53-1), Profenofos (41198-08-7), Simazine (122-34-9), and Tebuconazole (107534-96-3).

Test methods

4.5. The processor must ensure that any testing of samples required by this order is undertaken by analytical laboratories accredited by the National Association of Testing Authorities (NATA), or equivalent.

4.6. The processor must ensure that the chemicals and other attributes (listed in Column 1 of Table 1) in the organic outputs supplied are tested in accordance with the test methods specified below or other equivalent analytical methods. Where an equivalent analytical method is used the detection limit must be equal to or less than that nominated for the given method below.

4.6.1. Test method for measuring the mercury concentration:

4.6.1.1. Analysis using USEPA SW-846 Method 7471B Mercury in solid or semisolid waste (manual cold-vapor technique), or an equivalent analytical method with a detection limit < 20% of the stated absolute maximum concentration in Table 1, Column 2.

4.6.1.2. Results must be reported as mg/kg dry weight.

4.6.2. Test methods for measuring metals 2 – 9 and 16:

4.6.2.1. Sample preparation by digestion - USEPA SW-846 Method 3050B acid digestion of sediments, sludges, soils, and oils, or using an equivalent digestion method.

4.6.2.2. Analysis using USEPA SW-846 Method 6010C Inductively coupled plasma - atomic emission spectrometry, or an equivalent analytical method with a detection limit < 10% of the stated absolute maximum concentration in Table 1, Column 2.

4.6.2.3. Results must be reported as mg/kg dry weight.

4.6.3. Test method for measuring 10, 11, 17 and 18:

4.6.3.1. Analysis using USEPA SW-846 Method 8270D Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), or equivalent.

4.6.3.2. Results must be reported as mg/kg dry weight.

4.6.4. Test method for measuring PCBs:

4.6.4.1. Analysis using USEPA SW-846 Method 8082A Polychlorinated Biphenyls (PCBs) By Gas Chromatography (GC), or equivalent.

4.6.4.2. Measure the following PCBs: Aroclor 1016 (CAS Registry No. 12674-11-2), Aroclor 1221 (CAS Registry No. 11104-28-2), Aroclor 1232 (CAS Registry No. 11141-16-5), Aroclor 1242 (CAS Registry No. 53469-21-9), Aroclor 1248 (CAS Registry No. 12672-29-6), Aroclor 1254 (CAS Registry No. 11097-69-1), Aroclor 1260 (CAS Registry No. 11096-82-5).

4.6.4.3. Results must be reported as mg/kg dry weight.

4.6.5. Test method for measuring physical contaminants (13 and 14):

4.6.5.1. Analysis using Australian Standard AS4454-2003 Composts, soil conditioners and mulches, "Appendix H - Method For Determination Of Moisture Content And Level Of Visible Contamination".

4.6.5.2. Results must be reported as % contamination on a dry mass basis.

4.6.6. Test method for measuring maximum particle size:

4.6.6.1. Analysis using Australian Standard AS4454-2003 Composts, soil conditioners and mulches, "Appendix F – Method for Determination of Particle Size Grading".

4.6.6.2. Results must be reported as % by mass retained on a sieve with 16 mm apertures.

4.6.6.3. The entire sample must pass through the sieve.

4.6.7. Test method for measuring pesticides (non-scheduled):

4.6.7.1. Analysis using USEPA SW-846 Method 8270D Semivolatile Organic Compounds By Gas Chromatography/Mass Spectrometry (GC/MS) for all pesticides (non-scheduled) or equivalent, except for the following:

(a) Analysis of Dichlofluanid – AOAC method 2007.01 Pesticide Residues in Foods by GC/MS.

(b) Emamectin benzoate – acceptable analytical methods for the determination of emamectin benzoate include high-performance liquid chromatography (HPLC) with fluorescence detection.

(c) Brodifacoum – acceptable analytical methods for the determination of brodifacoum include high-performance liquid chromatography (HPLC) with fluorescence detection such as AOAC International 18th Edition, Method 983.11 and *Journal of Chromatography A*, 1985, Volume 321, Pages 255-272.

4.6.7.2. Results must be reported as mg/kg dry weight.

4.6.8. Test method for measuring monobutyltin:

4.6.8.1. Analysis using International Organization for Standardization ISO/DIS 23161.2:2007 Selected organotin compounds – Soil quality by Gas-chromatographic method (GC), or equivalent.

4.6.8.2. Results must be reported as mg/kg dry weight.

Notification

4.7. On or before each transaction, the processor must obtain a written statement of compliance in accordance with clauses 7.18 of 'the organic outputs derived from mixed waste exemption 2014'.

4.8. On or before each transaction, the processor must provide the following to each person to whom the processor supplies the organic outputs:

- a written statement of compliance certifying that all the requirements set out in this order have been met;
- a copy of the organic outputs exemption, or a link to the EPA website where the organic outputs exemption can be found; and
- a copy of the organic outputs order, or a link to the EPA website where the organic outputs order can be found.

Record keeping and reporting

4.9. The processor must keep a written record of the following for a period of six years:

- the sampling plan required to be prepared under clause 4.2.1;
- all characterisation sampling results in relation to organic outputs supplied;
- the quantity of any organic outputs supplied;
- the name and address of each person to whom the processor supplied the organic outputs;
- the location(s) where the organic outputs are applied, including the address and paddock or plot identification;
- the rate(s) at which the organic outputs are applied to the land at each location as defined above; and
- the date(s) upon which the organic outputs are applied to the land at each location as defined above.

4.10. The processor must provide, on request, the most recent characterisation results for organic outputs that are supplied to any consumer of the organic outputs.

4.11. The processor must notify the EPA within seven days of becoming aware that it has not complied with any requirement in clause 4.1 to 4.6.

5. Definitions

In this order:

animal waste means dead animals and animal parts and any mixture of dead animals and animal parts.

AOAC International 18th Edition means Dr. William Horwitz and Dr. George Latimer, Jr. Editors. "Official Methods of Analysis of AOAC International", 18 h Edition Revision 2 (2007), AOAC INTERNATIONAL, Gaithersburg, MD, USA.

application or apply to land means applying to land by:

- spraying, spreading or depositing on the land; or
- ploughing, injecting or mixing into the land; or

- filling, raising, reclaiming or contouring the land.

biological stabilisation means a process whereby mixed waste undergoes a process of managed biological transformation for a period of not less than a total of 6 weeks of composting and curing, or until an equivalent level of biological stability can be demonstrated. Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

biologically stabilised means the mixed waste that has undergone biological stabilisation.

broad acre agricultural use means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.

composite sample means a sample that combines five discrete sub-samples of equal size into a single sample for the purpose of analysis.

consumer means a person who applies, or intends to apply, organic outputs to land.

food waste means waste from the manufacture, preparation, sale or consumption of food but does not include grease trap waste.

garden waste means waste that consists of branches, grass, leaves, plants, loppings, tree trunks, tree stumps and similar materials, and includes any mixture of those materials.

manure means faecal matter generated by any animal other than humans and includes any mixture of animal faecal matter and biodegradable animal bedding such as straw or sawdust.

mine site means land disturbed by mining on which rehabilitation is being carried out by or on behalf of:

(a) the holder of an authority under the *Mining Act 1992* pursuant to an approved rehabilitation plan, or

(b) the State of NSW.

mixed waste means:

(a) residual household waste that contains putrescible organics and/or

(b) waste from litter bins that are collected by or on behalf of local councils.

It may only be mixed with any one or more of the following:

(i) waste collected from commercial premises by or on behalf of councils as part of its kerbside household waste collection service,

(ii) commercial waste sourced from restaurants, clubs, pubs, hotels, motels, resorts, offices, schools and shopping centres that is similar in composition to household waste (but may include a higher proportion of food waste),

(iii) manure,

(iv) food waste,

(v) animal waste,

(vi) grit or screenings from sewage treatment systems that have been dewatered so that the grit or screenings do not contain free liquids,

(vii) up to 20% source separated household garden and food waste.

It must not contain any other waste. For example, it must not contain:

(a) any special waste, hazardous waste, restricted solid waste or liquid waste as defined in clause 49 of Schedule 1 to the Act; or

(b) any source separated recyclable household waste other than those set out in (vii) above.

N/A means not applicable.

non-contact agricultural use means application to land where the land is used for the growing of fruit or nut trees or vines but not where fallen produce is or may be collected off the ground. It does not include application to land where the land is used for grazing or for any other cropping purpose.

pasteurisation means a process to significantly reduce the numbers of plant and animal pathogens and plant propagules. Pasteurisation requires that the entire mass of organic material be subjected to either of the following:

(a) Appropriate turning of outer material to the inside of the windrow so that the whole mass is subjected to a minimum of 3 turns with the internal temperature reaching a minimum of 55°C for 3 consecutive days before each turn. Where materials with a higher risk of containing pathogens are present, including but not limited to manure and food waste, the core temperature of the material mass should be maintained at 55°C or higher for 15 days or longer, and during this period the windrow should be turned a minimum of 5 times.

(b) An alternative process that guarantees the same level of pathogen reduction, and the reduction of plant propagules as in (a). Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

pasteurised means that the mixed waste that has been subject to a process of pasteurisation.

pathogen means a living organism that could be harmful to humans, animals, plants or other living organisms.

plantation forestry use means application to an area of land on which the predominant number of trees or shrubs forming, or expected to form, the canopy are trees or shrubs that have been planted (whether by sowing seed or otherwise) for the purpose of timber production.

processor means a person who processes, mixes, blends, or otherwise incorporates organic outputs into a material in its final form for supply to a consumer.

source separated recyclable household waste means household waste from kerbside waste collection services that has been separated for the purpose of recycling.

transaction means:

- in the case of a one-off supply, the supply of a batch, truckload or stockpile of organic outputs that is not repeated,
- in the case where the supplier has an arrangement with the recipient for more than one supply of organic outputs the first supply of organic outputs as required under the arrangement.

Manager Waste Strategy and Innovation

Environment Protection Authority

(by delegation)

Notes

The EPA may amend or revoke this order at any time. It is the responsibility of each of the generator and processor to ensure it complies with all relevant requirements of the most current order. The current version of this order will be available on www.epa.nsw.gov.au

In gazetting or otherwise issuing this order, the EPA is not in any way endorsing the supply or use of this substance or guaranteeing that the substance will confer benefit.

The conditions set out in this order are designed to minimise the risk of potential harm to the environment, human health or agriculture, although neither this order nor the accompanying exemption guarantee that the environment, human health or agriculture will not be harmed.

Any person or entity which supplies organic outputs should assess whether the material is fit for the purpose the material is proposed to be used for, and whether this use may cause harm. The supplier may need to seek expert engineering or technical advice.

Regardless of any exemption or order provided by the EPA, the person who causes or permits the application of the substance to land must ensure that the action is lawful and consistent with any other legislative requirements including, if applicable, any development consent(s) for managing operations on the site(s).

The supply of organic outputs remains subject to other relevant environmental regulations in the POEO Act and Waste Regulation. For example, a person who pollutes land (s. 142A) or water (s. 120), or causes air pollution through the emission of odours (s. 126), or does not meet the special requirements for asbestos waste (Part 7 of the Waste Regulation), regardless of this order, is guilty of an offence and subject to prosecution.

This order does not alter the requirements of any other relevant legislation that must be met in supplying this material, including for example, the need to prepare a Safety Data Sheet.

Failure to comply with the conditions of this order constitutes an offence under clause 93 of the Waste Regulation.

Research program

The goal of the Resource Recovery Order and Resource Recovery Exemption for organic outputs is to facilitate the resource recovery of fit for purpose organic outputs by minimising the amount of physical and chemical contaminants.

Trials and research will be conducted to examine the environmental and human health impacts of contaminants in the organic outputs.

The EPA intends to extend the RRE for agricultural uses following a review of the results of the research and trials. The nature of the extended RRE for broad acre agricultural use, non-contact agricultural use and plantation forestry use will be determined taking into account:

- trials that are to be conducted in collaboration with the processors of mixed waste,
- the goal of the exemption,
- the environmental, agricultural and human health impacts of the use of organic outputs,
- the technological capabilities of AWT facilities including the adequacy of pre-sorting processes, and
- community acceptance of the use of organic outputs.

Resource Recovery Exemption under Part 9, Clauses 91 and 92 of the Protection of the Environment Operations (Waste) Regulation 2014

The organic outputs[1] derived from mixed waste exemption 2014

Introduction

This exemption:

- is issued by the Environment Protection Authority (EPA) under clauses 91 and 92 of the Protection of the Environment Operations (Waste) Regulation 2014 (Waste Regulation); and
- exempts a consumer of organic outputs derived from mixed waste (organic outputs) from certain requirements under the *Protection of the Environment Operations Act 1997* (POEO Act) and the Waste Regulation in relation to the application of that waste to land, provided the consumer complies with the conditions of this exemption.

This exemption should be read in conjunction with 'the organic outputs derived from mixed waste order 2014'.

1. Waste to which this exemption applies

1.1 This exemption applies to organic outputs that are, or are intended to be, applied to land as a soil amendment.

1.2 Organic outputs are the pasteurised and biologically stabilised organic outputs produced from the mechanical biological treatment of mixed waste.

2. Persons to whom this exemption applies

2.1 This exemption applies to any person who applies, or intends to apply, the organic outputs to land as set out in 1.1.

3. Duration

3.1 This exemption commences on 24 November 2014 and is valid until revoked by the EPA by notice published in the Government Gazette.

[1]These organic outputs are not the same as the source segregated outputs that are covered by the exemptions for compost, pasteurised garden organics, or raw mulch.

4. Premises to which this exemption applies

4.1 This exemption applies to the premises at which the consumer's actual or intended application of organic outputs is carried out.

5. Revocation

5.1 'The organic outputs derived from mixed waste exemption 2014' which commenced on 6 June 2014 is revoked from 24 November 2014.

6. Exemption

6.1 Subject to the conditions of this exemption, the EPA exempts each consumer from the following provisions of the POEO Act and the Waste Regulation in relation to the consumer's actual or intended application of organic outputs to land as a soil amendment at the premises:

- section 48 of the POEO Act in respect of the scheduled activities described in clauses 39 and 42 of Schedule 1 of the POEO Act;
- Part 4 of the Waste Regulation;
- section 88 of the POEO Act; and
- clause 109 and 110 of the Waste Regulation.

6.2 The exemption does not apply in circumstances where organic outputs are received at the premises for which the consumer holds a licence under the POEO Act that authorises the carrying out of the scheduled activities on the premises under clause 39 'waste disposal (application to land)' or clause 40 'waste disposal (thermal treatment)' of Schedule 1 of the POEO Act.

7. Conditions of exemption

The exemption is subject to the following conditions:

General conditions

7.1 At the time the organic outputs are received at the premises, the material must meet all chemical and other material requirements for organic outputs which are required on or before the supply of organic outputs under 'the organic outputs order 2014'.

7.2 The organic outputs can only be applied to land as a soil amendment for:

7.2.1 soil improvement or site rehabilitation at mine sites, or

7.2.2 plantation forestry use, or

7.2.3 non-contact agricultural use, or

7.2.4 broad acre agricultural use.

7.3 The organic outputs must not be used:

7.3.1 in urban landscaping,

7.3.2 at public contact sites,

7.3.3 on or in home lawns and gardens,

7.3.4 in potting mix, or

7.3.5 in turf production.

7.4 The consumer must ensure that no windblown litter leaves the premises as a result of the application to land of organic outputs.

7.5 All organic outputs applied to land must be evenly applied across the designated land application area at the application rate prescribed for that land use in clauses 7.6, 7.7 and 7.8.

7.6 For mine sites, no more than 140 tonnes/hectare (dry weight) of organic outputs may be applied in total to a given location.

7.7 For plantation forestry use and for non-contact agricultural use, no more than 50 tonnes/hectare (dry weight) of organic outputs may be applied in total to a given location.

7.8 For broad acre agricultural use, no more than 10 tonnes/hectare (dry weight) of organic outputs may be applied in total to a given location.

7.9 Organic outputs must not be applied to:

7.9.1 land with a slope in excess of 18% (10^0), unless used for mine site rehabilitation where all practicable measures have been taken to control stability and prevent runoff, or

7.9.2 soil having a pH of less than 5.0* when measured in a 1:5 soil:water extract, or

7.9.3 land that is within the buffer zones for the protected areas specified in Table 1.

7.10 Animals must not be allowed to graze the land for 30 days after the application of organic outputs to land.

7.11. Lactating and new born animals must not be allowed to graze the land for 90 days after the application of organic outputs to land.

7.12. Crops must not be harvested for 30 days after the application of organic outputs to land.

Table 1 Buffer zones for protected areas

Column 1	Column 2	Column 3	Column 4
Protected Area	**Minimum width of Buffer Zones (m)**		
	Flat (< 3% or 2° slope)	**Downslope (> 3% or 2° slope)**	**Upslope**
Surface waters	50	100	5
Drinking water bores	250	250	250
Other bores	50	50	50

*Where organic outputs are proposed for land application on soils (such as mine sites) where the pH is less than 5.0, a specific exemption may be considered where low concentrations of metals can be achieved.

Sampling requirements

7.13. Prior to receiving and land applying any organic outputs, where the application will result in greater than 10 tonnes/hectare (dry weight) total organic outputs in or on the land, the consumer must sample the soil to which the organic outputs are to be applied by taking the following samples at a depth of 0 to 15 centimetres:

7.13.1. For plantation forestry use and non-contact agricultural use:

(i) For land equal to, or less than 10 hectares - 2 composite samples, and

(ii) For land greater than 10 hectares - 1 composite sample per 10 ha.

7.13.2. For mine site rehabilitation:

(i) For land equal to, or less than, 20 hectares - 2 composite samples, and

(ii) For land greater than 20 hectares - 1 composite sample per 20 ha.

7.14. The soil where the organic outputs have been applied to land must be re-sampled and re-tested as set out in clause 7.13 prior to receiving or applying any additional organic outputs to the land.

Chemical and other material requirements

7.15. Prior to receiving and land applying the organic outputs, where the application will result in greater than 10 tonnes/hectare (dry weight) total organic outputs, the consumer must ensure that:

7.15.1. each of the composite samples referred to in section 7.13 are tested for the contaminants listed in Column 1 of Table 2.

7.15.2. the contaminant concentrations in the soil prior to application of organic outputs to the land do not exceed the maximum levels specified for those contaminants for the relevant land use in either Column 2 or Column 3 of Table 2.

Table 2 Maximum allowable soil contaminant concentrations[1] prior to organic outputs application to land

Column 1	Column 2	Column 3
Contaminant	**Mine sites** **Maximum allowable soil contaminant concentration** (dry weight of soil in mg/kg, unless otherwise specified)	**Plantation forestry use, non-contact agricultural use and broad acre agricultural use land** **Maximum allowable soil contaminant concentration** (dry weight of soil in mg/kg, unless otherwise specified)
1. Mercury	4	1
2. Arsenic	20	20
3. Cadmium	5	1
4. Chromium (total)	250	100
5. Copper	375	100
6. Lead	150	150
7. Nickel	125	60
8. Selenium	8	5
9. Zinc	700	200

10. DDT/DDD/DDE	0.5	0.5
11. Aldrin	0.2	0.02
12. Dieldrin	0.2	0.02
13. Chlordane	0.2	0.02
14. Heptachlor	0.2	0.02
15. Hexachlorobenzene (HCB)	0.2	0.02
16. Lindane	0.2	0.02
17. Benzene hexachloride (BHC)	0.2	0.02
18.Polychlorinated Biphenyls (PCBs)	0.3	ND[2]

Notes and Definitions for the purposes of Table 2:

1. Maximum allowable soil contaminant concentrations are mean concentration values based on the sampling requirements set out in Section 7.13.
2. No detected PCBs at a limit of detection of 0.1 mg PCB/kg soil. Organic outputs must not be applied to land where any individual PCB Aroclor has been detected at a limit of detection of 0.1 mg PCB/kg.

Test methods

7.16. The consumer must ensure that any testing of samples required by this exemption is undertaken by analytical laboratories accredited by the National Association of Testing Authorities (NATA), or equivalent.

7.17. The consumer must ensure that the contaminants (listed in Column 1 of Table 2) in the soil are tested in accordance with the test methods specified below or other equivalent analytical methods. Where an equivalent analytical method is used the detection limit must be equal to or less than that nominated for the given method below.

7.17.1. Test method for measuring the mercury concentration:

7.17.1.1. Analysis using USEPA SW-846 Method 7471B Mercury in solid or semisolid waste (manual cold-vapor technique), or an equivalent analytical method with a detection limit < 20% of the applicable stated maximum allowable concentration in Table 2, Columns 2 and 3.

7.17.1.2. Results must be reported as mg/kg dry weight.

7.17.2. Test methods for measuring metals 2 – 9:

7.17.2.1. For sample preparation by digestion - USEPA SW-846 Method 3050B acid digestion of sediments, sludges, soils, and oils, or using an equivalent digestion method.

7.17.2.2. Analysis using USEPA SW-846 Method 6010C Inductively coupled plasma - atomic emission spectrometry, or an equivalent analytical method with a detection limit < 10% of the applicable stated maximum allowable concentration in Table 2, Columns 2 and 3.

7.17.2.3. Results must be reported as mg/kg dry weight.

7.17.3. Test method for measuring 10 – 18 in Table 2:

7.17.3.1. Analysis using USEPA SW-846 Method 8270D Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), or equivalent.

7.17.3.2. Results must be reported as mg/kg dry weight.

Notification

7.18. On or before each transaction, the consumer must provide a written statement of compliance to each generator or supplier that the consumer has engaged to supply the organic outputs, certifying that:

- all the sampling and testing requirements set out in clause 7.13 to 7.17 of this exemption have been met; and
- none of those test results show that existing contaminant concentrations in the soil exceed any of the maximum allowable soil contaminant concentrations in Table 2.

Record keeping and reporting

7.19 The consumer must keep a written record of the following for a period of six years for each delivery of organic outputs received:

- the quantity of the organic outputs received;
- the name and address of the supplier of organic outputs received;
- the location(s) where the organic outputs are applied including the address and paddock or plot identification;
- the rate(s) at which the organic outputs are applied to the land at each location as defined above;
- the date(s) upon which the organic outputs are applied to the land at each location as defined above; and
- for land application sites, other than mine sites, where the consumer is not the owner of the land on which the organic outputs are applied, the consumer must obtain a statement of consent from the owner of the land that the owner has received a copy of the exemption and accepts the application on the land.

7.20 The consumer must make any records required to be kept under this exemption available to authorised officers of the EPA on request.

7.21 The consumer must ensure that any application of organic outputs to land must occur within a reasonable period of time after its receipt.

8 Definitions

In this exemption:

animal waste means dead animals and animal parts and any mixture of dead animals and animal parts.

application or apply to land means applying to land by:

- spraying, spreading or depositing on the land; or
- ploughing, injecting or mixing into the land; or
- filling, raising, reclaiming or contouring the land.

biological stabilisation means a process whereby mixed waste undergoes a process of managed biological transformation for a period of not less than a total of 6 weeks of composting and curing, or until an equivalent level of biological stability can be demonstrated. Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

biologically stabilised means the mixed waste that has undergone biological stabilisation.

broad acre agricultural use means application to land where the land is used for agriculture. This does not include the keeping and breeding of poultry or pigs, food root crops, vegetables or crops where the harvested parts touch or are below the surface of the land.

composite sample means a sample that combines five discrete sub-samples of equal size into a single sample for the purpose of analysis.

consumer means a person who applies, or intends to apply, organic outputs to land.

food waste means waste from the manufacture, preparation, sale or consumption of food but does not include grease trap waste.

garden waste means waste that consists of branches, grass, leaves, plants, loppings, tree trunks, tree stumps and similar materials, and includes any mixture of those materials.

manure means faecal matter generated by any animal other than humans and includes any mixture of animal faecal matter and biodegradable animal bedding such as straw or sawdust.

mine site means land disturbed by mining on which rehabilitation is being carried out by or on behalf of:

(a) the holder of an authority under the *Mining Act 1992* pursuant to an approved rehabilitation plan, or

(b) the State of NSW.

mixed waste means:

(a) residual household waste that contains putrescible organics and/or

(b) waste from litter bins that are collected by or on behalf of local councils.

It may only be mixed with any one or more of the following:

(i) waste collected from commercial premises by or on behalf of councils as part of its kerbside household waste collection service,

(ii) commercial waste sourced from restaurants, clubs, pubs, hotels, motels, resorts, offices, schools and shopping centres that is similar in composition to household waste (but may include a higher proportion of food waste),

(iii) manure,

(iv) food waste,

(v) animal waste,

(vi) grit or screenings from sewage treatment systems that have been dewatered so that the grit or screenings do not contain free liquids, or

(vii) up to 20% source separated household garden and food waste.

It must not contain any other waste. For example, it must not contain:

(a) any special waste, hazardous waste, restricted solid waste or liquid waste as defined in clause 49 of Schedule 1 to the Act; or

(b) any source separated recyclable household waste other than those set out in (vii) above.

non-contact agricultural use means application to land where the land is used for the growing of fruit or nut trees or vines but not where fallen produce is or may be collected off the ground. It does not include application to land where the land is used for grazing or for any other cropping purpose.

pasteurisation means a process to significantly reduce the numbers of plant and animal pathogens and plant propagules. Pasteurisation requires that the entire mass of organic material be subjected to either of the following:

(a) Appropriate turning of outer material to the inside of the windrow so that the whole mass is subjected to a minimum of 3 turns with the internal temperature reaching a minimum of 55°C for 3 consecutive days before each turn. Where materials with a higher risk of containing pathogens are present, including but not limited to manure and food waste, the core temperature of the material mass should be maintained at 55°C or higher for 15 days or longer, and during this period the windrow should be turned a minimum of 5 times.

(b) An alternative process that guarantees the same level of pathogen reduction, and the reduction of plant propagules as in (a). Any such alternative process must be clearly defined in writing and validated by a suitably qualified person prior to claiming compliance with this exemption. A written record of the validation report must be kept for a minimum period of three years.

pasteurised means that the mixed waste that has been subject to a process of pasteurisation.

pathogen means a living organism that could be harmful to humans, animals, plants or other living organisms.

plantation forestry use means application to an area of land on which the predominant number of trees or shrubs forming, or expected to form, the canopy are trees or shrubs that have been planted (whether by sowing seed or otherwise) for the purpose of timber production.

processor means a person who processes, mixes, blends, or otherwise incorporates organic outputs into a material in its final form for supply to a consumer.

public contact sites means land with a high potential for contact by the public, including public parks, fields, cemeteries, plant nurseries and golf courses.

source separated recyclable household waste means household waste from kerbside waste collection services that has been separated for the purpose of recycling.

transaction means:

- in the case of a one-off supply, the supply of a batch, truckload or stockpile of organic outputs that is not repeated,
- in the case where the supplier has an arrangement with the recipient for more than one supply of organic outputs the first supply of organic outputs as required under the arrangement.

Manager Waste Strategy and Innovation

Environment Protection Authority

(by delegation)

Notes

The EPA may amend or revoke this exemption at any time. It is the responsibility of the consumer to ensure they comply with all relevant requirements of the most current exemption. The current version of this exemption will be available on www.epa.nsw.gov.au.

In gazetting or otherwise issuing this exemption, the EPA is not in any way endorsing the use of this substance or guaranteeing that the substance will confer benefit.

The conditions set out in this exemption are designed to minimise the risk of potential harm to the environment, human health or agriculture, although neither this exemption nor the accompanying order guarantee that the environment, human health or agriculture will not be harmed.

The consumer should assess whether or not the organic outputs is fit for the purpose the material is proposed to be used for, and whether this use may cause harm. The consumer may need to seek expert advice from a certified professional soil scientist (http://www.cpss.com.au/index.php/locate-a-cpss/cpss-register).

Regardless of any exemption provided by the EPA, the person who causes or permits the application of the substance to land must ensure that the action is lawful and consistent with any other legislative requirements including, if applicable, any development consent(s) for managing operations on the site(s).

The receipt of organic outputs remains subject to other relevant environmental regulations in the POEO Act and the Waste Regulation. For example, a person who pollutes land (s. 142A) or water (s. 120), or causes air pollution through the emission of odours (s. 126), or does not meet the special requirements for asbestos waste (Part 7 of the Waste Regulation), regardless of having an exemption, is guilty of an offence and subject to prosecution.

This exemption does not alter the requirements of any other relevant legislation that must be met in utilising this material, including for example, the need to prepare a Safety Data Sheet (SDS).

Failure to comply with the conditions of this exemption constitutes an offence under clause 91 of the Waste Regulation.

Additional information

Application at the maximum rates allowed in this exemption can add physical contaminants to land as follows:

Glass, metal and rigid plastics > 2 mm	3.5 tonnes per hectare for mine sites
	0.75 tonnes per hectare for plantation forestry use and non-contact agricultural use
	0.15 tonnes per hectare for broad acre agricultural use
Plastics – light, flexible or film > 5 mm	0.35 tonnes per hectare for mine sites
	0.1 tonnes per hectare for plantation forestry use and non-contact agricultural use
	0.02 tonnes per hectare for broad acre agricultural use

Physical contaminants may also be present in substantial quantities below 2 mm (for glass, metal and rigid plastics) and 5 mm (for Plastics – light, flexible or film).

Appendix B Plant Uptake Factor Equations

Plant uptake of organic compounds has been estimated in the derivation of HILs using the equations presented by EA (UK EA 2009), which are detailed as follows (refer to (UK EA 2009) for further explanation of the basis for these equations):

Root Crops

$$CF_{root} = \frac{\frac{Q}{Koc\ x\ Foc}}{\frac{Q}{\frac{W}{\rho_p}+\frac{L}{\rho_p}\ x\ 1.22K_{ow}^{0.77}}+(k_g+K_m)\rho_p RV}$$ **Equation 1**

where:

CFroot = Concentration factor (mg/kg fw plant per mg/kg dw soil)
Q = transpiration stream flow rate, (cm^3/day) (assumed equal to the default of 1000)
Koc =organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
Foc = fraction of organic carbon in the soil, (unitless)
Kow = octanol–water partition coefficient, (unitless) (compound-specific)
W = root water content, (g/g) (assumed equal to the default of 0.89)
L = root lipid content on a mass basis, (g/g) (assumed equal to the default of 0.025)
ρ_p = plant root density, (g/cm^3) (assumed equal to the default of 1)
k_g = first order growth rate constant, per day (assumed equal to the default of 0.1)
K_m = first order metabolism rate constant, (per day) (assumed equal to the default of 0)
RV = root volume, (cm^3) (assumed equal to the default of 1000)

Tuber Crops

Calculations presented for tuber crops are based on potatoes as representative crops for this group:

$$CF_{tuber} = \frac{k1}{k2+k_g}$$ **Equation 2**

where:

$$k1 = k2(\frac{K_{pw}}{Koc\ x\ Foc})$$ **Equation 3**

$$K_{pw} = \frac{W}{\rho_p} + (f_{ch}K_{ch}) + \left(\frac{L}{\rho_p}\right)1.22K_{ow}^{0.77}$$ **Equation 4**

$$k2 = \frac{\frac{23(3600D_{water}(\frac{W^{2.333}}{\rho_p})}{K_{pw}}}{R^2}$$ **Equation 5**

where:

k1 = rate of chemical flux into the potato, (per hour) (Equation 3)
k2 = rate of chemical flux out of the potato, (per hour) (Equation 5)
k_g = exponential rate of growth of the potato, (per hour) (assumed equal to the default of 0.0014)
Foc = fraction of organic carbon in the soil, (unitless)
Koc =organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
D_{water} = chemical diffusion coefficient in water, (m^2/s) (compound-specific)
ρ_p = potato tissue density, (g/cm^3) (assumed equal to the default of 1)

R = radius of the potato, (m) (assumed equal to the default of 0.04)
W = water content of potato, (g/g) (assumed equal to the default of 0.79)
K_{pw} = equilibrium partition coefficient between potato and water, (cm^3/g) (Equation 25)
f_{ch} = fraction of carbohydrates in the potato, (unitless) (assumed equal to the default of 0.209)
L = lipid content of potato on a mass basis, (g/g) (assumed equal to the default of 0.001)
Kow = octanol–water partition coefficient, (unitless) (compound-specific)
K_{ch} = carbohydrate–water partition coefficient, (cm^3/g) (calculated from chemical lipophilicity according to the following table)

Chemical log Kow	Chemical Kch (cm^3/g)
<0	0.1
≥0 but <1	0.2
≥1 but <2	0.5
≥2 but <3	1
≥3 but <4	2
≥4	3

Green Vegetables

$$CF_{green} = \left(10^{0.95logKow-2.05} + 0.82\right) x \left(0.784\ x\ 10^{\frac{-0.434(\ logKow-1.78)^2}{2.44}}\right) x \left(\frac{\rho_s}{\theta_{ws}+(\rho_s\ x\ Koc\ x\ foc)}\right)$$ **Equation 6**

where:
Koc =organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
foc = fraction of organic carbon in the soil, (unitless)
Kow = octanol-water partition coefficient, (unitless) (compound-specific)
ρ_s = dry soil bulk density, (g/cm^3)
θ_{WS} = soil-water content by volume, (cm^3/cm^3)

Tree Fruit

$$CF_{fruit} = \frac{0.001\ x\ \left(M_f\ x\ Q_{fruit}\ x\ DM_{fruit}\right)\left(\frac{C_{stem}}{K_{wood}}\right)/M_f}{C_{soil}}$$ **Equation 7**

where:

$$C_{stem} = \frac{\left[\left(\frac{C_{soil}}{Koc\ x\ Foc}\right)0.756e^{\frac{-(logKow-2.5)2}{2.58}}\right]\left(\frac{Q}{M}\right)}{\frac{Q}{K_{wood}\ x\ M}+k_e+k_g}$$ **Equation 8**

$$logK_{wood} = 0.27 + 0.632\ logKow$$ **Equation 9**

where:
M_f = mass of fruit, (g fw) (assumed equal to the default of 1)
Q_{fruit} = water flow rate per unit mass of fruit, (cm^3/g fw) (assumed equal to the default of 20)
DM_{fruit} = dry matter content of fruit, (g/g) (assumed equal to the default of 0.16)
C_{stem} = chemical concentration in the woody stem (mg/g) (Equation 8)
K_{wood} = wood–water partition coefficient, (mg/g dw wood per mg/cm^3 water) (Equation 9)
C_{soil} = total chemical concentration in soil, (mg/kg dw) (assumed to be 1 for establishing ratio)
Koc = organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
foc = fraction of organic carbon in the soil, (unitless)
Kow = octanol–water partition coefficient, (unitless) (compound-specific)
Q = transpiration stream flow rate, (cm^3/year) (assumed equal to the default of 25,000,000)

M = mass of the woody stem, (g dw) (assumed equal to the default of 50,000)
k_e = rate of chemical metabolism, (per year) (assumed equal to the default of 0)
k_g = rate of dilution due to wood growth, (per year) (assumed equal to the default of 0.01)

Fraction of Organic Carbon in the Soil

As noted in Section 5.3.5.3 of Schedule B7 of the NEPM (1999 amended 2013) it is noted that for vapour intrusion calculations in the NEPM an organic carbon content of 0.3% has been assumed. For calculating the plant uptake factors, an organic carbon content of 2% has been assumed as any soil in a home grown produce garden will have been augmented with organic carbon to enable good quality growth of the produce.

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Appendix C Risk Calculations

Exposure to Chemicals via Incidental Ingestion of Soil

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowance for Assessment (TDI - Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	0.5		3.3E-06	--	0.167
Sum Br1 to Br9 (minimum)		1.0E-04	80%	0.000020	0.0008		5.3E-09	--	0.000267
Sum Br1 to Br9 (maximum)		1.0E-04	80%	0.000020	5.5		3.7E-05	--	1.833
Deca BDE (mean)		7.0E-03	80%	0.001400	0.02		1.3E-07	--	0.0000952
Deca BDE (minimum)		7.0E-03	80%	0.001400	0.0004		2.7E-09	--	0.00000190
DecaBDE (maximum)		7.0E-03	80%	0.001400	0.06		4.0E-07	--	0.000286
PFOS		2.[illegible]E-05	[illegible]0%	0.000018	0.0002		1.3E-09	--	0.0000741
PFOA		1.6[illegible]E-4	10%	0.000144	0.0002		1.3E-09	--	0.00000926

Exposure to Chemicals via Incidental Ingestion of Soil

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	
Exposure Duration (ED, years)	29	Assumed duration of exposure
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowance for Assessment (less Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	0.5		3.6E-07	--	0.0179
Sum Br1 to Br9 (minimum)		1.0E-04	80%	0.000020	0.0008		5.7E-10	--	0.0000286
Sum Br1 to Br9 (maximum)		1.0E-04	80%	0.000020	5.5		3.9E-06	--	0.196
Deca BDE (mean)		7.0E-03	80%	0.001400	0.02		1.4E-08	--	0.0000102
Deca BDE (minimum)		7.0E-03	80%	0.001400	0.0004		2.9E-10	--	0.000000204
DecaBDE (maximum)		7.0E-03	80%	0.001400	0.06		4.3E-08	--	0.0000306
PFOS		2.0E-05	10%	0.000018	0.0002		1.4E-10	--	0.00000794
PFOA		1.60E-04	10%	0.000144	0.0002		1.4E-10	--	0.000000992

Dermal Exposure to Chemicals via Contact with Soil

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Surface Area (SAs, cm^2)	2700	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	6	Exposures occur from areas 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.5		2.7E-06	--	0.135
Sum Br1 to Br9 (minimum)		1.0E-04	80%	0.00002	0.1	0.0008		4.3E-09	--	0.000216
Sum Br1 to Br9 (maximum)		1.0E-04	[illegible]%	[illegible]	0.1	5.5		3.0E-05	--	1.485
Deca BDE (mean)		7.0E-03	[illegible]%	[illegible]40	0.01	0.02		1.1E-08	--	0.00000771
Deca BDE (minimum)		7.0E-03	[illegible]%	0.00140	0.01	0.0004		2.2E-10	--	0.000000154
DecaBDE (maximum)		7.0E-03	[illegible]%	0.00140	0.01	0.06		3.2E-08	--	0.0000231

Dermal Exposure to Chemicals via Contact with Soil

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Surface Area (SAs, cm^2)	6300	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA (2004)
Fraction of Day Exposed	1	Assume the adult remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	29	Assumed duration of exposure
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.5		1.4E-06	--	0.0675
Sum Br1 to Br9 (minimum)		1.0E-04	80%	0.00002	0.1	0.0008		2.2E-09	--	0.00011
Sum Br1 to Br9 (maximum)		1.0E-04	80%	0.00002	0.1	5.5		1.5E-05	--	0.743
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	0.02		5.4E-09	--	0.00000386
Deca BDE (minimum)		7.0E-03	80%	0.00140	0.01	0.0004		1.1E-10	--	0.0000000771
DecaBDE (maximum)		7.0E-03	80%	0.00140	0.01	0.06		1.6E-08	--	0.0000116

Soil to Air Particulate Emission Factor (PEF) - Outdoors

(Reference: USEPA Soil Screening Guidance (1996), Supplemental Guidance (2002))

$$PEF = \frac{Q/C \bullet 3600}{0.036 \bullet (1-V) \bullet (\frac{U_m}{U_t})^3 \bullet F_x}$$

where:

		Site Data	Comments
A	area of site (acres)	**2.50**	Area of concern covers approx. 0.1 ha
Q/C =	dispersion factor ($g/m^2/s$ per kg/m^3)	**71.01**	Calculated using equations for outd worker fr US EPA, 02
V =	fraction of vegetative cover (unitless)	**0.5**	Assume half of the area has veg on cover
U_m =	mean annual windspeed (m/s)	**3.6**	Mean windspeed from 9am and 3p ading Research Institute Met Station
U_t =	equivalent threshold value (m/s)	**11.3**	Calculated for a thresh of 1 m/ S EPA, 1996)
U_t/U_m =	ratio of threshold value to windspeed	**3.1**	Ratio
F_x =	windspeed distribution function (unitless)	**3.91E-02**	Value based on um ratio, Cowher 1985)

PEF = 1.13E+10 m^3/kg)

COPC	Soil Concentration, C_{soil} (mg/kg)	Dust Concentration C_{dust} [=C_{soil}/PEF] (mg/m^3)
Sum Br1 to Br9 (mean)	0.50	4.4E-11
Sum Br1 to Br9 (minimum)	0.0008	7.
Sum Br1 to Br9 (maximum)	5.50	4.9 0
Deca BDE (mean)	0.02	1.8E-
Deca BDE (minimum)	0.000	3.5E-1
DecaBDE (maximum)	0.06	5.3E-12

PEF for fugitive dust emissio consider relevant for the quantification of inhalation exposures by outdoor workers on a residential or commercial/industrial site (inc ing garde g and landscaping activities). However it is noted that the fugitive model may not be relevant for activities and condi ns that result i e generation of potentially high dust emissions such as dry soils (MC<8%) , fine soils (high silt or clay content) gh annual ave winds (3 m/s) and less than 50% vegetative cover.

Inhalation of Dust (derived from Soil Source) - Children and Adults

$$Inhalation\ Exposure\ Conc_P = C_a \bullet \frac{ET \bullet FI \bullet DF \bullet CC \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Parameters Relevant to Quantification of Exposureto Residents		
Exposure Time (ET, hr/day)	24	Assumed time spent at the site each d
Exposure Time Indoors (hours/day)	20	ASC NEPM (2013)
Exposure Time Outdoors (hours/day)	4	ASC NEPM (2013)
Fraction Inhaled from Contaminated Source (FI, unitless)	1	Assume all of dust is from site ted soil
Deposition Fraction (DF, unitless)	0.75	Assume 75% inhaled dust reaches ngs
Cilliary Clearance (CC, unitless)	0.5	Assume 50% small enough to penetr deep enough for absorption
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	35	Duration of exposu as young chi nd ad
Averaging Time - NonThreshold (Atc, hours)	613200	USEPA 2009
Averaging Time - Threshold (Atn, hours)	306600	USEPA 2009

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	in Air (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Sum Br1 to Br9 (mean)		0.0001		0.000	4.4E-11		1.7E-11	--	8.30E-07
Sum Br1 to Br9 (minimum)		0.0001	%0	0.00002	7.1E-14		2.7E-14	--	1.33E-09
Sum Br1 to Br9 (maximum)		0.0001	8 %	0.00002	4.9E-10		1.8E-10	--	9.13E-06
Deca BDE (mean)		0.007	80	0.00140	1.8E-12		6.6E-13	--	4.74E-10
Deca BDE (minimum)		0.007	80%	0.00140	3.5E-14		1.3E-14	--	9.49E-12
DecaBDE (maximum)		0.007	80%	0.00140	5.3E-12		2.0E-12	--	1.42E-09

Consumption of Fruit and Vegetables by Adults and Children

Percentage of Fruit and Veg per produce group (as per Table 7 in Schedule B7)

Produce Group	Adults (%)	Adult Consumption Rate (g/day)	Children (%)	Child Consumption Rate (g/day)
Green Vegetables	59	153.4	55	55
Root Vegetables	18	46.8	17	17
Tuber Vegetables	23	59.8	28	28
Tree Fruit	100	140	100	180
Total consumption		400		280

Uptake and Intake from Produce - Organics

Soil bulk density (g/cm^3)	1.63	Assumed for typical soil in root zone
Soil-water content by volume (cm^3/cm^3)	0.13	Assumed for typical soil in root zone
Fraction organic carbon (foc)	2%	Noted in Section 5.3.5.3 in Schedule B7
Fraction Homegrown (HIL A)	35%	As per Cross and Taylor (1996)

Consumption rates (from above table, with change of units)	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Consumption Rate Adults (kg/day)	0.1534	0.0468	0.0598	0.14
Consumption Rate Children (kg/day)	0.055	0.017	0.028	0.18

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	Chemical Properties (as per RAIS 2010)					Intermediate Calculations						
	Koc (cm^3/g)	Log Kow	Ko	(m^2/s)	ow (cm^2/s)	K_{ch} (cm^3/g) (as per Appendix B)	K_{pw} (cm^3/g) (as per Equation 25)	k_2 (per hour) (as per Equation 26)	k_1 (per hour) (as per Equation 24)	K_{wood} (mg/g dw wood per mg/cm^3 water) (as per Equation 30)	Cxy (intermediate for calculating C_{stem})	C_{stem} (mg/g) (as per Equation 29)
Sum Br1 to Br9 (mean)	2.17E+04	8.4	2.51E+		6.01E-06	3	3.59E+03	5.00E-06	4.14E-05	1.09E+05	1.26E+03	4.33E+07
Sum Br1 to Br9 (minimum)	2.17E+04	6.5	3.16E+0	4.22E-10	4.22E-06	3	1.25E+02	1.01E-04	2.91E-05	6.89E+03	8.61E-01	5.21E+03
Sum Br1 to Br9 (maximum)	2.17E+04	6.5	3.16E+06	6.10E-10	6.10E-06	3	1.25E+02	1.46E-04	4.20E-05	6.89E+03	8.61E-01	5.21E+03
DecaBDE (maximum)	2.76E+05	6.3	2.00E+06	9.78E-10	9.78E-06	3	8.80E+01	3.32E-04	5.29E-06	5.15E+03	3.69E-02	1.72E+02

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	Soil to Plant Concen... (mg/kg ... h weight to mg/kg soil dry weig...)				Plant Uptake Factor - Adults (UF_{VA}) (kg/day) as per Equation 16	Plant Uptake Factor - Young Children (UF_{VC}) (kg/day) as per Equation 16
	Green Vegetables (CF_{gr} ... as per E... tion 27	...ot Vege...s (CF_{rt}) as pe... E... ...on 22	Tuber Vegetables (CF_{tuber}) as per Equation 23	Tree Fruit (CF_{fruit}) (as per Equation 28)		
Sum Br1 to Br9 (mean)	...47E-05	2.3... 2	8.28E+00	1.27E+00	2.36E-01	1.61E-01
Sum Br1 to Br9 (minimum)	2.63E-03	2.30E-...	2.88E-01	2.42E-03	6.67E-03	3.16E-03
Sum Br1 to Br9 (maximum)	2.63E-...	2.30E-02	2.88E-01	2.42E-03	6.67E-03	3.16E-03
DecaBDE (maximum)	...84E-...	1.80E-03	1.59E-02	1.07E-04	3.83E-04	1.79E-04

UK (2009) note that care should be taken in calculating uptake into green vegetables for these compounds (outside range considered in study)

Exposure to Chemicals via Ingestion of Home-Grown Produce - Children

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \textbf{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \textbf{(kg/da}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF [illegible] FHG (kg	
Consumption Rate - Children	0.055	0.017	0.028	0.18		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (mean)	2.47E-05	2.31E-02	8.28E+00	1.27E+00	1.61E-0	(mg/kg produce per mg/kg soil)
DecaBDE (maximum)	2.84E-04	1.80E-03	1.59E-02	1.07E-04	1.79E-04	

Parameters Relevant to Quantification of Exposure to Young Children		
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day [illegible]e year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Agricultural Application

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Bioaccessible Concentration in Soil (=Cs*B)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intak[illegible]DI)	TDI [illegible]wable f[illegible] Assess[illegible]t (TDI - Backgr[illegible]d)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		[illegible]/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.5	0.5		5.4E-03		268.583
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.0008	0.0008		8.6E-06		0.430
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	5.5	5.5		5.9E-02		2954
Deca BDE (mean)		0.007	[illegible]0%	0.0014	0.02	0.02		2.4E-07		0.000170
Deca BDE (minimum)		[illegible]	[illegible]	0.0014	0.0004	0.0004		4.8E-09		0.00000341
DecaBDE (maximum)		[illegible]07	[illegible]	0.0014	0.06	0.06		7.2E-07		0.000511

Exposure to Chemicals via Ingestion of Home-Grown Produce - Adults

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \text{(kg/day)}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF [illegible] FHG (kg	
Consumption Rate Adults (kg/day)	0.1534	0.0468	0.0598	0.14		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (mean)	2.47E-05	2.31E-02	8.28E+00	1.27E+00	2.36E-0	(mg/kg produce per mg/kg soil)
DecaBDE (maximum)	2.84E-04	1.80E-03	1.59E-02	1.07E-04	3.83E-04	

Parameters Relevant to Quantification of Exposure to Adults		
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day [illegible]e year
Exposure Duration (ED, years)	29	Duration of exposure as adult
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Agricultural Application

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Bioaccessible Concentration in Soil (=Cs*B)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intak[illegible]DI)	TDI A[illegible]vable f[illegible] Assessm[illegible]t (TDI - Backgr[illegible]d)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		[illegible]/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.5	0.5		1.7E-03		84.2
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.0008	0.0008		2.7E-06		0.135
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	5.5	5.5		1.9E-02		926
Deca BDE (mean)		0.007	[illegible]0%	0.0014	0.02	0.02		1.1E-07		0.0000782
Deca BDE (minimum)		[illegible]	[illegible]	0.0014	0.0004	0.0004		2.2E-09		0.00000156
DecaBDE (maximum)		[illegible]07	[illegible]	0.0014	0.06	0.06		3.3E-07		0.000235

Exposure to Chemicals via Ingestion of Eggs from On-Site Hens - Children

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \textbf{(mg/kg/day)}$$

C_{eggs} = (Daily Intake)$_{chickens}$ x Transfer Factor **(mg/kg fresh produce)**

(Daily Intake)$_{chickens}$ = C_{soil} x Irsoil x B **(mg/day)** (assumes bio[illegible]ility for c[illegible]kens is 100%)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate of Eggs (IR_{eggs}, kg/day)	0.036	Mean value for consumers as per FSAN[illegible]011, Ta[illegible]12.3 i[illegible]5 years
Fraction Home-Grown Eggs Consumed (FHG)	100%	Assumed relevant for eggs from back[illegible]rd
Ingestion Rate of Soil by Hens (IRs, kg/day)	0.012	10% of feed ingestion rate assume[illegible] comprise soil (up[illegible]r value)
Exposure Frequency (EF, days/year)	365	Assume produce consumed every da[illegible] the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Agricultural Application

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in eggs)/(mg/day intake of contaminant by hen)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/da[illegible]		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	10	0.5		1.4E-04	--	7.20
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	10	0.0008		2.3E-07	--	0.0115
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	10	5.5		1.6E-03	--	79.2
Deca BDE (mean)		[illegible]	[illegible]	0.0014	3	0.02		1.7E-06	--	0.00123
Deca BDE (minimum)		[illegible]007	[illegible]	0.0014	3	0.0004		3.5E-08	--	0.0000247
DecaBDE (maximum)		0.0[illegible]	80%	0.0014	3	0.06		5.2E-06	--	0.00370

Exposure to Chemicals via Ingestion of Eggs from On-Site Hens - Adult

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \textbf{(mg/kg/day)}$$

C_{eggs} = (Daily Intake)$_{chickens}$ x Transfer Factor **(mg/kg fresh produce)**

(Daily Intake)$_{chickens}$ = C_{soil} x Irsoil x B **(mg/day)** (assumes bio[illegible]ility for c[illegible]kens is 100%)

Parameters Relevant to Quantification of Exposure to Adult		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate of Eggs (IR_{eggs}, kg/day)	0.059	Mean value for consumers as per FSAN[illegible]011, Ta[illegible]12.3 f[illegible]dults
Fraction Home-Grown Eggs Consumed (FHG)	100%	Assumed relevant for eggs from back[illegible]rd
Ingestion Rate of Soil by Hens (IRs, kg/day)	0.012	10% of feed ingestion rate assume[illegible] comprise soil (up[illegible]r value)
Exposure Frequency (EF, days/year)	365	Assume produce consumed every da[illegible] the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Agricultural Application

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in eggs)/(mg/day intake of contaminant by hen)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/da[illegible]		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	10	0.5		5.1E-05	--	2.529
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	10	0.0008		8.1E-08	--	0.00405
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	10	5.5		5.6E-04	--	27.81
Deca BDE (mean)		[illegible]	[illegible]	0.0014	3	0.02		6.1E-07	--	0.000433
Deca BDE (minimum)		[illegible]007	[illegible]	0.0014	3	0.0004		1.2E-08	--	0.00000867
DecaBDE (maximum)		0.0[illegible]	80%	0.0014	3	0.06		1.8E-06	--	0.00130

Exposure to Chemicals via Ingestion of Milk from On-Site Goats or Cows - Children

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \qquad \text{(mg/kg/day)}$$

$$C_{milk} = (Daily\ Intake)_{goat} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

$$(Daily\ Intake)_{goat} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

$$(Daily\ Intake)_{goat} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

(assumes bioacessibility is 100%)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.097	Maximum mean value for 2-5 year olds as per FSANZ 2011; FSANZ 2014
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Ingestion Rate of Soil by Cows (IRs, kg/day)	2.4	As per API 2004
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Agricultural Application

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in milk)/(mg/day intake of contaminant by hen)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.04	0.5		3.5E-03	–	176
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.04	0.0008		5.6E-06	–	0.281
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	0.04	5.5		3.9E-02	–	1931
Deca BDE (mean)		0.007	80%	0.0014	0.0006	0.02		2.1E-06	–	0.00150
Deca BDE (minimum)		0.007	80%	0.0014	0.0006	0.0004		4.2E-08	–	0.0000301
DecaBDE (maximum)		0.007	80%	0.0014	0.0006	0.06		6.3E-06	–	0.00451

Mine Rehabilitation Application

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in milk)/(mg/day intake of contaminant by hen)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.04	6.8		4.8E-02	–	2387
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.04	0.01		7.0E-05	–	3.51
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	0.04	75		5.3E-01	–	26328
Deca BDE (mean)		0.007	80%	0.0014	0.0006	0.2		2.1E-05	–	0.0150
Deca BDE (minimum)		0.007	80%	0.0014	0.0006	0.006		6.3E-07	–	0.000451
DecaBDE (maximum)		0.007	80%	0.0014	0.0006	0.8		8.4E-05	–	0.0602

Exposure to Chemicals via Ingestion of Milk from Cows - Adult

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \qquad \text{(mg/kg/day)}$$

$$C_{milk} = (Daily\ Intake)_{goat} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

$$(Daily\ Intake)_{goat} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

$$(Daily\ Intake)_{goat} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

(assumes bioacessibility is 100%)

Parameters Relevant to Quantification of Exposure to Adult		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.295	Maximum mean value for 2-5 year olds as per FSANZ 2011; FSANZ 2014
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Ingestion Rate of Soil by Cows (IRs, kg/day)	2.4	As per API 2004
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Agricultural Application

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in milk)/(mg/day intake of contaminant by hen)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.04	0.5		8.9E-04	–	44.4
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.04	0.0008		1.4E-06	–	0.0710
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	0.04	5.5		9.8E-03	–	488
Deca BDE (mean)		0.007	80%	0.0014	0.0006	0.02		5.3E-07	–	0.000381
Deca BDE (minimum)		0.007	80%	0.0014	0.0006	0.0004		1.1E-08	–	0.00000761
DecaBDE (maximum)		0.007	80%	0.0014	0.0006	0.06		1.6E-06	–	0.00114

Mine Rehabilitation Application

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in milk)/(mg/day intake of contaminant by hen)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.04	6.8		1.2E-02	–	604
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.04	0.01		1.8E-05	–	0.888
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	0.04	75		1.3E-01	–	6660
Deca BDE (mean)		0.007	80%	0.0014	0.0006	0.2		5.3E-06	–	0.00381
Deca BDE (minimum)		0.007	80%	0.0014	0.0006	0.006		1.6E-07	–	0.000114
DecaBDE (maximum)		0.007	80%	0.0014	0.0006	0.8		2.1E-05	–	0.0152

Exposure to Chemicals via Ingestion of Meat - Children (Beef)

$$Daily\ Chemical\ Intake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \qquad (mg/kg/day)$$

$$C_{meat} = (Daily\ Intake)_{grazinganimal} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

$$(Daily\ Intake)_{grazinganimals} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

(assumes bioacessibility is 100%)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)		Total value for all meats based on NHMRC dietary guidelines
Beef	0.085	Total Dietary Survey (Table 16 in text)
Fraction Home-Grown Meat Consumed (FHG)	100%	Assumed relevant
Ingestion Rate of Soil by Cows (IRs, kg/day)	2.4	As per API 2004
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

AGRICULTURAL APPLICATION

Beef
100% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	0.5		1.4E-02	--	680
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.0008		2.2E-05	--	1.09
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	5.5		1.5E-01	--	7480
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.02		5.4E-06	--	0.00389
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.0004		1.1E-07	--	0.0000777
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.06		1.6E-05	--	0.0117

75% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	0.5		1.0E-02	--	510
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.0008		1.6E-05	--	0.816
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	5.5		1.1E-01	--	5610
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.02		4.1E-06	--	0.00291
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.0004		8.2E-08	--	0.0000583
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.06		1.2E-05	--	0.00874

50% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	0.5		6.8E-03	--	340
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.0008		1.1E-05	--	0.544
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	5.5		7.5E-02	--	3740
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.02		2.7E-06	--	0.00194
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.0004		5.4E-08	--	0.0000389
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.06		8.2E-06	--	0.00583

Exposure to Chemicals via Ingestion of Meat - Children (Beef) (Mine Rehabilitation)

$$Daily\ Chemical\ Intake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \qquad (mg/kg/day)$$

$$C_{meat} = (Daily\ Intake)_{grazinganimals} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

$$(Daily\ Intake)_{grazinganimals} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

(assumes bioacessibility is 100%)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)		Total value for all meats based on NHMRC dietary guidelines
Beef	0.085	Total Dietary Survey (Table 16 in text)
Fraction Home-Grown Meat Consumed (FHG)	100%	Assumed relevant
Ingestion Rate of Soil by Cows (IRs, kg/day)	2.4	As per API 2004
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

MINE REHABILITATION APPLICATION

Beef

100% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	6.8		1.8E-01	--	9248
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.01		2.7E-04	--	13.6
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	75		2.0E+00	--	102000
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.2		5.4E-05	--	0.0389
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.006		1.6E-06	--	0.00117
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.8		2.2E-04	--	0.155

75% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	6.8		1.4E-01	--	6936
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.01		2.0E-04	--	10.2
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	75		1.5E+00	--	76500
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.2		4.1E-05	--	0.0291
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.006		1.2E-06	--	0.000874
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.8		1.6E-04	--	0.117

50% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	6.8		9.2E-02	--	4624
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.01		1.4E-04	--	6.80
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	75		1.0E+00	--	51000
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.2		2.7E-05	--	0.0194
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.006		8.2E-07	--	0.000583
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.8		1.1E-04	--	0.0777

Exposure to Chemicals via Ingestion of Meat - Adult (Beef)

$$Daily\ Chemical\ Intake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \qquad \text{(mg/kg/day)}$$

$$C_{meat} = (Daily\ Intake)_{grazinganimal} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

$$(Daily\ Intake)_{grazinganimals} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

(assumes bioacessibility is 100%)

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)		
Beef	0.163	Total Dietary Survey (Table 16 in text)
Fraction Home-Grown Meat Consumed (FHG)	100%	Assumed relevant
Ingestion Rate of Soil by Cows (IRs, kg/day)	2.4	As per API 2004
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

AGRICULTURAL APPLICATION

Beef
100% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	0.5		5.6E-03	--	279
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.0008		8.9E-06	--	0.447
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	5.5		6.1E-02	--	3074
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.02		2.2E-06	--	0.00160
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.0004		4.5E-08	--	0.0000319
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.06		6.7E-06	--	0.00479

75% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	0.5		4.2E-03	--	210
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.0008		6.7E-06	--	0.335
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	5.5		4.6E-02	--	2305
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.02		1.7E-06	--	0.00120
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.0004		3.4E-08	--	0.0000240
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.06		5.0E-06	--	0.00359

50% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	0.5		2.8E-03	--	140
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.0008		4.5E-06	--	0.224
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	5.5		3.1E-02	--	1537
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.02		1.1E-06	--	0.000798
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.0004		2.2E-08	--	0.0000160
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.06		3.4E-06	--	0.00240

Exposure to Chemicals via Ingestion of Meat - Adult (Beef) (Mine Rehabilitation)

$$Daily\ Chemical\ Intake_{meat} = C_{meat} \bullet \frac{IR_{meat} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \qquad \text{(mg/kg/day)}$$

$$C_{meat} = (Daily\ Intake)_{grazinganimal} \bullet (Transfer\ Factor) \qquad (mg/kg\ fresh\ weight)$$

$$(Daily\ Intake)_{grazinganimals} = C_{soil} \bullet IR_{soil} \bullet B \qquad (mg/day)$$

(assumes bioacessibility is 100%)

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)		
Beef	0.163	Total Dietary Survey (Table 16 in text)
Fraction Home-Grown Meat Consumed (FHG)	100%	Assumed relevant
Ingestion Rate of Soil by Cows (IRs, kg/day)	2.4	As per API 2004
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

MINE REHABILITATION APPLICATION

Beef
100% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	6.8		7.6E-02	--	3800
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.01		1.1E-04	--	5.59
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	75		8.4E-01	--	41914
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.2		2.2E-05	--	0.0160
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.006		6.7E-07	--	0.000479
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.8		8.9E-05	--	0.0639

75% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	6.8		5.7E-02	--	2850
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.01		8.4E-05	--	4.19
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	75		6.3E-01	--	31436
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.2		1.7E-05	--	0.0120
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.006		5.0E-07	--	0.000359
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.8		6.7E-05	--	0.0479

50% of beef consumed

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in meat)/(mg/day intake of contaminant by cow)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2	6.8		3.8E-02	--	1900
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	2	0.01		5.6E-05	--	2.79
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	2	75		4.2E-01	--	20957
Deca BDE (mean)		0.007	80%	0.0014	0.02	0.2		1.1E-05	--	0.00798
Deca BDE (minimum)		0.007	80%	0.0014	0.02	0.006		3.4E-07	--	0.000240
DecaBDE (maximum)		0.007	80%	0.0014	0.02	0.8		4.5E-05	--	0.0319

Exposure to Chemicals via Ingestion of Wheat/barley/oats - Children

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \textbf{(mg/kg/day)}$$

C_{eggs} = (Daily Intake)$_{chickens}$ x Transfer Factor **(mg/kg fresh produce)**

(Daily Intake)$_{chickens}$ = C_{soil} x Irsoil x B **(mg/day)** (assumes bio[illegible]ility for c[illegible]kens is 100%)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.038	2/3rds of bread consumption from FSA[illegible]otal Die[illegible]rvey
Fraction Home-Grown (FHG)	35%	Assumed relevant for wheat grown in[illegible]ds where mate[illegible] is appl
Exposure Frequency (EF, days/year)	365	Assume produce consumed every [illegible] of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 ye[illegible]
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in wheat)/(mg/kg soil)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for [illegible]ssment (TDI [illegible]ground			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg[illegible]ay)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	8[illegible]	[illegible]0002	7	0.5		3.1E-03	--	155
Sum Br1 to Br9 (minimum)		0.0001	80	0.00002	7	0.0008		5.0E-06	--	0.248
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	7	5.5		3.4E-02	--	1707
Deca BDE (mean)		0.007	80%	0.0014	7	0.02		1.2E-04	--	0.0887
Deca BDE (minimum)		0.007	[illegible]0%	0.0014	7	0.0004		2.5E-06	--	0.00177
DecaBDE (maximum)		[illegible]	[illegible]%	0.0014	7	0.06		3.7E-04	--	0.266

Exposure to Chemicals via Ingestion of Wheat/barley/oats - Adult

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \textbf{(mg/kg/day)}$$

C_{eggs} = (Daily Intake)$_{chickens}$ x Transfer Factor **(mg/kg fresh produce)**

(Daily Intake)$_{chickens}$ = C_{soil} x Irsoil x B **(mg/day)** (assumes bio[illegible]ility for c[illegible]kens is 100%)

Parameters Relevant to Quantification of Exposure to Adult		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.095	2/3rds of bread consumption from FSA[illegible]otal Die[illegible]rvey
Fraction Home-Grown (FHG)	35%	Assumed relevant for wheat grown in[illegible]ds where mate[illegible] is appl[illegible]
Exposure Frequency (EF, days/year)	365	Assume produce consumed every[illegible] of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 ye[illegible]
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in wheat)/(mg/kg soil)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	[illegible]DI Allowable for [illegible]ssment (TDI [illegible]ground[illegible]			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg[illegible]day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	8[illegible]	[illegible]0002	7	0.5		1.7E-03	--	83.1
Sum Br1 to Br9 (minimum)		0.0001	80	0.00002	7	0.0008		2.7E-06	--	0.133
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	7	5.5		1.8E-02	--	914
Deca BDE (mean)		0.007	80%	0.0014	7	0.02		6.7E-05	--	0.0475
Deca BDE (minimum)		0.007	[illegible]0%	0.0014	7	0.0004		1.3E-06	--	0.000950
DecaBDE (maximum)		[illegible]	[illegible]%	0.0014	7	0.06		2.0E-04	--	0.143

Exposure to Chemicals via Ingestion of Home-Grown Blueberries - Children

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \textbf{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \textbf{(kg/da}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF [illegible] FHG (kg	
Consumption Rate - Children	0.055	0.017	0.028	0.18		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (mean)	2.47E-05	2.31E-02	8.28E+00	1.27E+00	1.61E-0	(mg/kg produce per mg/kg soil)
DecaBDE (maximum)	2.84E-04	1.80E-03	1.59E-02	1.07E-04	1.79E-04	

Parameters Relevant to Quantification of Exposure to Young Children		
Exposure Frequency (EF, days/year)	180	Assume a punnet is consumed every s[illegible]nd day
Fraction Home-Grown (FHG)	35%	
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (201[illegible]

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Bioaccessible Concentration in Soil (=Cs*B)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intak[illegible]DI)	TDI A[illegible]wable f[illegible] Assess[illegible]t (TDI - Backgr[illegible]d)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		[illegible]/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	2.5	2.5		6.6E-03		328
Sum Br1 to Br9 (minimum)		0.0001	80%	0.00002	0.004	0.004		1.1E-05		0.525
Sum Br1 to Br9 (maximum)		0.0001	80%	0.00002	27.5	27.5		7.2E-02		3612
Deca BDE (mean)		0.007	[illegible]0%	0.0014	0.1	0.1		2.2E-08		0.0000158
Deca BDE (minimum)		[illegible]	[illegible]	0.0014	0.002	0.002		4.4E-10		0.000000317
DecaBDE (maximum)		[illegible]07	[illegible]	0.0014	0.3	0.3		6.7E-08		0.0000475

Exposure to PFAS - Children

$$DailyChemicalIntake_{\square} = C \bullet \frac{IR_{\square} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
green vegetables	0.055	as per PBDE assessment
root vegetables	0.017	as per PBDE assessment
tuber vegetables	0.028	as per PBDE assessment
tree fruit	0.18	as per PBDE assessment
wheat/oats/barley	0.038	as per PBDE assessment
eggs	0.036	as per PBDE assessment
milk	1.097	as per PBDE assessment
meat	0.085	as per PBDE assessment
Fraction Home-Grown Eggs, Milk, Wheat etc (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Fruit, Meat, Vegetables (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce (as per Table 14 and 15)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg ww)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS									
Green Vegetables		2.0E-05	10%	0.000018	0.0001		1.3E-07	--	0.00713
Root Vegetables		2.0E-05	10%	0.000018	0.00002		7.9E-09	--	0.000441
Tuber Vegetables		2.0E-05	10%	0.000018	0.00002		1.3E-08	--	0.0726
Tree Fruit		2.0E-05	10%	0.000018	0.000004		1.7E-08	--	0.[illegible]
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0002		5.1E-07	--	0.0[illegible]
Eggs		2.0E-05	10%	0.000018	0.0001		2.4E-07	--	0.013[illegible]
Milk		2.0E-05	10%	0.000018	0.00002		1.5E-06	--	0.0813
Meat		2.0E-05	10%	0.000018	0.00004		7.9E-08	--	0.00441
PFOA									
Green Vegetables		1.6E-04	10%	0.000144	0.00008		1.0E-07	--	0.000713
Root Vegetables		1.6E-04	10%	0.000144	0.00002		7.9E-09	--	0.0000551
Tuber Vegetables		1.6E-04	10%	0.000144	0.00003		[illegible]0E-08	--	0.000136
Tree Fruit		1.6E-04	10%	0.000144	0.000002		[illegible]-09	--	0.0000583
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.001		[illegible]	--	0.0176
Eggs		1.6E-04	10%	0.000144	0.000		7.2[illegible]	--	0.000500
Milk		1.6E-04	10%	0.000144	0.000000		5.9E-[illegible]	--	0.0000406
Meat		1.6E-04	10%	0.000144	0.000000		6.0E-10	--	0.00000413

Average Case

Key Chemical	Toxicity Data				Concentration [illegible]roduce (as [illegible]able 14 a[illegible]5)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) [illegible]day)	(mg/kg	[illegible]hreshold [illegible]day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS									
Green Vegetables		2.0E-05	10%	[illegible]0018			9.0E-08	--	0.004990741
Root Vegetables		2.0E-05	10%	0.[illegible]18			4.0E-09	--	0.0002203704
Tuber Vegetables		2.0E-05	10%	0.000	0.000008		5.2E-09	--	0.0002903704
Tree Fruit		2.0E-05	10%	0.0000[illegible]	0.000002		8.4E-09	--	0.0004666667
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0001		2.5E-07	--	0.0141
Eggs		2.0E-05	10%	0.000018	0.00005		1.2E-07	--	0.00667
Milk		2.0E-05	10%	[illegible]00018	0.00001		7.3E-07	--	0.0406
Meat		2.0E-05	10%	[illegible]0018	0.00002		4.0E-08	--	2.20E-03
PFOA									
Green Vegetables		1.6[illegible]	10%	0.0[illegible]	0.00005		6.4E-08	--	0.0004456019
Root Vegetables		[illegible]04	10%	0.000[illegible]	0.00001		4.0E-09	--	0.00002754630
Tuber Vegetables		[illegible]04	10%	0.000144	0.00002		1.3E-08	--	0.00009074074
Tree Fruit		1.[illegible]	[illegible]	0.000144	0.000001		4.2E-09	--	0.00002916667
Wheat/Oats/Barley		1.6E-[illegible]	[illegible]%	0.000144	0.0008		2.0E-06	--	0.0141
Eggs		1.6E-04	10%	0.000144	0.00002		4.8E-08	--	0.000333
Milk		1.6E-04	10%	0.000144	0.00000005		3.7E-09	--	2.54E-05
Meat		1.6E-04	[illegible]0%	0.000144	0.0000002		4.0E-10	--	2.75E-06

Exposure to PFAS - Adult

$$DailyChemicalIntake_{\square} = C \bullet \frac{IR_{\square} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
green vegetables	0.15	as per PBDE assessment
root vegetables	0.05	as per PBDE assessment
tuber vegetables	0.06	as per PBDE assessment
tree fruit	0.14	as per PBDE assessment
wheat/oats/barley	0.095	as per PBDE assessment
eggs	0.059	as per PBDE assessment
milk	1.295	as per PBDE assessment
meat	0.163	as per PBDE assessment
Fraction Home-Grown Eggs, Milk, Wheat etc (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Fruit, Meat, Vegetables (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce (as per Table 14 and 15)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS									
Green Vegetables		2.0E-05	10%	0.000018	0.0001		7.5E-08	--	0.00417
Root Vegetables		2.0E-05	10%	0.000018	0.00002		5.0E-09	--	0.000278
Tuber Vegetables		2.0E-05	10%	0.000018	0.00002		6.0E-09	--	0.00033
Tree Fruit		2.0E-05	10%	0.000018	0.000004		2.8E-09	--	0.00
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0002		2.7E-07	--	0.0
Eggs		2.0E-05	10%	0.000018	0.0001		8.4E-08	--	0.00468
Milk		2.0E-05	10%	0.000018	0.00002		3.7E-07	--	0.0206
Meat		2.0E-05	10%	0.000018	0.00004		3.3E-08	--	0.00181
PFOA									
Green Vegetables		1.6E-04	10%	0.000144	0.00008		6.0E-08	--	0.000417
Root Vegetables		1.6E-04	10%	0.000144	0.00002		5.0E-09	--	0.0000347
Tuber Vegetables		1.6E-04	10%	0.000144	0.00003		9E-09	--	0.000063
Tree Fruit		1.6E-04	10%	0.000144	0.000001		09	--	0.0000097
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.0		1	--	0.00942
Eggs		1.6E-04	10%	0.000144	0.000		2.5E	--	0.000176
Milk		1.6E-04	10%	0.000144	0.000000		1.5E-0	--	0.0000103
Meat		1.6E-04	10%	0.000144	0.000000		2.4E-10	--	0.00000170

Average Case

Key Chemical	Toxicity Data				Concentration in Produce (as per Table 14 and	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		nThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)			(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS									
Green Vegetables		2.0E-05	10%	0.0	0.0		5.3E-08	--	0.002916667
Root Vegetables		2.0E-05	10%	0.00	0.00001		2.5E-09	--	0.0001388889
Tuber Vegetables		2.0E-05	10%	0.0000	0.000008		2.4E-09	--	0.0001333333
Tree Fruit		2.0E-05	10%	0.000018	0.000002		1.4E-09	--	0.0000777778
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0001		1.4E-07	--	0.0075
Eggs		2.0E-05	10%	000018	0.00005		4.2E-08	--	0.00234
Milk		2.0E-05	10%	018	0.00001		1.9E-07	--	0.0103
Meat		2.0E-	10%	8	0.00002		1.6E-08	--	9.06E-04
PFOA									
Green Vegetables		4	10%	0.0001	0.00005		3.8E-08	--	0.0002604167
Root Vegetables		1	1	0.000144	0.00001		2.5E-09	--	0.00001736111
Tuber Vegetables		1.6E		0.000144	0.00002		6.0E-09	--	0.00004166667
Tree Fruit		1.6E-0	0%	0.000144	0.000001		7.0E-10	--	0.00000486111
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.0008		1.1E-06	--	0.0075
Eggs		1.6E-04	10%	0.000144	0.00002		1.7E-08	--	0.000117
Milk		1.6E-04	%	0.000144	0.00000005		9.3E-10	--	6.42E-06
Meat		1.6E-04		0.000144	0.0000002		1.6E-10	--	1.13E-06

Appendix C Office of Chief Scientist and Engineer Report

NSW GOVERNMENT | Office of the Chief Scientist & Engineer

Review of Polybrominated Diphenyl Ethers in Mixed Waste Organic Outputs to Provide Values for a Human Health and Ecological Risk Assessment

Final Report

Independent Scientific Review Panel on Soil and Chemistry

May 2019

This report has been amended for public release

Errata

- Grammatical and formatting revisions: '13' to '12.6' (pg. iv); 'object' to subject' (pg. 9 Table 4); 'had' to 'was' (pg. 15); 'Appendix' to 'Appendix 10' (pg. 23); 'Error! Reference source not found' to 'Table 12' (pg. 24); 'is' to 'was' (pg. 26); 'h' to 'ha' (pg. 26); 'environmental' to 'environment' (pg. 34); 'Error! Reference source not found' to '4.2' (pg. 49); 'MWOO' to 'PBDE' (pg. 50); 'needs' to 'needed' (pg. 54); PBDE19 to PBDE10 (pg. 87)
- pg. 1 – revised 'ceased' to 'was revoked, with the use of MWOO on plantation forests and mining rehabilitation land ceased until further controls could be considered'
- pg. 13 – revised 'A list of the samples and the sample codes' to 'A de-identified list of the samples actually collected'
- pg. 14 heading – revised 'AND EVENTUAL USE' to 'AND USE OF DATA BY THE PANEL'
- pg. 44 Table 21 – revised '41.2' to '14.2'

Addenda

- pg. i – added 'The version reviewed by the Panel was the draft interim HHERA (Report Reference NSWEPA/18/AWT001; Revision A-Draft; Dated 11 October 2018).
- pg. 1 – added 'and subject to certain conditions' and 'only'
- pg. 2 – added 'the formation of a Technical Advisory Committee (TAC) convened by the EPA to review the research and provide recommendations'
- pg. 2 footnote – added 'This report is based on the draft interim HHERA (Report Reference NSWEPA/18/AWT001; Revision A-Draft; Dated 11 October 2018) watermarked as 'DRAFT'.
- pg. 5 added 'approximately' and 'additional studies'
- pg. 8 – added 'Table 3 provides an overview of the terms used in Equation 1 and their equivalence terms in the draft HHERA. Further information is also provided in Appendix 9'.
- pg. 11 Table 5 – added 'Resource Recovery'
- pg. 22 – reference added (NSW EPA, 2018b)
- pg. 30 – added 'to grazing cattle'
- pg. 47 – added 'derived' to table heading

Corrigendum

- throughout document – Clarified the Panel's work and report is based on the report entitled 'Human Health Risk and Ecological Risk Assessment Report' by Environmental Risk Sciences, NSWEAP/18/AWT001, Revision A – Draft, 11 October 2018. Referred to as 'draft interim HHERA' as appropriate.
- throughout document – AWT facility information and sample identifiers have been de-identified or removed
- pg. 2 Table 1 – removed 'predominately' and 'own mine'
- pg. 2 – removed 'Technical Advisory Committee' and 'convened by EPA'
- pg. 13 – removed 'A member of the Panel and a member of the secretariat attended an MWOO sampling visit to observe proceedings'.
- pg. 14 footnote – changed 'are' to 'were'
- pg. 20 – removed 'footnote'
- pg. 25 – removed 'Applying Choate (et al) to MWOO in Sydney Basin soil'
- pg. 29 – removed 'undertaken by EnRiskS in 2018'

Office of the Chief Scientist & Engineer

Mr Mark Gifford
Acting Chair and CEO
Environmental Protection Authority
PO Box A290
SOUTH SYDNEY NSW 1232

Dear Mr Gifford

Report – Independent Scientific Review Panel on Soil and Chemistry

In October 2018, the then Acting Chair and CEO of the EPA wrote to the Chief Scientist & Engineer requesting that the Office of the Chief Scientist & Engineer form an independent Scientific Review Panel to advise on further sampling and testing of Mixed Waste Organic Outputs (MWOO), and advise on additional scenarios that could be modelled through a Human Health and Environmental Risk Assessment (HHERA) methodology considering the half-lives of polybrominated diphenyl ethers (PBDEs) in soil, soil ingestion and bioaccessibility/bioavailability.

This report provides the outcomes of the work of the Panel and proposes some values that can be incorporated in a HHERA.

I would like to acknowledge the work of the Panel, staff in laboratories and facilities that undertook analyses, and the secretariat in OCSE in undertaking this project and drafting the report.

Yours sincerely

Dr Chris Armstrong PSM
Deputy NSW Chief Scientist & Engineer

20 May 2019

EXECUTIVE SUMMARY

On 19 October 2018 the Acting Chair and CEO of the NSW Environmental Protection Authority (EPA) requested the Office of the NSW Chief Scientist & Engineer to establish an Independent Scientific Review Panel on Soil and Chemistry (the Panel) to provide advice on assumptions that had been used in the development of the draft interim Human Health and Ecological Risk Assessment: Application of Alternative Waste Technologies Materials to Agricultural Land (the draft interim HHERA) commissioned by the EPA in 2018. The version reviewed by the Panel was the draft interim HHERA (Report Reference NSWEPA/18/AWT001; Revision A-Draft; Dated 11 October 2018).

Mixed Waste Organic Outputs

A number of commercial operators have manufactured Mixed Waste Organic Outputs (MWOO) material, which is prepared and stored in facilities over a number of weeks. The preparation process may include: mixing, sieving, milling, magnet extraction, composting, and pasteurisation. This produces a matrix of fine material with particles of metal, plastic and glass mixed throughout. This material had been placed on certain types of agricultural land until October 2018 under an EPA Resource Recovery Exemption at a maximum permissible rate of 10 tonnes per hectare (t/ha), and on mining sites at a rate of 140 t/ha. A range of application restrictions were applied under the Exemption.

Previous analyses

In 2011 the EPA commissioned a Research Program to understand the benefits and risks of the application of MWOO to soils. The program results were assessed by a Technical Advisory Committee convened by the EPA and reported its findings in 2018. Following receipt of this report, the EPA commissioned the interim HHERA, which focused on hazardous chemicals that may be present in MWOO that were classified as high or very high priority, including polybrominated diphenyl ethers (PBDEs).

In undertaking an assessment on the human health and ecological risk, the interim HHERA drew on values from the Research Program, values in expert literature and technical guidelines for inputs into calculations to estimate a hazard index for adults and children from exposure to PBDE in MWOO. The interim HHERA was undertaken in accordance with guidelines used by Australian environment and health agencies, including the National Environment Protection (Assessment of Site Contamination) Measure 1999 and Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards. In accordance with these guidelines, the interim HHERA addressed potential worst case exposure to the chemicals likely to provide a conservative or overestimate of exposure and risk.

As explained in the enHealth guidelines, an accumulation of worst-case exposures is often worse than any remotely plausible case because it represents an extreme set of conditions that are unlikely to be observed in actual populations. The Panel was tasked with providing advice on specific assumptions used in the HHERA relating to PBDE. This request to the Panel included undertaking further sampling and measurements and assessing the outcomes to provide input to the HHERA modelling assumptions.

The approach of the interim HHERA was to calculate a hazard index (HI) for the contaminant. The HI is the sum of a set of hazard quotients (HQ), specific to each identified exposure pathway. The request to the Panel was to provide additional information that could be used as inputs into the HHERA and its HQ for an ingestion pathway associated with cattle in relation to ingestion of PBDE. Other exposure pathways, foods and chemicals are not considered in this report.

Studies undertake by the Panel

The new information requested of the Panel included providing a better understanding of PBDE distribution in MWOO, PBDE half-life in soils, soil ingestion by cattle, and bioaccessibility of PBDE in cattle. To ensure the information and data provided by the Panel was useful and able to be interpreted, the Panel endeavoured throughout each step of the project to employ rigorous statistical treatments.

A suite of laboratory and literature studies was commissioned or undertaken by the Panel to provide clarity on the assumptions in question, and values used in the HHERA for the cattle exposure pathway. The experiments and analyses have been designed to model more closely the application and interactions of MWOO with a farm environment, and the exposure pathway of the relevant PBDEs from the paddock to beef.

The Panel has made best efforts to develop and commission studies, and analyse literature and results to ensure the scientific integrity of the work, and provide results that are statistically meaningful and useful.

Work commissioned or undertaken included:

1. Establishing a sampling methodology, obtaining samples from all five facilities.
2. Processing these samples to ensure appropriate mixing and conditions for further analyses.
3. Characterising plastic particles, noting size and density influence their passage through the exposure pathway, and reviewing the literature on how characteristics influence leachability.
4. Undertaking accelerated toluene extraction of samples to measure the mass of PBDE in samples of MWOO and statistical analyses of results.
5. From a selection of these characterised samples, running a set of leaching studies that mimic a ruminant gastrointestinal tract, and a set that mimics environmental conditions in a field.
6. Undertaking kinetics experiments for both leaching studies.
7. Measuring the PBDE content of the sorption sinks used in the leaching experiments and undertaking statistical analyses of results.
8. Undertaking mass distribution studies on three sets of samples that included measurement of PBDE on the sorption sink, in the GI fluid and in residual MWOO to determine whether the kinetics are rate limited by desorption from the MWOO or adsorption to the sink.
9. Undertaking literature reviews on the ingestion dynamics of ruminants to understand the exposure pathway conditions for the MWOO and plastic in the paddock and the ruminant.

The Panel's report is structured to reflect the HQ equation:

$$Q_h = \frac{\gamma_{\mathrm{PBDE}} f_{\mathrm{dil}} m_{\mathrm{soil}} \beta f_{\mathrm{home}} t_{\mathrm{home}} \tau m_{\mathrm{meat}} t_{\mathrm{meat}}}{h m_{\mathrm{body}} \chi_{\mathrm{tox}} (1 - f_{\mathrm{back}})}$$

The report concentrates effort on developing values for the following terms of the equation: $\gamma_{\mathrm{PBDE}} \times \beta$, being the bioaccessibility of PBDE mobilised from the MWOO; f_{dil}, the dilution factor of MWOO in soil; τ, the transfer factor and m_{soil}, the mass of soil ingested per day.

($\gamma_{\mathrm{PBDE}} \times \beta$) bioaccessibility of PBDE mobilised from MWOO

As noted above, the Panel undertook a number of studies to assess the bioaccessibility of PBDE, particularly in the ruminant GI tract. Early results from these studies suggested there wasn't a correlation between the total mass of PBDE in MWOO (toluene extraction) and the amount of PBDE bioaccessible as measured using aqueous leaching experiments to model cattle GI tract. Instead, PBDE levels extracted were relatively constant between samples and

not reflecting the high concentrations measured in some accelerated solvent extraction experiments in toluene. To confirm this, the Panel undertook a mass distribution study which showed that the bulk of PBDE remained unextracted from the MWOO and any extracted PBDE was transferred efficiently through the GI extractant (liquid) into the silicon cord phase, which represented the GI tract lining. The results supported the understanding that the experiments were extraction-limited.

Based on this knowledge the Panel then calculated the bioaccessible component of PBDE mobilised ($\gamma_{PBDE\ x}\beta$) by first using a first-order kinetic model, to determine the maximum accessible mass of PBDE from the results of the ruminant kinetic study, and then using the 24 hour absorption (ruminant leaching) experiments and adjusting for time, the bioaccessible mass of PBDE was compared to the total PBDE values from the equivalent toluene experiments from eight samples (where both toluene and aqueous data were available). These data were then used to establish a model of bioaccessibility as a function of the total PBDE from the toluene total mass studies.

The bioaccessibility of the remaining 41 toluene extracted samples with lognormally-distributed total PBDE contents were calculated from the modelled bioaccessibility from the ruminant model studies. Given the observation that the available PBDE in unground MWOO was approximately constant and independent of the total PBDE content, a mean bioaccessible content was calculated as 236 ng/g (*s* 72 ng/g) for PBDE Br3 to Br9, and 361 ng/g (*s* 145 ng/g) for PBDE Br10. For the purposes of an HHERA, this value represents ($\gamma_{PBDE\ x}\beta$), being the bioaccessible mass of PBDE.

The results in this study demonstrate that when estimating the mass of PBDE that would be accessible to cattle from MWOO, measurements of PBDE from accelerated solvent extraction using toluene should not be used on their own. The calculation of bioavailable PBDE should be based on leaching experiments in aqueous conditions that reflect the environment of the material *in situ*. The mobilisation of PBDE from MWOO in aqueous media is limited by a range of factors including the hydrophobicity of the PBDE molecules and the role of the plastic particles themselves encapsulating the PBDE within them. In an accelerated solvent extraction process using toluene, these factors are overcome, meaning the mass of PBDE mobilised is greatly enhanced and accelerated. In the experiments described in this report, the mass of PBDE that mobilises from MWOO is extraction-limited and sits within a relatively low and narrow mass band.

τ transfer factors

The Panel investigated the use of the Tanimoto Similarity Coefficient to assess similarity between PBDE Br3 to Br 9 and PCB congeners. The Tanimoto Similarity Coefficient suggested the congeners to be different and the Panel could draw no meaningful correlation. The Panel also sought to determine whether there was a correlation between τ and log k_{ow} values for Br3 to Br 9 PBDEs and PCBs and related molecules. However, no meaningful correlation was found.

The Panel then adopted the approach used in the draft interim HHERA for Br10 ($\tau = 0.02$), and for Br3 to Br9 calculated a weighted average for PBDE congeners present in MWOO using the τ for the corresponding PCB. The weighted average of τ for Br3 to Br9 was calculated for all 49 MWOO samples analysed in this study using accelerated solvent extraction with toluene and a mean (0.53) and standard deviation (0.12) calculated.

m_{soil} mass of soil ingested per day

The Department of Primary Industries (DPI) assisted the Panel by undertaking a review of cattle exposure to MWOO via soil ingestion. The review identified that there has been no research conducted in Australia on soil ingestion by cattle. Variable ingestion rates were identified in the literature; with the 2.4 kg/day value (from an overseas study) used in the draft interim HHERA sitting at the extreme end of the reported range and representing a

temporary peak within a season. DPI recommended a revised rate of 0.5 kg/day, which is similar to recommended ingestion rate in other international guidelines for risk assessments.

f_{dil} dilution factor of MWOO in soil

The Panel considered a number of factors potentially affecting the dilution factor of MWOO in soil. These included the ingestive behaviour of cattle, the potential for MWOO to adhere to plants (above ground plant material) and roots, and the mixing of MWOO in the field. The manner in which cattle graze means they are only likely to ingest soil incidentally, mainly due to soil adherence to plants or roots. Soil adherence to plants appears to be influenced by their size, with soil particle sizes of less than 0.125 mm being retained on plants. For roots, both particle size and particle type influence adherence. Clay particles are more likely to adhere than coarser sized particles, including plastic particles of a given particle size.

Using the information from experiments on particle size in MWOO, the information on adherence and assuming an application at a rate of 10 t/ha, the Panel found dilution factors range from 12.6 to 130. The range depends on whether the MWOO is mixed with the soil and if the MWOO adheres to plant or roots. Based on this finding, the Panel recommend a dilution factor of 12.6 be applied.

Application rates are also relevant to calculating the dilution rate. The review undertaken by DPI considered this, interrogating industry records of delivery and use, and matching these with property stock data to estimate the likely time cattle were grazed on MWOO treated land. Based on this analysis, it was estimated that cattle were likely to be on MWOO treated land 52 days per year.

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1 INTRODUCTION

1.1 MIXED WASTE ORGANIC OUTPUTS

Mixed Waste Organic Outputs (MWOO) is a soil amendment made with the organic material in household general waste (NSW EPA, 2018b). It is made by first removing as much of the non-organic material as possible. The organic material is then processed by mixing, sieving, milling, magnet extraction, composting, pasteurisation and biological stabilisation.

Under the NSW Environment Protection Authority's (EPA) Resource Recovery Exemption *The organic outputs derived from mixed waste exemption 2014* (NSW EPA, 2014a) and subject to certain conditions, MWOO could only be applied to:

- broad acre agriculture at an application rate of no more than 10 t/h (dry weight) in total to a given location – excluding land used to keep/breed poultry or pigs, root crops, and vegetables or crops where the harvested parts touch the ground or are below the surface of the land
- non-contact agriculture at an application rate of no more than 50 t/h in total to a given location – defined as lands used for the growing of fruit or nut trees or vines but not where fallen produce is or may be collected from the ground
- plantation forestry at an application rate of no more than 50 t/h in total to a given location
- mine sites at an application rate of no more than 140 t/h (dry weight) in total to a given location – defined as including land disturbed by mining on which rehabilitation is being carried out.

MWOO application was restricted to soil with a pH of 5.0 or greater (measured in a 1:5 soil:water extract) and a land slope not exceeding 18% (NSW EPA, 2014a). Buffer zones were defined for where MWOO could not be applied to land within a certain distance of surface waters, drinking water bores and other bores. Other restrictions included:

- no grazing of animals within 30 days of application
- no grazing of lactating and new born animals within 90 days of application
- not harvesting crops for at least 30 days after application.

In October 2018, the exemption for application of MWOO on agricultural land was revoked, with the use of MWOO on plantation forests and mining rehabilitation land ceased until further controls could be considered (NSW EPA, 2018b).

1.1.1 NSW MWOO production facilities

There are five alternative waste treatment (AWT) facilities producing MWOO in NSW (Table 1). MWOO material is prepared and stored in facilities over a number of weeks. The process produces a matrix of fine organic material with particles of metal, plastic and glass mixed throughout.

Table 1: MWOO production facilities in NSW

Facility	Broad-acre agriculture	Mine sites
Facility A	√	√
Facility B		√
Facility C	√	
Facility D	√	√
Facility E		√

1.2 BACKGROUND TO THE ESTABLISHMENT OF THE PANEL

The establishment of the Panel was preceded by a multidisciplinary program of research, the formation of a Technical Advisory Committee (TAC) convened by the EPA to review the research and provide recommendations and a draft interim human health and ecological risk assessment (HHERA)[1] commissioned by the EPA.

1.2.1 NSW Environment Protection Authority's Research Program

In 2011, the EPA initiated a Research Program (the Research Program) on the risks and benefits of applying MWOO to land in NSW. The Research Program included:

- assessing the impacts of physical contaminants in MWOO on the soil environment
- a field evaluation of MWOO for use as a soil amendment
- characterising leachate from MWOO including toxicity
- assessing the effect of application of MWOO on different soil types.

The overall outcomes and conclusions from the Research Program were assessed by a TAC. Key findings of the TAC review of the Research Program included:

- the use of MWOO on broad acre agricultural land at the current application rate could not be classified as beneficial reuse for improving crop production nor has beneficial effects on soil chemical or physical properties (NSW EPA, 2018a)
- if higher application rates were used to achieve beneficial reuse, there is the risk of greater contamination of soils by metals, persistent organic chemicals and physical contaminants (NSW EPA, 2018a)
- based on current application rates for broad acre agriculture, there is a concern for human and environmental health from some contaminants including polybrominated diphenyl ethers (PBDEs) (NSW EPA, 2018a).

A number of recommendations relating to the management of its use and the need for further research were made by the TAC. In addition, the Research Program identified a number of chemicals of concern, both in respect to human health and ecology (Table 2) (NSW OEH, 2016).

[1] This report is based on the draft interim HHERA (Report Reference NSWEPA/18/AWT001; Revision A-Draft; Dated 11 October 2018) watermarked as 'DRAFT'.

Table 2: Summary of chemicals categorised as high and very high priority

Solid Material		Leachates			
Ecological	**Human Health**	**Ecological**	**Human Health**	**Livestock drinking water**	**Irrigation water**
Aluminium*	PBDEs*	Aluminium*	Antimony	Copper	Copper
Copper		Barium	Arsenic		Iron
Manganese*		Cadmium	Cadmium		Manganese
Zinc		Chromium*	Lead		Molybdenum
Phenol*		Cobalt	Nickel		Nickel
Bis-2-ethylhexyl adipate		Copper*			Dicamba (herbicide)
Bis-2-ethylhexyl phthalate		Iron			Phosphorus
Dibutyl phthalate*		Lead			
Bisphenol A		Mercury			
Dibutyl tin		Nickel			
Penta-BDE*		Tin			
		Zinc*			
		Sulfate			
		Sulfide			
		MCPA			
		Ammonia			
		Nitrate			
		Phosphorus*			

* Identified as very high priority
Source: (NSW OEH, 2016)

1.2.2 Draft interim human health and ecological risk assessment

To address the chemicals of concern to human health and ecology, the EPA commissioned EnRiskS to conduct a HHERA on the chemicals listed in Table 2. The draft interim HHERA was undertaken in accordance with guidelines and protocols used by Australian environment and health agencies, including:

- Environmental Health Risk Assessment, *Guidelines for assessing human health risks from environmental hazards* (enHealth, 2012b)
- Australian Exposure Factor Guide *Guidelines for assessing human health risks from environmental hazard*s (enHealth, 2012a)
- National Environmental Protection (Assessment of Site Contamination) Measure (NEPC, 2013a).

The draft interim HHERA found that for most of the chemicals listed in Table 2 and for per- and polyfluoroalkyl substances (PFAS), the risk due to the chemicals present in the soil or leachate is low and acceptable (EnRiskS, 2018). The only exception to this was polybrominated diphenyl ethers (PBDEs) for farmers consuming their own produce (EnRiskS, 2018).

In response to the outcomes of the Research Program, the TAC recommendations, and the interim HHERA, the EPA stopped the use of MWOO on agricultural land and ceased its use on plantation forests and mining rehabilitation until further controls could be considered (NSW EPA, 2018b). The EPA requested that further work be undertaken by an independent scientific panel convened by the Office of the Chief Scientist & Engineer (OCSE) (NSW EPA, 2018b).

1.3 ESTABLISHMENT OF THE PANEL

The draft interim HHERA assumed worst-case scenarios with conservative assumptions, and noted that "*Uncertainty in any assessment refers to a lack of knowledge (that could be better defined through the collection of additional data or conduct of additional studies) and is an important aspect of the risk assessment process*" (EnRiskS, 2018). Further, the Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards also states that *"There is a need for caution when applying the concept of 'worst-case exposure'. These exposures are often based on the accumulation of a range of unlikely but individually plausible scenarios. Such worst exposure cases are often worse than any remotely plausible case because they can represent a 'hypothetical individual and an extreme set of conditions [that] will usually not be observed in actual populations' (US EPA 1992 p. 22901)." (*enHealth*, 2012b)*

To address this need for additional data the EPA requested the OCSE to establish a Panel to provide advice on the presence of PBDEs in MWOO, in particular:

- the validity of doing further testing on MWOO samples collected and stored from the Research Program
- the validity (and approach) to further sampling of MWOO at AWT facilities and then testing those samples
- the appropriateness (and approach) of undertaking soil sampling at sites where MWOO has been applied
- the inputs that could be modelled through the HHERA methodology considering such variables as:
    - distribution of PBDEs in MWOO
    - half-life of PBDEs in soils
    - soil ingestion by cattle (particularly in drought)
    - bioaccessibility/bioavailability of PBDE in cattle.

The Panel was also requested to provide guidance in statistical significance and confidence intervals for data where possible.

1.3.1 Panel composition

The Panel was established in late October 2018 and consisted of:

- Dr Chris Armstrong (Chair), Deputy Chief Scientist & Engineer
- Associate Professor Cameron Clark, School of Life and Environmental Sciences, The University of Sydney – expert in the field of ruminants
- Emeritus Distinguished Professor Paul Haddad, University of Tasmania – expert in the fields of analytical chemistry and separation science
- Emeritus Professor Brynn Hibbert, School of Chemistry, University of New South Wales – expert in the fields of analytical chemistry and chemometrics
- Professor Balwant Singh, School of Life and Environmental Sciences, The University of Sydney – expert in soil science and soil chemistry.

The Office of the NSW Chief Scientist & Engineer provided secretariat support to the Panel.

1.3.2 Panel process

The Panel met formally on approximately 25 occasions via teleconference over the course of the project.

The Panel commissioned a set of additional studies, reviews and analyses to better understand the issues and to enable it to provide the advice requested by the EPA. These additional studies have been undertaken by staff at the NSW Office of Environment and Heritage (OEH), the NSW Department of Primary Industries (DPI), the University of South Australia (UniSA) and the National Measurement Institute (NMI), with literature reviews and analyses also undertaken by Panel members.

2 CONCEPTUALISATION OF THE ISSUE AND WORK PROGRAM

To inform its approach, the Panel undertook an initial review of literature. It also held discussions with staff from the EPA and EnRiskS to better understand work undertaken previously, including the draft interim HHERA. This process led to the development of a work program, a key consideration being exposure pathways, as discussed below.

The Panel's work program required analysis of samples from multiple MWOO piles at multiple MWOO production sites that would have variations within and between them. The experimental approach employed by the Panel also included several sequential and parallel experimental steps. To manage this complexity and to ensure that the end result from the work would be sound, robust, able to be interpreted and useful, the Panel undertook a careful assessment of data, gaining a statistical understanding of the work and ensuring appropriate analytical and statistical tools were deployed. The Panel aimed to ensure that the sampling and analytical choices made at each stage would give an end product that met these soundness and utility requirements.

2.1 UNDERSTANDING POLYBROMINATED DIPHENYL ETHERS

PBDEs (Figure 1) are a group of 209 congener anthropogenic molecules some of which have been used as fire retardants in plastic products including polyurethane foam, textiles and electronic equipment (US EPA, 2010). Depending on the number (1-10) and location of bromine atoms on the two benzene rings, there are 209 possible PBDE compounds, or congeners. The diagram in Figure 1 illustrates the structure of the molecules with the two benzene rings bonded to an oxygen atom in an ether structure. Each benzene ring has five carbon atoms on which between 0 and 5 bromine atoms can attach.

The sites of location of the bromines to the rings will have implications for the chemical characteristics of the molecules including on debromination pathways.

The molecules absorb light in the environmental spectrum, up to ultraviolet light and may be susceptible to photodegradation, with the higher brominated molecules more susceptible to photolysis than the lower brominated congeners (ATSDR, 2017).

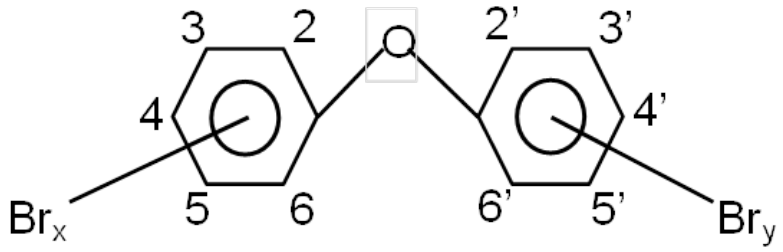

Figure 1: Polybrominated dephenyl ethers have a common structure with between 1 and 10 bromine atoms attached to the two benzene (phenyl) rings , so that x + y = 1 to 10.

Not all congeners are found in product formulations, environmental media or exposure media, and many congeners are not stable. The common formulations used in industry were (Redfern et al., 2017):

- the ‘deca-BDE mixture’, which included deca-BDE (Br10) and nona-BDE (Br9)
- the ‘octa-BDE mixture’, which contained deca, nona, octa, hepta and hexa
- the ‘penta-BDE mixture’, containing hexa, penta, tetra and tri-BDE.

2.2 PREVIOUS MWOO ANALYSIS – PBDEs

The Research Program analysed PBDEs in MWOO from two facilities in 2013 and 2014 (NSW OEH, 2014). A preliminary analysis of these results appears to indicate that the results are within a log normal distribution, with the highest value being a statistical outlier. Further observations about outliers appears in Section 6.7.4.1 and Appendix 5, which describe the statistical analysis of both the ‘old’ data from 2013/14 and ‘new’ data recollected and analysed for this study, including descriptions of how and where data can be compared.

The Panel decided that further analysis of MWOO from all facilities was needed to better understand the concentrations and distribution of PBDEs in MWOO. This would also provide a baseline to compare against any work undertaken in respect to bioaccessibility.

An early consideration for the Panel was the analytical methodology used in the Research Program to extract and analyse PBDEs, and how this related to the level of PBDEs that would be mobilised in a soil or gastrointestinal setting. The method is described in Section 4.1, and involves accelerated extraction using toluene under heat and pressure. The aim of the extraction method is to measure the total mass of PBDEs, including that held within plastics. The approach is more aggressive than potential leaching in soil in the terrestrial environment or in the ruminant gastrointestinal setting, and therefore the mass of PBDEs extracted with toluene was presumed to be greater than would occur in aqueous solution at atmospheric pressure and near room temperature. The work conducted in the present study aimed to test this hypothesis. The toluene extraction results from the 2013/14 samples had formed the basis of the draft interim HHERA values for PBDEs.

2.3 EXPOSURE PATHWAYS

An important aspect of the development of a HHERA is the conceptualisation of the exposure pathways of the chemical or pathogen to the human receptor (enHealth, 2012b). The following exposure pathways for MWOO are relevant:

1. application of MWOO to agricultural or mining sites
2. uptake of MWOO or liberated components (in this case PBDE congeners) from the field (located on soil, in soil or on leaf) into a grazing animal or into a plant
3. extraction of PBDEs from MWOO and mobilisation in the gastrointestinal (GI) tract to the inner wall of the GI tract
4. absorption through the GI wall and release to the circulatory system, transport and deposition into an organ, milk or tissue of the ruminant
5. a person then consuming the meat, milk or other tissues would then be exposed. The quantity that the person is exposed to is related to the quantity of the food product that they consume and the concentration of the PBDEs contained in the portions consumed.

For the purposes of the work of this Panel, the pathway components 1, 2, 3 are the main focus with some discussion of 4 in the context of transfer factors and bioavailability.

2.4 HAZARD QUOTIENTS

The work of the Panel focussed on developing values for inclusion in a HQ for an ingestion pathway associated with cattle products, and only deals with ingestion of a single family of chemicals, namely PBDEs. Other exposure pathways, foods, animals and chemicals are not considered in this report, nor are risks to environmental flora and fauna.

In order to provide a clear overview of the set of experiments and studies undertaken, and how they contribute to a HHERA, the Panel elected to present its program of work and this report with a structure that reflects the variables and inputs into the HQ equation (Equation (1)). This approach assists in explaining the variables and statistics generated in the studies and how each of the study components fits together. Table 3 provides an overview of the terms used in Equation 1 and their equivalence terms in the draft interim HHERA. Further information is also provided in Appendix 9.

$$Q_h = \frac{\gamma_{\mathrm{PBDE}} f_{\mathrm{dil}} m_{\mathrm{soil}} \beta f_{\mathrm{home}} t_{\mathrm{home}} \tau m_{\mathrm{meat}} t_{\mathrm{meat}}}{h m_{\mathrm{body}} \chi_{\mathrm{tox}} (1 - f_{\mathrm{back}})} \qquad \textbf{Equation 1}$$

Table 3: Terms used in Equation (1)

Symbol	Description	Unit	Equivalence draft interim HHERA
Q_h	hazard quotient	1	*HQ*
γ_{PBDE}	PBDE content bioaccessible from MWOO	mg kg^{-1}	[1]
f_{dil}	dilution factor	1	[1]
m_{soil}	mass of soil ingested by cow per day	kg d^{-1}	*IRsoil*
β	bioaccessibility ratio	1	B
f_{home}	fraction of diet from home	1	FHG
t_{home}	time exposed to diet per year	d y^{-1}	EF
τ	transfer factor	d kg^{-1}	transfer factor (no symbol)
m_{meat}	ingestion of meat per day	kg d^{-1}	*IRmeat*
t_{meat}	total time exposed to diet	y	ED
h	averaging time for exposure for a threshold contaminant	d	AT
m_{body}	body mass	kg	BW
χ_{tox}	tolerable daily intake	mg kg^{-1} d^{-1}	TDI
f_{back}	background intake factor	1	-

[1] Draft interim HHERA assumed MWOO mixed with soil to a depth of 10cm and assumed dilution x100

The approach taken in the draft interim HHERA was to separate the PBDE congeners into two groups, those with 3 to 9 bromine atoms (represented as Br3 – Br9), and the other for the single congener with 10 bromine atoms (Br10, congener 209). It is noteworthy that the NEPM Assessment of Site Contamination 2013 also considers the PBDE Br3 to Br9 congeners distinctly from PBDE Br10 (NEPC, 2013b).

Examining the components of Equation 1, the numerator brings together a set of terms that reflect the amount of PBDE ingested, how much of that appears in the meat and then how much meat the person eats:

- the mass of PBDE taken up in a soil/MWOO mixture by a cow (γ_{PBDE}) (f_{dil}) (m_{soil})
- the bioaccessibility (β), which represents the ratio of the mass of PBDE that would mobilise from the matrix (MWOO) in the cow's GI tract becoming accessible to ingestion, such as by absorbing to the gut wall, against the total PBDE mass in MWOO. Typically bioaccessibility is expressed as a ratio. The work by the Panel

is providing guidance as to the actual amount of PBDE mobilised in the GI tract and thereby accessible for absorption in the GI tract
- the mass of PBDE under steady state conditions that transfers from the animal's consumption of MWOO to the meat - a transfer factor or transfer coefficient (τ), which is a value inferred from experiments and represents the ratio of contaminant concentration in fresh weight animal product to the daily intake of the contaminant by the animal at a steady state
- a set of four terms that relate to the consumption by the person of the meat, including the amount of meat and timeframe-related terms – this information is brought together by the authors of the HHERA and not considered further in this report.

As noted, gaining a better understanding of the values in the first three points in this numerator list comprises the main focus of the work undertaken by the Panel and material presented in the report.

The denominator brings together terms that reflect:

- the body mass of the person ingesting the meat
- variables that reflect the toxicity of the substance including an averaging time for exposure, which is dependent on whether the substance is a threshold or non-threshold contaminant (h) and also the reference value of the toxicity of the substance, typically referred to as tolerable daily intake (χ) adjusted for other possible background exposures for the substances.

The denominator values are brought together by the authors of the HHERA and not considered further in this report.

Some of the values in Table 3 and Equation 1 are constants or are an assumed or accepted standard quantity (e.g. mass of child = 15 kg), whereas other values can vary depending on the site, situation or chemical being assessed (e.g. γ_{PBDE}). The majority of the effort and the work described in this report relates to the terms in Table 4.

Table 4: Parameters used in Equation 1 that will be the subject of further analysis in the remainder of the report

Mass soil/MWOO taken up by cow	m_{soil}	mass of soil ingested by cow per day	Chapter 5
	f_{dil}	dilution factor	Chapter 5
	γ_{PBDE}	PBDE content bioaccessible from MWOO	Chapter 4
Bioaccessibility	γ_{PBDE}	PBDE content bioaccessible from MWOO	Chapter 4
	β	bioaccessibility	Chapter 6
Steady state transfer from MWOO to meat	τ	transfer factor	Chapter 6

2.5 WORK PROGRAM

Having regard to the exposure pathway elements and the requested advice, the Panel identified the following issues as relevant:

- application of MWOO in the field (amount of MWOO in paddock)
- livestock access to MWOO-treated field (used to determine the mass of PBDEs in cattle)
- soil ingestion by cattle (used to determine the amount of PBDEs in cattle)

- route of transport of soil from field to cattle (used to determine dilution of PBDE in soil)
- plastic in MWOO (density and size fractions used to determine amount of PBDE available in the GI tract)
- PBDEs in MWOO (used to determine amount of PBDE available in the GI tract)
- PBDEs leached from MWOO and bioaccessibility (measure of the amount of PBDE solubilised in the GI tract that can potentially be absorbed into blood)
- transfer factor (ratio of the amount of PBDEs in beef meat over the amount available in cattle GI tract/food)

Details of the program are summarised in Table 5.

This report provides details of the activities undertaken to address the work program, which includes:

- the presence of PBDEs in MWOO
- review of particles present in MWOO
- the potential presence of PBDEs in soil due to the use of MWOO – the Panel addressed this through modelling of PBDE in soil and the potential uptake in cattle.
- the potential ingestion of MWOO (and PBDEs) by ruminants which includes
    - soil ingestion rates
    - route of soil ingestion by ruminants
    - residence time of ingested material in ruminants
- bioaccessibility of PBDEs both in the environment and in ruminants
- half-life of PBDEs in soil.

Many of these activities are interrelated. For example, adherence of particles in soil to plants, and in turn their ingestion by ruminants, is dependent on the size of the particles. Particle size and also particle density influence the residence time within the GI tract of ruminants and therefore influence the time over which PBDEs may be leached from the ingested material in the GI tract, thereby influencing the amount that is bioaccessible. Therefore, it is important that the report is read in its entirety as explanations of the different concepts appear sequentially.

Table 5: Work program summary

Program	Aim	Reasoning
PBDEs and plastic in MWOO	To provide further guidance on the PBDEs and plastic content in MWOO	To provide further information on the presence of PBDEs in MWOO
		To understand the contribution pieces of plastic may be making to the total PBDEs present in MWOO
		To assist with understanding the potential residence time of plastic in the gastrointestinal tract of cattle
		To assist with understanding the leachability of PBDEs in plastic in the gastrointestinal tract of cattle
Concentration of MWOO in the soil	To examine the assumptions made in the draft interim HHERA (application rate based on Resource Recovery Exemption order)	To assist in understanding the potential amount of MWOO that might be ingested by cattle
Bioaccessibility	To examine the assumption made in the draft interim HHERA of 100% of PBDEs in MWOO is bioaccessible	To consider if 100% bioaccessibility of PBDEs in MWOO is valid and if not, to inform future work to better understand bioaccessibility. Literature review to look at leachability of PBDEs from plastic particles.
		To assess the leachability of PBDE from MWOO using an environmental extractant in order to determine whether PBDEs are likely to enter the environment and the food chain
		To provide a better understanding of the potential bioaccessibility of PBDEs in MWOO after ingestion by cattle
		To provide an understanding of the residence time of material in ruminant gastrointestinal tract
Soil ingestion by cattle	To examine the assumptions made in the draft interim HHERA (2.4 kg of soil per day)	Better understand background to assumption and assess any new data
Livestock exposure to treated pasture	To examine the assumptions made in the draft interim HHERA (access by cattle to MWOO-treated field 365 days per year)	Assess assumption
Half-life of PBDE in soil	To examine the assumptions made in the draft interim HHERA (no half-life, no decay)	Review any updated information

2.6 PANEL COMMISSIONED WORK: SAMPLE COLLECTION FROM MWOO PILES

Samples of MWOO were collected from all five AWT facilities (Table 1). For facilities producing broad acre agricultural material, it was proposed to collect 10 composite samples from one pile, with one composite sample taken from up to five other piles from both broad acre agricultural and non-agricultural MWOO.

2.6.1 Sampling procedure

To enable comparisons to be made, the sampling procedure used by the Panel was based on the sampling procedure employed in the Research Program and involved the following:

- At the facility, sample sites within the piles were chosen randomly
- The surface of the MWOO was removed using a metal shovel to expose MWOO within the pile
- Five grab samples were collected with a metal shovel. Grab samples were approximately 5 L and placed into individual polypropylene buckets (total 5 grab samples)
- A 2 L portion of each grab sample (obtained using a 2 L scoop) was transferred to another polypropylene bucket to form a 10 L composite sample
- The bucket with the composite sample was sealed and mixed by rolling.
- All sampling equipment was decontaminated using distilled water between sampling for each composite sample and stockpile
- At each facility, a blank (mulch) was taken to provide assurances of no cross-contamination from sampling equipment, including the polypropylene bucket
- A duplicate of one of the composite samples was also taken at each facility.
- All composite samples were labelled, chain of custody completed and sent to the OEH laboratories at Lidcombe NSW
- At the OEH laboratory, one subsample of the composite sample was taken from the composite bucket for coning and quartering
- After coning and quartering, between 150 - 400 g wet mass of the subsample was sent to the NMI laboratory for PDBE analysis
- The remaining composite sample was stored at the OEH laboratory for future analysis.

An illustration of the sampling commissioned by the Panel of an agricultural MWOO pile is at Figure 2.

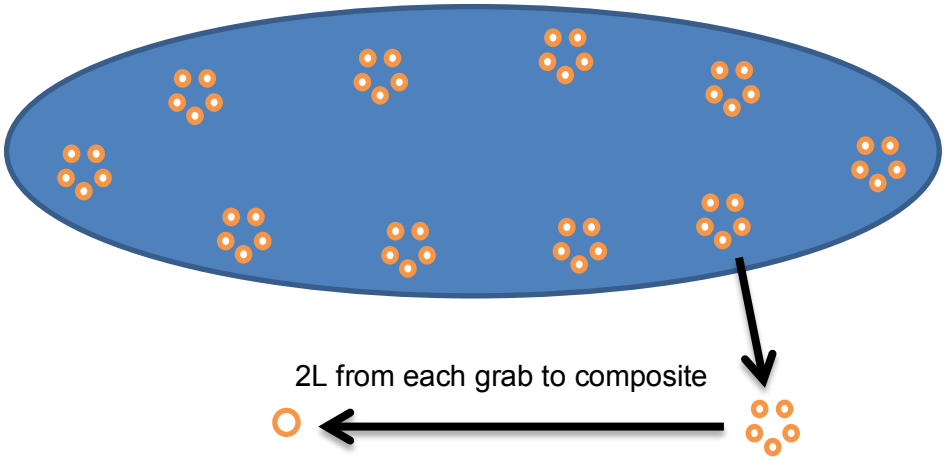

Figure 2: Example sampling for an agricultural MWOO pile

2.6.2 Samples collected

While every attempt was made to collect the samples as per the proposed methodology, the actual sampling was dependent on the MWOO available on the day of sampling. A member of the Panel and a member of the secretariat attended an MWOO sampling visit to observe proceedings.

A de-identified list of the samples actually collected is presented in Appendix 2. It should be noted that for each batch of samples, laboratory protocol was used whereby one sample was randomly chosen for duplicate analysis, which means that there are more results in the appendices than there are physical samples. The duplicate sample is noted in the appendices' tables.

3 MWOO PLASTIC PARTICLE CHARACTERISATION

The assumption that the PBDE-containing components of the waste stream are typically polymer or plastic materials, such as electronic products, means that the characterisation of plastics in MWOO was relevant for the Panel. The processing steps of MWOO result in plastic fragments being present in the end product. The size and specific gravity of plastic particles influences the exposure pathway for PBDEs contained in MWOO. This is discussed in Sections 5.3 and 6.6 in terms of potential attachment to plant material, residence time in the ruminant GI tract, and also the rate of extraction of PBDEs from particles of differing size in the GI tract. This Chapter sets out the procedures and results of experiments undertaken to characterise plastic particles contained in MWOO.

The Panel requested the OEH laboratory to undertake a number of studies to characterise the particles, particularly plastic particles (where possible) present in MWOO samples collected in 2018. The following analyses were undertaken:

- analysis of particle size[2] based on methods used previously(NSW EPA, 2014b)
- analysis of the size of particles of MWOO smaller than 2 mm
- distribution in MWOO of particles of rigid plastic greater than 2 mm
- density of plastic particles greater than 2 mm.

3.1 NOTE ON CHARACTERISATION EXPERIMENTS AND USE OF DATA BY THE PANEL

As will be discussed in later chapters (Chapters 5 and 6), cattle leaching experiments were undertaken over a 24 hour period to obtain a mass of PBDE extracted per gram of MWOO. The Panel therefore needed to develop an approach to multiply these results to account for residence time of MWOO in the GI tract longer than 24 hours as cattle ingest food for a longer time period. The methodology described in this chapter initially had a primary purpose of informing the determination of those multipliers. However, as the Panel proceeded through analyses and looking at the role of the transfer factor in the HHERA, it was evident a different approach was needed to develop the residence time multiplier. This was because:

a. the variability in particulate type, specific gravity and size

b. the gained understanding that transfer factors as they are used in HHERAs already take account of excretion.

The Panel then debated whether to remove this Chapter altogether, but it was felt pertinent to retain it to demonstrate its' approach and reasoning. There was also utility in considering the effect of grinding and not grinding of particulates (grinding is used in the HRGC/HRMS), and discussions about particulate size in relation to soil in Chapter 5. Overall however, it is less significant than other sections of the report.

[2] Note - under the requirements of the Resource Recovery Order, there were tests used to identify 'particle size' that are distinct from processes to test 'physical contaminants'. The reader should refer to (NSW EPA, 2014b) for more information. For the purposes of this report, 'particle size' simply refers to the size of particles in the MWOO sample, which could include particles of any size made from plastic, metal, glass, bark or other materials.

3.2 EXPERIMENTAL PROCEDURES

3.2.1 Particle size characterisation

3.2.1.1 Method for analysing particles in MWOO greater than 2 mm

Approximately 1 kg of sample was dried at 55°C to constant weight. The dried sample was passed through 16 mm, 5 mm and 2 mm sieves. The mass of material retained on the 16 mm sieve was measured. Flexible plastic >5 mm was physically sorted and weighed. Glass, metal and rigid plastic >2 mm was physically sorted and weighed. This analysis was undertaken on three samples: D2, D4 and D7. These samples were chosen as at the time the particle size experiment commenced, MWOO from this facility were the only samples where results for PBDE (toluene extraction) were available and the Panel requested the work to commence promptly. In consultation with the Panel, these three samples were chosen as representative of the range of PBDE results, being high (14,258 ng/g), mid-range (5559 ng/g) and low (1658 ng/g).

3.2.1.2 Method for analysing rigid plastic in MWOO greater than 2 mm

Rigid plastic separated as per section 3.2.1.1 that was >2 mm was isolated, by hand, from the samples. The rigid plastic was passed through 9.5 mm, 6.7 mm, 5.0 mm, 4.0 mm and 2.0 mm sieves. The mass of material retained on each sieve was measured. Plastic < 2 mm was not assessed due to the difficulties of visually inspecting and manually separating out such small particles. This analysis was undertaken on three samples: D2, D4 and D7 (see Section 3.2.1.1).

3.2.1.3 Method for analysing particles in MWOO (unground and ground)

To potentially assist with interpreting the leaching results for unground and ground[3] MWOO samples, analysis was undertaken to understand the size distribution of the smaller particles.

Approximately 20 g each of MWOO subsamples (unground and ground[3] subsamples of D4) were added to water to form slurries. Each slurry was passed through successively smaller sieves (2 mm, 1 mm, 500 µm, 250 µm, 125 µm, 63 µm and 38 µm) with water. The material retained on each sieve was transferred to a pre-weighed beaker. The sorted particles were dried at 105^{o}C, re-weighed and the percentage distribution calculated.

3.2.2 Methods used to determine the specific gravity of rigid plastic particles in MWOO

The rigid plastic fractions from the experiment on particle size distribution (Section 3.2.1.2) were recombined. To determine the ratio of plastic with a specific gravity below and above 1.0, all the rigid plastic was placed in a beaker with water. The particles that floated (specific gravity <1.0) were separated from those that did not float (specific gravity >1.0). The mass of each fraction was measured after drying.

To measure the average specific gravity of non-floating plastic, vials were filled with water up to a set mark. The non-floating plastic pieces were added, which increased the volume of water in the vial. A Pasteur pipette was used to remove the additional volume of water and then weighed. The specific gravity was then calculated.

A second experiment was undertaken on the same plastic particles to identify the amounts of plastics in the following specific gravity ranges: <1.1, 1.1-1.7, and >1.7. These values were chosen following a review of literature that suggested that plastic particles of specific gravities between 1.1-1.7 travel faster through the GI tract of ruminants compared to particles < 1.1 and >1.7. (Welch, 1982)

[3] The procedure for grinding samples is described in Section 4.1.1

Two salt solutions were prepared: 15 g NaCl was dissolved in 85 mL water to create a solution with a density of 1.1 g/cm^3 and 32 g $ZnCl_2$ was dissolved in approximately 20 mL water to create a solution with a density of 1.7 g/cm^3. The density of each solution was verified by weighing 10 mL of each salt solution.

For each sample, all rigid plastic >2 mm was added to the NaCl solution. Plastics that floated in this solution (specific gravity <1.1) were transferred to a pre-weighed aluminium dish. The plastics that did not float in the NaCl solution were transferred to the $ZnCl_2$ solution. Plastics that floated in the $ZnCl_2$ solution (specific gravity between 1.1-1.7) and plastics that did not float (specific gravity >1.7) were transferred to pre-weighed aluminium dishes. The dishes were dried at 40°C, reweighed and the percentage of each calculated.

3.3 RESULTS

The results from the different experiments on particle size and specific density are presented in Table 6 to Table 10. The results from the particle size distribution of unground and ground MWOO (Table 8) were also plotted (Figure 3).

The amount of rigid plastic particles >2mm appears to represent a small proportion of MWOO, being less than 0.23%. Most plastic particles >2mm fall within a range of 2 - 6.7 mm, with one sample having plastic particles >6.7 mm but <9.5 mm.

As expected, the process of laboratory grinding results in a change in particle size distribution. Prior to grinding greater than 80% of MWOO has a particle size >1mm, whereas after grinding close to 90% was <1 mm. Grinding also appears to result in a more even distribution across the different size fractions of <1 mm.

In respect to density, results from the first experiment showed that most rigid plastic particles (79 to 88%) had a specific gravity >1, with the average specific density of those plastic particles being 1.1 to 1.3. In the subsequent experiment, 75% to 80% of the rigid plastic had a specific gravity <1.1.

Table 6: Distribution of particles in MWOO greater than 2 mm

Sample Code	Particle size > 16 mm (all particles)	Flexible plastic > 5 mm	Glass, metal and rigid plastic > 2 mm
D2 (% w/w)	<0.1	<0.1	2.1
D4 (% w/w)	<0.1	<0.1	3.2
D7 (% w/w)	<0.1	<0.1	1.5

Table 7: Distribution of rigid plastic greater than 2 mm

Sample Code	Rigid plastic > 2 mm size distribution (% of rigid plastic > 2mm)					
	>9.5 mm	6.7-9.5 mm	5.0-6.7 mm	4.0-5.0 mm	2.0-4.0 mm	Total mass of rigid plastic > 2mm
D2 (%)	0	10	26	50	15	1.68 g (0.19% of total sample)
D4 (%)	0	0	20	27	53	2.28 g (0.23% of total sample)
D7 (%)	0	0	50	12	37	1.81 g (0.17% of total sample)

Table 8: MWOO particle size distribution for sample D4 – unground and ground

Size	>2000 µm	1000 - 2000 µm	500 - 1000 µm	250 - 500 µm	125 - 250 µm	63 - 125 µm	38 - 63 µm	<38 µm
Unground – fraction (%)	50	34	4.4	3.8	1.9	1.0	0.6	4.1
Ground – fraction (%)	0.2	10	19	20	15	10	6.0	20

Table 9: Specific gravity of plastic particles (greater than 2mm rigid plastic) using water

Sample Code	Status of rigid plastic	Ratio in water (% w/w)	Average specific gravity
D2	Floating	21	nd
	Non-Floating	79	1.3
D4	Floating	12	nd
	Non-Floating	88	1.2
D7	Floating	13	nd
	Non-Floating	87	1.1

Table 10: Percentage of rigid plastic greater than 2mm by specific gravity ranges (sodium chloride solution and zinc chloride solution)

Sample Code	<1.1 (%)	1.1-1.7 (%)	>1.7 (%)
D2	80	13	7
D4	75	10	15
D7	79	11	10

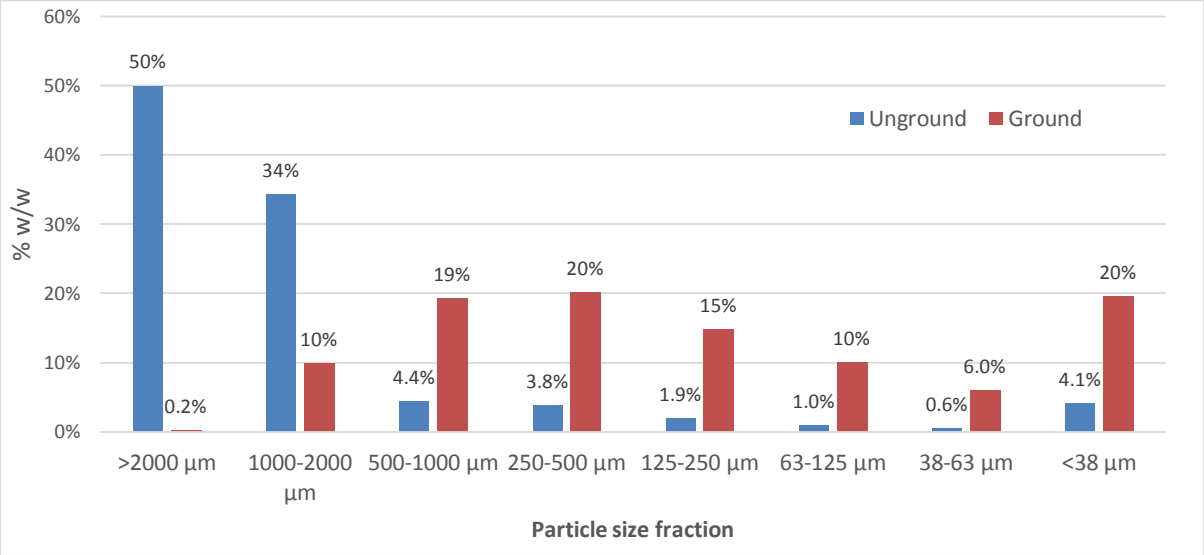

Figure 3: Particle size distribution of a ground and unground MWOO sample (D4)

3.4 DISCUSSION

If the PBDE in MWOO is associated with plastic, the size and specific gravity of plastic particles influences the exposure pathway for PBDE in MWOO.

The experimental work on rigid plastics from facility D showed that the rigid particles may be up to 9.5 mm, although the majority would be expected to be <6.7 mm. In respect to specific gravity, most of the rigid plastics have a specific gravity >1. With the results from the two experiments, it would appear that most rigid plastic from this facility had a specific gravity of between 1 and 1.2, although up to 15% may be as high as 1.7. However, it is noteworthy that some facilities employed a hammer milling processing step whereas others may not have, so it is difficult to ascertain how comparable the particle size fractions are between facilities.

The results from the unground and ground MWOO particle size distribution demonstrates what the expected outcome from a grinding process used in the NMI sample preparation protocol. That is, particle size decreases and a more even distribution of particle sizes is observed. This is considered further in relation to the results from both unground and ground MWOO in the leaching studies (Sections 6.5 and 6.6).

Of importance in interpreting the data and results in the following Chapters on the leaching experiments is that they were done on MWOO samples as applied to fields, and not on separated plastic fragments. Therefore, whether the PBDE is located in rigid or soft plastic, or fabrics, or whether the MWOO had been hammer milled or not does not impact the results – the PBDE that leaches from the unground MWOO sample is as would occur on the field or in the cattle GI tract as well as can be modelled. As noted in section 3.1, the Panel decided not to develop a multiplier for residence time based on density and size information but used an alternative approach which is set out in Section 6.7.

4 LABORATORY STUDIES TO CHARACTERISE PBDE CONTENT IN MWOO γ_{PBDE}

A suite of new analyses was performed on the newly collected MWOO samples to characterise the PBDE content. The first of these analyses was accelerated toluene extractions of samples to identify the total PBDE content of MWOO (γ_{PBDE}) which is a variable of Equation 1.

4.1 TOLUENE EXTRACTION FOR TOTAL PBDE CONTENT

4.1.1 Sample preparation

PBDE analyses were undertaken by the Australian Ultra Trace Laboratory at the National Measurement Institute (NMI) at North Ryde.

Accurately weighed masses of fifteen ^{13}C isotopically-labelled PBDE were spiked into each sample to act as internal standards.

Coarse solid samples were frozen in covered foil trays, and then freeze dried using a vacuum pump and condensation chamber until no significant off gassing was observed using a vacuum gauge below 0.1 Torr. The dry sample was then ground in a small rotary knife mill for 45 to 60 seconds and transferred into a hexane rinsed glass storage jar with Teflon lined lid for storage. Dried samples were extracted using Pressurised Solvent Extraction using toluene (1500 psi, 150ºC, two static cycles).

The grinding and freeze drying process is typically used in toluene extractions for HRGC/HRMS to maximise the extraction of materials and to remove water from the sample. As the toluene accelerated extractions of the MWOO were all freeze dried and ground, this meant that when ruminant leaching experiments were undertaken, these were also done on a set of freeze dried and ground samples. In addition to this, equivalent samples that were not ground were also run in the leaching experiments, and their moisture levels adjusted in the data treatment. These unground samples more closely reflect the MWOO product put on the field, so the bioaccessibility calculations in Chapter 6 are done on the unground samples.

4.1.2 Accelerated extraction and analysis

Accelerated solvent extraction was undertaken and the resultant extract was concentrated and split, before undergoing a clean-up process. Sample clean-up included back-extraction with acid and/or base, gel permeation chromatography (GPC) to remove sulfur contamination, followed by silica gel and alumina column clean-up using the FMS Power-Prep. Four other isotopically-labelled PBDE injection standards were then added to sample extracts immediately before HRGC/HRMS analysis, to allow the quantification of internal standard recovery.

Qualitative/quantitative analysis for PBDE was performed with a high-resolution gas chromatograph/high-resolution mass spectrometer/computerised data system. Two characteristic ions were selectively monitored for each PBDE congener group. Analyte identification was confirmed when target ions were detected in the correct abundance ratio within established retention time windows. Quantification was based on the use of the labelled internal standards.

For each batch of samples analysed, a random sample was selected, ground and run in duplicate from the extraction step onwards.[4]

[4] Note that samples are freezer dried and ground to aid extraction of the chemicals.

The Limit of Reporting (LOR) was determined for each compound in each sample based on noise and blank levels, as these can vary based on instrument performance and sample contamination. The higher mass PBDE can thermally degrade in the Gas Chromatograph, so a short column was used, along with a broad range of labelled recovery standards. The list of PBDE congeners reported and limits of detection and representative limits of reporting are presented in Appendix 3. The PBDE congeners covered by the analysis represent those congeners prominent in commercial PBDE mixtures (Stockholm Convention, 2017). The suite is also based on the availability of certified chemical standards and isotopically labelled internal standards.

Results that were reported from the analyses included LOR levels for certain congeners. These were taken into account in the data handling steps of the Panel by assuming a value of 50% of the LOR. 'x' is known as the limit of quantitation (LOQ), or limit of reporting (LOR). Results that are given as "<x" imply that the value of the measurand is 0 or any value less than x.[5] The rationale for LOQ/2 is that the value of the measurand must lie in the range [0 to LOQ] and with no other information its most probable value is LOQ/2. When there are a few results <LOQ and the mean of the distribution is much greater than the LOQ, the approach taken (leave out, 0, LOQ, LOQ/2) does not have a great effect on the statistical parameters. A full statistical treatment of results including results given as '<LOQ' involves treating these results as 'censored values' and using maximum likelihood methods to integrate the censored values into the distribution (Committee Analytical Methods, 2001).

4.2 PBDE RESULTS

The PBDE results for MWOO from each of the facilities are presented in Appendix 4. These tables include the field and laboratory duplicates. For each sample the mass for each PBDE congener per gram of MWOO has been presented as well as the sum of PBDE: Br3 to Br9, deca-BDE (Br10) and the sum of all congeners. Where the result was below the limit of reporting, half the limit of reporting was taken as the value.

The Panel undertook statistical analysis of the PBDE results for MWOO, including these from the Research Program. This analysis is presented in Appendix 5.

In summary:

- data in the current study ("New Data") encompassed
    - PBDE congeners (3 – 10 bromines, plus hexabromobiphenyl (HBBP)) mass content, and
    - total PBDE mass content (mass of PBDE divided by dry weight of MWOO sample, all in ng/g)
- there were 63 samples taken from different sites, prepared for different use (broad acre agriculture/non agriculture), comprised of different types (MWOO/FOGO), and included samples, controls and duplicates
- statistical analysis of "New Data" showed lognormal distributions of 44 data points after averaging duplicates, and excluding three clear statistical outliers, controls and non-MWOO samples
- the mean mass content of the lognormal distribution of the data points was 1700 ng/g. Three samples excluded from the statistical analysis (extreme values) had PBDE mass contents ranging from 14359ng/g (D2) to 97918 ng/g (D13).
- "Old Data" from the Research Program were 12 samples with analyses undertaken of PBDE congeners (3 – 10 bromines) and HBBP. They too followed a lognormal distribution with mean 1,800 ng/g but with variance significantly greater than that of the "New Data"
- there were no significant differences between PBDE mass contents taken from different sites and prepared for different uses

[5] If the result were x, it would be given without qualification.

- principal components analysis on the mass contents of the congeners showed some grouping of data by source site but with overlap, and no grouping by use.

5 MWOO INGESTION BY RUMINANTS $f_{dil,}$ m_{soil}

This Chapter describes the literature on soil ingestion rates, routes and timeframes for ruminants, particularly cattle. These three factors are important as they inform the amount of MWOO that is ingested into the GI tract, and how much PBDE could be present. The discussion below leads to the development of values for Equation 1 for the dilution factor (f_{dil}) and mass of soil ingested per day (m_{soil}).

The experiments described below utilise MWOO samples, which contain materials such as rigid plastics, flexible particles and fabric fibres that contain and release PBDE. The Research Program reported that the majority of physical contaminant in MWOO treated topsoil on a mass basis is rigid plastic (NSW EPA, 2018). As PBDE has predominantly been used in rigid plastics, the experimental design uses whole MWOO samples as would be applied to fields.

5.1 SOIL INGESTION RATES USED IN THE DRAFT INTERIM HHERA

The draft interim HHERA assumed that the MWOO was mixed into the soil to a depth of 10 cm, which thereby diluted the MWOO. The ratio of this soil/MWOO take-up by cattle is an input into the HHERA.

The draft interim HHERA assumed that 2.4 kg/day of soil is ingested by cattle. As neither enHealth (2012b) or NEPC (2013a) nominate a standard for soil ingestion by cattle, the draft interim HHERA assumptions were based on a review undertaken by the American Petroleum Institute (API, 2004). This document nominates a number of values or screening levels when assessing cattle's exposure to petroleum. Incidental soil ingestion by livestock is included in these values, with the authors suggesting:

- 2.42 kg/day for dairy cattle
- 2.13 kg/day for beef cattle
- 0.235 kg/day for calves.

Table 11 sets out the ranges of soil ingestion rates calculated from papers cited in the API (2004) literature review. These indicate soil ingestion rates range from 0.2% to 18.8% of food consumed by cattle or 0.1 kg to 2.52 kg of soil per day. Some papers note that rates vary depending on season and other factors, such as the condition of pasture and land conditions (Healy, 1968; Thornton & Abrahams, 1983; Zach & Mayoh, 1984) .

Table 11: Ruminant soil ingestion rates calculated from literature

Soil as a percentage of food ingested	kg of soil ingested per day	Reference
1.2 – 18.8 (range cattle)	0.5 – 1.2 (high of 2.2)	(Zach & Mayoh, 1984)
4 – 14 (dairy cattle)	0.72 – 2.56	(Fries, 1982)
2 - 14		(Healy, 1968)
0.2 – 17.9 (range or beef cattle)		(Thornton & Abrahams, 1983)
Max. 17.9 (agricultural cattle)		(Abrahams & Thornton, 1994)
Max. 18.8 (calves and beef cattle)		(Kennedy & Strenge, 1992)

Given the variability of ingestion rates identified in the literature and the potential impacts that may influence soil intake, the Panel concluded that a closer review of ingestion rates was warranted.

5.2 DPI REVIEW OF SOIL INGESTION

To assist the Panel, DPI undertook a review of cattle exposure to MWOO via soil ingestion. A summary is provided here, with the review presented in Appendix 10. It is recommended that the review be read in its entirety.

In considering the likely exposure of cattle to MWOO through soil ingestion, the DPI's review of published literature evaluated three key areas, being soil ingestion rates most appropriate for NSW conditions, international guidance for undertaking risk assessments and mode of application. In summary:

Soil ingestion rate most appropriate for NSW conditions

- no research conducted in Australia was identified, with published studies being undertaken in New Zealand, England and United States of America
- limited literature was identified where soil ingestion had been measured (11 studies), with the majority using weak methodologies that involved a degree of uncertainty (e.g. assumed input variables)
- variable ingestion rates were identified in the literature; with the 2.4 kg/day value used in the draft interim HHERA sitting at the extreme end of the reported range and representing a temporary peak within a season. Estimated soil ingestion levels recorded under conditions most similar to NSW range from 0.1 to 1.5 kg/day/animal (Mayland et al., 1975)
- average yearly soil intake is considered more representative when assessing soil residues in meat animals than maximum recorded values; with the highest monthly soil intake for worst-case evaluation found in dairy cattle (Fries, 1982)
- multiple factors influence soil intake, especially seasonal conditions; with incidental ingestion being the main route for domestic ruminants (i.e. via soil adhered to foliage or roots)
- no studies were identified on ingestion of compost-like material by cattle.

Identified international guidelines for risk assessments

- US EPA recommends soil ingestion values of 0.4 kg/day in dairy cattle and 0.5 kg/day in beef cattle for risk assessments (US EPA, 2005); these values considered appropriate for use in agricultural settings. (Beyer & Fries, 2005)

Mode of application, i.e. surface application vs soil mixing, and the influence this may have on the MWOO content of ingested soil

- research indicates the main pathway of incidental ingestion varies under differing climatic conditions, with ingestion via roots being the likely dominant pathway under dry conditions. Ingested soil may come from the top 10cm of the soil profile.
- some mixing of soil and MWOO over time would be expected through physical and/or biological processes

In addition, industry records merged with land and stock data for properties where MWOO had been delivered were interrogated in order to estimate the likely time-period cattle would be exposed to MWOO during the course of a year. This work considered:

- the proportion of farming enterprises treated with MWOO. On average, this was estimated to be 14% (calculated using on site-specific data of tonnage delivered, application rate and land area)
- grazing management practices in NSW

- withholding periods.

Based on their review, DPI concluded that:

- the soil ingestion rate for cattle of 2.4 kg/day used in the draft interim HHERA is overly conservative and is not supported by scientific literature or consideration of Australian conditions. A revised rate of 0.5 kg/day is recommended
- the recommended ingestion rate of 0.5 kg/day corresponds with identified international guidelines for risk assessments
- the draft interim HHERA assumed a 10cm mixing depth; this assumption was later questioned as MWOO was known to have been surface applied in some cases. The original assumption is upheld based on published studies and guidelines which support likely cattle ingestion of a soil/MWOO mix regardless of application method
- The assumption in the HHERA that cattle would be exposed to MWOO every day over the course of a year is not supported by the site-specific data. A revised period of 52 days per year is recommended (52/365 = 0.14) which has a lognormal distribution. This was based on the assumption that the time cows are exposed to MWOO is 14% of the year (calculated on site-specific data of MWOO tonnage delivered, application rate and land area).

5.3 SOIL INGESTION ROUTES

As described in the introduction to this report, the purpose of this study is to better understand the propensity of MWOO and its constituents, particularly plastic particles, for releasing PBDE into an environment where it would mobilise into a cattle GI tract and become bioavailable. Therefore, a key consideration was how the MWOO and its constituent plastic particles would transport from the field to the cattle gut.

The Panel independently considered the mode of application of MWOO to the soil, implications for the mixing of MWOO into soil, and the propensity for cattle to ingest MWOO in combination with soil having regard to soil adherence to plants (above ground plant material) and roots.

Due to the anatomy of cattle and ingestive behaviour, cattle are limited as to how close they graze to the ground. When cattle eat grass, their tongue sweeps out in an arc, wraps around the plant parts, then pulls the plant parts between the teeth on the lower jaw and a pad on the upper jaw. The cow then swings its head so its teeth can sever the grass, grinding the food and mixing it with saliva before swallowing. The lips, teeth, and jaws of a cow make it difficult to get closer than 5 centimetres from the soil, greatly limiting the ability to ingest soil or plant stems close to the ground.

Pasture pulling that exposes roots for consumption is associated with dry conditions, friable soil type, increased nitrogen fertiliser use, insect attack, plant type and plant variety and compaction. The majority of pasture roots are in the top 10cm, although there appears to be an exception in drought conditions, where the distribution of roots shifts to lower depths (20cm or below). (Thom et al., 1996)

Table 12 provides information on particle size in soil, with particle size less than 0.125 mm being either very fine sand, silt or clay (Gee & Bauder, 1986; Hazelton & Murphy, 2016).

Table 12: Soil particle size description and range

Particle size description	Australian and International particle size range	Particle size description	USDA particle size range
Clay	<0.002 mm or <2 µm	Clay	<0.002 mm or <2 µm
Silt	0.002-0.02 mm	Silt	0.002-0.05 mm
Fine sand	0.02-0.2 mm	Very fine sand	0.05-0.10 mm
Coarse sand	0.2-2 mm	Fine sand	0.10-0.25 mm
		Medium sand	0.25-0.5 mm
		Coarse sand	0.5-1.0 mm
		Very coarse sand	1.0-2.0 mm

While not a focus of this report, the Panel noted that in contrast to cows, sheep can graze much closer to the ground as they do not extend their tongues. Rather, their split lips move away from the teeth on the lower jaw, bringing in feed and cutting it across a dental pad on the upper jaw. Sheep take smaller bites than cows and can be more selective.

5.3.1 Soil and MWOO adherence to plants

Studies on adherence of soil to plants show there are clear seasonal effects (Beresford & Howard, 1991). As expected, more soil appears to adhere to the lower parts of the plant (Hinton et al., 1995) as compared to the upper parts. Adherence of soil to plants is also shown to be associated with soil particle size. Pinder et al. (1989) found that particles less than 0.125 mm are preferentially retained on plant surfaces. During periods of rain, no particles greater than 0.105 mm were detected on plants (Dreicer et al., 1984), with most less than 0.053 mm at less than 4 cm height above ground.

A model for adherence and particle size can be used as per Choate et al. (2006) where soil was applied to participants hands (study protocol being open end of a container filled with soil covered with hand and container inverted 10 times). The soil that adhered to the skin was fractionated according to particle size (study protocol being no handwashing). Even when wet, no particles adhered to the skin when particle size was greater than 0.25 mm. These data align with rain splash work on plants (where particles of less than 0.125 mm are preferentially retained on plant surfaces, as noted by Choate et al. (2006)).

Taking the work of Choate (et al) 2006 and using soil characteristics typical for Sydney Basin soil along with the plastic particles sizes determined in Section 3.3 a model can be developed to predict the adherence of MWOO to plants. Table 13 presents the predicted adherence of MWOO to plants. This table assumes that hard plastic, at each given size fraction, has conservatively half the adherence of clay or silt. It also assumes the worse-case scenario of MWOO being applied to the surface and that the particles will actually splash onto plant material.

In respect to soil ingestion from adherence to above ground plant material, by conservatively assuming that MWOO has half of the adherence capacity of clay using the model developed from Choate et al. (2006) a dilution factor of 12.6 should be applied (see Table 13).

Table 13: Applying Choate (et al) to MWOO in Sydney Basin soil

Size fraction	% typical Sydney soil in each fraction	% MWOO in each fraction	% typical soil adheres in each fraction	% MWOO that adheres in each fraction
<20 µm[1]	37	2	25	12.5
20-200 µm[2]	33	6	15	7.5
200-2000 µm	30	92	0.5	0.5
Weighted mean % adhering			14.5	1.2
Dilution Factor				**14.5/1.2 = 12.6**

1. Silt and clay are pooled together for a typical Sydney Basin soil [clay (<2 µm) = 18%], [silt (2-20 µm) = 19%]
2. Sydney Basin soils tend to have a very small proportion in the 25-63 µm fraction so values have been moderated

5.3.2 Soil and MWOO adherence to roots

A number of studies have investigated soil adherence to roots. Similar to plants (described above), particle size and type (including shape) influence adherence to roots.

Soil adhesion increases with the proportion of clay (< 2 µm) in soil. Adhesion is associated with the shape of soil particles rather than weight. Clay particles are mostly made up of minerals with thin and flat morphologies that are more likely to adhere than coarser size particles. Thus, the particles in MWOO will be less likely to adhere to plants than clay, particularly the coarser hard plastic particles of a given particle size.

Soil particles that are likely to adhere to pasture roots are most likely to be aggregated soil particles. Soil aggregation involves binding together of sand, silt and clay-sized particles into secondary units, called soil aggregates. These aggregates could include MWOO components such as small plastic particles or fibres. Soil may be ingested during the grazing process and in this process soil aggregates, in particular micro-aggregates (< 250 µm) and clay particles (< 2 µm) that are adhered to plant roots and leaves are ingested.

Soil aggregation is a complex process involving multiple biotic (plants and microbes) and abiotic (e.g. soil texture) factors. Plant roots contribute to soil aggregation through several direct and indirect processes. Direct processes (Gregory, 2006) include:

- wetting and drying phenomena
- the accumulation of inorganic chemicals at the root surface that may act as cementing agents
- the release of organic compounds or root exudates that promote aggregation of particles
- the structural support of undecayed, senescent roots that act like steel rods in reinforced concrete.

Indirectly, plant roots release organic carbon compounds that serve as a substrate for microbes, contributing to soil aggregation.

Assuming MWOO was added at a rate of 10 t/ha (NSW EPA, 2014a), and mixed into the soil to 10cm, where the majority of roots are located, and a bulk density of 1.3 g/cm^3 (EnRiskS, 2018), would result in a dilution factor of 130x for the ingestion of

soil on roots where MWOO was mixed into the soil down to 10cm. In other words, the amount of MWOO ingested at a soil intake of 0.5 kg/d would be 0.5/130 kg/d.

At the same application rate and with no mixing of MWOO into the soil, the dilution would greatly exceed 130 as the roots would be pulled through the soil with minimal MWOO adherence through underground soil-MWOO aggregates.

5.3.3 Level of adherence

The results from the experiments on plastic particle size set out in Chapter 3 showed that the majority of plastic particles were less than 6.7 mm. The rigid plastic particles of <5 mm size in MWOO are most likely to have morphologies that are not as flat and platy as clay particles. Soil clay particles (e.g. illite, smectite and kaolinite) often have flat, thin morphologies and very fine particle size. The possibility of relatively large (mm scale) rigid plastic particles sticking to foliage is expected to be minimal, in contrast to the clay particles in soils that readily stick to foliage. The smaller sized particles from MWOO samples would be more likely to stick to plant parts than would larger sized particles. Table 13 above compares percentage of different particle size fractions from soil and from MWOO and compares against the propensity to adhere to plants, assumed to be 50%, which is conservative and based on morphology of the particle types.

Having regard to all of the above, the incidental ingestion of plastic rigid particles attached to leaves above ground, or soil containing MWOO attached to roots pulled out during grazing would be low.

5.4 DISCUSSION

There is no direct literature relating to Australian conditions and no study to directly determine the predominant route of soil ingestion, adherence to plants or roots are both potential routes of soil ingestion for cattle.

Both the root and leaf mechanisms occur, and one may predominate over another depending on conditions (i.e. dry conditions increase root pull, wet conditions increase splashing onto the leaves). Mixing of MWOO into soil would increase the amount of MWOO/ plastic particles in the deeper profile of the soil and ingested on roots and would decrease the amount of particles attaching to leaves. In contrast, surface application of MWOO would increase the leaf pathway (up to 12.6 x) and decrease the relative importance of the root ingestion pathway. To account for this variability, the Panel has taken a conservative approach and taken the lowest dilution factor from the calculation of attachment via roots and leaves, being 12.6 via adherence to leaves and plant parts above ground and assuming no mixing.

5.5 RECOMMENDATIONS

As there is no definitive research demonstrating which of the two aforementioned routes is the primary mode of intake, the Panel recommends a conservative approach using the dilution factor of 12.6. Considering that the intake of soil through adherence to the roots of plants would be terminal over time for perennial pasture production and there is a paucity of pasture renovation across our pastoral sector, adherence of soil to the plant above ground (above growing points) would appear to be the primary ongoing route of soil ingestion. In summary, the Panel recommends:

- soil ingestion rate of 0.5 kg/day
- dilution factor of 12.6 to take into account adherence of MWOO to plants
- exposure period of 52 days per year = 14%, ln (f_{area})-2.03.

6 BIOACCESSIBILITY (β) AND TRANSFER FACTORS (τ)

The initial work of Panel and subsequent efforts have been targeted to obtaining insight and data on the relationship between the mass of PBDE in an MWOO sample in total, and the amount of this PBDE that would be mobilised from the sample in an aqueous medium. The physical and chemical properties of the rigid plastic and also fabric matrices in which PBDE are located are important, as are the PBDE molecules' hydrophobic nature.

Chapter 6 provides information to allow readers to gain an improved understanding of the properties of the MWOO and PBDE, through both literature and experimentation, and provides recommendations on values for inclusion in the HHERA. The first two sections provide an overview and advice on transfer factors. Sections 6.3 to 6.7.4 describe the experimental and analytical approach to developing advice on bioaccessibility and contextual advice related to the mass of PBDE leaching from MWOO samples in aqueous media. Section 6.9 sets out the recommended values for inclusion in HHERA calculations.

6.1 EMPHASIS OF THE REPORT

The concepts of bioaccessibility and transfer factors are fundamental to the development and understanding of HHERAs and also to the approach of this report through Equation 1. The Panel was requested to provide advice on bioaccessibility and bioavailability in the context of the draft interim HHERA.

Through the course of the work a number of observations were made by the Panel:

- the concepts of bioaccessibility and bioavailability are sometimes confused and sometimes conflated in the literature, and care should be taken when interpreting the literature;
- values for bioaccessibility and transfer factor are required in the Equation 1 used to calculate, however bioavailability is not;
- the concept of bioavailability could be interpreted to be a subcomponent of a transfer factor – the former relating the amount of contaminant in ruminant's food to the amount that enters the ruminant's circulatory system, the latter relating a contaminant in ruminant food to a steady state amount in meat or other tissue.

Therefore, in this report, to avoid confusion the concept of bioavailability is largely put to the side, with emphasis on discussion about bioaccessibility and some discussion of transfer factors.

6.2 TRANSFER FACTORS

Transfer factors are expressed in units of day/kilogram (d/kg), and represent the ratio of contaminant concentration in fresh weight animal product (mg/kg) to the daily intake of contaminant by the animal (in mg/day) (California EPA, 2015). The values are derived from studies investigating chemical concentrations in food products resulting from animal intake of the chemical usually in its food source as a natural contaminant or added under experimental conditions (California EPA, 2015). In many cases, including with PBDEs, transfer factor values for specific chemicals are not available in the literature so values are inferred from other chemicals where data are available.

6.2.1 Approach used in the draft interim HHERA

There are no reliable literature values of transfer factors for PBDEs and for this reason the draft interim HHERA used data from compounds similar to PBDEs to infer suitable values of τ to be used in the calculation of hazard quotient.

The procedure used for Br3-9 PBDEs was to infer the PBDE transfer factor values using those of polychlorinated biphenyls (PCBs). Because of the difficulty in choosing a specific PCB to infer the transfer factor of a particular PBDE congener, the approach taken was to adopt a worst-case scenario by choosing the highest reported value of τ (namely 2) for all of the PCBs for which values of τ were available. It should be noted here that the reported values of τ for PCBs fall in the range 0.07-2. The τ value of 2 was then applied to all PBDE Br3 to Br9 congeners, summed together. In the case of the PBDE Br10 congener, the approach taken was to use the τ value for octachlorodibenzofuran on the basis that this molecule, like PBDE Br10, was fully halogenated and had a similar hydrophobicity to PBDE Br10, as determined by its log k_{ow} value. The value of τ for PBDE Br10 used in the draft interim HHERA was 0.02.

6.2.2 Alternative approaches to estimation of transfer factors for PBDEs

The Panel investigated two further approaches to the estimation of transfer factors for PBDEs. The first of these involved the use of the Tanimoto Similarity Coefficient in an attempt to determine which PCB congener was most similar in structure to the PBDE congeners Br 3 to Br 9 in order to provide an objective basis to choose the PCB congener which should be used to infer the transfer factor for each PBDE congener.

In brief, the Tanimoto coefficient is calculated by disassembling a molecule into its component structural motifs (for example, C=O, C-OH, C-Cl, etc.) and to then compare how many of these same motifs exist in the comparator molecule. A Tanimoto coefficient of 0 means that there are no common motifs between the target and comparator molecules, whereas a value of 1 means that all structural motifs are common between the two molecules. Tanimoto similarity measures are used widely in many branches of chemistry.

When values of the Tanimoto coefficient were calculated for PBDEs and PCBs, low values (0.10-0.13) were obtained for all pairwise calculations (i.e. for each PBDE congener compared to all PCB congeners). The reason for this is that the different halogens present in the PCBs (chlorine atoms) and the PBDEs (bromine atoms) are viewed as dissimilar, meaning that there were very few structural motifs in common between the two classes of molecules. It was therefore considered impractical to use the Tanimoto approach to assist in inferring the τ values for PBDEs.

In a second approach, the Panel considered the use of log k_{ow} values to facilitate the choice of which PCB congener should be used to infer the τ value of a particular Br3 to Br9 PBDE congener. The underlying assumption was that there was a direct relationship between log k_{ow} and τ for PCBs. The available data on log k_{ow} and τ for PCBs (and also for polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF)) were examined closely (California EPA, 2000). Unfortunately, no meaningful correlation between τ and log k_{ow} could be found for the Br3-Br9 congeners so this approach was abandoned.

6.2.3 Recommended approach to estimation of τ values

The Panel recommends the adoption of a modification of the approach used by EnRiskS in the draft interim HHERA for selecting the value of τ to be used for the Br3 to Br9 PBDE congeners. In this modification, instead of using the highest value of τ for all of the PCBs, it is recommended that a weighted average be used based on the

amount of each PBDE congener present in MWOO. The recommended procedure is as follows:

- PCB congeners having the same number of chlorine atoms are grouped and the highest value of τ for the congeners in the group is then assigned to that group.
- For each PBDE congener, the number of bromine atoms present is used to identify the corresponding PCB group and the τ value for that group is then assigned to the PBDE congener.
- A weighted average of the τ values for all congeners present is calculated, with the weighting based on the mass content of each PBDE congener expressed as a fraction of the sum of all Br3 to Br9 congeners.
- The weighted average of τ was calculated for all 49 MWOO samples analysed in this study using accelerated solvent extraction with toluene and a mean (0.53) and standard deviation (0.12) calculated.

In the case of the PBDE Br10 congener, the Panel supports the approach taken by in the draft interim HHERA, namely the use of octachlorodibenzofuran as a surrogate molecule.

Recommendation
The Panel recommends that a τ value of 0.53 (with standard deviation of 0.12) be used for PBDE Br3- to Br9 and a value of 0.02 be used for PBDE Br10.

6.3 UPDATING INFORMATION ON BIOACCESSIBILITY

6.3.1 Bioaccessibility of PBDE in MWOO

The starting point for the Panel was to understand and differentiate between the total PBDE in an MWOO sample and the amount that would be extractable under various conditions, and so be able to be absorbed by the cattle GI tract. Therefore, a literature review was undertaken that would assist with better understanding the potential bioaccessibility of PBDE in MWOO and inform any bioaccessibility studies.

The Panel notes that the HHERA assumed that 100% of the PBDE present in the MWOO applied to agricultural areas would be bioaccessible to grazing cattle.

From the literature reviewed in respect to the GI tract, bioaccessibility is the portion of the contaminant ingested that is extracted into the liquid within the GI tract and is thereby potentially available for absorption into the blood stream, while bioavailability is the portion of contaminant that is actually absorbed into the blood stream (enHealth, 2012b; Cui et al., 2016).

The literature review on the characteristics of PBDE extraction from plastics under conditions reflective of environmental conditions in a field (aqueous conditions, 1 atmosphere pressure and room or body temperature) identified a number of relevant papers (Table 14). Key findings include:

- leaching solutions containing dissolved organic material (e.g. humic acid) are more effective at extracting PBDEs than distilled water (10 times more effective)
- while leaching solutions containing dissolved organic material are more effective than water, PBDE leaching using these solutions is still extremely low
- the maximum leaching of PBDEs from plastics, landfill, electronic wastes and mixed waste is 0.13% of the total PBDEs in the solid material, noting that this figure is based on a relatively small number of publications
- a mathematical model has been developed to predict the release of PBDEs from plastics over time

- methods exist that can measure the bioaccessibility of PBDEs in MWOO samples. These methods rely on sorption of PBDEs onto a solid adsorbent (termed a “sorption sink”) followed by laboratory analysis by HRGC/HRMS.

The sorption sink approach simulates the passive molecular diffusion of contaminants across the small intestine thereby creating a concentration gradient to facilitate the mobilisation of desorbable contaminants from the soil matrix. As the desorbable fraction is considered to be the maximum fraction available for absorption across the intestinal epithelium of the GI tract, assessment of contaminant bioaccessibility using the sorption sink approach may provide a conservative estimate of contaminant bioavailability.

Based on the literature review it was suggested that if the PBDE detected in MWOO is largely associated with hard plastics, then the amount of PBDE leached and thus potentially bioavailable under environmental conditions would be less than around 0.1% of the total PBDE in the plastic. A caveat on this observation is that the hard plastics considered in the literature review contained a maximum of 4.5% total PBDE. Other hard plastics can contain up to 30% PBDE and this could lead to higher extraction levels using environmental extractants. The rate of leaching was expected to be dependent on the size of the plastic particles that may be present, with a smaller particle size resulting in a larger surface area for a sample and increased leaching rate.

The work described in the remainder of this chapter endeavours to compare the PBDE measured in accelerated solvent extraction experiments with the values of PBDE mobilised in aqueous leaching experiments in more environmentally benign conditions of temperature and pressure. The draft interim HHERA described earlier drew on toluene extracted PBDE data as an input, while the work here aims to obtain PBDE input data for a HHERA that more readily relates to actual conditions in a cow’s stomach or in a field. These aqueous data can then be used as an input to an updated HHERA.

Table 14: Summary of papers reviewed

Sample/matrix	PBDE	Extractant/leachant	Max [PBDE] in extractant	Max extraction %	Reference	Comments
LEACHING STUDIES						
TV housings and raw materials before moulding processing (2.5% PDBE)	1-10 Br substituted PBDE	Water, 20% methanol, 1g/L dissolved humic solution (DHS)	23 ug/L for 20% methanol, 1.2 ug/L for DHS	0.0005% for aq. MeOH, 0.00003% for DHS	(Kim et al., 2006)	3 mm particles 5 days extraction
TV moulding plastic pellets containing about 3% PBDE	10 PBDE	Water and DHS solution at 1g C/L using liquid: solid of 100:1	Approx. 1 ug/L in distilled water and 10 ug/L in DHS	0.004%	(Choi et al., 2008)	2-3 mm particles Extraction tested for 0.25, 1, 5, 20 days >95% extraction after 5 days
Waste printed circuit boards from waste electrical and electronic equipment (WEEE) such as plastics, printed circuit boards, crushed before analysis. Contains 0.3% total PBDE	5 PBDE and total PBDE	Toxicity characteristic leaching procedure (TCLP) using acetic acid and synthetic precipitation leaching procedure (SPLP) using sulfuric and nitric acids methodologies. Also analysed actual landfill leachates	Not detected in TCLP or SPLP. PBDE in actual landfill leachates was 5.7 ng/L	Effectively 0% in TCLP and SPLP tests	(Zhou et al., 2013)	3 size fractions studied <420 µm, 420-841 µm, >841 µm. Extracted with actual landfill leachate at 40:1 LSR for 0-90 days. >95% extraction after 10 days
Waste from 12 waste-handling facilities in Norway. Includes WEEE, vehicles, ash, etc. containing up to 4.5% total PBDE vehicles	1-10 PBDE	Extracted with water over 28 days using a solid:liquid 1:10. Natural leachates also tested. Solid samples (containing approx. 0.2% PBDE in the plastics component) subjected to ASE using toluene.	Synthetic leachates gave a max [PBDE] of 0.01 ug/kg. Natural leachates gave a max of 140 ng/L	5×10^{-5}% for synthetic leaching.	(Morin et al., 2017)	2-4 mm particle size PDMS sorption sink 28 days extraction
Waste cathode ray tube plastic housing chips containing approx. 3 g total PBDE per kg (0.3%)	5 PBDE and total PBDE	Extracted with DHS solution 1g/L at a solid:liquid of 1:25	Max [PBDE] observed was 200 ug/L after 48 h	Max extraction was 0.13% after 48 hr	(Stubbings & Harrad, 2016)	Particle size <250 µm 6, 24 48 h extractions at different T (20-80^{o}C) and pH (5.8-8.5). 90% extraction after 24 h. Only T>50^{o}C caused increased extraction. Extraction increased with increasing pH but from pH 6.5-8.5 only a 6% increase occurred.

6.4 BACKGROUND TO LEACHING STUDIES

Based on the previous literature review (see Section 6.3), the Panel identified studies that could inform the bioaccessibility of PBDE, an environmental leaching study and a ruminant leaching study.

6.4.1 Literature review on extraction of PBDE from plastics

A review of the literature from Section 6.3 identified analytical methods that could be used to assess the environmental leachability of PBDE from hard plastics in MWOO, using dissolved organic material, such as humic acid, as the extractant. Comments from the review are included in the last column in Table 14. The literature suggested that the main factors affecting the leaching of PBDE from hard plastics and waste electrical samples were extraction time, particle size, temperature, pH and the presence of a sorption sink.

6.4.1.1 Extraction time

In general the extraction tends to follow first-order kinetics for the initial rapidly desorbing PBDE fraction, but there is also suggestion of a further extraction of a slowly-desorbing fraction. The entire desorption process has been modelled both by first order (Choi et al., 2008; Zhou et al., 2013) and second order kinetics (Stubbings & Harrad, 2016). Extraction curves show that full extraction usually takes a very long time, but extractions of over 90% of the final equilibrium amount can be achieved in much shorter times (Fig 4 in (Choi et al., 2008) and Fig 1 in Zhou et al. (2013)). Extraction times chosen for different experimental studies vary from 6 hours to 28 days. The optimum extraction time to be used in the studies of bioaccessibility will depend on a range of variables including particle size, temperature, pH, and whether or not a sorption sink is present. These are discussed below.

6.4.1.2 Particle size

Particle sizes in the literature survey vary from <250 µm to approx. 3 mm. Samples consisting of the larger particles are generally subjected to much longer extraction times than smaller particles. For example, 5 days is a typical extraction time for 2-3 mm samples (Kim et al., 2006; Choi et al., 2008), compared to 24 hours for a 90% extraction of a sample with particle size <250 µm (Stubbings & Harrad, 2016).

6.4.1.3 Temperature

Extraction temperatures in the range 20-80°C have been studied (Stubbings & Harrad, 2016). Extraction increased with temperature, but in the range 20-50 °C there was virtually no increase in extraction. However, extraction almost doubled when the temperature was increased from 50°C to 80°C.

6.4.1.4 pH

Extraction has been performed at pH values of 5.8, 6.5 and 8.5 (Stubbings & Harrad, 2016). At pH 8.5 there was only a moderate (6%) increase in extraction compared to pH 6.5.

6.4.1.5 Sorption sink

Having a sorption sink present usually accelerates the extraction somewhat (de la Cal et al., 2008; Meng et al., 2015). It has been recommended that a fixed extraction time of 6 hours in the presence of a sorption sink is suitable for measurement of bioaccessibility (Meng et al., 2015). A sorption sink is appropriate to model systems where the removal of the contaminant by the system would drive the equilibrium of the extraction, such as may occur in a ruminant GI tract. In cases such as ambient conditions in a field where there is no apparent pathway for removal of PBDE from the solution, a sorption sink is not required. Further discussion of sorption sinks is taken up in Section 6.6.

6.5 MOBILISATION OF PBDE IN THE TERRESTRIAL ENVIRONMENT

An environmental leaching study was undertaken to assess whether the PBDE is leached into the environment or remains with the organic matter and potential ingestion by cattle.

6.5.1 Study background

While there is literature to support an extraction time of 48 hours for small particle sizes (Stubbings & Harrad, 2016), there is also literature suggesting this extraction time may not be long enough for larger particles. The extraction time will be dependent on the size of particles within the samples of which there will be expected to be a range of size (see Chapter 3). To account for differing timeframes it was decided that a kinetic study should be undertaken using extraction times of 6,12, 24, 48 and 120 hours. Once the kinetics of the leaching are known it would be possible to extrapolate the 48 hour extraction data to predict the equilibrium mass of PBDE extracted per gram of MWOO.

Based on the literature review, humic acid sodium salt (1g organic carbon per litre) was used in the environmental leaching study to reflect the organic carbon in soil.

6.5.2 Sample preparation and procedure

The environmental leaching studies were undertaken by the OEH at the request of the Panel using a similar procedure to that used in the Research Program, Project 3 modified to take into account the above. An overview of the procedure is described below.

Humic acid extraction fluid was prepared by dissolving 17.9 g of humic acid sodium salt (Aldrich, H16752) in 7 litres of Milli-Q water (equivalent to contain 1 g carbon/L). 50 g of MWOO material was weighed into a 2 L Teflon extraction bottle, and 1 L of humic acid extraction fluid added. The bottles were capped, placed in a tumbler and rotate at 30 rpm at 23 ± 2°C. At the end of the desired leaching time (see above), the bottle was taken out of the tumbler and the sample allowed to settle for 30 minutes. After that the 300 mL of the leachate was centrifuged at 3000 rpm for 5 minutes. 150 mL of centrifuged leachate was added to a filter holder and the leachate filtered through a glass fibre membrane filter (0.7µm pore size) (cat#.1810-142). A pressure of 50 psi was applied to assist the filtration. 100 mL of the filtered leachate was placed into hexane rinsed glass jars, kept in cool room and submitted to NMI for PBDE analysis. A list of the samples included in the environmental leaching study is presented in Table 15. The samples were analysed for PBDE by NMI as per Section 4.1.2, without the accelerated solvent extraction.

Table 15: Samples included in the environmental leaching study

Study	Sample
Kinetics	Unground MWOO D2
	Ground MWOO D2
Bioaccessibility	Ground MWOO A3
	Ground MWOO C6
	Ground MWOO C7
	Ground MWOO C8
	Unground MWOO D2
	Ground MWOO D2
	Ground MWOO D4
	Ground MWOO D7

6.5.3 Results

The results as reported by the laboratory are presented in Appendix 6. During the analysis, the laboratory had issues with the method which resulted in some poor internal standard (surrogate) recoveries. The analysis was repeated for some samples although recoveries did not improve. The laboratory also found that labelled BDE209 surrogate recoveries were too low to allow quantitation. These results have been reported as non-quantitation.

As the unground MWOO were included in the environmental leaching study as received (i.e. wet), the results were adjusted to dry matter to allow comparison to the ground results. Table 16 provides an overview of the adjusted results for the kinetic study including the cumulative mass of PBDE and the percent mobilised over time from the MWOO sample. Table 17 provides an overview of the 48 hour mobilised results.

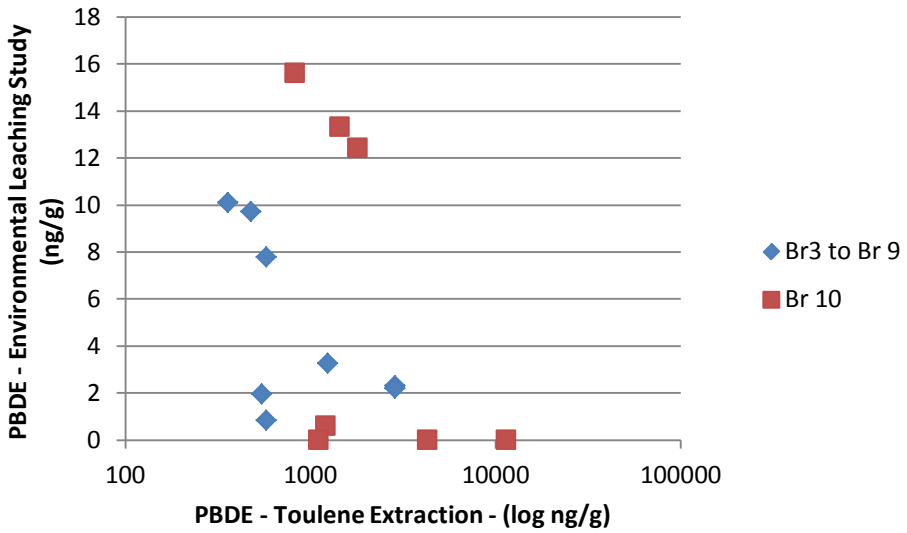

Figure 4: 48 hour environmental leaching PBDE results compared to the MWOO toluene extraction result

Table 16: Environmental kinetic study – results

Sample Code	Time (hrs)	PBDEs – Br3 to Br9			PBDE Br10			Total PBDE		
		Result (ng/g)	Cumulative amount (ng/g)	Mobilised (%)	Result (ng/g)	Cumulative amount (ng/g)	Mobilised (%)	Result (ng/g)	Cumulative amount (ng/g)	Mobilised (%)
Ground MWOO D2 (toluene extraction)		2858.94			11500			14358.94		
Unground MWOO D2	6	0.26	0.26	0.01	0.17	0.17	<0.01	0.43	0.43	<0.01
	12	0.21	0.47	0.02	0.11	0.28	<0.01	0.32	0.75	<0.01
	24	0.30	0.77	0.03	0.17	0.45	<0.01	0.47	1.22	<0.01
	48	0.30	1.07	0.04	0.26	0.71	0.01	0.56	1.78	0.01
	120	0.20	1.27	0.04	0.22	0.93	0.01	0.42	2.20	0.03
Ground MWOO D2	6	0.35	0.35	0.01	0.18	0.18	<0.01	0.53	0.53	<0.01
	12	0.29	0.64	0.02	0.05	0.23	<0.01	0.34	0.87	0.01
	24	0.45	1.09	0.04	0.33	0.56	0.01	0.78	1.65	0.01
	48	0.27	1.37	0.05	0.19	0.75	0.01	0.46	2.12	0.02
	120	0.35	1.72	0.06	0.32	1.07	0.01	0.67	2.79	0.02

Table 17: Environmental leachability study – 48 hour leachability results

	PBDEs – Br3 to Br9			PBDE Br10			Total PBDE		
	Toluene extract result (ng/g)	Result (ng/g)	Mobilised (%)	Toluene extract result (ng/g)	Result (ng/g)	Mobilised (%)	Toluene extract result (ng/g)	Result (ng/g)	Mobilised (%)
Ground MWOO A3	577.20	0.84	0.15	1210.00	0.59	0.05	1787.20	1.43	0.08
Ground MWOO #1 C6	578.65	7.78	1.34	1810.00	12.40	0.69	2388.65	20.18	0.85
Ground MWOO #2 C7	359.71	10.10	2.81	830.00	15.60	1.88	1189.71	25.70	2.16
Ground MWOO #3 C8	476.03	9.71	2.04	1450.00	13.30	0.92	1926.03	23.01	1.2
Unground MWOO #1 D2	2858.94	2.32	0.08	11500.00	*		14358.94	2.32	0.02
Ground MWOO #1 D2	2858.94	2.19	0.08	11500.00	*		14358.94	2.19	0.02
Ground MWOO #2 D4	1238.93	3.25	0.26	4320.00	*		5558.93	3.25	0.06
Ground MWOO #3 D7	547.88	1.95	0.36	1110.00	*		1657.88	1.95	0.12

* non-quantitation

6.5.4 Half-life of PBDE in soils

As discussed in Section 2.1, PBDE congeners can undergo processes of debromination including through effects of sunlight. This mechanism would be impacted in a soil environment where light may only penetrate the top few millimetres. Degradation of PBDEs can occur slowly in soils under aerobic or anaerobic conditions. Studies have been undertaken into the timeframes, conditions and products of biodegradation of several PBDEs. A range of half-lives for Br10 in a loam sediment preparation have been estimated from 6 – 50 years (ATSDR, 2017).

A recent study calculated PBDE residence times in active agricultural soils by using field-measured data for the first time (Andrade et al., 2017). From the analysis of sample from a subset of fields that received single biosolids applications, a median residence time of 704 d or 1.93 years was calculated for BDE-47 (Br4) +BDE-99 (Br5) (n = 5 fields) and of 1440 d or 3.93 years (n = 3 fields) for BDE-209 (Br10).

According to these authors the most influential processes that can affect the residence times of these chemicals in soil are (1) microbial degradation, (2) photodegradation, (3) volatilization, (4) wind erosion of soil, and (5) movement within the soil.

6.5.5 Discussion

During the kinetic study, the mass of PBDE leached from the solid matter (both ground and unground) into the humic acid environmental leaching solution and then measured was low, with 2.79 ng/g of the total PBDE leaching after 120 hours or 0.02% of the mass found in the ground MWOO. A leachability percentage can be seen for Br3 to Br9 BDEs at 0.06% and 0.01% for Br10 in the ground sample.

In the 48 hour leachability study, the amount of total PBDE leaching into the humic acid environmental leaching solution ranged from 1.43 ng/g (Br3-10 ground MWOO from facility A) to 25.7 ng/g (ground MWOO from facility C), with the unground MWOO from facility D being within this range. The percentage PBDE mobilised ranged from 0.02 to 2.16% when compared to the ground MWOO result extracted using toluene.

Given the low rates of mobilisation it is difficult to assess whether the initial mass of PBDE influenced the rate. It is noteworthy that the results for the samples from facility D are not complete as values for PBDE Br10 were not measured, which may have been due to the interaction with the humic acid phase in the experiment binding the PBDE Br10.

6.5.6 Conclusion

Overall it can be concluded that after application of MWOO to a paddock, the vast majority of PBDE remains with the MWOO and is not leached into the environmental to a significant extent. Upon leaving the MWOO, PBDE may bind with the soil grains, and potentially photolyse, or could attach via a plate-shaped grain to a plant part. However, given the low mass of PBDE leaving the MWOO, environmental leaching will not significantly influence the overall mass of PBDE that may be ingested by cattle.

6.6 MOBILISATION OF PBDE IN THE RUMINANT GUT

The mass of PBDE bioaccessible in the ruminant gut will reflect the amount that is extracted from the MWOO/plastic in the GI tract of the ruminant. This section models this occurrence through a ruminant leaching study.

When the Panel initially conceptualised this study, the proposed approach was to calculate the residence time of MWOO/plastic particles in cattle, informed by Chapter 3, and scale the leached PBDE values from a ruminant leaching study. This approach is described in the following sections and an alternative scaling approach described in section 6.7.

6.6.1 Retention time of hard plastic in cattle

The retention time of plastic in ruminants is dependent in part on specific gravity, with plastics in MWOO estimated with a specific gravity of 1.2 (see Section 3).

There is a paucity of data on retention time of ingested plastic in ruminants. However, two key studies, conducted close to 30 years apart have similar findings. Data for retention of plastic, of specific gravity of close to 1.2, from (Welch, 1990) and (Seyama et al., 2017) are shown in Table 18.

Table 18: Retention of plastic expressed as a percentage. Data from (Welch, 1990) and (Seyama et al., 2017)

size (mm)	4	6	8	Welch	
specific gravity	1.19	1.19	1.19	1.18	Mean
24 hr	9	18	21	0	12
48 hr	60	82	84	40	67
72 hr	73	93	96	70	83
96 hr	75	94	97	84	88
120 hr	77	94	97	85	88

The data shows a first order process following a lag time. This is captured in the model

$$f_e = 0 \qquad t \le t_{lag}$$
$$f_e = f_{max}\left(1 - e^{-k_{out}\left(t - t_{lag}\right)}\right) \qquad t > t_{lag}$$

Equation 2

where

f_e is the fraction of MWOO excreted, f_{max} the maximum fraction that could be excreted, k_{out} the rate constant for excretion, t_{lag} the lag time.

Figure 5 shows the data with a fit to Equation 2, with the optimum parameters presented in Table 19. This model can be combined with an absorption model to calculate the total PBDE absorbed during the residence of plastics containing PBDE in the cow's system.

Table 19: Optimum parameters for model

Parameter	Fitted value	Standard error
f_{max} %	89.1	*0.5*
k_{out} /h^{-1}	0.052	*0.002*
t_{lag} /h	21.2	*0.2*

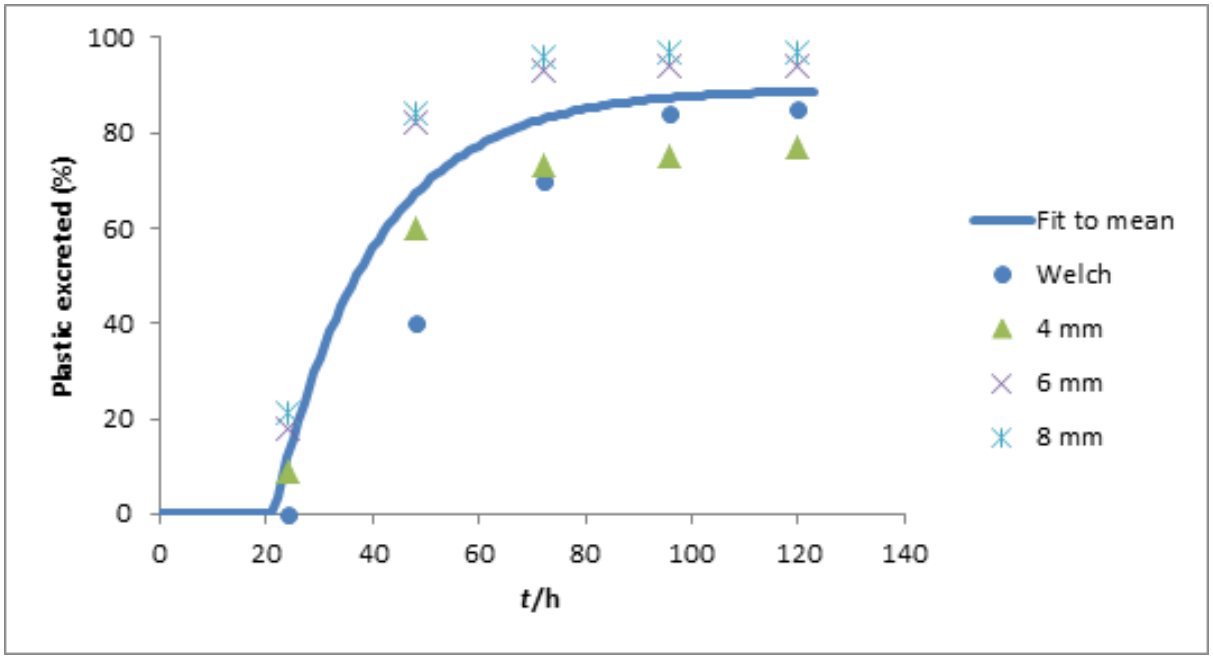

Figure 5: Excretion of plastic fitted to a lagged, first order model

The approach described above had been developed in the study, enabling the Panel to draw on specific gravity and particle size information, to estimate retention time and then use this first order model to develop a multiplier for the 24 h extractions in the aqueous leaching experiments. However, with the uncertainty about the particle sizes and specific gravity and resulting residence time, it was decided instead to use the approach in section 6.7.1 to develop the multiplier and 'a' value in Equation 3.

6.6.2 Ruminant leaching study

The general comments made in Section 6.5 on environmental leaching apply also to the ruminant leaching studies. However, the ruminant leaching study protocol also needed to consider the effect of inclusion of a sorption sink (silicone cord) and the residence time of plastics inside a ruminant. On the first point, the presence of a sorption sink should shorten the required extraction time. On the second point, the residence time is not conclusive because of uncertainty of the density distribution of the plastics in MWOO. However, if kinetic data are obtained on ground and unground MWOO samples an extraction time of 24 hours can be applied and any necessary adjustments then made using the kinetic model. A pH value of 7.2 and a temperature of 37°C can be considered to be appropriate (see Sections 6.4.1.3 and 6.4.1.4) as the use of a sorption cord has been previously validated at this temperature (Juhasz, Tang, et al., 2016) and the temperature closely resembles that of the GI tract of ruminants.

The ruminant leaching studies included a kinetic study of both ground and unground MWOO using extraction times of 6, 12, 24, 48, and 120 hours. First order kinetics were applied.

The silicone cord was used in experiments as a driver for the equilibrium in the model system. Extraction or dissolution of chemical substances from a solid into a liquid phase will occur under an equilibrium which is dependent on the concentration in solution. As the concentration in solution increases, this has a dampening effect on the extraction from the solid until equilibrium is established. This however is not representative of a situation in the GI tract where the chemicals being desorbed from the solid are then removed from solution into the GI tract. This, in effect, drives the equilibrium to the right with more extensive extraction from the solid being expected. To model this in the leaching experiment, a silicone cord sink has been used, based on previous work of Cui & Juhasz (2016), Cui (2013).

Silicone cord is highly hydrophobic and in solution preferentially binds hydrophobic molecules such as PBDEs.

6.6.2.1 Study Background and Overview

The Future Industries Institute at the University of South Australia (UniSA) was engaged to undertake an assessment of the bioaccessibility of PBDE in MWOO within the gastrointestinal (GI) tract. A project proposal was developed and submitted to the Panel, with the Panel working with UniSA experts to refine and finalise the study proposal.

In summary, the study includes kinetic studies to determine the rate, efficacy and capacity of the sorption sink to recover PBDE from in vitro solutions and based on this, to assess the PBDE bioaccessibility in MWOO samples.

UniSA has previously undertaken similar research involving the determination of the bioaccessibility of polycyclic aromatic hydrocarbons (PAH) in contaminated soil using pseudo-gastrointestinal fluids and a sorption sink (Juhasz, Herde, et al., 2016; Juhasz, Tang, et al., 2016). This approach is conservative as the composition of the GI fluid varies from rumen fluid and the use of the fluid and sorption sink (silicone cord) has been shown to achieve maximum desorption of PAH and organochlorine pesticides. The methodology has been correlated to an *in vivo* animal model (mice) (Juhasz, Herde, et al., 2016).

6.6.2.2 Analysis of Silicone Cord for Ruminant Leaching Study

Sample preparation and procedure

For each of the samples, 1.0 g of MWOO was added to a flask containing 8 g (1 metre) of silicone cord and 100 mL of the GI fluid (containing 15.0 g of glycine, 8.8 g of NaCl, 1.0 g of pepsin, 5.0 g of bovine serum albumin and 2.5 g of mucin per litre, pH 1.5) (org-PBET solution). After 1 hour, gastric phase conditions were modified to the intestinal phase by adjusting the pH to 7.2 ± 0.2 and by adding bile (4.0 g L^{-1}) and pancreatin (0.6 g L^{-1}). During gastrointestinal extraction, each flask was incubated at 37°C and shaken at 40 rpm on a suspension mixer. For the kinetic study a piece of silicone cord was placed in the solution and removed and replaced with new silicone cord at 6, 12, 24 and 48 hours. At 120 hours the final silicone cord was removed. For the bioaccessibility study the silicone was removed after 24 hours.

Initially, two duplicate kinetic leaching extractions were run on ground and unground samples. This kinetic study used 1 g MWOO, 1 m lengths of silicone cord per subsample, placed in solution over intervals that covered 120 hours as follows:

i. Cord 1: 0 – 6^{th} hr = 6hrs of cord in solution
ii. Cord 2: 6^{th} -12^{th} hr = 6hrs of cord in solution
iii. Cord 3: 12^{th} to 24^{th} hr = 12hrs of cord in solution
iv. Cord 4: 24^{th} to 48^{th} hr = 24 hrs of cord in solution
v. Cord 5: 48^{th} to 120^{th} hr = 72hrs of cord in solution

Three of these runs were analysed at NMI, 2x unground and 1x ground subsample runs. The duplicate ground sample was not analysed. The sample that was extracted in the kinetic study was a sample that had been measured in the accelerated solvent extraction analysis as having a high total PBDE content – namely 14,359 ng/g total PBDE (BDE3-9: 2858 ng/g; BDE10: 11500 ng/g)

All samples of silicone cord, as well as a control silicone cord, were sent to NMI for PBDE analysis. The analytical procedure used was the same as that described in Section 4.1, although no sample preparation was required prior to extraction.

To model the intestinal tract absorption, the silicone cord only was measured at 24 h. The reason that the PBDE in the GI extractant fluid (at 24 h) are not added to this value is explained as follows.

The experiment can be seen as being comprised of three phases: the MWOO contaminant source, the sorption sink that mimics the intestinal or gut wall, and the GI extractant fluid that models fluid in the cattle gut. We can think of the GI fluid in the gut performing two roles that need to be considered – being (1) mobilising PBDE from the MWOO to the gut wall and (2) mobilising PBDE from MWOO toward excretion (in the fluid phase or by PBDE reabsorbing into MWOO, with MWOO eventually excreted from the animal).

To account in the study for role (1), after analysing the PBDE content from the silicone cord at 24 h from the ruminant leaching experiment (Section 6.6.2.3), this measured mass of PBDE is then scaled to an 'a' value that accounts for additional time in the gut and consequent PBDE mobilised after the 24 h time frame (Section 6.7.1). This multiplier step therefore models and accounts for the mass of PBDE absorbing into the intestinal wall out of the GI extractant over the following hours.

To account for role (2), as described in Section 6.2 the transfer factor (τ) used in the HQ calculation takes into account excretion, as well as other physiological transport pathways between the cattle's food source and its meat or organs.

Section 6.8 sets out a mass distribution study at 24 hr, including the three components of sorption sink, GI extractant and residual MWOO. The mass distribution study shows that the system is extraction-limited. That is, the GI extractant acts as a conduit for the extractable component of the PBDE in the MWOO (which is 15-20% of the toluene extracted PBDE) to be transferred to the silicone cord. The amount of PBDE in the GI extractant is low because of the efficient adsorption of PBDEs by the silicone cord. Therefore, the PBDE content in the cord is the most important and the PBDE in the GI extractant is in a state of flux and can be either eventually adsorbed on the cord or readsorbed onto the MWOO.

The PBDE component measured in that experiment (Table 25) would notionally either mobilise to the sorption sink (over time), reabsorb into the MWOO residue and be excreted, or mobilise to excretion in the fluid phase, both scenarios dealt with in the Panel's treatment.

Table 20 lists the samples included in the ruminant leaching study which include unground and ground MWOO and unground MWOO mixed with soil. The soil used was a sample of Sydney Basin Soil sourced from Sydney University's Westwood farm Camden (sand 63%, silt 19%, clay 18% and organic carbon 2.5% with a cation-exchange capacity of 4.3 cmol(+)/kg). The ruminant leaching study commenced prior to the all results from the PBDE analysis on MWOO being available. Therefore the sample selection was based on the MWOO facilities where results were available, selecting from each facility a sample with a high and median PBDE mass concentration.

Table 20: Samples included in the ruminant leaching study

Study	Sample
Kinetics	Unground MWOO D2 (duplicate samples)
	Ground MWOO D2
Bioaccessibility (duplicate samples)	Unground MWOO A3
	Ground MWOO A3
	Unground MWOO A5
	Unground MWOO A5 + Soil
	Ground MWOO A5
	Ground MWOO A5 + Soil
	Unground MWOO A8
	Unground MWOO C6
	Unground MWOO C6 + Soil
	Ground MWOO C6
	Ground MWOO C6 + Soil
	Unground MWOO C7
	Unground MWOO C8
	Ground MWOO C8
	Ground MWOO D4
	Unground MWOO D4
	Unground MWOO D7
	Unground MWOO D7 + Soil
	Ground MWOO D7
	Ground MWOO D7 + Soil

6.6.2.3 Silicone Cord Extraction Results

The PBDE results from the ruminant leaching study are presented in Appendix 7. Data in Appendix 7 are reported in ng/sample – where the sample was 1m of silicone cord that had been exposed to 1g MWOO in GI fluid.

Prior to assessing the results unground MWOO results were adjusted to dry matter to allow comparison with the results from ground MWOO. The adjusted results for the ruminant kinetic study are presented in Table 21, with the adjusted results from the 24 hour bioaccessibility study presented in Appendix 7.

Figure 6 shows the data from the kinetic study. Figure 7 and Figure 8 show the mass of leached PBDE after 24 h for ground and unground MWOO plotted against the toluene-leached content. Observations across both the ground and unground data sets in Figure 7 and Figure 8 demonstrate a relatively consistent mass (between 50 and 250 ng) of PBDE leached per gram of MWOO over 24 h.

Table 21: Ruminant kinetic study – results and bioaccessibility

	Time (hrs)	PBDE – Br3 to Br9			PBDE Br10			Total PBDE		
		Result (ng/sample)	Cumulative (ng/sample)	Bioaccessibility (%)	Result (ng/kg)	Cumulative (ng/kg)	Bioaccessibility (%)	Result (ng/kg)	Cumulative (ng/kg)	Bioaccessibility (%)
Ground MWOO D2 (toluene extraction)		2858.94 ng/g			11500 ng/g			14358.94 ng/g		
Unground MWOO D2	6	61.4-64.9	61.4-64.9	2.1-2.3	50.9-62.3	50.9-62.3	0.4-0.5	115.7-123.7	115.7-123.7	0.8-0.9
	12	41.4-52.3	106.2-113.7	3.7-4.0	42.0-49.6	92.9-111.9	0.8-1.0	83.3-101.9	199.1-225.6	1.4-1.6
	24	61.4-65.4	171.7-175.1	6.0-6.1	104.3-109.4	202.3-216.2	1.8-1.9	165.7-174.8	373.9-391.3	2.6-2.7
	48	70.9-74.0	245.7-246.0	8.6	127.2	329.5-343.4	2.9-3.0	198.1-201.2	575.1-589.5	4.0-4.1
	120	61.8-84.1	307.5-330.1	10.8-11.5	139.9-152.6	469.4-496.1	4.1-4.3	201.7-236.7	776.9-826.2	5.4-5.8
Ground MWOO D2	6	96.4	96.4	3.4	71	71	0.6	167.4	167.4	1.2
	12	67.0	163.4	5.7	56	127	1.1	123.0	290.4	2.0
	24	80.0	243.4	8.5	110	237	2.1	190.0	480.4	3.3
	48	68.7	312.1	10.9	150	387	3.4	218.7	699.1	4.9
	120	94.2	406.3	14.2	220	587	5.1	294.2	993.3	6.9

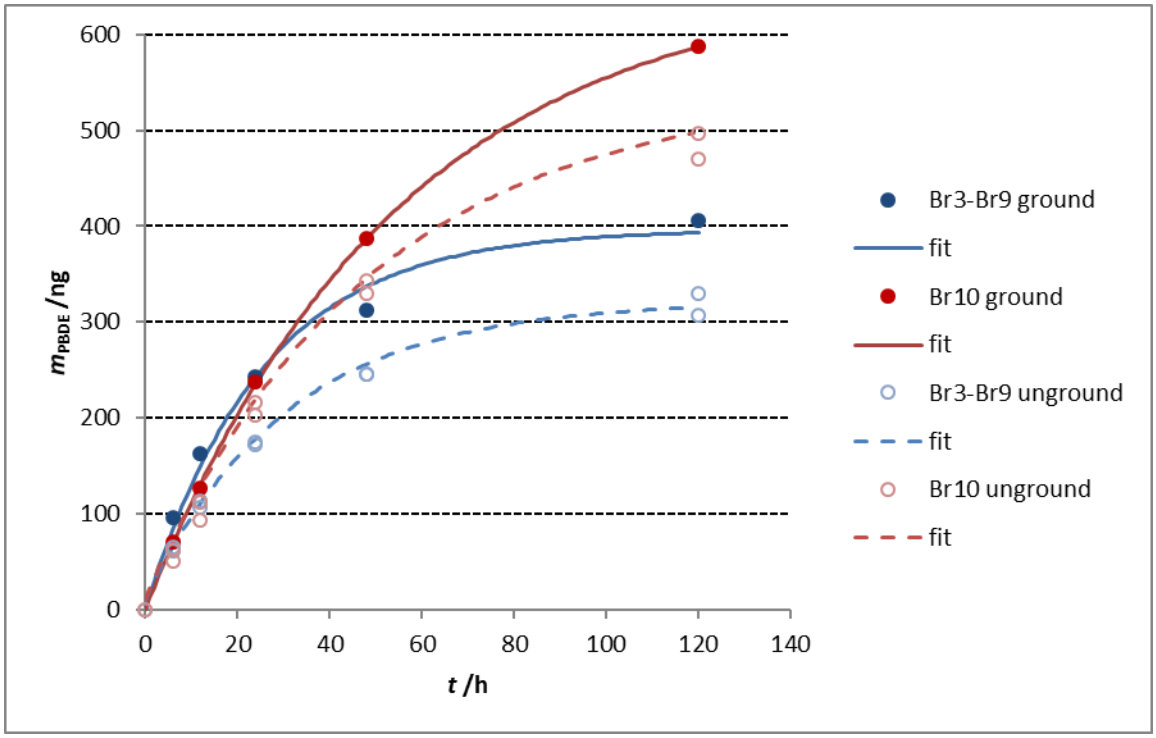

Figure 6: Mass of PBDE taken up in silicone cord experiment fitted to a first-order kinetic model. 'unground' indicates MWOO as received ('ground' is MWOO with particle size reduced to <2 mm)

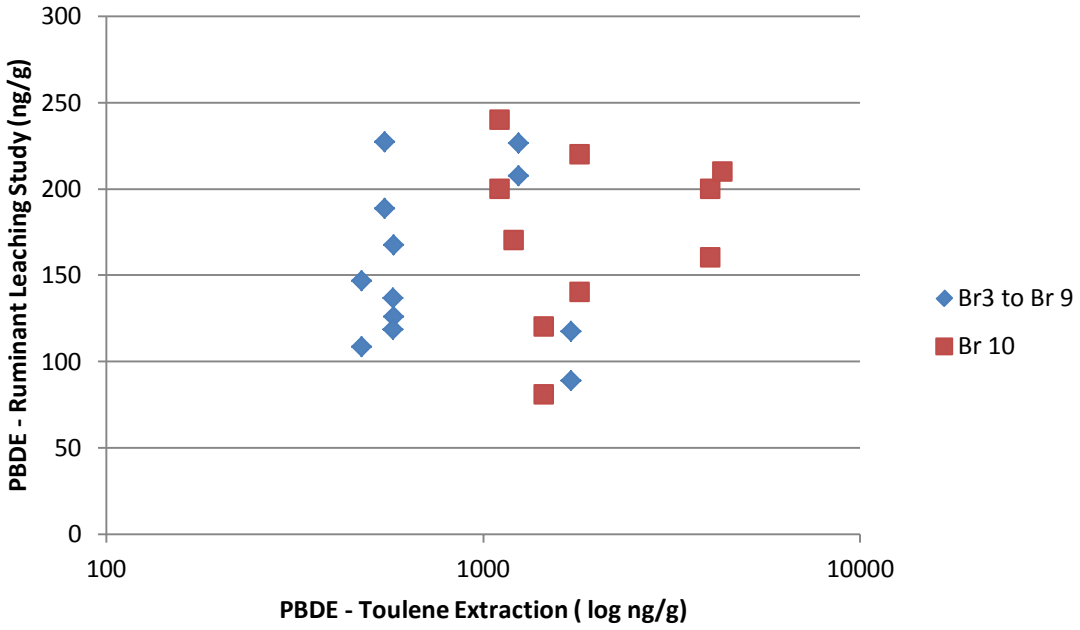

Figure 7: 24 hour ruminant leaching PBDE results compare to the MWOO toluene extraction result – ground MWOO

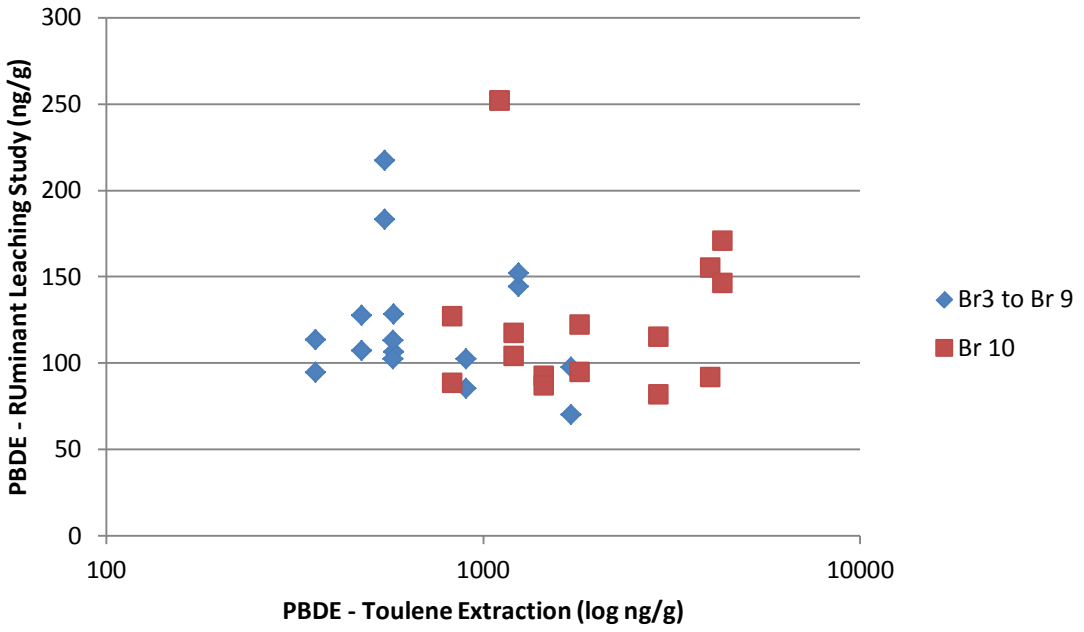

Figure 8: 24 hour ruminant leaching PBDE results compare to the MWOO toluene extraction result – unground MWOO

6.7 BIOACCESSIBLE PBDE

There are three levels of the calculation based on our knowledge of the bioaccessible PBDE mass content, i.e. $(\gamma_{\mathrm{PBDE}} \times \beta)$ in Equation 1.

6.7.1 Measured bioaccessibility from kinetic model

One sample, D2 with total PBDE of 14,358 ng/g, was used to study the kinetics of leaching (see Section 6.6). By fitting the uptake of PBDE into a silicone cord to a first-order kinetic model the maximum accessible mass of PBDE (*a* in Equation 3).

$$m_t = a\left(1 - e^{-kt}\right)$$

Equation 3

m_t is the mass of PBDE absorbed at time *t*, and *k* is the rate constant for absorption. Fitting to duplicated unground MWOO samples gave values for *a* of 322 ng/g (standard error 7 ng/g) for PBDE Br3 to Br9, and 542 ng/g (standard error 4 ng/g) for PBDE Br10.

6.7.2 Calculated bioaccessibility from mass leached in 24 h

Eight samples were extracted for 24 h only. Multiplying the moisture-corrected mass leached at 24 hours by a factor calculated as a/m_{24}, gives an estimate of the bioaccessible mass for that sample. Results are given in Table 22.

Table 22: Calculated bioaccessible PBDE derived from 24 h absorption experiments

Sample	Br3 to-Br9 /ng	Br10 /ng
A3	200	286
A5	156	319
A8	174	254
C6	217	280
C7	193	279
C8	218	232
D4	275	410
D7	371	651

It was observed that there was an approximately inverse power relationship between the bioaccessible PBDE content and the total (toluene leachable) PBDE content (see Figure 9 for Br1 to Br9 and Figure 10 for Br10). This allowed a model of bioaccessibility as a function of total PBDE to be established.

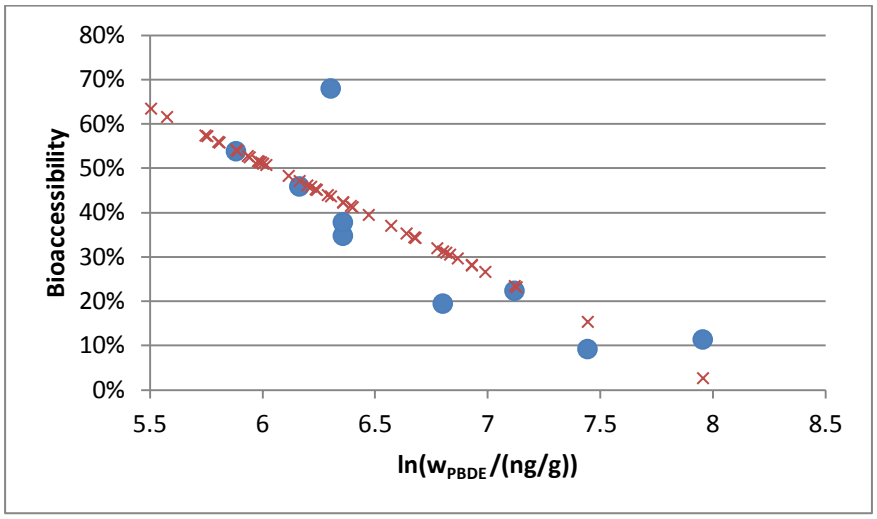

Figure 9: Bioaccessibility of D2 and eight 24 h leached samples plotted against log (total PBDE) content for Br3 – Br 9. Red crosses are calculated values of 41 other samples

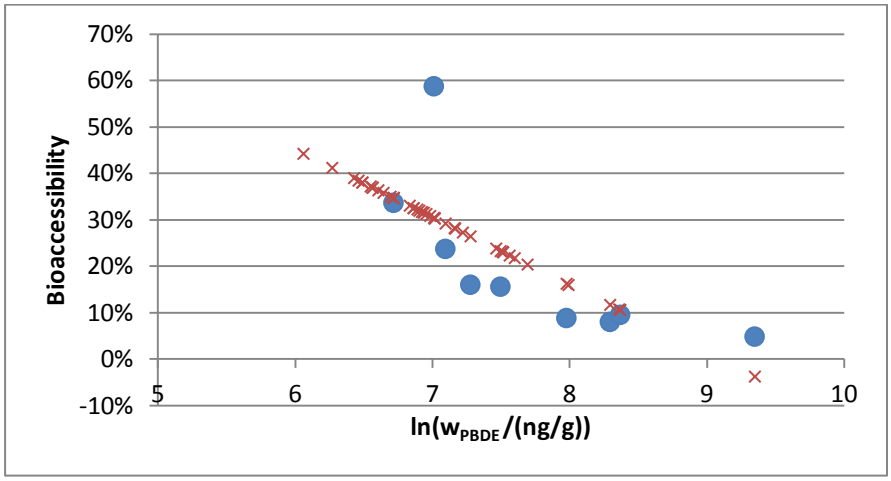

Figure 10: Bioaccessibility of D2 and eight 24 h leached samples plotted against log (total PBDE) content for Br10. Red crosses are calculated values of 41 other samples

6.7.3 Calculated bioaccessibility from total PBDE

The bioaccessibility values of the remaining 41 samples (with lognormally-distributed total (toluene extracted) PBDE contents) were calculated from the modelled bioaccessibility shown in Figure 9 and Figure 10. Under the hypothesis that the available PBDE in unground MWOO is approximately constant and independent of the total PBDE content, a mean bioaccessible content was calculated as 236 ng/g (*s* = 72 ng/g) for PBDE Br3 – Br9, and 361 ng/g (*s* = 145 ng/g) for PBDE Br10.

Bringing together the different levels of assessment of bioaccessibility, Tables 23 and 24 gives calculated bioaccessibility values for each sample.

Table 23: Bioaccessibility values for samples analysed in this study

	$\gamma_{PBDE} \times \beta$ **Br3 to Br9 /ng**	$\gamma_{PBDE} \times \beta$ **Br10 /ng**
D2	322	542
A3	200	286
A5	156	319
A8	174	254
C6	217	280
C7	193	279
C8	218	232
D4	275	410
D7	371	651
Mean value for HHERA	236	361

Table 24: Bioaccessibility values from bioaccessibility model and total toluene-extracted PBDE

	$\gamma_{PBDE} \times \beta$ **Br3 to Br9 /ng**	$\gamma_{PBDE} \times \beta$ **Br10 /ng**
A1	186	241
A2	204	275
A4	289	454
A6	232	415
A7	156	218
A9	194	312
A10	138	190
A11b	264	435
C1	200	312
C2	180	269
C3	176	295
C3 (dup)	196	349
C4	163	251
C5	180	246
C9	206	260

	$\gamma_{PBDE} \times \beta$ Br3 to Br9 /ng	$\gamma_{PBDE} \times \beta$ Br10 /ng
C10	193	234
C10	216	324
D1	231	322
D3	248	332
D5	287	422
D6	247	339
D8	262	319
D8	276	314
D9	284	448
D10	255	327
D11	289	414
D12 dup	257	293
D14	283	339
D15	289	430
D16	282	307
E1	208	251
E2	207	262
E3	287	374
E4	237	287
E5	229	287
E6	199	262
E7	273	474
E8	272	423
E9	232	365
E10 (dup)	203	362
E11	227	319

6.7.4 Discussion

The bioaccessibility study leaching experiments demonstrate that the mass of PBDE that mobilises from PBDE onto the silicone cord sorption sink in the aqueous phase is not proportional to the total mass of PBDE in the MWOO samples measured using accelerated solvent extraction using toluene. None of the samples that underwent the ruminant leaching process showed levels that approached the high values in the toluene extraction studies. This includes the aqueous leaching studies performed on the sample that had the high level outlier value (14359 ng/g), as identified in section 4.2. It would be expected that even the higher results from the previous sampling in 2013/14, extracted PBDE would be expected to be in a similar range to the leachate results for 2018. However as the 2013/14 samples were extracted using accelerated solvent extraction in toluene and not in the sorption sink aqueous leaching studies, the 2013/14 data are not presented here.

6.7.4.1 Toluene outliers and measured bioaccessibility

Over the course of the Panel's work it collected and analysed samples from many different MWOO piles and facilities. Primarily these analyses relied on accelerated solvent extraction

using toluene to obtain a measure for the total PBDE in the MWOO, as well as experiments using aqueous leaching protocols mimicking cattle gut and environmental conditions.

The accelerated solvent extraction using toluene results for PBDE mass followed a lognormal distribution when three outlier results were excluded, FOGO/MWOO-mixed samples were excluded and controls were excluded (see Chapter 4 and Appendix 5). Even excluding the outliers, these data had a wide range values from 632.98 to 5723.09 ng/g.

However, when the aqueous extraction experiments were performed, they were remarkably similar to each other (ranging within a band of approximately 200ng/g) and weren't proportional to the total PBDE mass in the samples. Rather, there was an approximately inverse power relationship between the bioaccessible PBDE content (from leaching) and the total (toluene leachable) PBDE content.

Following extensive consideration, the Panel concluded that the mass of PBDE that leaches in aqueous media is related to the surface area of the particles, while the amount that is liberated through toluene extraction is related to the volume of the particles.

Using the nine samples (one outlier (14359 ng/g D2) and eight non-outliers) where the Panel had both toluene PBDE results and aqueous results (leaching data of unground MWOO with the silicone cord sorption sinks) for PBDE mass (Section 6.7), the Panel was able to develop a statistical model against which the remaining 41 toluene samples with lognormal distribution for total PBDE could be fitted (Figures 9 and 10). The reader may question why outlier and other specific samples were not included in this model. The following three paragraphs explain the reasoning.

1. Toluene outliers – two of the three outliers (A11a (47050 ng/g) (Table 34) and D13 (97918 ng/g) (Table 36)) weren't leached in aqueous experiments. The Panel determined that it would not make statistical sense to attempt to include these in the model (Figures 9 and 10) when equivalent aqueous leaching data wasn't available. This contrasts with the third outlier (D2 sample), where both aqueous and toluene data were available.
2. MWOO/FOGO mixtures – MWOO from one facility was evidently mixed with FOGO, with samples collected in both the 2013/2014 and 2018 reflecting this mixture. These samples were measured with toluene extraction. However, the FOGO heavily diluted the MWOO material, resulting in PBDE concentrations that were far lower than the set examined in this work from the other sites. These samples were not included in the ruminant and environmental leachate experiments as the concentrations were far lower than the samples from the other sites, so sites with the higher concentrations would be protective of these. Consequently, when fitting the aqueous cattle leaching results to the toluene results to model bioaccessibility, the set of MWOO/FOGO results (whether from 2013/14 or 2018 samples) were not included.
3. Old dataset – The 2013/14 data are presented in Appendix 1 and Appendix 5. These data were not included in the cattle leaching study. The toluene levels from these samples had a lognormal mean of 1800 ng/g, similar to the levels from 2018. However, the distribution of the data from the 2013/14 set had a significantly greater variance than the new set (Appendix 5). In addition, as the Panel had not undertaken leaching experiments on these five samples, their inclusion in the model (Section 6.7) would not add any statistical power, and therefore no benefit.

6.8 MASS DISTRIBUTION STUDY

6.8.1 Introduction

A feature of the results obtained in the ruminant leaching studies conducted was that the absolute mass of PBDEs extracted onto the silicone cord sorption sink was relatively

independent of the total PBDEs in the sample, as determined by accelerated solvent extraction using toluene. Results from the ruminant leaching study showed that the amount of extracted total PBDE from 1 g of MWOO varied in the approximate range of 100-500 ng for MWOO samples containing approximately 1,000 to15,000 ng of PBDEs. That is, the extracted amount varied over a five-fold range for samples in which the total PBDEs varied over a fifteen-fold range.

The observed behaviour could be attributed to two main scenarios. First, the extraction-limited scenario. Here, the PBDEs are extracted from the MWOO samples to only a limited degree, perhaps as a result of variations in particle size of the plastics present in the MWOO. Second, the adsorption-limited scenario. Here, the amount of extracted PBDE which can adsorb onto the silicone cord is limited by the adsorption capacity of the silicone cord, either as a result of limited primary adsorption capacity or as a result of modification of the silicone cord adsorption sites by labile organic components extracted from the MWOO.

To move forward in interpreting results, it was important for the Panel to examine these scenarios. A convenient way to differentiate between these two scenarios was to conduct a mass-distribution experiment on a range of samples having differing PBDE contents.

6.8.2 Principle of mass-distribution experiment

The extraction setup is a three-phase system consisting of MWOO, GI extractant, and silicone cord. By determining the mass of PBDE present in each phase after extraction it should be possible to distinguish between the extraction-limited and adsorption-limited scenarios. This is shown in Figure 11.

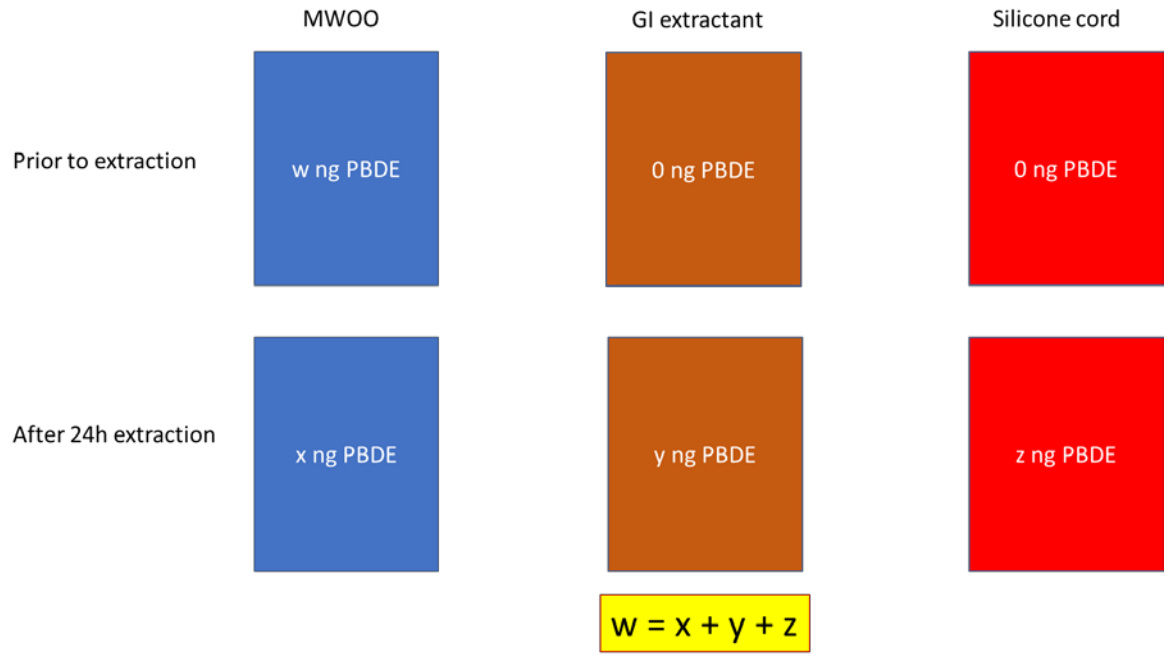

Figure 11: Schematic of mass distribution experiment

If three different MWOO samples were taken (e.g. w = 1,000, 5,000, 15,000 ng) the observations that had been made in the ruminant leaching study suggested that the amount of PBDE extracted onto the silicone cord (i.e. z in Figure 11) would be roughly constant. If the amount of PBDE present in the extractant (i.e. y) were small and roughly constant, but the amount of PBDE remaining in the MWOO after 24 h (i.e. x) were high and varied roughly in proportion to the original amount present prior to extraction (i.e. w) this would indicate that the adsorption capacity of the silicone cord was not exceeded and therefore the process was extraction-limited. However, if x were approximately constant and y varied in proportion to

the original amount present prior to extraction, this would indicate that the process was adsorption-limited.

6.8.3 Procedure

Three ground and three unground MWOO samples representative of low, medium and high PBDE mass content were selected. The candidates selected were those shown below:

- Ground MWOO A5
- Ground MWOO C8
- Ground MWOO D2

Duplicate 1 g samples were mixed with 100 mL of GI extractant and 1 m of silicone cord and extracted for 24 h at 37°C. At the end of the extraction, the silicone cord was removed and the MWOO recovered by filtration (0.5 µm glass fibre filters) with retention of the filtrate. Note that one sample was also subjected to treatment using 2 m of silicone cord in order to further explore whether there was evidence of saturation of the adsorption sites on the cord, which would occur if the process was adsorption-limited.

Separate analyses were conducted on the samples of the residual MWOO, the GI extractant solution, and the silicone cord and the mass of PBDE present in each phase determined.

6.8.4 Results from mass distribution study

The raw results from the mass distribution are presented in Appendix 8. These results were adjusted back to the original sample size/weight and the proportion of PBDE in each sample type calculated and shown in Table 25.

Table 25: Percentage of PBDE in mass distribution study samples

Sample Code	Sample type	Total PBDE (Br3 to10) present in each phase (ng)	Sum of PBDE(Br3 to 10) present in residual solid, liquid and silicone cord (ng)	Percentage of PBDE (Br3-10) in each phase (%)
Unground A5	MWOO after extraction	670	827	81.0
	GI extraction	27		3.3
	Silicone cord – 1m	130		15.7
Ground A5	MWOO after extraction	1850	2134	86.7
	GI extraction	54		2.5
	Silicone cord – 1m	230		10.8
Ground C3	MWOO after extraction	1150	1456	79.0
	GI extraction	76		5.2
	Silicone cord – 1m	230		15.8
Unground C7	MWOO after extraction	890	1096	81.2
	GI extraction	46		4.2
	Silicone cord – 1m	160		14.6
Unground D2	MWOO after extraction	1050	1387	75.7

	GI extraction	87		6.3
	Silicone cord – 1m	250		18.0
Ground D2	MWOO after extraction	1860	2326	80.0
	GI extraction	86		3.7
	Silicone cord – 1m	380		16.3
Ground D2	MWOO after extraction	2310	2832	81.6
	GI extraction	62		2.2
	Silicone cord – 2m	460		16.2

6.8.5 Discussion

The mass distribution study demonstrated the following:

- the mass of PBDE present in the silicone cord varied over the range 130-460 ng and therefore exhibited the same behaviour as that observed previously in the ruminant leaching study. It is also noteworthy that increasing the length of silicone cord from 1 m to 2 m for sample D2 resulted in only a relatively small increase in the extracted mass of PBDE (from 380 ng to 460 ng) although these values were the same as a percentage of total PBDE (16%)
- in all cases, the percentage of PBDEs present in the liquid phase (GI extractant) was the smallest of all three phases and ranged between 2.5% and 6.7%
- in all cases, the largest amount of PBDEs was present in the residual solid MWOO, indicating that the overall extraction efficiency was poor. The percentage of residual PBDE remaining in the MWOO after extraction ranged from 75.3% to 86.7%.

These results suggest strongly that the experiments undertaken in the ruminant leaching study were extraction-limited. That is, the bulk of the PBDE remained unextracted from the sample and the extracted PBDEs were transferred efficiently through the GI extractant to the silicone cord phase. There is no evidence that any adsorption-limited behaviour occurred.

As mentioned earlier, a plausible explanation for the system being extraction-limited lies in a consideration of the effect of the size of plastic particles on the mass of PBDEs leached over a fixed period of time.

An important observation from the ruminant leaching sorption sink results examined in HRGC/HRMS in comparison to the PBDE toluene extraction results is that the PBDE in the MWOO samples appears to be firmly encased in particles. When comparing the ruminant leaching results that emerged for samples that had previous high versus low toluene results, the leachate samples were relatively similar. This indicates that the amount that is leached out is independent of the toluene PBDE measurement.

Figure 12 illustrates particle size effects on PBDE extraction and demonstrates how the presence of a distribution of large particles amongst smaller particles can have a considerable impact on the quantity of PBDE not liberated by an aqueous extractant, but that would be observed using toluene which dissolves all particles, thus releasing PBDEs.

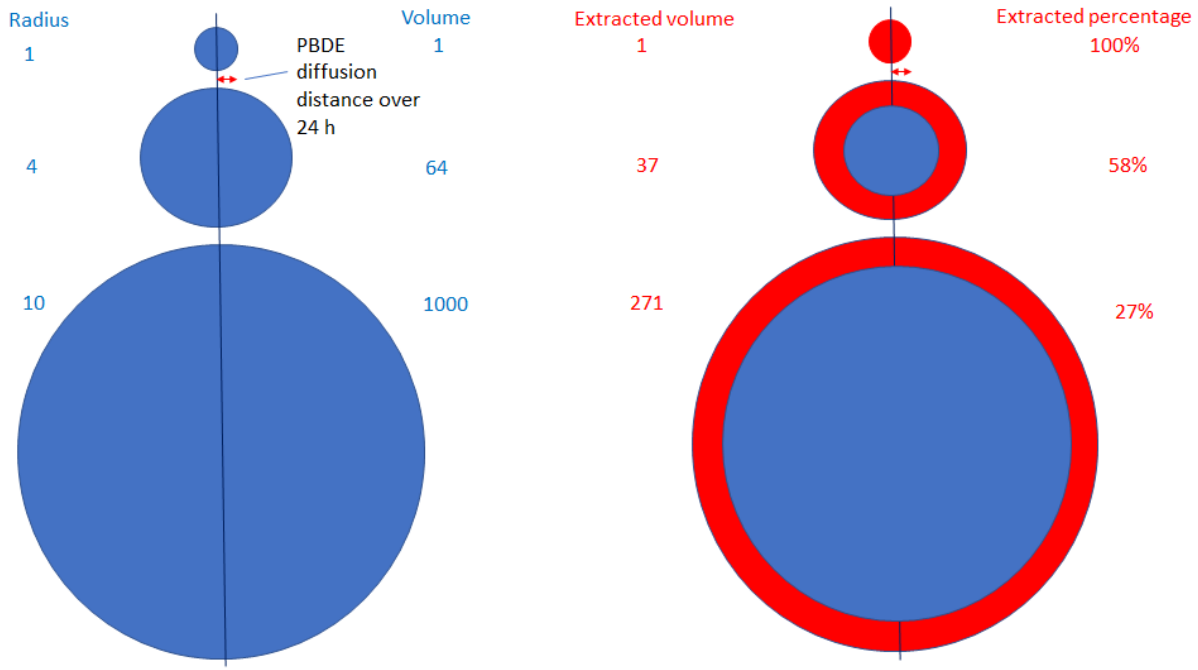

Figure 12: Illustration of the concept of particle size effects on PBDE extraction.
Numbers and figures are not to scale. The diagram serves to demonstrate the relationships between particle radius, surface area, the volume of particle that would be extracted, and total particle volume. The red component of the diagrams represents the fraction of the particles where PBDE would leach in aqueous experiments. The blue portion of the figures represents the volume of the particle that could release PBDE when using accelerated toluene extraction protocols.

6.9 RECOMMENDATIONS

The results in this study demonstrate that when estimating the mass of PBDE that would be accessible to cattle from MWOO, measurements of PBDE from accelerated solvent extraction using toluene should not be used on their own. The calculation of bioavailable PBDE should be based on leaching experiments in aqueous conditions that reflect the environment of the material *in situ*. The mobilisation of PBDE from MWOO in aqueous media is limited by a range of factors including the hydrophobicity of the PBDE molecules and the role of the plastic particles themselves encapsulating the PBDE within them. In an accelerated solvent extraction process using toluene, these factors are overcome, meaning the mass of PBDE mobilised is greatly enhanced and accelerated. In the experiments described in this report, the mass of PBDE that mobilises from MWOO is extraction-limited and sits within a relatively low and narrow mass band.

The Panel recommends that

- For transfer factors, a τ value of 0.53 (with standard deviation of 0.12) be used for PBDE Br3 to B9 and a value of 0.02 be used for PBDE Br10
- No adjustment is needed for environmental leaching as the PBDE appears to remain in the MWOO
- The mean bioaccessible content of PBDE in MWOO is 236 ng/g (*s* 72 ng/g) for PBDE Br3 to Br9, and 361 ng/g (*s* 145 ng/g) for PBDE Br10, values that are derived from the aqueous cattle leaching studies. When using these data, the bioaccessibility ratio (β) is 1.

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ACROYNMS

Acronym	Complete Term
ASE	Accelerated solvent extraction
AWT	Alternative Waste Technology
BDE	Brominated diphenyl ethers
DHS	Dissolved humic solution
enHealth	Environmental Health Standing Committee
FOGO	Food Organic and Garden Organic
GI	Gastro-intestinal
HI	Hazard index
HQ	Hazard Quotient
HRGC	High resolution gas chromatography
HRMS	High resolution mass spectrometry
HHERA	Human Health and Ecological Risk Assessment
LOQ	Limit of Quantitation
LOR	Limit of Reporting
MWOO	Mixed Waste Organic Outputs
NEPC	National Environmental Protection Council
NMI	National Measurement Institute
DPI	NSW Department of Primary Industries
EPA	NSW Environment Protection Authority
OEH	Office of Environment and Heritage
OCSE	Office of the NSW Chief Scientist &Engineer
PCA	Principal Components Analysis
SPLP	Synthetic precipitation leaching procedure
TAC	Technical Advisory Committee
TCLP	Toxicity characteristic leaching procedure
UniSA	University of South Australia
WEEE	Waste Electrical and Electronic Equipment

APPENDIX 1: 2013 AND 2014 MWOO PBDE RESULTS FROM ACCELERATED SOLVENT EXTRACTIONS IN TOLUENE

Table 26: 2013/14 Facility A and Facility B
(data reported in ng/g)

Facility	**A**						**B**					
Season	**2013**	**2014**					**2013**	**2014**				
Round	1	1	2	3	3 dup	4	1	1	2	3	3 dup	4
Tribromodiphenyl ether	4.41	2.353	7.10	3.80	2.92	177.1	1.04	2.31	1.66	0.59	0.91	0.74
Tetrabromodiphenyl ether	56.25	28.01	75.45	38.87	32.64	1277.5	31.88	30.46	23.63	10.89	13.63	10.56
Pentabromodiphenyl ether	70.63	32.39	64.13	44.56	291.07	639.15	58.80	44.96	36.37	14.59	19.73	13.49
Hexabromodiphenyl ether	134.30	210.76	27.73	23.22	115660	1014.9	13.10	10.44	10.2	5.07	5.66	3.26
Hexabromobiphenyl	0.94	0.76	1.3	1.1	3	1.7	0.27	0.23	0.24	0.13	0.21	0.07
Heptabromodiphenyl ether	601.6	1083.7	61.88	67.98	332720	4290.7	10.25	13.76	13.7	3.30	6.63	3.31
Octabromodiphenyl ether	434.45	738.55	60.65	58.6	201675	2627	17.13	12.27	13.07	2.71	5.67	2.81
Nonabromodiphenyl ether	465	547	282	276	57710	1226	29	27.6	67	6.1	12.9	8
Decabromodiphenyl ether	2980	4720	3250	3630	7510	3330	180	220	810	54	100	70
PBDE – Br1 to Br9	**1767.59**	**2643.52**	**580.25**	**514.14**	**708094.36**	**11254.05**	**161.49**	**142.03**	**165.87**	**43.38**	**65.34**	**42.25**
PBDE10	**2980**	**4720**	**3250**	**3630**	**7510**	**3330**	**180**	**220**	**810**	**54**	**100**	**70**
Total PBDE	**4747.59**	**7363.52**	**3830.25**	**4144.14**	**715604.63**	**14584.05**	**341.49**	**362.03**	**975.87**	**97.38**	**165.34**	**112.25**

(Note: data extracted from NMI certificates of analysis, not detected treated as ½ limit of reporting see Section 4.1.2)

APPENDIX 2: MWOO SAMPLE INFORMATION

Table 27: MWOO sample information and analyses undertaken by sample code

Facility	Sample Number	Notes	Samples analysed						
			Particle size	PBDE – toluene extraction	Environmental Leaching Study		Ruminant Leaching Study		Mass Distribution Study
					Kinetic	Bioaccessibility	Kinetic	Bioaccessibility	
A	1			√					
	2			√					
	3			√		√		√	
	4			√					
	5			√		√			√
	6			√					
	7			√					
	8			√		√			
	9			√					
	10			√					
	11a			√					
	11b	Field duplicate		√					
	Trip Blank	Laboratory duplicate		√					
B	Trip Blank	Laboratory duplicate		√					
	1			√					
	2			√					
	3			√					
	4			√					

Facility	Sample Number	Notes	Samples analysed						
			Particle size	PBDE – toluene extraction	Environmental Leaching Study		Ruminant Leaching Study		Mass Distribution Study
					Kinetic	Bioaccessibility	Kinetic	Bioaccessibility	
C	1			√					
	2			√					
	3			√					√
	3	Field duplicate		√					
	4			√					
	5			√					
	6			√		√		√	
	7			√		√		√	√
	8			√		√		√	
	9			√					
	10	Laboratory duplicate		√					
D	1			√					
	2		√	√	√		√		√
	3			√					
	4		√	√		√		√	
	5			√					
	6			√					
	7		√	√		√		√	
	8	Laboratory duplicate		√					
	9			√					
	10			√					
	11			√					

Facility	Sample Number	Notes	Samples analysed						
			Particle size	PBDE – toluene extraction	Environmental Leaching Study		Ruminant Leaching Study		Mass Distribution Study
					Kinetic	Bioaccessibility	Kinetic	Bioaccessibility	
	12	Field duplicate of 11		√					
	Trip Blank			√					
	13			√					
	14			√					
	15			√					
	16			√					
E	Trip Blank	Laboratory duplicate		√					
	1			√					
	2			√					
	3			√					
	4			√					
	5			√					
	6			√					
	7			√					
	8			√					
	9			√					
	10	Field duplicate of 9		√					
	11			√					

APPENDIX 3: LIST OF PBDEs ANALYSED

Table 28: PBDE limit of detection (LOD) and limit of reporting (LOR)

Compound	Full name	Solids	
		LOD (ng/g)	Representative LOR (ng/g)
BDE 17	2,2,'4-Tribromodiphenyl ether	0.002	0.01
BDE 28 + 33	2,4,4'-Tribromodiphenyl ether + 2',3,4-Tribromodiphenyl ether	0.004	0.04
BDE 30	2,4,6-Tribromodiphenyl ether	0.002	0.01
BDE 47	2,2',4,4'-Tetrabromodiphenyl ether	0.01	0.1
BDE 49	2,2,'4,5'-Tetrabromodiphenyl ether	0.002	0.01
BDE 66	2,3',4,4'-Tetrabromodiphenyl ether	0.002	0.01
BDE 71	2,3,'4',6-Tetrabromodiphenyl ether	0.002	0.01
BDE 77	3,3',4,4'-Tetrabromodiphenyl ether	0.002	0.01
BDE 85	2,2',3,4,4'-Pentabromodiphenyl ether	0.002	0.01
BDE 99	2,2',4,4',5-Pentabromodiphenyl ether	0.04	0.2
BDE 100	2,2',4,4',6-Pentabromodiphenyl ether	0.1	0.5
BDE 119	2,3',4,4',6-Pentabromodiphenyl ether	0.002	0.01
BDE 126	3,3',4,4',5-Pentabromodiphenyl ether	0.002	0.01
BDE 138 + 166	2,2',3,4,4',5'-Hexabromodiphenyl ether + 2,3,4,4',5,6-Hexabromodiphenyl ether	0.005	0.03
BDE 139	2,2',3,4,4',6-Hexabromodiphenyl ether	0.005	0.03
BDE 140	2,2',3,4,4',6'-Hexabromodiphenyl ether	0.005	0.03
BDE 153	2,2',4,4',5,5'-Hexabromodiphenyl ether	0.005	0.03
BDE 154	2,2',4,4',5,6'-Hexabromodiphenyl ether	0.005	0.03
BDE 156 + 169	2,3,3',4,4',5-Hexabromodiphenyl ether + 3,3',4,4',5,5'-Hexabromodiphenyl ether	0.005	0.03
BB 153	2,2',4,4',5,5'-Hexabromobiphenyl	0.005	0.03
BDE 171	2,2',3,3',4,4',6-Heptabromodiphenyl ether	0.005	0.03
BDE 180	2,2',3,4,4',5,5'-Heptabromodiphenyl ether	0.002	0.01
BDE 183	2,2',3,4,4',5',6-Heptabromodiphenyl ether	0.005	0.03
BDE 184	2,2',3,4,4',6,6'-Heptabromodiphenyl ether	0.002	0.01
BDE 191	2,3,3',4,4',5',6-Heptabromodiphenyl ether	0.002	0.01
BDE 196	2,2',3,3',4,4',5,6'-Octabromodiphenyl ether	0.005	0.03
BDE 197	2,2',3,3',4,4',6,6'-Octabromodiphenyl ether	0.005	0.03
BDE 201	2,2',3,3',4,5',6,6'-Octabromodiphenyl ether	0.005	0.03
BDE 203	2,2',3,4,4',5,5',6-Octabromodiphenyl ether	0.005	0.03

Compound	Full name	Solids	
		LOD (ng/g)	Representative LOR (ng/g)
BDE 204	2,2',3,4,4',5,6,6'-Octabromodiphenyl ether	0.01	0.05
BDE 205	2,3,3',4,4',5,5',6-Octabromodiphenyl ether	0.01	0.05
BDE 206	2,2',3,3',4,4',5,5',6-Nonabromodiphenyl ether	0.01	0.3
BDE 207	2,2',3,3',4,4',5,6,6'-Nonabromodiphenyl ether	0.01	0.3
BDE 208	2,2',3,3',4,5,5',6,6'-Nonabromodiphenyl ether	0.01	0.3
BDE 209	2,2',3,3',4,4',5,5',6,6'-Decabromodiphenyl ether	0.2	3

APPENDIX 4: MWOO PBDE RESULTS FROM ACCELERATED SOLVENT EXTRACTIONS IN TOLUENE

Table 29: 2018/19 Facility A
(data reported in ng/g)

Sample Number	1	2	3	4	5	6	7	8	9	10	11a	11b	Trip Blank	Trip Blank
Tribromodiphenyl ether	0.9	0.76	1.13	0.725	2.19	0.87	1.12	1.73	1.57	0.44	1.01	1.86	0.04	0.03
Tetrabromodiphenyl ether	16.28	14.16	32.1	15.30	19.54	12.98	14.97	27.22	15.3	11.06	24.82	17.86	1.16	1.15
Pentabromodiphenyl ether	24.89	22.35	45.85	21.32	24.47	18.47	18.58	34.82	21.02	18.64	50.7	23.48	1.89	2.01
Hexabromodiphenyl ether	7.23	7.69	13.83	12.02	19.06	7.59	6.41	11.92	7.34	5.11	2357.3	9.77	0.46	0.38
Hexabromobiphenyl	0.13	0.33	0.21	0.19	0.53	0.15	0.18	0.19	0.13	0.18	17	0.16	0.01	<0.01
Heptabromodiphenyl ether	16.35	22.08	25.66	51.97	121.1	25.04	16.17	35.06	26.64	9.29	12489	33.89	0.51	0.12
Octabromodiphenyl ether	41.58	56.5	67.42	118.34	226.2	49.14	28.78	70.53	40.43	23.26	13710	87.68	0.40	0.13
Nonabromodiphenyl ether	225	272	391	1030	1300	400	160	720	249	135	5100	540	0.65	0.45
Decabromodiphenyl ether	620	770	1210	4280	4010	1750	530	2920	960	430	13300	2000	2	1.5
PBDE – Br1 to Br9	**332.35**	**395.86**	**577.21**	**1249.86**	**1713.09**	**514.23**	**246.21**	**901.46**	**361.43**	**202.98**	**33749.83**	**714.7**	**5.09**	**4.27**
PBDE10	**620**	**770**	**1210**	**4280**	**4010**	**1750**	**530**	**2920**	**960**	**430**	**13300**	**2000**	**2**	**1.5**
Total PBDE	**952.35**	**1165.86**	**1787.21**	**5529.86**	**5723.09**	**2264.23**	**776.21**	**3821.46**	**1321.43**	**632.98**	**47049.83**	**2714.7**	**7.09**	**5.77**

* Stockpile number reflects the number written in the sample code

Table 30: 2018/19 Facility B
(data reported in ng/g)

Sample Number	1	2	3	4	Trip Blank	Trip Blank
Tribromodiphenyl ether	0.33	0.42	0.32	0.36	0.01	0.01
Tetrabromodiphenyl ether	9.51	10.73	6.04	10.48	1.06	1.15
Pentabromodiphenyl ether	12.68	13.94	8.09	13.74	2.04	2.05
Hexabromodiphenyl ether	2.22	3.47	1.45	2.18	0.35	0.34
Hexabromobiphenyl	0.08	0.08	0.09	0.11	<0.01	<0.01
Heptabromodiphenyl ether	1.02	8.37	1.00	1.59	0.04	0.03
Octabromodiphenyl ether	7.94	18.04	6.45	16.1	0.17	0.15
Nonabromodiphenyl ether	28.1	79	50	103	0.65	0.65
Decabromodiphenyl ether	69	230	150	250	1.5	1.5
PBDE – Br1 to Br9	**61.87**	**134.05**	**73.42**	**147.55**	**4.32**	**4.37**
PBDE10	**69**	**230**	**150**	**250**	**1.5**	**1.5**
Total PBDE	**130.87**	**364.05**	**223.42**	**397.55**	**5.82**	**5.87**

Table 31: 2018/19 Facility C
(data reported in ng/g)

Sample Number	**1**	**2**	**3**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10**
Tribromodiphenyl ether	1.06	0.9	0.92	0.94	0.84	0.95	0.88	0.89	0.98	1.21	1.11	1.00
Tetrabromodiphenyl ether	26.65	21.21	20.14	21.19	21.00	21.30	20.03	21.24	21.55	25.75	26.67	27.72
Pentabromodiphenyl ether	45.19	34.13	32.75	35	32.86	34.08	31.73	34.01	33.95	41.6	44.04	47.77
Hexabromodiphenyl ether	27.69	21.87	20.54	19.82	18.76	20.46	20.35	23.05	32.83	25.76	30.19	34.47
Hexabromobiphenyl	0.57	0.59	0.6	0.55	0.76	0.91	1	0.41	0.72	0.83	0.43	0.62
Heptabromodiphenyl ether	57.28	53.41	46.94	45.53	41.97	49.99	56.58	53.38	86.81	61.25	68.33	86.3
Octabromodiphenyl ether	68.33	52.83	49.9	60.75	42.35	52.76	78.07	60.73	90.2	77.63	65.86	85.18
Nonabromodiphenyl ether	155	131	130	182	106	133	370	166	209	168	119	158
Decabromodiphenyl ether	960	740	870	1190	660	640	1810	830	1450	700	590	1030
PBDE – Br1 to Br9	**381.76**	**315.93**	**301.79**	**365.78**	**264.54**	**313.44**	**578.65**	**359.71**	**476.03**	**402.03**	**355.63**	**441.06**
PBDE10	**960**	**740**	**870**	**1190**	**660**	**640**	**1810**	**830**	**1450**	**700**	**590**	**1030**
Total PBDE	**1341.76**	**1055.93**	**1171.79**	**1555.78**	**924.54**	**953.44**	**2388.65**	**1189.71**	**1926.03**	**1102.03**	**945.63**	**1471.06**

Table 32: 2018/19 Facility D
(data reported in ng/g)

Sample Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**8**	**9**	**10**	**11**	**12**
Tribromodiphenyl ether	1.17	1.4	1.46	1.47	1.29	1.19	1.07	1.48	1.39	1.5	1.31	1.28	0.97
Tetrabromodiphenyl ether	39.81	44.96	57.10	56.04	59.94	54.43	47.72	58.74	54.96	60.20	54.71	44.27	41.08
Pentabromodiphenyl ether	73.53	97.57	98.59	103.43	102.91	95.67	99.72	98.64	98.55	109.09	102.73	74.35	70.38
Hexabromodiphenyl ether	24.79	33.55	30.6	38	36.02	31.05	32.31	31.54	32.23	33.71	32.62	21.56	21.76
Hexabromobiphenyl	0.11	0.46	0.45	0.4	0.41	0.32	0.45	0.37	0.38	0.45	0.33	0.43	0.32
Heptabromodiphenyl ether	43.19	72.5	45.89	57	62.1	52.37	49.41	52.85	52.69	54.9	46.98	38.35	36.53
Octabromodiphenyl ether	61.5	208.5	64.46	112.59	140.17	68.76	66.2	143.06	92.7	110.48	78.25	175.1	109.07
Nonabromodiphenyl ether	267	2400	304	870	620	294	251	443	368	590	331	740	379
Decabromodiphenyl ether	1020	11500	1080	4320	1830	1120	1110	970	1000	2200	1050	1740	860
PBDE – Br1 to Br9	**511.10**	**2858.9**	**602.56**	**1238.93**	**1022.84**	**597.79**	**547.88**	**829.68**	**700.902**	**960.34**	**647.94**	**1095.34**	**659.1**
PBDE10	**1020**	**11500**	**1080**	**4320**	**1830**	**1120**	**1110**	**970**	**1000**	**2200**	**1050**	**1740**	**860**
Total PBDE	**1531.10**	**14358.9**	**1682.56**	**5558.93**	**2852.84**	**1717.79**	**1657.88**	**1799.68**	**1700.90**	**3160.34**	**1697.94**	**2835.34**	**1519.1**

Sample Number	13	14	15	16	Trip Blank
Tribromodiphenyl ether	1.15	1.80	1.54	2.35	0.03
Tetrabromodiphenyl ether	48	56.35	50.23	58.05	1.27
Pentabromodiphenyl ether	83.15	97.16	80.82	89.35	2.16
Hexabromodiphenyl ether	81.43	29.92	30.96	30.59	0.36
Hexabromobiphenyl	0.43	0.34	0.27	0.39	0.01
Heptabromodiphenyl ether	424.2	53.45	65.95	56.73	0.04
Octabromodiphenyl ether	880.2	140.73	136.71	195.12	0.26
Nonabromodiphenyl ether	19800	550	720	480	1
Decabromodiphenyl ether	76600	1120	1930	930	2
PBDE – Br1 to Br9	**21318.56**	**929.75**	**1086.49**	**912.6**	**5.14**
PBDE10	**76600**	**1120**	**1930**	**930**	**2**
Total PBDE	**97918.56**	**2049.75**	**3016.49**	**1842.6**	**7.14**

Table 33: 2018/19 Facility E
(data reported in ng/g)

Sample Number	1	2	3	4	5	6	7	8	9	10	11	Trip Blank	Trip Blank
Tribromodiphenyl ether	0.72	0.78	1.65	1.095	1.47	0.69	0.65	1.34	0.96	0.86	1.37	0.02	0.02
Tetrabromodiphenyl ether	25.02	26.02	51.21	46.27	39.40	29.13	16.77	56.15	30.77	30.59	58.09	1.16	1.28
Pentabromodiphenyl ether	42.7	43.98	90.38	80.68	64.74	53.32	27.32	96.21	50.5	51.90	102.86	2.06	2.4
Hexabromodiphenyl ether	17.11	15.32	50.9	25.95	22.78	16	14	30.76	18.29	18.69	33.72	0.39	0.51
Hexabromobiphenyl	0.28	0.74	0.79	0.49	0.74	0.14	0.42	0.26	0.55	0.55	0.61	0.01	0.01
Heptabromodiphenyl ether	32.96	28.35	77.1	39.81	32.76	22.8	32.39	50.9	30.15	26.51	75.67	0.15	0.21
Octabromodiphenyl ether	59.38	56.16	202.19	69.04	59.02	41.95	84.61	106.73	60.35	43.13	69.11	0.21	0.38
Nonabromodiphenyl ether	233	234	550	277	280	214	620	450	324	219	152	0.9	1.36
Decabromodiphenyl ether	660	710	1370	830	830	710	2970	1840	1300	1280	1000	7.9	12
PBDE – Br1 to Br9	**411.17**	**405.35**	**1024.22**	**540.326**	**500.90**	**378.02**	**796.12**	**792.33**	**515.56**	**391.22**	**493.41**	**4.90**	**6.17**
PBDE10	**660**	**710**	**1370**	**830**	**830**	**710**	**2970**	**1840**	**1300**	**1280**	**1000**	**7.9**	**12**
Total PBDE	**1071.17**	**1115.35**	**2394.22**	**1370.326**	**1330.90**	**1088.02**	**3766.15**	**2632.33**	**1815.56**	**1671.22**	**1493.42**	**12.80**	**18.17**

APPENDIX 5: ANALYSIS OF PBDE RESULTS OF MWOO

DATA

Samples

The data in Appendices 1 and 4 represent the PBDE results for MWOO from accelerated solvent extraction measurements from 'Old' (2013/2014) samples and 'New' (2018) samples.

Data used were PBDE congener (3 – 10 bromines, plus hexabromobiphenyl) mass content, and total PBDE mass content (mass of PBDE divided by dry weight of MWOO sample, all in ng/g).

The New data comprised 63 samples consisting of 37 'Agriculture', 15 'Non-Agriculture', 7 'Control', 2 'FOGO', 2 'FOGO + 'MWOO' (Pile type). Three pairs were field duplicates and two pairs were laboratory duplicates, the values of which were averaged when calculating mean and standard deviation of the distribution.

Duplicates

Three pairs of field duplicates and four pairs of laboratory duplicates (of which two pairs were controls) were included in the data set. The log-scale field duplicates differed by 8%, 1% and –4%, and the log-scale two sample laboratory duplicates differed by 1% and –6%.

The variability of the results discussed below therefore includes dispersion due to the measurement, which will be present for any future measurements unless the measurement method is changed.

Old data

There are 12 data from 'Season 4 and 5' detailed in Research Program "Project 3: Assessing the Toxicity of Mixed Waste Compost Leachate" Tables 13 and 14. The data are for PBDEs and hexabromobiphenyl (HBBP). These data are compared with data of the present study in Figure 13.

PBDE (Br3 –Br10) from the Old data is lognormally distributed with mean 1800 ng/g. The means of old and new data are similar, however the Old-data distribution has a significantly greater variance than that of the New data. (F-test for equality of variance, $P = 8 \times 10^{-15}$). Because of the differences between Old and New data the Panel concluded that it would not be appropriate to merge the data. Further analyses were undertaken using the New data.

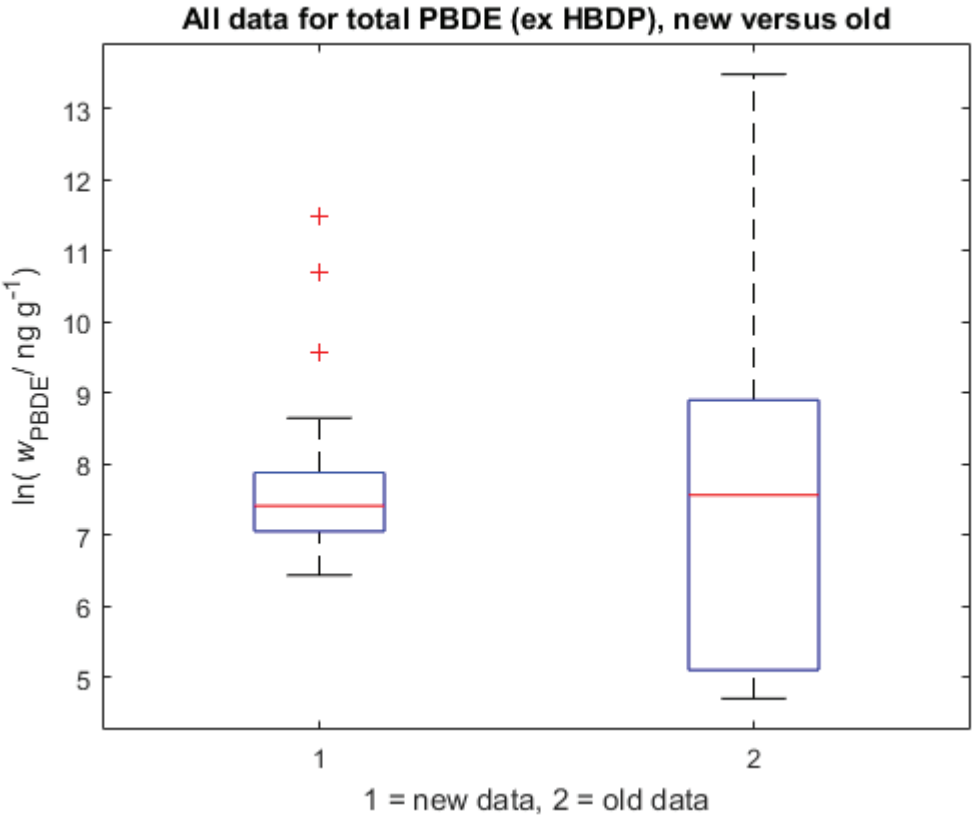

Figure 13: Total PBDE in 'New' and 'Old' data

TOTAL PBDE

The sum of the mass contents of congeners was studied, although it might be more biologically pertinent to use amount of substance.

Outliers – high mass fractions

There were three clear statistical outliers (Grubbs' test, one-sided ļ =0.05, recalculated after each outlier removed) on the log-transformed data, the following values: D13, 98 000 ng/g; A11a, 47 000 ng/g; D2, 14 000 ng/g. Comparing with the congener profile of the main data set, D13 and D2 were similar to the majority (PCA scores were calculated using the analysis of the majority congener fractions and the points in a scores plot fell with the majority), but A11a was not typical having considerably greater hexabromobiphenyl, and the heptamer and octomer.

These outlying results were not used to calculate the distribution parameters of the majority of MWOO samples, which, in their absence fit a lognormal distribution. They now have the status of 'extreme values' which must be considered separately, as discussed below.

Anova on site and pile type

There was little overlap between site and pile type. The ANOVA is therefore essentially two one-way ANOVAs. There was no significant difference (at the 95% confidence level) between sites or pile types. Inspecting the box plot (Figure 14), there is a wide range of data of all types.

Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
Site	1.8744	3	0.6248	2.65	0.0606
Agric?	0.0085	1	0.00855	0.04	0.8499
Error	10.3801	44	0.23591		
Total	12.2645	48			

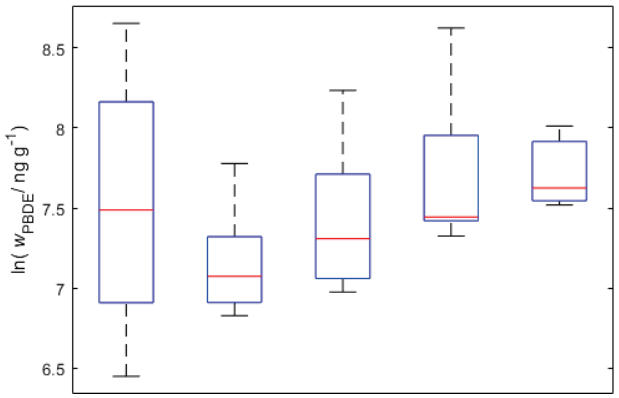

Figure 14: ANOVA and box plot for PBDE content by site and pile type (outliers excluded)

Probability Distribution of PBDE content

The data without outliers are reasonably lognormally-distributed (Figure 15). They are not normally distributed (log likelihood for lognormal: –361.77, log likelihood for normal: –375.27).

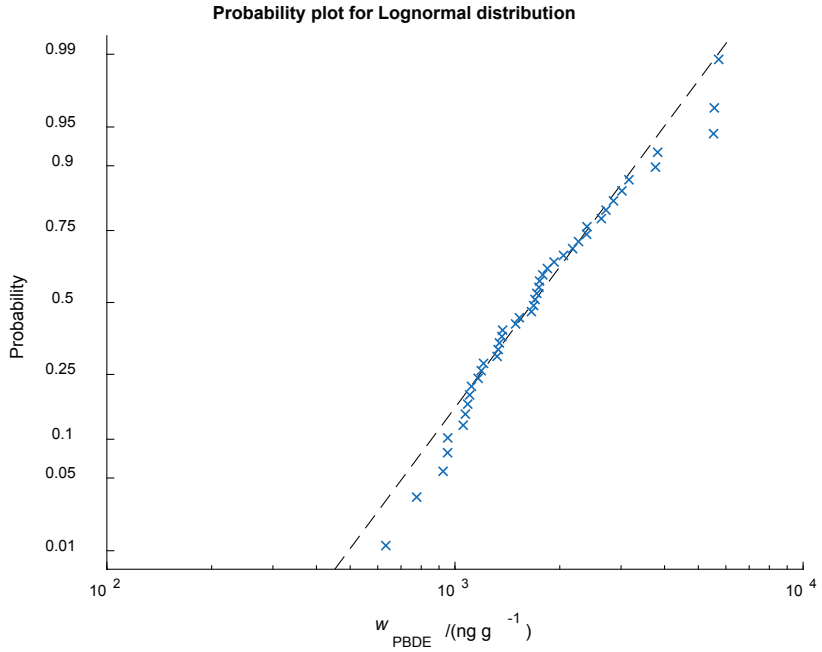

Figure 15: Probability plot of total PBDE content fitted to lognormal distribution

Fitted parameters for the lognormal distribution are given in Table 34.

Table 34: Fitted parameters for lognormal distribution of data – total PBDE

Probability fit	log	/(ng/g)		95% ci on parameters	
$\hat{\mu}$	7.5	1 700		7.3	7.6
$\hat{\sigma}$	0.52			0.43	0.66
upper 99%	8.7	5 900			

As discussed above the dispersion includes that due to the measurement.

Probability Distribution of PBDE Br3 to Br9 and PBDE Br10 content

The subsets of data distribute lognormally

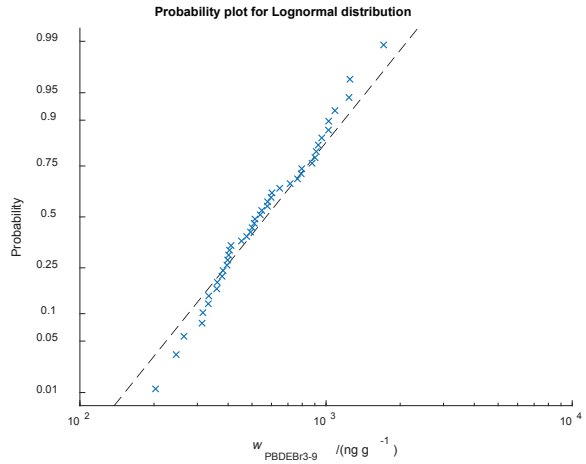

Figure 16: Probability plot of PBDE Br3 to Br9 content fitted to lognormal distribution

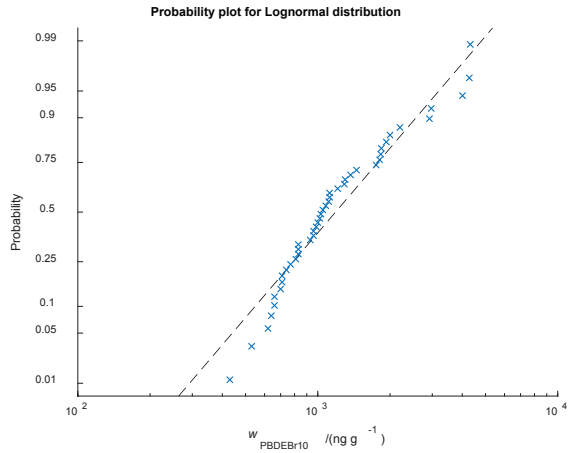

Figure 17: Probability plot of PBDE Br10 content fitted to lognormal distribution

Fitted parameters for the lognormal distributions of the subsets of Br3 – Br9 (including hexabromobiphenyl) are given in Table 35 and Table 36.

Table 35: Fitted parameters for lognormal distribution of data for PBDE Br3-Br9

Probability fit	log	/(ng/g)		95% ci on parameters	
$\hat{\mu}$	6.3	560		6.2	6.5
$\hat{\sigma}$	0.49			0.40	0.62
upper 99%	7.5	1 700			

Table 36: Fitted parameters for lognormal distribution of data for PBDE Br10

Probability fit	log	/(ng/g)		95% ci on parameters	
$\hat{\mu}$	7.1	1 200		6.9	7.2
$\hat{\sigma}$	0.54			0.46	0.71
upper 99%	8.4	4 300			

Congeners

A boxplot of the contents of PDBE congeners is shown in Figure 18 and Figure 19.

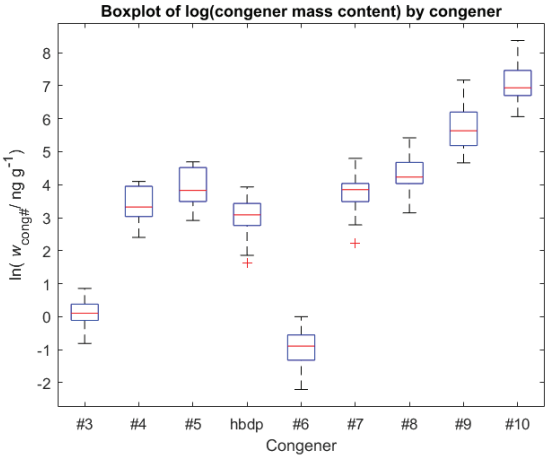

Figure 18: Boxplot of log (congener mass contents)

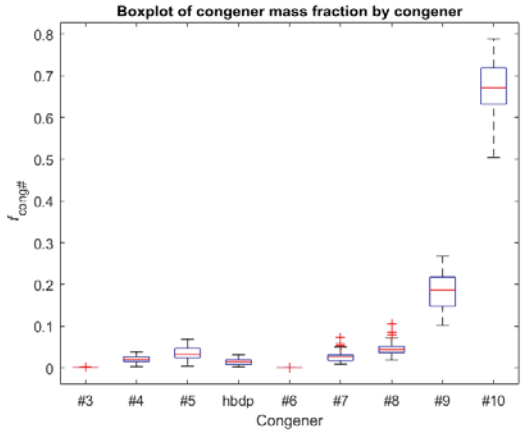

Figure 19: Boxplot of congener mass fractions

Principal Components Analysis

A principal components analysis (PCA) was performed on the logarithm of the congener content. The mass fraction is dominated by the decabromo congeners (#10) giving little discrimination.

Scores plots (PC1 v PC2) by site and pile type are shown in Figure 20 and Figure 21 for the log-scale congener mass content.

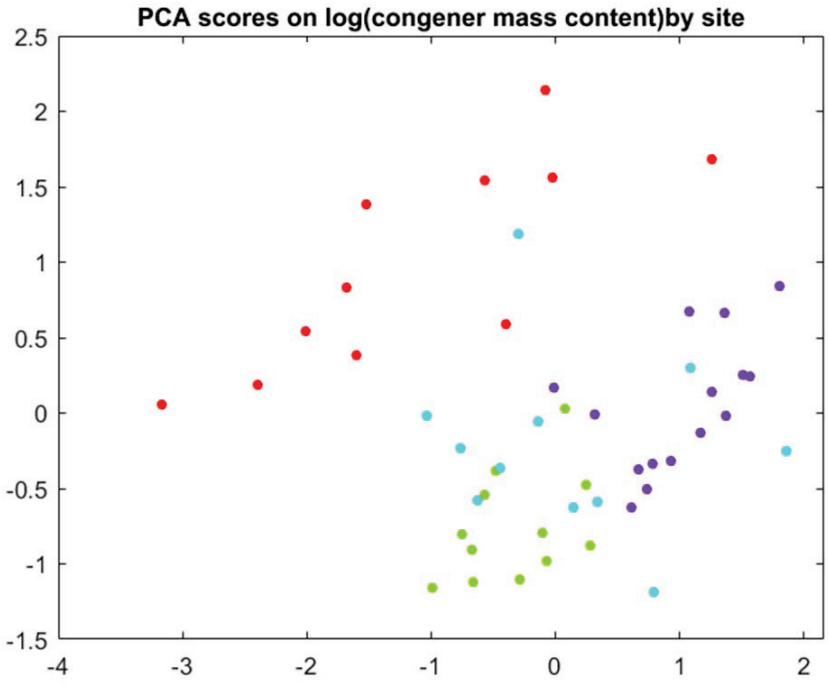

Figure 20: PCA scores plot of log (congener mass content) by site

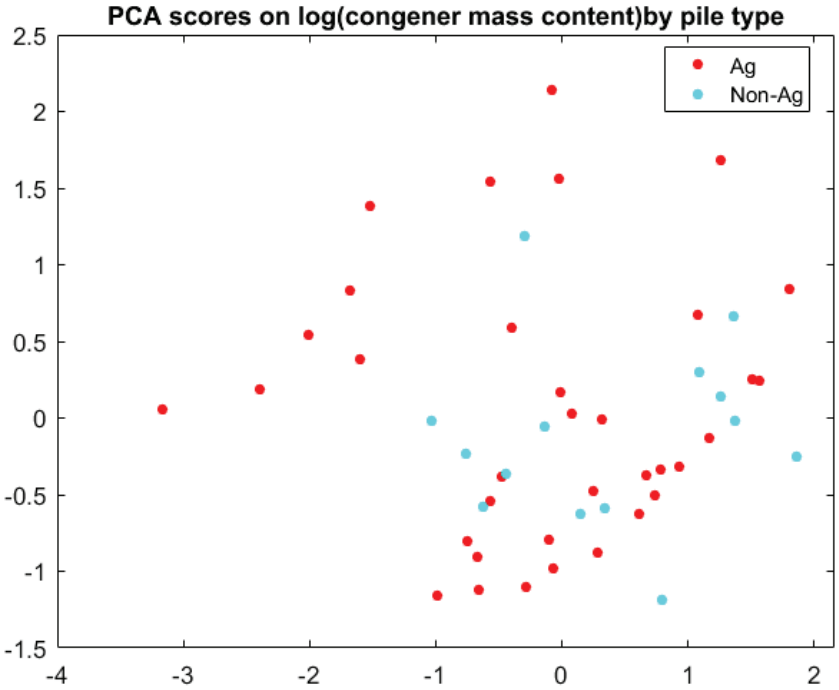

Figure 21: PCA scores plot of log (congener mass content) by pile type

A 3D Scores plot and 3D biplot are shown in Figure 22 and Figure 23

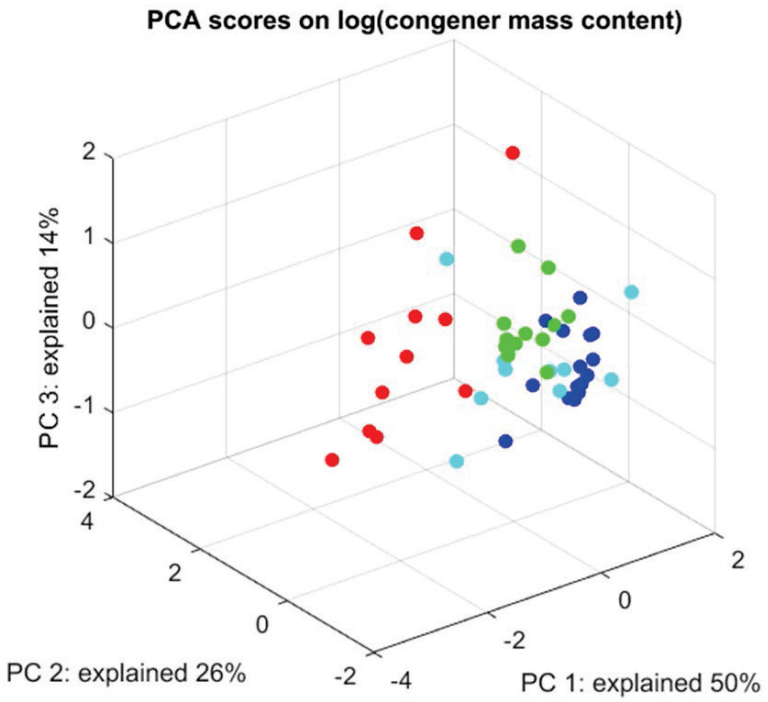

Figure 22: 3D PCA scores plot of log (congener mass content) by site

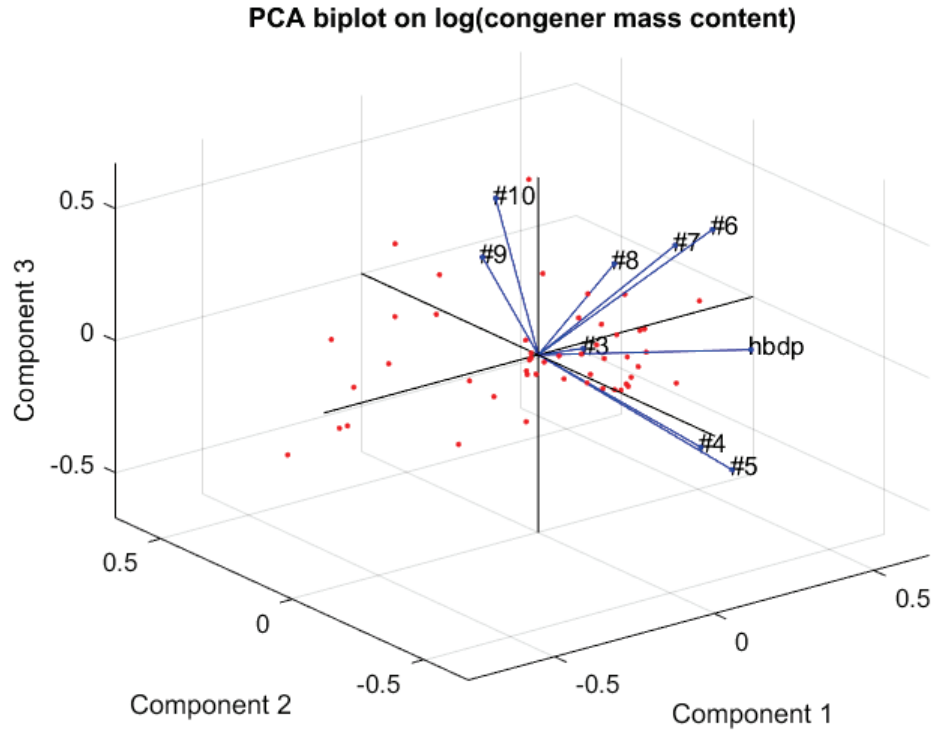

Figure 23: 3D PCA biplot of log(congener mass content) by site and biplot

The interpretation of the PCA suggests some grouping by site, but there is overlap between groups and no obvious favouring of one congener at one site.

Further discussion on extreme values

The sampling protocol was:

- five grab samples collected with a shovel (these are 5 kg each)
- Each grab sample placed into individual containers (total 5 grab samples)
- 2kg portion of each grab sample transferred to a bucket to form a 10 kg composite sample
- The bucket with the composite sample is sealed and mixed by rolling on the ground and shaking while at the site
- At site, one subsample (approx. 250 gram) taken from the composite bucket for PBDE analysis

There are two assumptions that may be made: (1) the 10 kg sample was sufficiently homogenised that the 250 g sub-sample taken for analysis is representative of the composite; and (2) the extreme content of PBDE was located in a minimal number of pieces of hard plastic in the composite sample and so represents the PBDE content of only that 250 g sub-sample. Three out of 52 samples had extreme PBDE mass contents. Therefore we would expect one extreme PBDE sample in every 52 î 10 /3 kJ ≈ 173 kg (DVVXPSWLRQ 1) RU 52 î 0.25/3 kJ § 4.3 kJ (DVVXPSWLRQ 2). However, as discussed in Chapter 6, the rate of leaching of PBDE and bioaccessibility across samples is relatively constant.

APPENDIX 6: PBDE RESULTS FOR THE ENVIRONMENTAL LEACHING STUDY

Table 37: PBDE results from kinetic study
(data reported in ng/kg [nanograms of PBDE per kilogram of MWOO])

	Unground MWOO D2					Ground MWOO D2					Blank
MWOO Moisture (%)					21.39					Dried	
Time (hrs)	6	12	24	48	120	6	12	24	48	120	
Tribromodiphenyl ether	1.06	0.855	1.44	1.01	0.84	1.46	1.195	1.87	1.17	1.47	0.09
Tetrabromodiphenyl ether	54.8	42.76	57.2	52.35	30.54	55.19	55.43	57.94	42.69	45.28	0.59
Pentabromodiphenyl ether	85.02	69.75	91.63	85.41	47.27	92.92	84.79	94.54	65.02	70.02	0.51
Hexabromodiphenyl ether	22.4	16.22	24.45	21.76	14.11	27.31	25.01	28.44	18.5	21.63	0.22
Hexabromobiphenyl	0.41	0.36	0.4	0.36	0.24	0.46	0.37	0.5	0.32	0.49	0.05
Heptabromodiphenyl ether	26.1	22.11	29.1	30.95	20.7	33.63	27.97	38.33	22.44	28.05	0.35
Octabromodiphenyl ether	16.65	17.85	27.05	27.85	20.4	44.5	34.95	68.95	34.45	53.2	0.45
Nonabromodiphenyl ether	50	41.7	66	83	61	90	64	164	87	131	0.6
Decabromodiphenyl ether	170	110	170	260	220	180	50	330	190	320	2
PBDEs – Br1 to Br9	**256.44**	**211.6**	**297.27**	**302.66**	**195.10**	**345.47**	**293.72**	**454.57**	**271.59**	**351.14**	**2.85**
PBDE10	**170**	**110**	**170**	**260**	**220**	**180**	**50**	**330**	**190**	**320**	**2**
Total PBDE	**426.44**	**321.6**	**467.27**	**562.66**	**415.105**	**525.47**	**343.72**	**784.57**	**461.59**	**671.14**	**4.85**

Table 38: PBDE results from bioaccessibility study
(data reported in ng/kg)

	Ground MWOO A3	Ground MWOO C6	Ground MWOO C7	Ground MWOO C8	Unground MWOO D2	Ground MWOO D2	Ground MWOO D4	Ground MWOO D7
MWOO Moisture (%)	Dried	Dried	Dried	Dried	21.39	Dried	Dried	Dried
Time (hrs)	48	48	48	48	48	48	48	48
Tribromodiphenyl ether	1.53	3.6	3.25	3.05	1.28	0.75	1.65	0.85
Tetrabromodiphenyl ether	22.38	66.75	82	92.6	46.1	44.95	59.62	42.75
Pentabromodiphenyl ether	23.75	99.1	120.75	139.4	74.77	67.25	94.55	61.35
Hexabromodiphenyl ether	4.75	47.5	63.4	118.4	18.6	16.67	32.02	17.2
Hexabromobiphenyl	0.19	2	7.7	2.9	0.1	0.46	0.75	0.2
Heptabromodiphenyl ether	8.11	119.1	158.5	244.5	23.95	22.7	34.6	20.5
Octabromodiphenyl ether	6.94	65.5	134	106	13.8	19.2	30.3	18.7
Nonabromodiphenyl ether	16.6	374	440	264	52.8	47	72	33.5
Decabromodiphenyl ether	59	1240	1560	1330	*	*	*	*
PBDEs – Br1 to Br9	**84.25**	**777.55**	**1009.6**	**970.85**	**231.4**	**218.98**	**325.49**	**195.05**
PBDE10	**59**	**1240**	**1560**	**1330**	**0**	**0**	**0**	**0**
Total PBDE	**143.25**	**2017.55**	**2569.6**	**2300.85**	**231.4**	**218.98**	**325.49**	**195.05**

* non-quantitation

	Westwood Soil	Bottle Blank	Bottle Blank	Bottle Blank
MWOO Moisture				
Time (hrs)		Blank	Blank	Blank
Tribromodiphenyl ether	0.25	0.13	0.1	0.14
Tetrabromodiphenyl ether	2.82	0.71	0.85	1.13
Pentabromodiphenyl ether	1.44	0.52	0.56	0.84
Hexabromodiphenyl ether	0.30	0.22	0.27	0.45
Hexabromobiphenyl	0.04	0.05	0.05	0.05
Heptabromodiphenyl ether	0.25	0.25	0.35	0.6
Octabromodiphenyl ether	0.44	0.45	1.1	1.55
Nonabromodiphenyl ether	0.3	0.3	0.8	1.5
Decabromodiphenyl ether	1	0	0	0
PBDEs – Br1 to Br9	**5.83**	**2.62**	**4.06**	**6.26**
PBDE10	**1**	**0**	**0**	**0**
Total PBDE	**6.83**	**2.62**	**4.06**	**6.26**

APPENDIX 7: PBDE RESULTS FOR THE RUMINANT LEACHING STUDY

Table 39: PBDE results from kinetic study
(data reported in ng/sample – where the sample was 1m of silicone cord that had been exposed to 1g MWOO in GI fluid)

	Unground MWOO D2					**Ground MWOO D2**					**Unground MWOO D2**				
Moisture (%)					21.39					Dried					21.39
Time (hrs)	6	12	24	48	120	6	12	24	48	120	6	12	24	48	120
Tribromodiphenyl ether	0.29	0.15	0.14	0.13	2.20	0.73	0.20	0.16	0.11	0.048	0.33	0.13	0.39	0.09	0.08
Tetrabromodiphenyl ether	8.92	5.13	4.55	4.33	9.29	21.89	7.83	5.005	2.81	2.49	10.52	4.88	5.18	4.56	3.82
Pentabromodiphenyl ether	12.77	9.51	9.42	8.27	10.20	31.5	15.22	12.04	6.62	5.28	16.42	8.71	9.97	8.44	6.68
Hexabromodiphenyl ether	3.12	3.03	3.70	3.10	3.18	7.66	5.08	5.22	3.24	2.43	3.92	2.57	3.68	2.74	2.54
Hexabromobiphenyl	0.04	0.04	0.06	0.05	0.05	0.11	0.07	0.08	0.06	0.04	0.06	0.04	0.06	0.05	0.02
Heptabromodiphenyl ether	3.22	3.45	5.31	5.06	4.52	7.19	5.85	7.85	6.79	5.53	4.30	3.44	5.94	5.13	4.30
Octabromodiphenyl ether	4.5	5.15	6.31	7.9	6.34	7.25	8.13	12.75	11.15	14.42	3.72	3.14	6.22	8.75	6.33
Nonabromodiphenyl ether	15.4	14.6	18.8	26.9	30.3	20	24.6	36.9	37.9	64	11.7	9.6	20	28.4	24.8
Decabromodiphenyl ether	49	39	82	100	120	71	56	110	150	200	40	33	86	100	110
PBDE – Br1	**48.27**	**41.08**	**48.29**	**55.75**	**66.10**	**96.39**	**66.99**	**80.02**	**68.67**	**94.24**	**50.99**	**32.52**	**51.45**	**58.17**	**48.59**
PBDE10	**49**	**39**	**82**	**100**	**120**	**71**	**56**	**110**	**150**	**200**	**40**	**33**	**86**	**100**	**110**
Total PBDE	**97.27**	**80.08**	**130.294**	**155.753**	**186.10**	**167.39**	**122.99**	**190.02**	**218.67**	**294.24**	**90.99**	**65.52**	**137.45**	**158.17**	**158.59**

Table 40: PBDE results from bioaccessibility study
(data reported in ng/sample – where the sample was 1m of silicone cord that had been exposed to 1g MWOO in GI fluid)

	Ground MWOO C6		Ground MWOO C6 + Soil		Unground MWOO C6		Unground MWOO C6 + Soil		Unground MWOO C7	
MWOO Moisture (%)	Dried	Dried	Dried	Dried	45.97	45.97	45.97	45.97	45.64	45.64
Time (hours)	24	24	24	24	24	24	24	24	24	24
Tribromodiphenyl ether	0.71	0.64	0.15	0.06	0.31	0.26	0.05	0.08	0.24	0.29
Tetrabromodiphenyl ether	15.48	14.37	1.20	1.1	5.92	6.85	0.99	1.105	5.47	5.77
Pentabromodiphenyl ether	23.96	22.53	1.795	1.88	9.32	10.17	1.52	1.62	8.23	8.95
Hexabromodiphenyl ether	10.98	11.91	1.04	1.01	4.42	5.08	0.74	0.7	4.23	4.89
Hexabromobiphenyl	0.53	0.68	0.03	0.04	0.45	0.26	0.05	0.12	0.08	0.084
Heptabromodiphenyl ether	19.88	29.03	2.21	1.69	9.32	10.9	1.52	1.49	8.69	10.38
Octabromodiphenyl ether	16.19	28.6	1.5	1.46	7.61	9.85	1.2	1.26	7.11	8.8
Nonabromodiphenyl ether	38.4	60	3.04	3.25	20.1	25.9	2.51	3.02	17.4	22.6
Decabromodiphenyl ether	140	220	17	15	51	66	7.3	11	48	69
PBDEs – Br1 to Br9	**126.11**	**167.75**	**10.94**	**10.47**	**57.45**	**69.3**	**8.57**	**9.48**	**51.45**	**61.71**
PBDE10	**140**	**220**	**17**	**15**	**51**	**66**	**7.3**	**11**	**48**	**69**
Total PBDE	**266.11**	**387.75**	**27.94**	**25.47**	**108.45**	**135.3**	**15.87**	**20.48**	**99.45**	**130.71**

	Ground MWOO C8		Unground MWOO C8		Ground MWOO A3		Unground MWOO A3	
MWOO Moisture (%)	Dried	Dried	45.76	45.76	Dried	Dried	32.5	32.5
Time (hours)	24	24	24	24	24	24	24	24
Tribromodiphenyl ether	0.61	0.68	0.24	0.38	0.90	1.03	0.54	0.53
Tetrabromodiphenyl ether	13.4	14.50	5.64	6.67	19.08	21.33	9.92	12.65
Pentabromodiphenyl ether	18.9	21.53	8.09	9.48	25.92	28.43	16.14	17.13
Hexabromodiphenyl ether	12.39	14.31	5.80	7.26	6.70	7.25	6.82	3.82
Hexabromobiphenyl	0.26	0.35	0.18	0.16	0.19	0.25	0.1	0.12
Heptabromodiphenyl ether	22.87	28.98	13.9	16.24	9.78	11.23	15.6	5.34
Octabromodiphenyl ether	16.75	25.45	9.23	10.85	11.15	15.2	9.32	5.72
Nonabromodiphenyl ether	23.6	41	15	18.2	45	52	17.9	23.8
Decabromodiphenyl ether	81	120	50	47	170	170	79	70
PBDEs – Br1 to Br9	**108.77**	**146.80**	**58.07**	**69.24**	**118.70**	**136.72**	**76.33**	**69.10**
PBDE10	**81**	**120**	**50**	**47**	**170**	**170**	**79**	**70**
Total PBDE	**189.77**	**266.80**	**108.07**	**116.24**	**288.70**	**306.72**	**155.33**	**139.10**

	Ground MWOO A5		Ground MWOO A5 + Soil		Unground MWOO A5		Unground MWOO A5 Soil		Unground MWOO A8	
MWOO Moisture (%)	Dried	Dried	Dried	Dried	35.5	35.5	35.5	35.5	31.5	31.5
Time (hours)	24	24	24	24	24	24	24	24	24	24
Tribromodiphenyl ether	1.87	2.28	0.22	0.24	1.59	0.83	0.07	0.24	0.84	0.75
Tetrabromodiphenyl ether	13.72	15.71	1.25	1.13	9.70	7.51	1.06	1.38	11.62	13.89
Pentabromodiphenyl ether	16.03	18.48	1.36	1.34	10.57	9.87	1.39	1.87	18.60	18.33
Hexabromodiphenyl ether	4.17	5.66	0.47	0.43	2.71	2.63	0.41	0.46	4.23	3.8
Hexabromobiphenyl	0.12	0.17	0.01	0.01	0.1	0.07	0.01	0.03	0.09	0.08
Heptabromodiphenyl ether	7.89	12.26	0.71	0.70	5.52	50.	0.94	0.85	5.30	5.04
Octabromodiphenyl ether	7.33	13.85	0.49	0.60	5.44	3.65	1.08	0.69	5.76	3.34
Nonabromodiphenyl ether	37.7	49	2.02	2.97	27.4	15.7	4.6	3.21	23.9	13.3
Decabromodiphenyl ether	160	200	18	13	100	59	16	11	79	56
PBDEs – Br1 to Br9	**88.82**	**117.41**	**6.52**	**7.40**	**63.02**	**45.21**	**9.56**	**8.72**	**70.32**	**58.52**
PBDE10	**160**	**200**	**18**	**13**	**100**	**59**	**16**	**11**	**79**	**56**
Total PBDE	**248.82**	**317.41**	**24.52**	**20.40**	**163.02**	**104.21**	**25.56**	**19.72**	**149.32**	**114.52**

	Ground MWOO D4		Unground MWOO D4		Ground MWOO D7		Ground MWOO D7 + Soil		Unground MWOO D7		Unground MWOO D7 + Soil	
MWOO Moisture (%)	Dried	Dried	17.82	17.82	Dried	Dried	Dried	Dried	24.47	24.47	24.47	24.47
Time (hours)	24	24	24	24	24	24	24	24	24	24	24	24
Tribromodiphenyl ether	0.86	0.94	0.51	0.46	0.90	0.90	0.07	0.08	1.16	0.46	0.08	0.06
Tetrabromodiphenyl ether	33.86	35.76	18.6	19.81	32.75	34.76	2.67	2.66	21.62	21.62	2.37	2.24
Pentabromodiphenyl ether	56.42	58.45	31.55	33.97	55.55	58.18	5.06	5.02	36.59	36.65	4.14	3.78
Hexabromodiphenyl ether	22.38	17.22	8.82	9.58	15.22	16.11	1.66	1.58	11.99	10.15	1.22	1.15
Hexabromobiphenyl	0.21	0.23	0.12	0.16	0.24	0.25	0.03	0.02	0.17	0.15	0.025	0.01
Heptabromodiphenyl ether	20.86	20.49	10.89	11.25	19.43	21.43	1.83	1.82	16.99	14.57	1.82	1.69
Octabromodiphenyl ether	19.86	24.6	11.1	10.6	15.77	22.55	2.45	1.85	12.95	17.55	1.54	2.03
Nonabromodiphenyl ether	53	69	37	39	49	73	9.3	7.9	36.9	63	5.3	6.4
Decabromodiphenyl ether	210	210	120	140	200	240	26	27	190	190	22	24
PBDEs – Br1 to Br9	**207.47**	**226.69**	**118.58**	**124.82**	**188.85**	**227.17**	**23.07**	**20.91**	**138.36**	**164.15**	**16.49**	**17.35**
PBDE19	**210**	**210**	**120**	**140**	**200**	**240**	**26**	**27**	**190**	**190**	**22**	**24**
Total PBDE	**417.47**	**436.69**	**238.58**	**264.82**	**388.85**	**467.17**	**49.07**	**47.91**	**328.36**	**354.15**	**38.49**	**41.35**

Table 41: Ruminant leaching study – 24 hour bioaccessibility adjusted results

Sample	PBDE – Br1 to Br9			PBDE10			Total PBDE		
	Toluene extract result (ng/g)	Result (ng/g)	Bioaccessibility (%)	Toluene extract result (ng/g)	Result (ng/g)	Bioaccessibility (%)	Toluene extract result (ng/g)	Result (ng/g)	Bioaccessibility (%)
Ground MWOO C6	578.65	126.11	21.79	1810.00	140.00	7.73	2388.65	266.11	11.14
		167.75	28.99		220.00	12.15		387.75	16.23
Ground MWOO C6 + Soil		10.94	1.89		17.00	0.94		27.94	1.17
		10.47	1.81		15.00	0.83		25.47	1.07
Unground MWOO C6		106.32	18.37		94.39	5.21		200.70	8.40
		128.26	22.16		122.15	6.75		250.40	10.48
Unground MWOO C6 + Soil		15.85	2.74		13.51	0.75		29.36	1.23
		17.55	3.03		20.36	1.12		37.91	1.59
Unground MWOO C7	359.71	94.66	26.31	830.00	88.31	10.64	1189.71	182.96	15.38
		113.52	31.56		126.94	15.29		240.47	20.21
Ground MWOO C8	476.03	108.77	22.85	1450.00	81.00	5.59	1926.03	189.77	9.85
		146.80	30.84		120.00	8.28		266.80	13.85
Unground MWOO C8		107.06	22.49		92.19	6.36		199.25	10.34
		127.65	26.82		86.66	5.98		214.31	11.13
Ground MWOO A3	577.21	118.70	20.56	1210.00	170.00	14.05	1787.21	288.70	16.15
		136.72	23.69		170.00	14.05		306.72	17.16
Unground A3		113.08	19.59		117.04	9.67		230.12	12.88
		102.38	17.74		103.70	8.57		206.08	11.53
Ground MWOO A5	1713.09	88.82	5.18	4010.00	160.00	3.99	5723.09	248.82	4.35
		117.41	6.85		200.00	4.99		317.41	5.55
Ground MWOO A5 + Soil		6.52	0.38		18.00	0.45		24.52	0.43
		7.40	0.43		13.00	0.32		20.40	0.36
Unground MWOO A5		97.71	5.70		155.04	3.87		252.75	4.42

Sample	PBDE – Br1 to Br9			PBDE10			Total PBDE		
	Toluene extract result (ng/g)	Result (ng/g)	Bioaccessibility (%)	Toluene extract result (ng/g)	Result (ng/g)	Bioaccessibility (%)	Toluene extract result (ng/g)	Result (ng/g)	Bioaccessibility (%)
		70.09	4.09		91.47	2.28		161.57	2.82
Unground MWOO A5 + Soil		14.82	0.87		24.81	0.62		39.63	0.69
		13.52	0.79		17.05	0.43		30.58	0.53
Unground MWOO A8	901.46	102.36	11.36	2920.00	114.99	3.94	3821.46	217.36	5.69
		85.18	9.45		81.51	2.79		166.70	4.36
Ground MWOO D4	1238.93	207.47	16.75	4320.00	210.00	4.86	5558.93	417.47	7.51
		226.69	18.30		210.00	4.86		436.69	7.86
Unground MWOO D4		144.30	11.65		146.02	3.38		290.32	5.22
		151.89	12.26		170.36	3.94		322.25	5.80
Ground MWOO D7	547.88	188.85	34.47	1110.00	200.00	18.02	1657.88	388.85	23.45
		227.17	41.46		240.00	21.62		467.17	28.18
Ground MWOO D7 + Soil		23.07	4.21		26.00	2.34		49.07	2.96
		20.91	3.82		27.00	2.43		47.91	2.89
Unground MWOO D7		183.18	33.43		251.55	22.66		434.73	26.22
		217.33	39.67		251.55	22.66		468.88	28.28
Unground MWOO D7 + Soil		21.83	3.98		29.13	2.62		50.96	3.07
		22.97	4.19		31.77	2.86		54.75	3.30

APPENDIX 8: MASS DISTRIBUTION STUDY

Table 42: Raw results from mass distribution study (units ng/sample)

Sample Code	**Ground D2**			**Ground D2**			**Unground D2**			
Sample type	MWOO after extraction	GI extraction	Silicone cord – 1m	MWOO after extraction	GI extraction	Silicone cord – 2m	MWOO after extraction	GI extraction	Silicone cord – 1m	GI extraction (dup)
Tribromodiphenyl ether	0.38	0.01	0.74	0.51	0.02	0.75	0.74	0.01	0.62	0.011
Tetrabromodiphenyl ether	14.08	0.23	29.63	17.39	0.13	29.48	32.56	0.26	19.69	0.3
Pentabromodiphenyl ether	25.3	0.65	48.30	31.23	0.33	49.36	60.75	0.69	31.64	0.72
Hexabromodiphenyl ether	9.25	0.41	13.52	9.88	0.23	13.56	19.74	0.41	8.51	0.41
Hexabromobiphenyl	0.16	0.01	0.2	0.16	<0.01	0.22	0.32	0.01	0.16	<0.01
Heptabromodiphenyl ether	16.56	0.97	18.23	17.95	0.47	19.46	31	0.89	12.44	1.14
Octabromodiphenyl ether	27.55	1.17	16.85	39.85	1.16	20.24	43.3	1.58	11.19	1.8
Nonabromodiphenyl ether	321	6.5	50	390	5.1	71	155	7.7	33	6.4
Decabromodiphenyl ether	1440	33	200	1810	24	260	700	35	130	29
PBDE – Br1 to Br9	**414.28**	**9.95**	**177.45**	**506.97**	**7.44**	**204.06**	**343.4**	**11.55**	**117.24**	**10.78**
PBDE – Br10	**1440**	**33**	**200**	**1810**	**24**	**260**	**700**	**35**	**130**	**29**
Total PBDE	**1854.28**	**42.95**	**377.45**	**2316.97**	**31.44**	**464.06**	**1043.4**	**46.55**	**247.24**	**39.78**

Sample Code	**Ground A5**			**Unground A5**			
Sample type	MWOO after extraction	GI extraction	Silicone cord – 1m	MWOO after extraction	GI extraction	Silicone cord – 1m	GI extraction (dup)
Tribromodiphenyl ether	0.44	0.018	2.48	0.7	0.01	1.22	0.01
Tetrabromodiphenyl ether	3.78	0.24	16.57	6.11	0.13	10.15	0.07
Pentabromodiphenyl ether	4.99	0.4	18.77	9.43	0.26	11.65	0.14
Hexabromodiphenyl ether	3.66	0.2	5.38	4.06	0.15	3.01	0.09
Hexabromobiphenyl	0.08	<0.01	0.14	0.09	<0.01	0.07	<0.01
Heptabromodiphenyl ether	20.43	0.48	8.74	12.4	0.33	5.12	0.22
Octabromodiphenyl ether	18.55	0.6	7.08	13.65	0.44	3.8	0.26
Nonabromodiphenyl ether	224	3.43	33.4	88	2.19	16	1.33
Decabromodiphenyl ether	1570	21	140	530	13	80	8.5
PBDE – Br1 to Br9	**275.92**	**5.36**	**92.55**	**134.45**	**3.52**	**51.02**	**2.12**
PBDE – Br10	**1570**	**21**	**140**	**530**	**13**	**80**	**8.5**
Total PBDE	**1845.92**	**26.36**	**232.55**	**664.45**	**16.52**	**131.02**	**10.62**

Sample Code		**Ground C3**			**Unground C7**		
Sample type	MWOO after extraction	GI extraction	Silicone cord – 1m	MWOO after extraction	GI extraction	Silicone cord – 1m	GI extraction (dup)
Tribromodiphenyl ether	0.29	0.014	0.7	0.42	0.01	0.5	0.01
Tetrabromodiphenyl ether	6.49	0.15	13.4	12.27	0.15	8.94	0.09
Pentabromodiphenyl ether	11.75	0.29	20.29	21.63	0.33	13.87	0.2
Hexabromodiphenyl ether	12.25	0.35	9.87	15.95	0.4	7.25	0.27
Hexabromobiphenyl	0.26	0.02	0.28	0.18	0.02	0.08	0.01
Heptabromodiphenyl ether	47.53	1.28	20.06	42.26	1.41	15.46	1.15
Octabromodiphenyl ether	62.93	1.73	15.26	48.55	1.79	11.76	1.37
Nonabromodiphenyl ether	211	5.1	30.4	151	4.03	22.2	2.7
Decabromodiphenyl ether	790	29	120	600	20	76	13
PBDE – Br1 to Br9	**352.5**	**8.91**	**110.25**	**292.25**	**8.14**	**80.05**	**5.81**
PBDE – Br10	**790**	**29**	**120**	**600**	**20**	**76**	**13**
Total PBDE	**1142.5**	**37.91**	**230.25**	**892.25**	**28.14**	**156.05**	**18.81**

APPENDIX 9: COMPARISON OF EQUATIONS FROM THIS REPORT AND THE DRAFT INTERIM HHERA

Equations from draft interim HHERA

$$Daily\ Intake_{\ grazinganimal} = C_{\ soil} \times IR_{\ soil} * B \qquad (mg/day)$$

$$C_{\ meat} = Daily\ Intake_{\ grazinganimal} \times Transfer\ Factor \qquad (mg/kg\ fresh\ weight)$$

$$Daily\ Chemical\ Intake_{\ meat} = \frac{C_{\ meat} \times IR_{\ meat} \times FHG \times EF \times ED}{AT \times BW}$$

Equation that was used in the present report

$$Q_h = \frac{\gamma_{\mathrm{PBDE}} f_{\mathrm{dil}} m_{\mathrm{soil}} \beta f_{\mathrm{home}} t_{\mathrm{home}} \tau m_{\mathrm{meat}} t_{\mathrm{meat}}}{h m_{\mathrm{body}} \chi_{\mathrm{tox}} (1 - f_{\mathrm{back}})}$$

Equation (1)

Table 43: Comparison of input values for Hazard Quotients

Symbol	Description	Unit	Equivalence draft interim HHERA	Draft interim HHERA value	ISRP Value for inclusion
Q_h	Hazard quotient	1	*HQ*	*multiple*	*Not calculated*
γ_{PBDE}	Bioaccessible PBDE content from MWOO	mg kg^{-1}	C_{soil}[1]	Br1-Br9 – 5.5 (max) Br10 - 75	Br3-Br9 – 0.236 Br10 – 0.361
			B	1	
f_{dil}	Dilution factor	1	Included in C_{soil}	[1]	12.6[2]
m_{soil}	mass of soil ingested by cow per day	kg d^{-1}	*IRsoil*	2.4	0.5
β	bioaccessibility	1	B	1	1 (β LQ FXG Hd LQ γ_{PBDE})
f_{home}	fraction of diet from home	1	FHG	0.5, 0.75. 1	[3]
t_{home}	time exposed to diet per year	d y^{-1}	EF	365	[3]
τ	transfer factor	d kg^{-1}	transfer factor (no symbol)	Br1-Br9 = 2 Br10 = 0.02	Br3-Br9 = 0.53 Br10 = 0.02
m_{meat}	ingestion of meat per day	kg d^{-1}	*IRmeat*	0.085 (child) 0.163 (adult)	[3]
t_{meat}	total time exposed to diet	y	ED	6 (child) 29 (adult)	[3]
h	Averaging time for exposure for a threshold contaminant	d	AT	2190 (child) 10585 (adult)	[3]
m_{body}	body mass	kg	BW	70 (adult)	[3]
χ_{tox}	tolerable daily intake	mg kg^{-1} d^{-1}	TDI		[3]
f_{back}	background intake factor	1	-		[3]
$ln(f_{area})$	Area under MWOO (lognormal distribution)			1	0.14

[1] Draft interim HHERA assumed MWOO mixed with soil to a depth of 10cm and assumed dilution x100
[2} f_{dil} = VOLUME OF MWOO applied per hectare divided by the volume of soil mixed with
[3] Out of scope of ISRP

{$C_{soil} = \gamma_{PBDE} / (f_{dil} \times \exp(\ln(f_{area})))$}

APPENDIX 10: DPI REVIEW OF CATTLE EXPOSURE TO MWOO VIA SOIL INGESTION

Consideration of cattle exposure to MWOO via soil ingestion

Recommendations

1. **Based on available information, a conservative and defensible value for modelling the rate of soil ingestion by individual cattle in the final revised HHERA is considered to be 0.5 kg/day.**
2. **Based on available information, a conservative and defensible value for assessing the exposure period of cattle to MWOO where it has been applied is 52 days per year.**
3. **That the interim HHERA assumption that MWOO is mixed into soil is likely to provide a realistic estimate of MWOO content in ingested soil, for both surface applied MWOO and cultivated MWOO.**

Summary

The independent, interim Human Health and Environmental Risk Assessment (HHERA 2018), on application of mixed waste organic outputs (MWOO) to agricultural land, commissioned by NSW Environment Protection Authority (EPA), made a number of conservative assumptions to estimate how much exposure a person might have to chemicals present in the material. Following consultation with NSW Government, NSW EPA asked the NSW Office of Chief Scientist and Engineer (OSCE) to conduct further work to inform a final, revised risk assessment considering more realistic exposures to MWOO. As part of this work, the Independent Scientific Review Panel on Soil and Chemistry, established by the Office of the NSW Chief Scientist & Engineer, asked the NSW Department of Primary Industries to undertake a literature review on the soil ingestion rates of cattle. A rate of 2.4kg/animal/day was assumed in the interim HHERA for soil consumed by cattle.

In considering the likely exposure of cattle to MWOO through soil ingestion, DPI's review of published literature evaluated three key areas, with the following key outcomes:

- Soil ingestion rate most appropriate for NSW conditions
  - (i) no research was identified in Australia, with published studies in New Zealand, England, France, United States of America
  - (ii) limited literature was identified where soil ingestion had been measured (11 studies), majority used weak methodologies that involved a degree of uncertainty (eg assumed input variables)
  - (iii) variable ingestion rates were identified in the literature; the 2.4kg/day value used in the interim HHERA sits at the extreme end of the reported range and represents a temporary peak within a season. Estimated soil ingestion levels recorded under conditions most similar to NSW range from 0.1 to 1.5kg/day/animal (Mayland et al 1975)
  - (iv) average yearly soil intake is considered more representative when assessing soil residues in meat animals than maximum recorded values; highest monthly soil intake for worst-case evaluation in dairy cattle (Fries 1982)
  - (v) multiple factors influence soil intake primarily seasonal conditions; incidental ingestion is the main route for domestic ruminants (ie via material adhered to foliage or roots)
  - (vi) no studies were identified on ingestion of compost-like material by cattle
- Identified international guidelines for risk assessments

(i) US EPA recommends soil ingestion values of 0.4kg/day in dairy cattle and 0.5kg/day in beef cattle for risk assessments (USEPA 2005); these values are considered appropriate for use in agricultural settings (Beyer and Fries 2005)

- Mode of application, ie surface applied vs soil mixing, and the influence this may have on the MWOO content of ingested soil
  (i) Research indicates main pathway of incidental ingestion varies under differing climatic conditions, with ingestion via roots likely dominant pathway under dry conditions. Ingested soil may come from top 10cm of soil profile
  (ii) Some mixing of soil and MWOO over time would be expected through physical and/or biological processes

- In addition, industry records merged with land and stock data for properties where MWOO had been delivered were interrogated, to estimate the time-period cattle would likely be exposed to MWOO during the course of a year. This work considered:
  (i) proportion of farming enterprises treated with MWOO – average 14% estimated (calculated on site-specific data of tonnage delivered, application rate, land area)
  (ii) grazing management practices in NSW
  (iii) with-holding periods

The following conclusions have been drawn:

- The soil ingestion rate for cattle of 2.4kg/day used in the interim HHERA is overly conservative and is not supported by scientific literature or consideration of Australian conditions; a revised rate of 0.5kg/day is recommended
- The recommended ingestion rate of 0.5kg/day corresponds with identified international guidelines for risk assessments
- The interim HHERA assumed a 10cm mixing depth; this assumption was later questioned as MWOO was known to have been surface applied in some cases. The original assumption is upheld based on published studies and guidelines which support likely cattle ingestion of a soil/MWOO mix regardless of application method
- The assumption in the interim HHERA that cattle would be exposed to MWOO every day over the course of a year is not supported by the site-specific data; a revised period of 52 days per year is recommended

The key findings of this review will likely be of significance in future assessment of contaminated land and impact on agriculture, particularly livestock management.

Introduction

The NSW Environment Protection Authority (NSW EPA) stopped the use of mixed waste organic outputs (MWOO; also known as alternative waste technologies materials) on agricultural land, and ceased its use on forestry and mining land pending further investigations, in October 2018. This decision followed a comprehensive, independent research program, involving research trials commissioned by EPA and in which DPI participated in two projects. The studies concluded there were limited agricultural or soil benefits from applying MWOO at the regulated rates, but there are physical contaminants and potential environmental risks.

As part of the Government's review of the information, NSW EPA commissioned an independent assessment of the human health and ecological risks (HHERA 2018) posed by MWOO application to agricultural land. The assessment used cautious assumptions ie worst case modelling to estimate how much exposure a person might have to chemicals present in the material. NSW Health and NSW DPI reviewed the initial findings of the assessment and considered that the risks to farmers who applied the material to their land was likely to be very low, but that further investigation was needed. Following consultation with NSW Government, NSW EPA asked the NSW Office of Chief Scientist and Engineer (OCSE) to conduct further investigations to inform a revised risk assessment considering more realistic exposures to MWOO. The OCSE formed an independent scientific review panel to undertake this work.

In considering the assumptions used in development of the interim HHERA (2018), the independent panel asked the NSW Department of Primary Industries to undertake a literature review on the soil ingestion rates of cattle, a key pathway for the uptake of chemicals that may be present in MWOO. The interim HHERA (2018) assumed a static soil ingestion rate of 2.4kg/animal/day over the course of a year and noted that significant uncertainty existed due to the variability in soil ingestion rate amongst individual animals; the independent panel also noted variable rates identified in the literature. The 2.4kg value was taken from the American Petroleum Institute guidance document for determining screening guidelines for petroleum hydrocarbons in livestock (API 2004), which reports a range in values for the percentage of soil found in cattle diet from 0.2%-18%; the 2.4kg value is derived from the highest end of this range. The interim HHERA (2018) also refers to lower guideline values used by the Office of Environmental Health Hazard Assessment, California EPA (OEHHA 2012), for soil ingestion by cattle, of 5% of food intake. The HHERA did not adopt the lower value, acknowledging that its exposure assessment of soil used a worst case scenario. In addition, the HHERA (2018) assumed that the mixed waste material was mixed into the soil to a depth of 10cm; field application methods were not reported in industry records and are considered by the independent panel to have potential influence on the exposure of cattle to MWOO.

Methodology

To better understand the key assumptions made in the HHERA (2018), in estimating the exposure of cattle to MWOO, DPI undertook a review of published literature together with analysis of property data, based on industry and land and stock return records. Four key aspects were evaluated:

1. soil ingestion rate most appropriate for NSW conditions, considering the 2.4kg/day value used in the HHERA (2018) and the variability in published ingestion rates
2. International guidelines for risk assessments
3. time-period cattle would likely be exposed to MWOO during the course of a year considering the HHERA's assumption that cattle were exposed to MWOO 365days a year
4. field treatment method used ie surface application or incorporation and the influence this may have on the MWOO content of ingested soil

Eleven published studies that featured original experimental data on soil ingestion of cattle were identified as part of the review, dating from the 1960s to present; multiple additional studies that cited the original work were also reviewed. Consideration was given to differences in reported levels, variables around those differences, reliability of methodology used and relevance to New South Wales. No studies under Australian conditions were identified, with research undertaken in New Zealand, England, France and the United States.

To estimate the time-period cattle would likely be exposed to MWOO on sites where the material had been applied, DPI merged two data sets and interrogated the data using statistical analysis, to understand the use of the material on individual farms in consideration of likely livestock management practices. 1. Industry records supplied by NSW EPA outlining specifics of tonnage delivered and application rate to individual properties and 2. property data and livestock records from the Local Land Services Land and Stock returns were interrogated. Note limitations of both data sets.

- Collated industry data (2010-2018) were provided to NSW EPA by the waste facilities, in September 2018. It was a condition of the regulations (Section 7, Resource Recovery Exemption under Part 9, Clauses 91 and 92 of the Protection of the Environment Operations (Waste) Regulation 2014; organic outputs derived from mixed waste exemption 2014), that consumers were to keep a written record of material received. The records were to include the name and address of the supplier, the quantity received, the address and paddock or plot identification where the organic outputs were applied, the application rate(s) and the date(s) upon which the organic outputs are applied to the land. Over 1700 sites deliveries were recorded but a number of errors were identified in the data, including addresses not found or information incomplete. In addition, application rates were either assumed or supplied in wet or dry tonnes per hectare, it is unclear if this was estimated or measured.
- Local land Services annual land and stock return (2017) including collated holding data – address, owner details, Property Identification Code (PIC), livestock present, noting accuracy relies on information provided by the landholder and that not all properties complete the annual return.

MWOO use

MWOO Application

Based on an analysis of MWOO industry records supplied by NSW EPA and Local Land Services annual land and stock returns it is understood that:

- There are no data on treatment method i.e. surface applied or incorporated (cultivated);
- 294 MWOO deliveries were made to 180 “properties” holding cattle;
- 146 real “properties” e.g. same ownership/Property Identification Code (PIC) and considered as separate entities;
- 111 (76%) of these properties are likely to have applied MWOO to 50% or less of the property;
- 15 properties received delivery in 2018, last delivery to agricultural land was September 2018, now 9 months ago; and
- 14 (9.6%) of 146 properties are likely to have had applications exceeding 100% and this may require further investigation/analysis.

Soil Ingestion by Cattle

Soil ingestion is predominantly incidental

Soil ingested by cattle can be incidental or deliberate. Incidental ingestion is either through soil adhered to plant material or soil adhered to roots when plants are pulled out during grazing. Active ingestion indicates an animal health issue for example cattle seeking a source of minerals if they are deficient (Beresford and Howard 1991; Healy 1973; Mayland et al 1975).

Incidental ingestion is the main route for domestic ruminants (Healy and Ludwig, 1965).

Soil ingestion measurement

Soil ingestion estimations are based on the ingestion of a nonabsorbed indicator, such as acid-insoluble ash or titanium oxide, which has very limited uptake by plants (Fries 1996). More recently radionuclides have been assessed as indicators to estimate soil ingestion (Doyle et al. 2012). Regardless of the indicator used, the level of indicator in faeces is used to calculate the proportion of soil ingested as a percentage of dry matter intake (DMI) using values for total dry matter consumed per day and the fraction of dry matter digested (digestibility).

Accurate estimation of soil ingestion therefore relies on an accurate understanding of total dry matter consumed per day and its digestibility (Fries 1996).

Reported soil ingestion values

No Australian studies

Published studies on soil ingestion in cattle under Australian conditions were not identified in this literature assessment.

Key input variables are often estimated rather than measured

Soil ingestion studies in cattle mostly use methodology that rely on crudely estimated input variables such as acid-insoluble ash concentrations in soil, feed digestibility, and feed intake which are then used to calculate soil ingestion. Fries et al (1982) noted that faecal ash content can be used as a rough indicator of faecal soil content but will not be the most reliable measure, due to animal and dietary variations. Most of the core literature on soil ingestion relies on assumed values for dry matter intake, or digestibility, or both. For example, Healy (1968), Kirby and Stuth, (1980), Fries et al, (1982), Abrahams and Thornton, (1994), and Thornton, (1973) all use assumed values for both dry matter intake and digestibility.

More recent work by Jurjanz et. al. (2012), measured all input values and reports average and maximum daily soil intake in individual dairy cattle of 0.47 kg/day and 1.3 kg/day respectively. Their work concludes that under good pasture conditions with sward height above 5 cm cows ingest less than 0.25 kg/day.

A wide range of values reported

A comparison of study results estimating soil intake per day is presented in Table 1a and b. In summary results range from:

- Average dairy cows 0.33 kg/day – 1.22 kg/day,
- Average range beef cattle 0.22 kg/day – 0.99 kg/day,

- Maximum range dairy cows 0.1kg/day – 2.61 kg/day, [maximum (NZ)];
- Maximum range beef cattle 0.28/day kg – 2.43 kg/day, [maximum (England)]

The highest soil ingestion values in cattle were recorded in a dairy herd in New Zealand (Healy 1968) and a beef herd in England (Thornton and Abrahams, 1983; Abrahams and Thornton, 1994). These values are at the extremes of the range of measured soil ingestion for cattle, representing a kilogram more than other results reported in the same study, and in other studies. They reflect temporary increases in soil ingestion, linked to season, stocking rate and other factors, and are not an indication of ongoing daily ingestion rate. Healy (1968) surmises that under New Zealand conditions annual intakes will range from about 250g/day to 1.24kg/day, with peaks in autumn and winter. The lowest value (0.1kg/day) reported in the literature was for dairy cows held on a paved surface. A number of studies note that even under conditions of abundant pasture growth, soil intake is never zero (e.g. Healy 1968).

Soil ingestion rates vary with season and conditions

Soil ingestion studies indicate that variability in soil ingestion rate is influenced by a range of factors, primarily seasonal conditions, but also soil type, stocking density, pasture availability and livestock management system including supplementary feeding.

The foundational work on soil ingestion (Healy 1968) clearly shows this strong seasonality under New Zealand conditions (Figure 1).

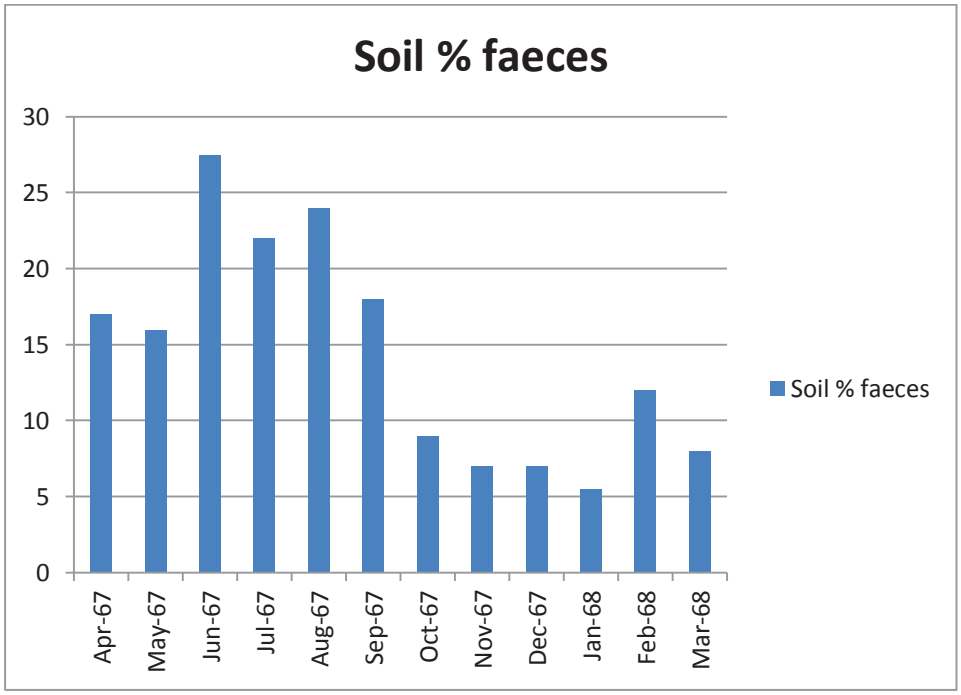

Figure 1. Soil content of faeces (%DM) plotted from table 2 where stocking rates and management where similar (No 1 and No 2 Unit) from Healy 1968.

The greatest intakes across all studies were recorded in the winter months in cool climates, when grass is in short supply. The highest recorded ingestion rate occurred during winter in New Zealand (Healy, 1968) and England (Thornton and Abrahams, 1983; Abrahams and Thornton, 1994), when stocking rates were at their highest, pasture growth was low, soil was muddiest and earth worm activity was high. Muddying of forage by trampling, raindrop splash and earthworm casts would have contributed to soil ingestion levels (Mayland 1975).

The widely cited maximum levels reported in New Zealand occurred under specific conditions where dairy herds were wintered on agistment blocks at higher stocking rates. DPI notes that livestock systems, climate, soil type, pasture species and other cumulative factors contributing to soil ingestion rates in the New Zealand study and indeed the majority of overseas studies reviewed, are unlikely to be comparable with conditions across most of New South Wales.

In considering the reviewed literature, the study of cattle held under semiarid conditions in the US (Mayland et al, 1975) is considered more comparable to much of New South Wales. This work reported daily soil ingestion levels of less than 1.33kg/day. They also noted that under these dry conditions, faecal-soil concentrations generally increased as the amount of available forage decreased, a result consistent with increased likelihood of soil exposure as pasture availability declined.

Appropriate Soil Ingestion values for Risk Assessment?

Value used in interim HHERA

The assessment of the human health and ecological risks posed by MWOO application to agricultural land assumed an ingestion rate of soil by individual cattle of 2.4 kg/day (HHERA 2018).

The 2.4 kg/day value was taken from the American Petroleum Institute guidance document for determining screening guidelines for petroleum hydrocarbons in livestock (API 2004). The literature review reported in the API (2004) showed a range of values for the percentage of soil found in the diet of cattle, from 0.2% to 18.8%. These values were then multiplied with the total daily food ingestion rate to derive the soil ingestion rates, with estimates ranging between 0.1 and 2.5 kg of soil per day.

The 2.4kg/day guidance value (API 2004), was derived from the maximum soil dietary percentage for dairy cattle; a lower value of 2.13kg/day was estimated for beef cattle. The values compare with the maximum ingestion rates reported by Healy (1968) and Thornton and Abrahams, (1983); Abrahams and Thornton, (1994). The HHERA (2018) noted the influence that variability in soil ingestion rate amongst individual animals may have on the modelling and acknowledges that it has used worst case scenario.

Appropriate values of soil ingestion per day for exposure period

When evaluating the significance of soil residues for meat animals, Fries (1982) recommended using the average yearly soil intake – i.e. average annual intake is more representative of soil ingestion and likely contamination levels in meat than single highest value. However, because milk is more responsive to changes in chemical levels in diet, worst case modelling of chemical contamination in dairy cattle, should use the average daily soil intake during the month of greatest intake (Fries 1982). Importantly regardless of meat or milk consideration, under neither circumstance does Fries (1982) recommend use of maximum soil ingestion value.

Our assessment of the literature reported here suggests a median of reported maximum values to be 0.88 kg/day, even when including the maximum values at the extremes of the range estimated under cold and wet conditions by Healy (1968), Thornton and Abrahams (1983); and Abrahams and Thornton (1994).

Mayland et al (1975) estimated soil ingestion levels under dry conditions to range from 0.1 to 1.5kg with a median around 0.5 kg/day, a value that DPI considers realistic for NSW conditions.

Fries (1996) reviewed ingestion by animals of organic chemicals in applied sludge. This work noted that use of conservative values for risk assessment parameters can lead to unrealistically high soil ingestion values in many situations, effectively skewing results for periods when these values could not apply. For example, using a static value for digestibility and dry matter intake in risk calculations does not take into consideration changes in pasture availability throughout the year, such as when forage is sparse or when livestock receive supplementary feed; the result would overestimate the amount of soil ingested. Beyer and Fries (2005) agree and consider even the average values reported in a number of studies on soil ingestion to be too high. One reason for this being for younger animals that make up the largest portion of the meat supply, because the assumed dietary intake value used in calculations is based on mature cattle. Jurjanz et al (2012) also noted the limitations of early studies which considered mixed herds, ie cattle with varying levels of dry matter intake.

International guidelines for risk assessments

The current US EPA, Human Health Risk Assessment Protocol for Hazardous Waste Combustion facilities recommends values of 0.4 kg/day for dairy cattle and 0.5 kg/day for beef (USEPA 2005). Beyer and Fries (2005) in Chapter 6 of the Handbook for Ecotoxicology support the use of these values in agricultural settings. They note that they provide a reasonable worst case for assessment of pasture grazing systems and in general, still overestimate risk.

US EPA (1993, 2002) and the US National Research Council (1996) use risk assessment models for soil ingestion that assumes that their intake of soil is 4% of total intake or lower, which results in daily intakes of 0.5 kg/day or less.

The ingestion of soil by grazing animals was considered by OEHHA (2015), who adopted a value of **0.05** (5%) for the fraction of soil in pasture and 0.01 for the soil fraction in feed. Using the equations provided by OEHHA (2015), this calculates to 0.27kg/day/head soil consumption for beef cattle grazed half on pasture, half feed and 0.45kg/day for beef cattle grazed solely on pasture. As noted by the interim HHERA (2018), a five percent value was considered a reasonable estimate of soil ingestion by beef and dairy cattle, as a percentage of pasture consumed, by OEHHA (2012).

A value of 0.04 fraction of soil in cattle diet was adopted by USEPA (2005). US EPA (1993, 1995), had earlier revised the fraction of sewage sludge in the diet of livestock grazing amended pastures from 8% to **1.5%** as a season-long average. This was in response to reviewer comments that long-term grazing under average field conditions was more appropriate when assessing soil ingestion of grazing animals than assuming short-term grazing under poor field conditions.

Cattle exposure period to MWOO

Livestock are not grazed on paddocks without sufficient pasture growth under normal Australian conditions and grazing management practices. Rather, livestock are rotated between paddocks to allow pasture to recover. In considering soil ingestion rate by cattle, the HHERA (2018) assumed that cattle would graze treated paddocks 365 days a year.

To better understand the likely exposure period of cattle to MWOO, DPI merged and analysed industry data and LLS property records, to identify cattle enterprises that had received deliveries of mixed waste material. 146 cattle properties were identified. The proportion of each property that had likely been treated with MWOO was then estimated based on the amount of MWOO delivered, the application rate and the area of each farm. Limitations of the data have already been noted.

111 or 76% of properties are likely to have had MWOO applied to less than half the farm, leaving the remaining property free of MWOO. The largest category was properties that are likely to have treated 10% or less of the total property with MWOO (fig. 2).

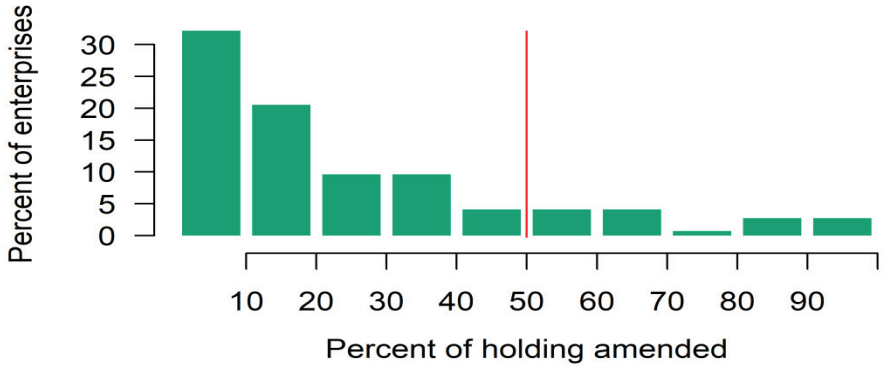

Figure 2. Percent of cattle enterprises likely amended as a proportion of total cattle enterprises. Estimated on the recorded tonnage of material delivered, the application rate and the size of the property.

The average rate of MWOO application across all treated farms is estimated to be 14% of total farm area, which means that on average, cattle on these farms are likely to be exposed to MWOO treated pasture for about 52 days a year, presuming all areas of the farm are suitable for grazing.

Based on DPI's analysis of the records, MWOO was rarely applied to whole farms and cattle would not have access to MWOO all year as they would be rotated between paddocks. Chaney et al. (1996) noted that there is a low likelihood that all pastures will receive surface applied biosolid treatments in any one year and that risk assessments should not make such an assumption. DPI notes anecdotal evidence that this is also the case in NSW.

Analysis of industry data - summary

- average rate of MWOO application across all treated farms is estimated to be 14% of total farm area
- largest category 49 (34% of cattle enterprises) likely treated 10% or less of total property
- 91 cattle enterprises (62%) likely treated less than 30% of property
- 111 (76%) of properties are likely to have applied MWOO to 50% or less of the property;
- 14 (9.6%) of 146 properties may have had applications exceeding 100%

A realistic estimate of the likely exposure of cattle to MWOO is 52 days a year.

Recommendation

1. Based on available information, a conservative and defensible value for modelling the rate of soil ingestion by individual cattle in the final revised HHERA is considered to be 0.5 kg/day

2 Based on available information, a conservative and defensible value for modelling the exposure period of cattle to MWOO where it has been applied is 52 days per year.

MWOO ingestion by Cattle?

MWOO consumption and soil mixing

Prior to EPA's decision to stop the use of MWOO on agriculture land, animals were not permitted to graze the land until 30 days after application (90 days for lactating and new born animals). This withholding period is likely to have provided a key risk reduction step to reduce livestock ingestion of MWOO.

Chaney et al. (1996) reviewed biosolids risk assessment and pointed to this as the reason for withholding periods on use of agricultural lands following biosolids application. Further, Chaney et al. 1996 (citing Decker et al. 1986) reported that 21 days after treating land with biosolids, animals grazing the land for 7 days had 2.5% biosolids in their diet compared to less than 1% when grazing land where biosolids were applied the previous season.

Biosolids and MWOO are different products. The sludge/liquid like nature of biosolids allow it to strongly adhere to above ground plant structures for a long period after application (Chaney and Lloyd 1979) in a way that is unlikely for MWOO.

There is limited information on the relative importance of different pathways for cattle to ingest soil, and no information on soil treatments such as MWOO. Broadly, Herlin (1996) in a review, notes key mechanisms such as soil adhered to pasture plants, fodder, and soil associated with roots. In summary the review stated "Soil ingestion will increase with low amounts of forage available, winter season conditions, high stocking rates, root intake, loose soils and management that produces pasture conditions with soil contaminating grass".

Mayland et al. (1975) make a clear comparison under likely Australian conditions noting that soil ingested by cattle grazing under semiarid conditions primarily came from the roots which were often pulled up and consumed with the above ground plant parts. In this study dust on leaves and stems accounted for only a small portion of ingested soil. The species involved was relatively shallow rooted which is typical of many species present in Australian pastures.

Importantly the US EPA (USEPA 1993) assumed that over time freshly applied sewage sludge will become mixed with soil. More recently US EPA (2002) assumed a mixing depth of 2cm for surface-applied biosolids to grazing paddocks, through cattle activity and/or other disturbance of soil by living organisms (bioturbation). Likewise, while the original USEPA (1993) recommended a 100% ingestion of sewage sludge for grazing animals, they noted that under average conditions, sludge is mixed into the top 15cm of soil through climatic conditions and biological factors. While work completed as part of the EPA commissioned research program found no significant movement of physical contaminants, soil nutrients or heavy metals within the soil profile below the depth of application, DPI notes that this work was undertaken under controlled conditions where no stock were present. Mechanical mixing of soil to a shallow depth, based on the literature, is likely through actions of cattle hooves.

Given that:

- **cattle activity and/or bioturbation will result in mixing of MWOO with soil, and**
- **the primary source of soil ingested by cattle in semiarid areas will be soil adhering to plant roots and this soil is likely to come from throughout the soil layer where the roots are growing (top 10 cm or deeper),**

Then the interim HHERA (2018) assumption that MWOO is mixed into soil may therefore provide a realistic estimate of MWOO content in ingested soil, for both surface applied and cultivated MWOO.

Recommendation

3. That the interim HHERA (2018) assumption that MWOO is mixed into soil is likely to provide a realistic estimate of MWOO content in ingested soil, for both surface applied MWOO and cultivated MWOO.

Table 1a. Estimated soil intake (kg/day or % DMI) of dairy cattle from published studies

Author	Year	Country	Grazing/Housed	Identifier	Method	Stocking Density (Cows/Ha)	DMI (kg/day)	Soil Intake kg/day Min	Soil Intake kg/day Max	Soil Intake kg/day Average	Soil Intake % DMI Min	Soil Intake % DMI Max
Dairy												
Healy[1]	1968	NZ	Grazing	Massey	Ti	1.85	12.43	0.15	**0.93**	0.37	1.20	**7.50**
			Grazing	Massey	Ti	2.47	12.43	0.22	**1.27**	0.70	1.80	**10.20**
			Grazing	Massey	Ti	3.71	12.43	0.56	**2.61**	1.12	4.50	**21.00**
			Platform Fed	Massey	Ti	3.71	12.43	0.48	**1.68**	0.84	3.90	**13.50**
			Grazing	Ruakura	Ti	3.71	12.43	0.28	**0.64**	0.46	2.25	**5.17**
			Grazing	Ruakura	Ti	4.94	12.43	0.38	**1.02**	0.60	3.07	**8.18**
Fries[2]	1982	USA	Paved	Cows	Ti	NI	18.00	0.03	**0.10**	-	0.14	**0.53**
			Unpaved, no veg	Cows	Ti	NI	18.00	0.11	**0.17**	-	0.60	**0.96**
			No vegetation	Heifers	Ti	NI	12.43	0.03	**0.29**	-	0.25	**2.41**
			Sparse vegetation	Heifers	Ti	NI	12.43	0.19	**0.42**	-	1.56	**3.77**
			Supplement	Heifers	Ti	NI	12.43	0.17	**0.29**	-	1.38	**2.43**
Green[3]	1988	England	Grazing	Cows	Ti	NI	13.61	-	**-**	0.33	-	**2.43**
Dewes[4]	1996	NZ	Supplemented	Early grazing	Ti	NI	18.0	0.06	**0.11**	-	-	**0.6**
			Unsupplemented	Mod. grazing	Ti	NI	18.0	1.2	**1.8**	-	-	**12.2**
Jurjanz[5]	2012	France	Grazing	Trial 1	AIA		15.12	0.06	**1.30**	0.40	0.6	**8.6**
			Grazing	Trial 2	AIA		13.06		**1.45**	0.47	0.1	**11.1**

[1]Assumptions for estimated DMI from Coop, 1965 (10,000 lb DM/year, as cited by Healy, 1968a); DMD = 70% DM; Soil Intake (kg/day) estimated from % soil in faeces (Healy, 1968a).
[2]Assumption for DMD = 60% DM (Fries et al., 1982).
[3]Data for % DMI are average values presented (Green and Dodd, 1988). Assumptions for DMD = 70% DM and DMI = 13.61 kg/day (30 lb/day) and the equation of Abrahams et al. (1994) to estimate soil intake from Ti content in soil and faeces.
[4]Data for % DMI are average values presented (Dewes, 1996).
[5]Pasture DMD estimated using Pepsin Cellulase digestibility. DMI calculated from presented data. Min and Max values presented in text of article or additional work by DPI (Jurjanz et al 2012)

Table 1b. Estimated soil intake (kg/day or % DMI) of beef cattle from published studies

Author	Year	Country	Grazing/Housed	Identifier	Method	Stocking Density (Cows/Ha)	DMI (kg/day)	Soil Intake kg/day Min	Soil Intake kg/day Max	Soil Intake kg/day Average	Soil Intake % DMI Min	Soil Intake % DMI Max
Beef												
Mayland[1]	1975	USA	Grazing	High density	Ti	0.31	9.0	0.14	**1.17**	-	1.55	**13.05**
			Grazing	Low density	Ti	0.07	9.0	0.35	**1.33**	-	3.85	**14.75**
Kirby[2]	1980	USA	Grazing	Tilled	AIA	3.2	3.88	0.41	**0.84**	-	11.7	**20.4**
			Grazing	Untreated	AIA	3.2	3.88	0.28	**0.61**	-	8.9	**12.7**
Abrahams[3]	1994	England	Grazing	April	Ti	Unknown	13.6	0.20	**2.43**	0.76	1.5	**17.9**
			Grazing	June	Ti	Unknown	13.6	0.03	**0.53**	0.20	0.2	**3.9**
			Grazing	August	Ti	Unknown	13.6	0.19	**0.64**	0.41	1.4	**4.7**
Thornton[4]	1973	England	Grazing	November	Ti	Unknown	13.61	0.14	**1.48**	0.62	1.10	**10.90**
			Grazing	January	Ti	Unknown	13.61	0.21	**0.82**	0.46	1.60	**6.00**
			Grazing	March	Ti	Unknown	13.61	0.66	**0.88**	0.78	4.90	**6.40**
Mayland[5]	1977	USA	Grazing	June	Ti	Unknown	10.4	0.69	**0.77**	0.73	6.6	**7.4**
			Grazing	Aug	Ti	Unknown	8.6	0.93	**1.05**	0.99	10.8	**12.2**
Thornton[6]	1983	England	Grazing	Derbyshire	Ti	Unknown	13.6	0.39	**0.50**		2.9	**3.7**
			Grazing	Cornwall	Ti	Unknown	13.6	0.03	**2.43**		0.2	**17.9**

[1]Stocking density = cow + calf; Assumption for DMD = 50% DM (Mayland et al., 1975).
[2]Estimated DMD of pasture using the method of Tilley & Terry; DMI estimated in 4 steers in a different paddock (Kirby and Stuth, 1980).
[3]Assumptions for DMD= 70% DM and DMI = 13.6 kg/day (Abrahams and Thornton, 1994).
[4]Assumptions for DMD= 70% DM and DMI = 13.61 kg/day (30 lb/day) (Thornton, 1973).
[5]Intake estimated using Cr_2O_3 (Mayland et al., 1977).
[6]Low value for Soil Intake from June, High value for Soil Intake from April (Thornton and Abrahams, 1983).

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Appendix D Calculations – Parked Chemicals

Derivation of Investigation Levels
Review of NEPM HILs
HIL A - Low Density Residential

Summary of Exposure Parameters		Abbreviation	units	Parameter	References/Notes
Soil and Dust Ingestion Rate	- Young children (0-5 years)	IR_{SC}	mg/day	100	Schedule B7, Table 5
	- Adults	IR_{SA}	mg/day	50	Schedule B7, Table 5
Surface Area of Skin	- Young children (0-5 years)	SA_C	cm^2/day	2700	Schedule B7, Table 5
	- Adults	SA_A	cm^2/day	6300	Schedule B7, Table 5
Soil-to-Skin Adherence Factor		AF	mg/cm^2/day	0.5	Schedule B7, Table 5
Time Spent Outdoors		ETo	hours	4	Schedule B7, Table 5
Time Spent Indoors		ETi	hours	20	Schedule B7, Table 5
Lung Retention Factor		RF	-	0.375	Schedule B7, Table 5
Particulate Emission Factor		PEFo	(m^3/kg)	2.9E+10	Calculated for scenario, refer to Equations 19 and 20 and assumptions in Schedule B7
Indoor Air Dust Factor		PEFi	(m^3/kg)	2.6E+07	As per Equation 21 based assumptions presented in Schedule B7
Fraction of indoor dust comprised of outdoor soil		TF	-	0.5	Assume 50% soil concentration present in dust as noted in Schedule B7
Indoor Air-to-Soil Gas Attenuation Factor		α	-	0.1	Value adopted as discussed in Section 5.5 of Schedule B7
Body weight	- Young children (0-5 years)	BW_C	kg	15	Schedule B7, Table 5
	- Adults	BW_A	kg	70	Schedule B7, Table 5
Exposure Frequency		EF	days/year	365	Schedule B7, Table 5
Exposure Duration	- Young children (0-5 years)	ED_C	years	6	Schedule B7, Table 5
	- Adults	ED_A	years	29	Schedule B7, Table 5
Averaging Time (non-carcinogenic)		AT_T	days	ED*365	Calculated based on ED for each relevant age group, multiplied by 24 hours for the assessment of inhalation exposures
Averaging Time (carcinogenic)		AT_{NT}	days	25550	Based on lifetime of 70 years, multiplied by 24 hours for the assessment of inhalation exposures

Threshold Calculations - Young Child aged 2-3 years

Compound	Toxicity Reference Value Oral (TRV_O) (mg/kg/day)	GI Absorption (GAF) (unitless)	Toxicity Reference Value Dermal (TRV_D) (mg/kg/day)	Oral Bioavailability BA_O (%)	Dermal Absorption Factor (DAF) (unitless)	Background Intake Oral/Dermal (BI_O) (% of TDI)	Toxicity Reference Value Inhalation (TRV_I) (mg/m^3)	Background Intake Inhalation (BIi) (% of TC)		Plant Uptake Factor (incl % intake) Adults (kg/day) (eqn 16)	Plant Uptake Factor (incl % intake) Children (kg/day) (eqn 16)	Pathway Specific HILs (mg/kg)				Soil Vapour HIL (mg/m^3) (eqn 12)	Derived Interim Soil Gas HIL - Threshold (to 1 or 2 s.f.) (mg/m3)	Derived Soil HIL (not rounded) (mg/kg) (eqn 2 for relevant pathways)	Derived Soil HIL (to 1 or 2 s.f.) (mg/kg)	Notes
												Soil Ingestion (eqn 3)	Home-grown produce (eqn 15)	Dermal (eqn 6)	Dust (eqn 9)					
Benzene Hexachloride	0.0080	1	0.008	100%	0.1	0%	0.03	0%			7.6E-05	1.2E+03	1.6E+03	8.9E+02	4.9E+06			386	**400**	
Brodifacoum	0.0000005	1	0.0000005	100%	0.1	0%	0.000002	0%			9.3E-03	7.5E-02	8.0E-04	5.6E-02	3.3E+02			0.0008	**0.0008**	
Chlorpyrifos	0.0030	1	0.003	100%	0.1	0%	0.01	0%			5.1E-04	4.5E+02	8.8E+01	3.3E+02	1.6E+06			60	**60**	
Cypermethrin	0.0500	1	0.05	100%	0.1	0%	0.2	0%			2.9E-04	7.5E+03	2.6E+03	5.6E+03	3.3E+07			1426	**1000**	
Dicamba	0.03	1	0.03	100%	0.1	0%	0.1	0%			2.3E-02	4.5E+03	2.0E+01	3.3E+03	1.6E+07			20	**20**	
Dichlofluanid	0.0300	1	0.03	100%	0.1	0%	0.1	0%			5.7E-03	4.5E+03	7.8E+01	3.3E+03	1.6E+07			75	**80**	
Emamectin benzoate	0.0020	1	0.002	100%	0.1	0%	0.007	0%			1.7E-02	3.0E+02	1.8E+00	2.2E+02	1.1E+06			2	**2**	
Fipronil	0.0002	1	0.0002	100%	0.1	0%	0.0007	0%			4.6E-04	3.0E+01	6.5E+00	2.2E+01	1.1E+05			4	**4**	
Lindane	0.0003	1	0.0003	100%	0.1	0%	0.001	0%			5.1E-04	4.5E+01	8.8E+00	3.3E+01	1.6E+05			6	**6**	
Metalaxyl	0.03	1	0.03	100%	0.1	0%	0.1	0%			1.2E-02	4.5E+03	3.8E+01	3.3E+03	1.6E+07			4499	**4000**	
Permethrin	0.05	1	0.05	100%	0.1	0%	0.2	0%			1.6E-04	7.5E+03	4.6E+03	5.6E+03	3.3E+07			2835	**3000**	
Profenofos	0.0001	1	0.0001	100%	0.1	0%	0.0004	0%			8.4E-03	1.5E+01	1.8E-01	1.1E+01	6.6E+04			0.17	**0.2**	
Prometryn	0.03	1	0.03	100%	0.1	0%	0.1	0%			3.1E-03	4.5E+03	1.4E+02	3.3E+03	1.6E+07			140	**100**	
Simazine	0.0050	1	0.005	100%	0.1	0%	0.02	0%			4.7E-03	7.5E+02	1.6E+01	5.6E+02	3.3E+06			15	**20**	
Tebuconazole	0.0300	1	0.03	100%	0.1	0%	0.1	0%			5.3E-03	4.5E+03	8.4E+01	3.3E+03	1.6E+07			81	**80**	
Thiabendazole	0.3000	1	0.3	100%	0.1	0%	1	0%			5.0E-04	4.5E+04	9.1E+03	3.3E+04	1.6E+08			6155	**6000**	
Aluminium	1.0000	1	1	100%	0.1	0%	3.5	0%			2.8E-05	1.5E+05	5.4E+05	1.1E+05	5.7E+08			57029	**60000**	
Iron	0.7000	1	0.7	100%	0.1	0%	2.5	0%			2.8E-05	1.1E+05	3.8E+05	7.8E+04	4.1E+08			39920	**40000**	
Lithium	0.0020	1	0.002	100%	0.1	0%	0.007	0%			1.8E-04	3.0E+02	1.7E+02	2.2E+02	1.1E+06			73	**70**	
Strontium	0.6000	1	0.6	100%	0.1	0%	2	0%			1.8E-02	9.0E+04	5.1E+02	6.7E+04	3.3E+08			507	**500**	
Titanium	1.0000	2	2	100%	0.1	0%	3.5	0%			3.8E-05	1.5E+05	3.9E+05	2.2E+05	5.7E+08			72856	**70000**	
Acenaphthene	0.0600	1	0.06	100%	0.1	0%	0.2	0%			5.1E-04	9.0E+03	1.8E+03	6.7E+03	3.3E+07			1203	**1000**	
Fluoranthene	0.0400	1	0.04	100%	0.1	0%	0.1	0%			7.6E-05	6.0E+03	7.9E+03	4.4E+03	1.6E+07			1930	**2000**	
Fluorene	0.0400	1	0.04	100%	0.1	0%	0.1	0%			3.2E-04	6.0E+03	1.9E+03	4.4E+03	1.6E+07			1083	**1000**	
Di-ethylhexyl adipate	0.6000	1	0.6	100%	0.1	0%	2	0%			2.9E-04	9.0E+04	3.1E+04	6.7E+04	3.3E+08			17155	**20000**	
Organotins (sum)	0.0003	1	0.0003	100%	0.1	0%	0.001	0%			1.1E-07	4.5E+01	4.1E+04	3.3E+01	1.6E+05			19	**20**	

Calculation of Uptake Factors for Home-Grown Produce - used in Derivation of HIL A

Consumption of Fruit and Vegetables by Adults and Children

Percentage of Fruit and Vegetables per produce group (as per Table 7 in Schedule B7)

Produce Group	Adults (%)	Adult Consumption Rate (g/day)	Children (%)	Child Consumption Rate (g/day)
Green Vegetables	59	153.4	55	55
Root Vegetables	18	46.8	17	17
Tuber Vegetables	23	59.8	28	28
Tree Fruit	100	140	100	180
Total consumption		400		280

Uptake and Intake from Produce - Inorganics

Fraction Home-grown (HIL A)	10%	As per Table 5 in Schedule B7

Consumption rates (from above table, with change of units)	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Consumption Rate Adults (kg/day)	0.1534	0.0468	0.0598	0.14
Consumption Rate Children (kg/day)	0.055	0.017	0.028	0.18

Inorganic Chemical	Soil-to-Plant Concentration Factors (mg/kg fresh weight to mg/kg soil dry weight)				Plant Uptake Factor - Adults (UF_{VA}) (kg/day) as per Equation 16	Plant Uptake Factor - Young Children (UF_{VC}) (kg/day) as per Equation 16	References and Comments for Soil-to-Plant Concentration F
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit			
Aluminium	1.00E-03	1.00E-03	1.00E-03	1.00E-03	4.0E-05	2.8E-05	Values from RAIS - soil to wet plant uptake
Iron	1.00E-03	1.00E-03	1.00E-03	1.00E-03	4.0E-05	2.8E-05	Values from RAIS - soil to wet plant uptake
Lithium	6.25E-03	6.25E-03	6.25E-03	6.25E-03	2.5E-04	1.8E-04	Values from RAIS - soil to wet plant uptake
Strontium	6.25E-01	6.25E-01	6.25E-01	6.25E-01	2.5E-02	1.8E-02	Values from RAIS - soil to wet plant uptake
Titanium	1.37E-03	1.37E-03	1.37E-03	1.37E-03	5.5E-05	3.8E-05	Values from RAIS - soil to wet plant uptake

Uptake and Intake from Produce - Organics

Soil bulk density (g/cm^3)	1.63	Assumed for typical soil in root zone
Soil-water content by volume (cm^3/cm^3)	0.13	Assumed for typical soil in root zone
Fraction organic carbon (foc)	2%	Noted in Section 5.3.5.3 in Schedule B7
Fraction Home-grown (HIL A)	10%	As per Table 5 in Schedule B7

Consumption rates (from above table, with change of units)	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit
Consumption Rate Adults (kg/day)	0.1534	0.0468	0.0598	0.14
Consumption Rate Children (kg/day)	0.055	0.017	0.028	0.18

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	Chemical Properties (as per RAIS 2010)					Intermediate Calculations						
	Koc (cm^3/g)	Log Kow	Kow	Dw (m^2/s)	Dw (cm^2/s)	K_{ch} (cm^3/g) (as per Appendix B)	K_{pw} (cm^3/g) (as per Equation 25)	k_2 (per hour) (as per Equation 26)	k_1 (per hour) (as per Equation 24)	K_{wood} (mg/g dw wood per mg/cm^3 water) (as per Equation 30)	Cxy (intermediate for calculating C_{stem})	C_{stem} (mg/g) (as per Equation 29)
Benzene Hexachloride	2.90E+01	2.21	1.62E+02	7.80E-10	7.80E-06	1	1.06E+00	2.20E-02	4.02E-02	1.34E+01	1.35E+00	1.80E+01
Brodifacoum	5.90E+03	4	1.00E+04	1.00E-09	1.00E-05	3	2.88E+00	1.04E-02	2.53E-04	1.81E+02	1.53E-02	2.77E+00
Chlorpyrifos	4.00E+01	1.7	5.01E+01	5.20E-10	5.20E-06	0.5	9.19E-01	1.69E-02	1.94E-02	6.37E+00	1.21E+00	7.72E+00
Cypermethrin	1.19E+05	6.5	3.16E+06	4.78E-10	4.78E-06	3	1.25E+02	1.14E-04	6.00E-06	6.89E+03	1.57E-01	9.49E+02
Dicamba	6.56E+02	3.51	3.24E+03	6.16E-10	6.16E-06	2	1.82E+00	1.01E-02	1.40E-03	8.88E+01	8.56E-02	7.58E+00
Dichlofluanid	1.74E+03	2.47	2.95E+02	6.46E-10	6.46E-06	1	1.10E+00	1.76E-02	5.54E-04	1.95E+01	2.17E-02	4.25E-01
Emamectin benzoate	1.40E+05	8.5	3.16E+08	1.00E-09	1.00E-05	3	4.28E+03	6.97E-06	1.07E-05	1.26E+05	3.10E+02	1.11E+07
Fipronil	7.28E+03	4.96	9.12E+04	4.46E-10	4.46E-06	3	9.46E+00	1.41E-03	9.15E-05	7.32E+02	5.42E-02	3.91E+01
Lindane	7.98E+04	6.6	3.98E+06	4.65E-10	4.65E-06	3	1.49E+02	9.33E-05	8.70E-06	7.97E+03	3.20E-01	2.20E+03
Metalaxyl	4.00E+02	3.7	5.01E+03	1.00E-09	1.00E-05	2	2.07E+00	1.44E-02	3.73E-03	1.17E+02	1.65E-01	1.93E+01
Permethrin	2.20E+02	5	1.00E+05	1.00E-09	1.00E-05	3	1.01E+01	2.97E-03	6.79E-03	7.76E+02	1.94E+00	1.48E+03
Profenofos	4.05E+02	4.68	4.79E+04	4.28E-10	4.28E-06	3	6.31E+00	2.02E-03	1.58E-03	4.87E+02	5.89E-01	2.84E+02
Prometryn	1.46E+02	2.18	1.51E+02	7.37E-10	7.37E-06	1	1.06E+00	2.08E-02	7.54E-03	1.28E+01	2.69E-01	3.45E+00
Simazine	4.30E+02	3.7	5.01E+03	1.00E-09	1.00E-05	2	2.07E+00	1.44E-02	3.47E-03	1.17E+02	1.54E-01	1.79E+01
Tebuconazole	2.81E+03	3.72	5.25E+03	5.00E-10	5.00E-06	2	2.10E+00	7.11E-03	2.66E-04	1.21E+02	2.40E-02	2.88E+00
Thiabendazole	2.81E+03	3.8	6.31E+03	5.00E-10	5.00E-06	2	2.24E+00	6.67E-03	2.66E-04	1.35E+02	2.59E-02	3.50E+00
Acenaphthene	5.00E+03	3.9	7.94E+03	4.74E-10	4.74E-06	2	2.44E+00	5.81E-03	1.42E-04	1.57E+02	1.62E-02	2.52E+00
Fluoranthene	5.50E+04	5.2	1.58E+05	5.69E-10	5.69E-06	3	1.37E+01	1.24E-03	1.54E-05	1.04E+03	1.16E-02	1.18E+01
Fluorene	9.20E+03	4.2	1.58E+04	5.91E-10	5.91E-06	3	3.51E+00	5.03E-03	9.59E-05	2.42E+02	1.26E-02	3.04E+00
Di-ethylhexyl adipate	3.60E+04	6.1	1.26E+06	4.26E-09	4.26E-05	3	6.21E+01	2.05E-03	1.77E-04	3.85E+03	1.60E-01	5.70E+02
Organotins (sum)	2.60E+07	4.1	1.26E+04	3.08E-09	3.08E-05	3	3.17E+00	2.90E-02	1.77E-07	2.10E+02	3.92E-06	8.18E-04

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	Soil-to-Plant Concentration Factors (mg/kg fresh weight to mg/kg soil dry weight)				Plant Uptake Factor - Adults (UF_{VA}) (kg/day) as per Equation 16	Plant Uptake Factor - Young Children (UF_{VC}) (kg/day) as per Equation 16
	Green Vegetables (CF_{green}) as per Equation 27	Root Vegetables (CF_{root}) as per Equation 22	Tuber Vegetables (CF_{tuber}) as per Equation 23	Tree Fruit (CF_{Tfruit}) (as per Equation 28)		
Benzene Hexachloride	2.14E+00	3.36E+00	1.83E+00	4.31E-03	5.95E-02	2.27E-02
Brodifacoum	5.03E-02	6.69E-02	2.44E-02	4.89E-05	1.23E-03	4.60E-04
Chlorpyrifos	1.06E+00	1.64E+00	1.15E+00	3.87E-03	3.08E-02	1.19E-02
Cypermethrin	4.79E-04	4.19E-03	5.24E-02	4.41E-04	3.47E-04	1.65E-04
Dicamba	3.50E-01	4.72E-01	1.39E-01	2.73E-04	8.41E-03	3.12E-03
Dichlofluanid	5.18E-02	7.17E-02	3.15E-02	6.95E-05	1.32E-03	4.96E-04
Emamectin benzoate	2.75E-06	3.57E-03	1.53E+00	2.81E-01	1.31E-02	9.34E-03
Fipronil	3.94E-02	6.54E-02	6.50E-02	1.71E-04	1.30E-03	5.13E-04
Lindane	6.01E-04	6.25E-03	9.32E-02	8.83E-04	6.08E-04	2.91E-04
Metalaxyl	6.43E-01	8.65E-01	2.59E-01	5.27E-04	1.55E-02	5.74E-03
Permethrin	1.26E+00	2.17E+00	2.28E+00	6.10E-03	4.32E-02	1.71E-02
Profenofos	7.64E-01	1.14E+00	7.80E-01	1.87E-03	2.18E-02	8.36E-03
Prometryn	4.58E-01	6.51E-01	3.62E-01	8.62E-04	1.22E-02	4.65E-03
Simazine	5.99E-01	8.04E-01	2.41E-01	4.90E-04	1.44E-02	5.34E-03
Tebuconazole	9.33E-02	1.24E-01	3.74E-02	7.65E-05	2.24E-03	8.31E-04
Thiabendazole	9.72E-02	1.29E-01	3.98E-02	8.26E-05	2.34E-03	8.68E-04
Acenaphthene	5.72E-02	7.60E-02	2.44E-02	5.16E-05	1.38E-03	5.13E-04
Fluoranthene	4.60E-03	8.81E-03	1.25E-02	3.63E-05	1.87E-04	7.59E-05
Fluorene	3.40E-02	4.57E-02	1.91E-02	4.01E-05	8.50E-04	3.19E-04
Di-ethylhexyl adipate	2.90E-03	1.38E-02	8.63E-02	4.74E-04	6.32E-04	2.90E-04
Organotins (sum)	1.18E-05	1.57E-05	6.09E-06	1.25E-08	2.91E-07	1.09E-07

Appendix E Plant Uptake Factor Equations

Plant uptake of organic compounds has been estimated in the derivation of HILs using the equations presented by EA (UK EA 2009), which are detailed as follows (refer to (UK EA 2009) for further explanation of the basis for these equations):

Root Crops

$$CF_{root} = \frac{\frac{Q}{Koc\ x\ Foc}}{\frac{Q}{\frac{W}{\rho_p}+\frac{L}{\rho_p}\ x\ 1.22K_{ow}^{0.77}}+(k_g+K_m)\rho_p RV}$$ **Equation 1**

where:

CFroot = Concentration factor (mg/kg fw plant per mg/kg dw soil)
Q = transpiration stream flow rate, (cm^3/day) (assumed equal to the default of 1000)
Koc =organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
Foc = fraction of organic carbon in the soil, (unitless)
Kow = octanol–water partition coefficient, (unitless) (compound-specific)
W = root water content, (g/g) (assumed equal to the default of 0.89)
L = root lipid content on a mass basis, (g/g) (assumed equal to the default of 0.025)
ρ_p = plant root density, (g/cm^3) (assumed equal to the default of 1)
k_g = first order growth rate constant, per day (assumed equal to the default of 0.1)
K_m = first order metabolism rate constant, (per day) (assumed equal to the default of 0)
RV = root volume, (cm^3) (assumed equal to the default of 1000)

Tuber Crops

Calculations presented for tuber crops are based on potatoes as representative crops for this group:

$$CF_{tuber} = \frac{k1}{k2+k_g}$$ **Equation 2**

where:

$$k1 = k2\left(\frac{K_{pw}}{Koc\ x\ Foc}\right)$$ **Equation 3**

$$K_{pw} = \frac{W}{\rho_p} + (f_{ch}K_{ch}) + \left(\frac{L}{\rho_p}\right)1.22K_{ow}^{0.77}$$ **Equation 4**

$$k2 = \frac{\frac{23(3600D_{water}(\frac{W^{2.333}}{\rho_p})}{K_{pw}}}{R^2}$$ **Equation 5**

where:

k1 = rate of chemical flux into the potato, (per hour) (Equation 3)
k2 = rate of chemical flux out of the potato, (per hour) (Equation 5)
k_g = exponential rate of growth of the potato, (per hour) (assumed equal to the default of 0.0014)
Foc = fraction of organic carbon in the soil, (unitless)
Koc =organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
D_{water} = chemical diffusion coefficient in water, (m^2/s) (compound-specific)
ρ_p = potato tissue density, (g/cm^3) (assumed equal to the default of 1)
R = radius of the potato, (m) (assumed equal to the default of 0.04)

W = water content of potato, (g/g) (assumed equal to the default of 0.79)
K_{pw} = equilibrium partition coefficient between potato and water, (cm^3/g) (Equation 25)
f_{ch} = fraction of carbohydrates in the potato, (unitless) (assumed equal to the default of 0.209)
L = lipid content of potato on a mass basis, (g/g) (assumed equal to the default of 0.001)
Kow =octanol–water partition coefficient, (unitless) (compound-specific)
K_{ch} = carbohydrate–water partition coefficient, (cm^3/g) (calculated from chemical lipophilicity according to the following table)

Chemical log Kow	Chemical Kch (cm^3/g)
<0	0.1
≥0 but <1	0.2
≥1 but <2	0.5
≥2 but <3	1
≥3 but <4	2
≥4	3

Green Vegetables

$$CF_{green} = \left(10^{0.95logKow-2.05} + 0.82\right) x \left(0.784\ x\ 10^{\frac{-0.434(\ \ logKow-1.78)^2}{2.44}}\right) x \left(\frac{\rho_s}{\theta_{ws}+(\rho_s\ x\ Koc\ x\ foc)}\right)$$ **Equation 6**

where:
Koc =organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
foc = fraction of organic carbon in the soil, (unitless)
Kow = octanol-water partition coefficient, (unitless) (compound-specific)
ρ_s = dry soil bulk density, (g/cm^3)
θ_{WS} = soil-water content by volume, (cm^3/cm^3)

Tree Fruit

$$CF_{fruit} = \frac{0.001\ x\ \left(M_f\ x\ Q_{fruit}\ x\ DM_{fruit}\right)\left(\frac{C_{stem}}{K_{wood}}\right)/M_f}{C_{soil}}$$ **Equation 7**

where:

$$C_{stem} = \frac{\left[\left(\frac{C_{soil}}{Koc\ x\ Foc}\right)0.756e^{\frac{-(logKow-2.5)2}{2.58}}\right]\left(\frac{Q}{M}\right)}{\frac{Q}{K_{wood}\ x\ M}+ k_e+k_g}$$ **Equation 8**

$$logK_{wood} = 0.27 + 0.632\ logKow$$ **Equation 9**

where:
M_f = mass of fruit, (g fw) (assumed equal to the default of 1)
Q_{fruit} = water flow rate per unit mass of fruit, (cm^3/g fw) (assumed equal to the default of 20)
DM_{fruit} = dry matter content of fruit, (g/g) (assumed equal to the default of 0.16)
C_{stem} = chemical concentration in the woody stem (mg/g) (Equation 8)
K_{wood} = wood–water partition coefficient, (mg/g dw wood per mg/cm^3 water) (Equation 9)
C_{soil} = total chemical concentration in soil, (mg/kg dw) (assumed to be 1 for establishing ratio)
Koc = organic carbon–water partition coefficient for the contaminant, (cm^3/g) (compound-specific)
foc = fraction of organic carbon in the soil, (unitless)
Kow = octanol–water partition coefficient, (unitless) (compound-specific)
Q = transpiration stream flow rate, (cm^3/year) (assumed equal to the default of 25,000,000)
M = mass of the woody stem, (g dw) (assumed equal to the default of 50,000)

k_e = rate of chemical metabolism, (per year) (assumed equal to the default of 0)
k_g = rate of dilution due to wood growth, (per year) (assumed equal to the default of 0.01)

Fraction of Organic Carbon in the Soil

As noted in Section 5.3.5.3 of Schedule B7 of the NEPM (1999 amended 2013) it is noted that for vapour intrusion calculations in the NEPM an organic carbon content of 0.3% has been assumed. For calculating the plant uptake factors, an organic carbon content of 2% has been assumed as any soil in a home grown produce garden will have been augmented with organic carbon to enable good quality growth of the produce.

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Refined Calculation – 2019

Methodology

The concentration of organic chemicals in edible fruit and vegetables has been estimated using published equations derived from experimental studies. General guidance has been provided by the documents RISC (Version 4, Users Guide, 2001) and “Higher Plant Accumulation of Organic Pollutants from Soils” (USEPA 1992) which draws on published models (Briggs et al. 1982; Travis & Arms 1988). Organic chemicals can enter and accumulate in plants through three main pathways:

1. Root uptake into conduction channels or oil cells (e.g. carrots, parsnips and cress) and subsequent translocation[1] throughout the plant via the transpiration stream.
2. Uptake of organic vapours in the surrounding air into leaves and shoots.

[1] Translocation is the transport or conduction of liquids within the plant.

3. Deposition of dust or soil onto leaves and shoots – not considered relevant in this assessment.

In nearly all cases, a combination of all of these pathways or events influences the total chemical concentration in the plant. The relative importance of each of the pathways will vary from chemical to chemical.

It is noted that the ASC NEPM makes use of the more complex models for estimating plant uptake of organic compounds recommended by the UK Environment Agency (UK EA 2006) (see description above).

The more simplified approach outlined below is an alternate approach and allows consideration of the leachability of the PBDEs in the MWOO. Leachability has been determined by considering the sum of PBDEs in MWOO leachate (maximum) to the maximum concentration present in solid MWOO.

While the empirical equations used in this assessment were derived for herbicides in barley (Briggs et al, 1982) and a limited number of lipophilic compounds in leafy aboveground plants (Travis & Arms 1988) a number of more recent evaluations and models have been developed (Trapp, Stefan 2004; Trapp, S. 2007; Trapp, S. et al. 2003) evaluating more polar chemicals such as MTBE, TCE, benzene, toluene and naphthalene as well as lipophilic compounds such as PAHs and dioxins in fruit trees. The comparison of the Briggs and Travis and Arms models with the Trapp models and measured data indicated the following:

- For polar compounds, there is good agreement between the Travis and Arms model and the Trapp model for the evaluation of concentration in aboveground produce.
- For polar compounds, there is good agreement between the Briggs model and the Trapp model for the evaluation of concentration in root crops.
- Unfortunately, there are no data available for polar chemicals in studies on plant uptake below or above ground for further comparison.
- For more lipophilic compounds (such as PAHs and dioxins with log Kow > 5) the Travis and Arms model tends to overestimate potential uptake into aboveground products based on comparison with the Trapp model and data from plant uptake studies. These studies and the Trapp model indicate that for these chemicals uptake into below ground produce is more important and the translocation into aboveground produce can be neglected. This finding is consistent with the assessment approach presented below for the determination of the importance of translocation within the plant.

Uptake into Roots

The concentration of organic chemicals in below ground vegetation is only required for vegetables such as carrots and potatoes which have edible roots, tubers etc. The basis for the equation used to calculate the concentration of contaminants in below ground vegetables is the experiments of Briggs (Briggs et al. 1982) on the uptake of chemicals into barley roots from growth solution, and the elaboration of a Root Concentration Factor (RCF). The concentration in below ground vegetables is given by:

$$C_{bgv} = C_w \bullet RCF \bullet VG_{bg}$$

where:

C_{bgv}	= fresh weight chemical concentration in below ground vegetables (mg/kg);
C_w	= chemical concentration in soil solution (mg/l);
RCF^*	= Root Concentration Factor: the ratio of the chemical concentration in roots (fresh weight basis) and the concentration in solution or water ((mg/kg)/(mg/l));
VG_{bg}	= empirical correction factor for below ground vegetation which accounts for difference in the barley roots (for which the RCF was derived) and bulky below ground vegetables (unitless).

Calculation of Root Uptake Factor

Briggs (Briggs et al. 1982) conducted experiments measuring the uptake of several compounds into barley roots from growth solution, and developed the following relationship for the lipophilic[2] compounds tested:

$$RCF = 10^{0.778 \log K_{ow} - 1.52} + 0.82$$

where:

RCF	= Root Concentration Factor: the ratio of the contaminant concentration in roots (fresh weight basis) and the concentration in water or solution ((mg/kg)/(mg/l));
K_{ow}	= contaminant octanol-water partition coefficient (unitless).

The above equation was based on experimental results and is generally only valid for lipophilic chemicals with molecular weights of less than 400. The uptake of chemicals with higher molecular weights tends to be dominated by different forces and no longer fit the above relationship. The equation is therefore relevant to the assessment for the key chemicals evaluated at Orica.

The equation for RCF provides a wet weight concentration in the plant root, however the equation was established for barley roots which have a different architecture to typical root vegetables, such that spatial distribution of the chemical may be important.

A correction factor VG_{bg} which relates the barley crops to the proportions of root vegetables of 0.01 for lipophilic compounds has been derived and used in the evaluation of dioxins (USEPA 1993, 2000b). While the value is typically universally applied to all chemicals, the greater potential for translocation of polar compounds (such as chlorinated hydrocarbons) within a plant compared to highly lipophilic compounds (dioxins and PAHs) suggests that the correction factor may not be relevant for the polar compounds. To provide a conservative evaluation of CHCs, VG_{bg} has been set to a value of 1.

Uptake by Above-Ground Crops

The uptake of organic chemicals into aboveground crops can arise through translocation through the plant from roots to shoots and absorption of vapours. Review of the potential uptake processes indicates that uptake from vapours is relatively insignificant in comparison to models for the uptake

[2] Lipophilic compounds are identified as those tested that have log K_{ow} of 2.0 or higher.

of organics into aboveground crops, particularly for chemicals which have a potential for translocation throughout the plant.

A number of studies on the plant uptake of herbicides indicate that translocation with plants is very difficult to predict and measure. Some studies (USEPA 1992) have indicated that although there may be a potential for translocation within a plant, most of the chemical concentration (i.e. 80% to 98% of the total concentration in the plant) was found to be in the root surface which can be removed by peeling rather than in the internal bulky portion of the roots and root cells. There have been even fewer studies undertaken on the effects of translocation of volatile chemicals within plants.

It should be noted that the concentration in below ground vegetables which contain oil cells such as carrots, parsnips and cress have been observed to differ from the relationships indicated in this section (USEPA 1992). The few studies that have been undertaken indicate that these plants will uptake chemicals from solution more readily, however most of the chemical (50% to 80%) tends to be located in the outer part of the root and hence easily removed when the vegetable is peeled prior to consumption.

The relative potential for the translocation of a chemical within a plant is described by the Transpiration Stream Concentration Factor (TSCF) which is related to the log K_{ow} (the octanol-water partition coefficient) of the chemical (Briggs et al. 1982). The TSCF for a chemical can be estimated as follows:

$$TSCF = 0.784 \bullet \exp\left(-\frac{(\log K_{ow} - 1.78)^2}{2.44}\right)$$

where:

TSCF = Transpiration Stream Concentration Factor. This is the ratio of the concentration of chemical in the transpiration stream of the plant (mg/l) to the concentration of the chemical in the external solution (mg/l).

K_{ow} = octanol water partition coefficient (unitless)

The TSCF relates the potential concentration of a contaminant in the transpiration stream water of a plant (i.e. the water within a plant which transports nutrients and other chemicals throughout the different part of the plant from the roots) to the concentration of the contaminant in the soil water. Translocation within the plant is considered to be of significance if the calculated TSCF is greater than 0.1. Application of this methodology correlates well with the model and plant uptake model presented by Trapp (Trapp, S. et al. 2003) which confirms that translocation of CHCs is important.

Calculation of Uptake Factor

The equation is used for calculating the concentration of chemicals in above ground vegetables (shown below) is based on empirical models (Travis & Arms 1988). The outcome these studies was a plant uptake factor B_v which can be calculated using the following equation associated with potential uptake from soils:

$$B_v = 10^{1.588 - 0.578 \bullet \log Kow} \bullet (1 - MC)$$

Where:

B_v	= uptake factor for above-ground crops (mg/kg fresh produce per mg/kg soil)
MC	= moisture content of fruit and vegetables, taken to be 0.85 or 85%
log K_{ow}	= chemical-specific log octanol/water partitioning coefficient (l/kg)

Appendix F UPDATED Risk Calculations – PBDEs

Home Grown Produce Ingestion

Cropping and Grazing Land Scenarios (where relevant)

(Mean Case is shown in highlighted cells on each spreadsheet)

Updated Exposure Assessment Parameters

Cattle exposed 6 months

Lower Bioaccessibility

Intake of Chemicals by Cattle (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 6 months per year)

$$Daily\ intake_{dairy\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{milk} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Milk to intake ratio =	0.01	0.0006	mg/kg (milk) / mg/d

Cattle

Exposure Parameters	Average	Reference	
Cattle water ingestion rate (L/day)	70	ANZECC & ARMCANZ (2000)	values changed
Cattle fodder ingestion rate (kg ww/day)	20	ANZECC & ARMCANZ (2000)	
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)	
CF (dw to ww)	0.15	Assumption 15% dry matter	
Fraction of produce from site in diet (FI)	100%	Maximum possible	
Exposure Frequency (EF, days/year)	183	6 months of year on treated areas	
Exposure Duration (ED, years)	4	Professional Advice	
Bioaccessibility (B) PBDEs (Br1to9)	12%	See **Section 3.4.1**	
Bioaccessibility (B) DecaBDE	4%	See **Section 3.4.1**	
Averaging Time - Threshold (Atn, days)	1460	ED*365	

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	5.4E-04	5.4E-06
Sum Br1 to Br9 (max)	710.000	NR	1.3E+01	1.3E-01
Sum Br1 to Br9 (mean)	15.0000	NR	2.7E-01	2.7E-03
Sum Br1 to Br9 (95th percentile)	20.0000	NR	3.6E-01	3.6E-03
Sum Br1 to Br9 (median)	0.5000	NR	9.0E-03	9.0E-05
Deca BDE (min)	0.0500	NR	9.0E-04	5.4E-07
Deca BDE (max)	13.0000	NR	2.3E-01	1.4E-04
Deca BDE (mean)	2.0000	NR	3.6E-02	2.2E-05
Deca BDE (95th percentile)	9.0000	NR	1.6E-01	9.7E-05
Deca BDE (median)	1.0000	NR	1.8E-02	1.1E-05
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	9.0E-04	9.0E-06
Sum Br1 to Br9 (max)	710.000	NR	2.1E+01	2.1E-01
Sum Br1 to Br9 (mean)	15.000	NR	4.5E-01	4.5E-03
Sum Br1 to Br9 (95th percentile)	20.000	NR	6.0E-01	6.0E-03
Sum Br1 to Br9 (median)	0.500	NR	1.5E-02	1.5E-04
Deca BDE (min)	0.050	NR	1.5E-03	9.0E-07
Deca BDE (max)	13.000	NR	3.9E-01	2.3E-04
Deca BDE (mean)	2.000	NR	6.0E-02	3.6E-05
Deca BDE (95th percentile)	9.000	NR	2.7E-01	1.6E-04
Deca BDE (median)	1.000	NR	3.0E-02	1.8E-05
Combined				
Sum Br1 to Br9 (min)	0.030	NR	1.4E-03	1.4E-05
Sum Br1 to Br9 (max)	710.000	NR	3.4E+01	3.4E-01
Sum Br1 to Br9 (mean)	15.000	NR	7.2E-01	7.2E-03
Sum Br1 to Br9 (95th percentile)	20.000	NR	9.6E-01	9.6E-03
Sum Br1 to Br9 (median)	0.500	NR	2.4E-02	2.4E-04
Deca BDE (min)	0.050	NR	2.4E-03	1.4E-06
Deca BDE (max)	13.000	NR	6.3E-01	3.8E-04
Deca BDE (mean)	2.000	NR	9.6E-02	5.8E-05
Deca BDE (95th percentile)	9.000	NR	4.3E-01	2.6E-04
Deca BDE (median)	1.000	NR	4.8E-02	2.9E-05

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	2.1E-05	2.1E-07
Sum Br1 to Br9 (max)	27.308	NR	4.9E-01	4.9E-03
Sum Br1 to Br9 (mean)	0.577	NR	1.0E-02	1.0E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	1.4E-02	1.4E-04
Sum Br1 to Br9 (median)	0.019	NR	3.5E-04	3.5E-06
Deca BDE (min)	0.002	NR	3.5E-05	2.1E-08
Deca BDE (max)	0.500	NR	9.0E-03	5.4E-06
Deca BDE (mean)	0.077	NR	1.4E-03	8.3E-07
Deca BDE (95th percentile)	0.346	NR	6.2E-03	3.7E-06
Deca BDE (median)	0.038	NR	6.9E-04	4.2E-07
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	3.5E-05	3.5E-07
Sum Br1 to Br9 (max)	27.308	NR	8.2E-01	8.2E-03
Sum Br1 to Br9 (mean)	0.577	NR	1.7E-02	1.7E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	2.3E-02	2.3E-04
Sum Br1 to Br9 (median)	0.019	NR	5.8E-04	5.8E-06
Deca BDE (min)	0.002	NR	5.8E-05	3.5E-08
Deca BDE (max)	0.500	NR	1.5E-02	9.0E-06
Deca BDE (mean)	0.077	NR	2.3E-03	1.4E-06
Deca BDE (95th percentile)	0.346	NR	1.0E-02	6.2E-06
Deca BDE (median)	0.038	NR	1.2E-03	6.9E-07
Combined				
Sum Br1 to Br9 (min)	0.001	NR	5.6E-05	5.6E-07
Sum Br1 to Br9 (max)	27.308	NR	1.3E+00	1.3E-02
Sum Br1 to Br9 (mean)	0.577	NR	2.8E-02	2.8E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	3.7E-02	3.7E-04
Sum Br1 to Br9 (median)	0.019	NR	9.3E-04	9.3E-06
Deca BDE (min)	0.002	NR	9.3E-05	5.6E-08
Deca BDE (max)	0.500	NR	2.4E-02	1.4E-05
Deca BDE (mean)	0.077	NR	3.7E-03	2.2E-06
Deca BDE (95th percentile)	0.346	NR	1.7E-02	1.0E-05
Deca BDE (median)	0.038	NR	1.9E-03	1.1E-06

Exposure to Chemicals via Ingestion of Milk - Children

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.097	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	1.4E-05		1.1E-06	--	0.053
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	3.4E-01		2.5E-02	--	1250
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	7.2E-03		5.3E-04	--	26
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	9.6E-03		7.0E-04	--	35.2
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	2.4E-04		1.8E-05	--	0.88000
Deca BDE (min)		0.007	80%	0.0014	0.05	1.4E-06		1.1E-07	--	0.00008
Deca BDE (max)		0.007	80%	0.0014	13	3.8E-04		2.7E-05	--	0.01961
Deca BDE (mean)		0.007	80%	0.0014	2	5.8E-05		4.2E-06	--	0.00302
Deca BDE (95th percentile)		0.007	80%	0.0014	9	2.6E-04		1.9E-05	--	0.01358
Deca BDE (median)		0.007	80%	0.0014	1	2.9E-05		2.1E-06	--	0.00151

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0012	5.6E-07		4.1E-08	--	0.00203
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.3077	1.3E-02		9.6E-04	--	48
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.5769	2.8E-04		2.0E-05	--	1.02
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.7692	3.7E-04		2.7E-05	--	1.35
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0192	9.3E-06		6.8E-07	--	0.03384632
Deca BDE (min)		0.007	80%	0.0014	0.0019	5.6E-08		4.1E-09	--	0.00000290
Deca BDE (max)		0.007	80%	0.0014	0.5000	1.4E-05		1.1E-06	--	0.00075429
Deca BDE (mean)		0.007	80%	0.0014	0.0769	2.2E-06		1.6E-07	--	0.00011604
Deca BDE (95th percentile)		0.007	80%	0.0014	0.3462	1.0E-05		7.3E-07	--	0.00052220
Deca BDE (median)		0.007	80%	0.0014	0.0385	1.1E-06		8.1E-08	--	0.00005802

Exposure to Chemicals via Ingestion of Milk - Adults

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.295	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	1.4E-05		2.7E-07	--	0.0134
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	3.4E-01		6.3E-03	--	316.1037
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	7.2E-03		1.3E-04	--	6.6782
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	9.6E-03		1.8E-04	--	8.9043
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	2.4E-04		4.5E-06	--	0.2226
Deca BDE (min)		0.007	80%	0.0014	0.05	1.4E-06		2.7E-08	--	0.0000191
Deca BDE (max)		0.007	80%	0.0014	13	3.8E-04		6.9E-06	--	0.0050
Deca BDE (mean)		0.007	80%	0.0014	2	5.8E-05		1.1E-06	--	0.000763
Deca BDE (95th percentile)		0.007	80%	0.0014	9	2.6E-04		4.8E-06	--	0.003435
Deca BDE (median)		0.007	80%	0.0014	1	2.9E-05		5.3E-07	--	0.000382

Grazing - Overall Dataset - Trampled In

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	5.6E-07		1.0E-08	--	0.00051
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	1.3E-02		2.4E-04	--	12.15783
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	2.8E-04		5.1E-06	--	0.25686
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	3.7E-04		6.8E-06	--	0.34247
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	9.3E-06		1.7E-07	--	0.00856
Deca BDE (min)		0.007	80%	0.0014	0.002	5.6E-08		1.0E-09	--	0.00000073
Deca BDE (max)		0.007	80%	0.0014	0.500	1.4E-05		2.7E-07	--	0.0001908
Deca BDE (mean)		0.007	80%	0.0014	0.077	2.2E-06		4.1E-08	--	0.0000294
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	1.0E-05		1.8E-07	--	0.0001321
Deca BDE (median)		0.007	80%	0.0014	0.038	1.1E-06		2.1E-08	--	0.0000147

Intake of Chemicals by Beef Cattle (stock watering, fodder watering, fodder soil, soil ingestio

(Updated Parameter Values with Cattle Present in Paddocks for 6 months per year)

$$Daily\ intake_{beef\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Meat to intake ratio =	0.53	0.02	mg/kg (meat) / mg/d

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	100%	Maximum possible
Exposure Frequency (EF, days/year)	183	Maximum possible
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B) PBDEs (Br1to9)	12%	See **Section 3.4.1**
Bioaccessibility (B) DecaBDE	4%	See **Section 3.4.1**
Averaging Time - Threshold (Atn, days)	730	ED*365

values changed

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	5.4E-04	2.9E-04
Sum Br1 to Br9 (max)	710.000	NR	1.3E+01	6.8E+00
Sum Br1 to Br9 (mean)	15.0000	NR	2.7E-01	1.4E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	3.6E-01	1.9E-01
Sum Br1 to Br9 (median)	0.5000	NR	9.0E-03	4.8E-03
Deca BDE (min)	0.0500	NR	3.0E-05	6.0E-07
Deca BDE (max)	13.0000	NR	7.8E-03	1.6E-04
Deca BDE (mean)	2.0000	NR	1.2E-03	2.4E-05
Deca BDE (95th percentile)	9.0000	NR	5.4E-03	1.1E-04
Deca BDE (median)	1.0000	NR	6.0E-04	1.2E-05
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	9.0E-04	4.8E-04
Sum Br1 to Br9 (max)	710.000	NR	2.1E+01	1.1E+01
Sum Br1 to Br9 (mean)	15.000	NR	4.5E-01	2.4E-01
Sum Br1 to Br9 (95th percentile)	20.000	NR	6.0E-01	3.2E-01
Sum Br1 to Br9 (median)	0.500	NR	1.5E-02	8.0E-03
Deca BDE (min)	0.050	NR	1.5E-03	3.0E-05
Deca BDE (max)	13.000	NR	3.9E-01	7.8E-03
Deca BDE (mean)	2.000	NR	6.0E-02	1.2E-03
Deca BDE (95th percentile)	9.000	NR	2.7E-01	5.4E-03
Deca BDE (median)	1.000	NR	3.0E-02	6.0E-04
Combined				
Sum Br1 to Br9 (min)	0.0300	NR	1.4E-03	7.7E-04
Sum Br1 to Br9 (max)	710.0000	NR	3.4E+01	1.8E+01
Sum Br1 to Br9 (mean)	15.0000	NR	7.2E-01	3.8E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	9.6E-01	5.1E-01
Sum Br1 to Br9 (median)	0.5000	NR	2.4E-02	1.3E-02
Deca BDE (min)	0.0500	NR	1.5E-03	3.1E-05
Deca BDE (max)	13.0000	NR	4.0E-01	8.0E-03
Deca BDE (mean)	2.0000	NR	6.1E-02	1.2E-03
Deca BDE (95th percentile)	9.0000	NR	2.8E-01	5.5E-03
Deca BDE (median)	1.0000	NR	3.1E-02	6.1E-04

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	2.1E-05	1.1E-05
Sum Br1 to Br9 (max)	27.308	NR	4.9E-01	2.6E-01
Sum Br1 to Br9 (mean)	0.577	NR	1.0E-02	5.5E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	1.4E-02	7.4E-03
Sum Br1 to Br9 (median)	0.019	NR	3.5E-04	1.8E-04
Deca BDE (min)	0.002	NR	1.2E-06	2.3E-08
Deca BDE (max)	0.500	NR	3.0E-04	6.0E-06
Deca BDE (mean)	0.077	NR	4.6E-05	9.3E-07
Deca BDE (95th percentile)	0.346	NR	2.1E-04	4.2E-06
Deca BDE (median)	0.038	NR	2.3E-05	4.6E-07
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	3.5E-05	1.8E-05
Sum Br1 to Br9 (max)	27.308	NR	8.2E-01	4.4E-01
Sum Br1 to Br9 (mean)	0.577	NR	1.7E-02	9.2E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	2.3E-02	1.2E-02
Sum Br1 to Br9 (median)	0.019	NR	5.8E-04	3.1E-04
Deca BDE (min)	0.002	NR	5.8E-05	1.2E-06
Deca BDE (max)	0.500	NR	1.5E-02	3.0E-04
Deca BDE (mean)	0.077	NR	2.3E-03	4.6E-05
Deca BDE (95th percentile)	0.346	NR	1.0E-02	2.1E-04
Deca BDE (median)	0.038	NR	1.2E-03	2.3E-05
Combined				
Sum Br1 to Br9 (min)	0.001	NR	5.6E-05	2.9E-05
Sum Br1 to Br9 (max)	27.308	NR	1.3E+00	7.0E-01
Sum Br1 to Br9 (mean)	0.577	NR	2.8E-02	1.5E-02
Sum Br1 to Br9 (95th percentile)	0.769	NR	3.7E-02	2.0E-02
Sum Br1 to Br9 (median)	0.019	NR	9.3E-04	4.9E-04
Deca BDE (min)	0.002	NR	5.9E-05	1.2E-06
Deca BDE (max)	0.500	NR	1.5E-02	3.1E-04
Deca BDE (mean)	0.077	NR	2.4E-03	4.7E-05
Deca BDE (95th percentile)	0.346	NR	1.1E-02	2.1E-04
Deca BDE (median)	0.038	NR	1.2E-03	2.4E-05

Exposure to Chemicals via Ingestion of Meat - Children

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.085	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	7.7E-04		1.5E-06	--	0.0759
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	1.8E+01		3.6E-02	--	1796.0954
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	3.8E-01		7.6E-04	--	37.9457
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	5.1E-01		1.0E-03	--	50.5942
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	1.3E-02		2.5E-05	--	1.2649
Deca BDE (min)		0.007	80%	0.0014	0.05	3.1E-05		6.1E-08	--	0.0000
Deca BDE (max)		0.007	80%	0.0014	13	8.0E-03		1.6E-05	--	0.0113
Deca BDE (mean)		0.007	80%	0.0014	2	1.2E-03		2.4E-06	--	0.0017
Deca BDE (95th percentile)		0.007	80%	0.0014	9	5.5E-03		1.1E-05	--	0.0078
Deca BDE (median)		0.007	80%	0.0014	1	6.1E-04		1.2E-06	--	0.0009

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	2.9E-05		5.8E-08	--	0.0029
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	7.0E-01		1.4E-03	--	69.0806
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	1.5E-02		2.9E-05	--	1.4594
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	2.0E-02		3.9E-05	--	1.9459
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	4.9E-04		9.7E-07	--	0.0486
Deca BDE (min)		0.007	80%	0.0014	0.002	1.2E-06		2.3E-09	--	0.00000167
Deca BDE (max)		0.007	80%	0.0014	0.500	3.1E-04		6.1E-07	--	0.000435
Deca BDE (mean)		0.007	80%	0.0014	0.077	4.7E-05		9.4E-08	--	0.0000669
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	2.1E-04		4.2E-07	--	0.0003009
Deca BDE (median)		0.007	80%	0.0014	0.038	2.4E-05		4.7E-08	--	0.0000334

Exposure to Chemicals via Ingestion of Meat - Adults

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.163	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	7.65E-04		6.2E-07	--	0.03119
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	1.81E+01		1.5E-02	--	738.05936
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	3.83E-01		3.1E-04	--	15.59280
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	5.10E-01		4.2E-04	--	20.79040
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	1.28E-02		1.0E-05	--	0.51976
Deca BDE (min)		0.007	80%	0.0014	0.05	3.07E-05		2.5E-08	--	0.0000179
Deca BDE (max)		0.007	80%	0.0014	13	7.98E-03		6.5E-06	--	0.00464
Deca BDE (mean)		0.007	80%	0.0014	2	1.23E-03		1.0E-06	--	0.00071
Deca BDE (95th percentile)		0.007	80%	0.0014	9	5.52E-03		4.5E-06	--	0.00322
Deca BDE (median)		0.007	80%	0.0014	1	6.14E-04		5.0E-07	--	0.000357

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	2.9E-05		2.4E-08	--	0.00120
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	7.0E-01		5.7E-04	--	28.38690
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	1.5E-02		1.2E-05	--	0.59972
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	2.0E-02		1.6E-05	--	0.79963
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	4.9E-04		4.0E-07	--	0.01999
Deca BDE (min)		0.007	80%	0.0014	0.002	1.2E-06		9.6E-10	--	0.00000069
Deca BDE (max)		0.007	80%	0.0014	0.500	3.1E-04		2.5E-07	--	0.0001786
Deca BDE (mean)		0.007	80%	0.0014	0.077	4.7E-05		3.8E-08	--	0.0000275
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	2.1E-04		1.7E-07	--	0.0001237
Deca BDE (median)		0.007	80%	0.0014	0.038	2.4E-05		1.9E-08	--	0.0000137

Updated Exposure Assessment Parameters

Cattle exposed 6 months

Upper Bioaccessibility

Intake of Chemicals by Cattle (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 6 months per year)

$$Daily\ intake_{dairy\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT}$$ (mg/day)

$$C_{milk} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Milk to intake ratio =	0.01	0.0006	mg/kg (milk) / mg/d

Cattle

Exposure Parameters	Average	Reference	
Cattle water ingestion rate (L/day)	70	ANZECC & ARMCANZ (2000)	values changed
Cattle fodder ingestion rate (kg ww/day)	20	ANZECC & ARMCANZ (2000)	
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)	
CF (dw to ww)	0.15	Assumption 15% dry matter	
Fraction of produce from site in diet (FI)	100%	Maximum possible	
Exposure Frequency (EF, days/year)	183	6 months of year on treated areas	
Exposure Duration (ED, years)	4	Professional Advice	
Bioaccessibility (B) PBDEs (Br1to9)	30%	See **Section 3.4.1**	
Bioaccessibility (B) DecaBDE	15%	See **Section 3.4.1**	
Averaging Time - Threshold (Atn, days)	1460	ED*365	

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	1.4E-03	1.4E-05
Sum Br1 to Br9 (max)	710.000	NR	3.2E+01	3.2E-01
Sum Br1 to Br9 (mean)	15.0000	NR	6.8E-01	6.8E-03
Sum Br1 to Br9 (95th percentile)	20.0000	NR	9.0E-01	9.0E-03
Sum Br1 to Br9 (median)	0.5000	NR	2.3E-02	2.3E-04
Deca BDE (min)	0.0500	NR	2.3E-03	1.4E-06
Deca BDE (max)	13.0000	NR	5.9E-01	3.5E-04
Deca BDE (mean)	2.0000	NR	9.0E-02	5.4E-05
Deca BDE (95th percentile)	9.0000	NR	4.1E-01	2.4E-04
Deca BDE (median)	1.0000	NR	4.5E-02	2.7E-05
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	2.3E-03	2.3E-05
Sum Br1 to Br9 (max)	710.000	NR	5.3E+01	5.3E-01
Sum Br1 to Br9 (mean)	15.000	NR	1.1E+00	1.1E-02
Sum Br1 to Br9 (95th percentile)	20.000	NR	1.5E+00	1.5E-02
Sum Br1 to Br9 (median)	0.500	NR	3.8E-02	3.8E-04
Deca BDE (min)	0.050	NR	3.8E-03	2.3E-06
Deca BDE (max)	13.000	NR	9.8E-01	5.9E-04
Deca BDE (mean)	2.000	NR	1.5E-01	9.0E-05
Deca BDE (95th percentile)	9.000	NR	6.8E-01	4.1E-04
Deca BDE (median)	1.000	NR	7.5E-02	4.5E-05
Combined				
Sum Br1 to Br9 (min)	0.030	NR	3.6E-03	3.6E-05
Sum Br1 to Br9 (max)	710.000	NR	8.5E+01	8.5E-01
Sum Br1 to Br9 (mean)	15.000	NR	1.8E+00	1.8E-02
Sum Br1 to Br9 (95th percentile)	20.000	NR	2.4E+00	2.4E-02
Sum Br1 to Br9 (median)	0.500	NR	6.0E-02	6.0E-04
Deca BDE (min)	0.050	NR	6.0E-03	3.6E-06
Deca BDE (max)	13.000	NR	1.6E+00	9.4E-04
Deca BDE (mean)	2.000	NR	2.4E-01	1.4E-04
Deca BDE (95th percentile)	9.000	NR	1.1E+00	6.5E-04
Deca BDE (median)	1.000	NR	1.2E-01	7.2E-05

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	5.2E-05	5.2E-07
Sum Br1 to Br9 (max)	27.308	NR	1.2E+00	1.2E-02
Sum Br1 to Br9 (mean)	0.577	NR	2.6E-02	2.6E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	3.5E-02	3.5E-04
Sum Br1 to Br9 (median)	0.019	NR	8.7E-04	8.7E-06
Deca BDE (min)	0.002	NR	8.7E-05	5.2E-08
Deca BDE (max)	0.500	NR	2.3E-02	1.4E-05
Deca BDE (mean)	0.077	NR	3.5E-03	2.1E-06
Deca BDE (95th percentile)	0.346	NR	1.6E-02	9.4E-06
Deca BDE (median)	0.038	NR	1.7E-03	1.0E-06
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	8.7E-05	8.7E-07
Sum Br1 to Br9 (max)	27.308	NR	2.1E+00	2.1E-02
Sum Br1 to Br9 (mean)	0.577	NR	4.3E-02	4.3E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	5.8E-02	5.8E-04
Sum Br1 to Br9 (median)	0.019	NR	1.4E-03	1.4E-05
Deca BDE (min)	0.002	NR	1.4E-04	8.7E-08
Deca BDE (max)	0.500	NR	3.8E-02	2.3E-05
Deca BDE (mean)	0.077	NR	5.8E-03	3.5E-06
Deca BDE (95th percentile)	0.346	NR	2.6E-02	1.6E-05
Deca BDE (median)	0.038	NR	2.9E-03	1.7E-06
Combined				
Sum Br1 to Br9 (min)	0.001	NR	1.4E-04	1.4E-06
Sum Br1 to Br9 (max)	27.308	NR	3.3E+00	3.3E-02
Sum Br1 to Br9 (mean)	0.577	NR	6.9E-02	6.9E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	9.3E-02	9.3E-04
Sum Br1 to Br9 (median)	0.019	NR	2.3E-03	2.3E-05
Deca BDE (min)	0.002	NR	2.3E-04	1.4E-07
Deca BDE (max)	0.500	NR	6.0E-02	3.6E-05
Deca BDE (mean)	0.077	NR	9.3E-03	5.6E-06
Deca BDE (95th percentile)	0.346	NR	4.2E-02	2.5E-05
Deca BDE (median)	0.038	NR	4.6E-03	2.8E-06

Exposure to Chemicals via Ingestion of Milk - Children

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.097	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	3.6E-05		2.6E-06	--	0.132
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	8.5E-01		6.2E-02	--	3124
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	1.8E-02		1.3E-03	--	66
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	2.4E-02		1.8E-03	--	88.0
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	6.0E-04		4.4E-05	--	2.20001
Deca BDE (min)		0.007	80%	0.0014	0.05	3.6E-06		2.6E-07	--	0.00019
Deca BDE (max)		0.007	80%	0.0014	13	9.4E-04		6.9E-05	--	0.04903
Deca BDE (mean)		0.007	80%	0.0014	2	1.4E-04		1.1E-05	--	0.00754
Deca BDE (95th percentile)		0.007	80%	0.0014	9	6.5E-04		4.8E-05	--	0.03394
Deca BDE (median)		0.007	80%	0.0014	1	7.2E-05		5.3E-06	--	0.00377

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0012	1.4E-06		1.0E-07	--	0.00508
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.3077	3.3E-02		2.4E-03	--	120
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.5769	6.9E-04		5.1E-05	--	2.54
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.7692	9.3E-04		6.8E-05	--	3.38
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0192	2.3E-05		1.7E-06	--	0.08461581
Deca BDE (min)		0.007	80%	0.0014	0.0019	1.4E-07		1.0E-08	--	0.00000725
Deca BDE (max)		0.007	80%	0.0014	0.5000	3.6E-05		2.6E-06	--	0.00188572
Deca BDE (mean)		0.007	80%	0.0014	0.0769	5.6E-06		4.1E-07	--	0.00029011
Deca BDE (95th percentile)		0.007	80%	0.0014	0.3462	2.5E-05		1.8E-06	--	0.00130550
Deca BDE (median)		0.007	80%	0.0014	0.0385	2.8E-06		2.0E-07	--	0.00014506

Exposure to Chemicals via Ingestion of Milk - Adults

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.295	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	3.6E-05		6.7E-07	--	0.0334
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	8.5E-01		1.6E-02	--	790.2592
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	1.8E-02		3.3E-04	--	16.6956
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	2.4E-02		4.5E-04	--	22.2608
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	6.0E-04		1.1E-05	--	0.5565
Deca BDE (min)		0.007	80%	0.0014	0.05	3.6E-06		6.7E-08	--	0.0000477
Deca BDE (max)		0.007	80%	0.0014	13	9.4E-04		1.7E-05	--	0.0124
Deca BDE (mean)		0.007	80%	0.0014	2	1.4E-04		2.7E-06	--	0.001908
Deca BDE (95th percentile)		0.007	80%	0.0014	9	6.5E-04		1.2E-05	--	0.008586
Deca BDE (median)		0.007	80%	0.0014	1	7.2E-05		1.3E-06	--	0.000954

Grazing - Overall Dataset - Trampled In

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	1.4E-06		2.6E-08	--	0.00128
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	3.3E-02		6.1E-04	--	30.39458
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	6.9E-04		1.3E-05	--	0.64214
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	9.3E-04		1.7E-05	--	0.85619
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	2.3E-05		4.3E-07	--	0.02140
Deca BDE (min)		0.007	80%	0.0014	0.002	1.4E-07		2.6E-09	--	0.00000183
Deca BDE (max)		0.007	80%	0.0014	0.500	3.6E-05		6.7E-07	--	0.0004770
Deca BDE (mean)		0.007	80%	0.0014	0.077	5.6E-06		1.0E-07	--	0.0000734
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	2.5E-05		4.6E-07	--	0.0003302
Deca BDE (median)		0.007	80%	0.0014	0.038	2.8E-06		5.1E-08	--	0.0000367

Intake of Chemicals by Beef Cattle (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 6 months per year)

$$Daily\ intake_{beef\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Meat to intake ratio =	0.53	0.02	mg/kg (meat) / mg/d

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	100%	Maximum possible
Exposure Frequency (EF, days/year)	183	Maximum possible
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B) PBDEs (Br1to9)	30%	See **Section 3.4.1**
Bioaccessibility (B) DecaBDE	15%	See **Section 3.4.1**
Averaging Time - Threshold (Atn, days)	730	ED*365

values changed

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	1.4E-03	7.2E-04
Sum Br1 to Br9 (max)	710.000	NR	3.2E+01	1.7E+01
Sum Br1 to Br9 (mean)	15.0000	NR	6.8E-01	3.6E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	9.0E-01	4.8E-01
Sum Br1 to Br9 (median)	0.5000	NR	2.3E-02	1.2E-02
Deca BDE (min)	0.0500	NR	1.1E-04	2.3E-06
Deca BDE (max)	13.0000	NR	2.9E-02	5.9E-04
Deca BDE (mean)	2.0000	NR	4.5E-03	9.0E-05
Deca BDE (95th percentile)	9.0000	NR	2.0E-02	4.1E-04
Deca BDE (median)	1.0000	NR	2.3E-03	4.5E-05
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	2.3E-03	1.2E-03
Sum Br1 to Br9 (max)	710.000	NR	5.3E+01	2.8E+01
Sum Br1 to Br9 (mean)	15.000	NR	1.1E+00	6.0E-01
Sum Br1 to Br9 (95th percentile)	20.000	NR	1.5E+00	8.0E-01
Sum Br1 to Br9 (median)	0.500	NR	3.8E-02	2.0E-02
Deca BDE (min)	0.050	NR	3.8E-03	7.5E-05
Deca BDE (max)	13.000	NR	9.8E-01	2.0E-02
Deca BDE (mean)	2.000	NR	1.5E-01	3.0E-03
Deca BDE (95th percentile)	9.000	NR	6.8E-01	1.4E-02
Deca BDE (median)	1.000	NR	7.5E-02	1.5E-03
Combined				
Sum Br1 to Br9 (min)	0.0300	NR	3.6E-03	1.9E-03
Sum Br1 to Br9 (max)	710.0000	NR	8.5E+01	4.5E+01
Sum Br1 to Br9 (mean)	15.0000	NR	1.8E+00	9.6E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	2.4E+00	1.3E+00
Sum Br1 to Br9 (median)	0.5000	NR	6.0E-02	3.2E-02
Deca BDE (min)	0.0500	NR	3.9E-03	7.7E-05
Deca BDE (max)	13.0000	NR	1.0E+00	2.0E-02
Deca BDE (mean)	2.0000	NR	1.5E-01	3.1E-03
Deca BDE (95th percentile)	9.0000	NR	7.0E-01	1.4E-02
Deca BDE (median)	1.0000	NR	7.7E-02	1.5E-03

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	5.2E-05	2.8E-05
Sum Br1 to Br9 (max)	27.308	NR	1.2E+00	6.5E-01
Sum Br1 to Br9 (mean)	0.577	NR	2.6E-02	1.4E-02
Sum Br1 to Br9 (95th percentile)	0.769	NR	3.5E-02	1.8E-02
Sum Br1 to Br9 (median)	0.019	NR	8.7E-04	4.6E-04
Deca BDE (min)	0.002	NR	4.3E-06	8.7E-08
Deca BDE (max)	0.500	NR	1.1E-03	2.3E-05
Deca BDE (mean)	0.077	NR	1.7E-04	3.5E-06
Deca BDE (95th percentile)	0.346	NR	7.8E-04	1.6E-05
Deca BDE (median)	0.038	NR	8.7E-05	1.7E-06
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	8.7E-05	4.6E-05
Sum Br1 to Br9 (max)	27.308	NR	2.1E+00	1.1E+00
Sum Br1 to Br9 (mean)	0.577	NR	4.3E-02	2.3E-02
Sum Br1 to Br9 (95th percentile)	0.769	NR	5.8E-02	3.1E-02
Sum Br1 to Br9 (median)	0.019	NR	1.4E-03	7.7E-04
Deca BDE (min)	0.002	NR	1.4E-04	2.9E-06
Deca BDE (max)	0.500	NR	3.8E-02	7.5E-04
Deca BDE (mean)	0.077	NR	5.8E-03	1.2E-04
Deca BDE (95th percentile)	0.346	NR	2.6E-02	5.2E-04
Deca BDE (median)	0.038	NR	2.9E-03	5.8E-05
Combined				
Sum Br1 to Br9 (min)	0.001	NR	1.4E-04	7.4E-05
Sum Br1 to Br9 (max)	27.308	NR	3.3E+00	1.7E+00
Sum Br1 to Br9 (mean)	0.577	NR	6.9E-02	3.7E-02
Sum Br1 to Br9 (95th percentile)	0.769	NR	9.3E-02	4.9E-02
Sum Br1 to Br9 (median)	0.019	NR	2.3E-03	1.2E-03
Deca BDE (min)	0.002	NR	1.5E-04	3.0E-06
Deca BDE (max)	0.500	NR	3.9E-02	7.7E-04
Deca BDE (mean)	0.077	NR	6.0E-03	1.2E-04
Deca BDE (95th percentile)	0.346	NR	2.7E-02	5.4E-04
Deca BDE (median)	0.038	NR	3.0E-03	6.0E-05

Exposure to Chemicals via Ingestion of Meat - Children

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.085	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	1.9E-03		3.8E-06	--	0.1897
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	4.5E+01		9.0E-02	--	4490.2384
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	9.6E-01		1.9E-03	--	94.8642
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	1.3E+00		2.5E-03	--	126.4856
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	3.2E-02		6.3E-05	--	3.1621
Deca BDE (min)		0.007	80%	0.0014	0.05	7.7E-05		1.5E-07	--	0.0001
Deca BDE (max)		0.007	80%	0.0014	13	2.0E-02		4.0E-05	--	0.0285
Deca BDE (mean)		0.007	80%	0.0014	2	3.1E-03		6.1E-06	--	0.0044
Deca BDE (95th percentile)		0.007	80%	0.0014	9	1.4E-02		2.8E-05	--	0.0198
Deca BDE (median)		0.007	80%	0.0014	1	1.5E-03		3.1E-06	--	0.0022

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	7.4E-05		1.5E-07	--	0.0073
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	1.7E+00		3.5E-03	--	172.7015
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	3.7E-02		7.3E-05	--	3.6486
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	4.9E-02		9.7E-05	--	4.8648
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	1.2E-03		2.4E-06	--	0.1216
Deca BDE (min)		0.007	80%	0.0014	0.002	3.0E-06		5.9E-09	--	0.00000422
Deca BDE (max)		0.007	80%	0.0014	0.500	7.7E-04		1.5E-06	--	0.001097
Deca BDE (mean)		0.007	80%	0.0014	0.077	1.2E-04		2.4E-07	--	0.0001688
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	5.4E-04		1.1E-06	--	0.0007597
Deca BDE (median)		0.007	80%	0.0014	0.038	6.0E-05		1.2E-07	--	0.0000844

Exposure to Chemicals via Ingestion of Meat - Adults

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.163	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	1.91E-03		1.6E-06	--	0.07796
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	4.53E+01		3.7E-02	--	1845.14839
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	9.57E-01		7.8E-04	--	38.98201
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	1.28E+00		1.0E-03	--	51.97601
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	3.19E-02		2.6E-05	--	1.29940
Deca BDE (min)		0.007	80%	0.0014	0.05	7.75E-05		6.3E-08	--	0.0000451
Deca BDE (max)		0.007	80%	0.0014	13	2.01E-02		1.6E-05	--	0.01172
Deca BDE (mean)		0.007	80%	0.0014	2	3.10E-03		2.5E-06	--	0.00180
Deca BDE (95th percentile)		0.007	80%	0.0014	9	1.39E-02		1.1E-05	--	0.00812
Deca BDE (median)		0.007	80%	0.0014	1	1.55E-03		1.3E-06	--	0.000902

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	7.4E-05		6.0E-08	--	0.00300
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	1.7E+00		1.4E-03	--	70.96725
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	3.7E-02		3.0E-05	--	1.49931
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	4.9E-02		4.0E-05	--	1.99908
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	1.2E-03		1.0E-06	--	0.04998
Deca BDE (min)		0.007	80%	0.0014	0.002	3.0E-06		2.4E-09	--	0.00000173
Deca BDE (max)		0.007	80%	0.0014	0.500	7.7E-04		6.3E-07	--	0.0004509
Deca BDE (mean)		0.007	80%	0.0014	0.077	1.2E-04		9.7E-08	--	0.0000694
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	5.4E-04		4.4E-07	--	0.0003122
Deca BDE (median)		0.007	80%	0.0014	0.038	6.0E-05		4.9E-08	--	0.0000347

Updated Exposure Assessment Parameters

Cattle exposed 52 Days

Lower Bioaccessibility

Intake of Chemicals by Cows (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 52 days per year)

$$Daily\ intake_{dairy\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{milk} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Milk to intake ratio =	0.01	0.0006	mg/kg (milk) / mg/d

Cattle

Exposure Parameters	Average	Reference	
Cattle water ingestion rate (L/day)	70	ANZECC & ARMCANZ (2000)	values changed
Cattle fodder ingestion rate (kg ww/day)	20	ANZECC & ARMCANZ (2000)	
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)	
CF (dw to ww)	0.15	Assumption 15% dry matter	
Fraction of produce from site in diet (FI)	100%	Maximum possible	
Exposure Frequency (EF, days/year)	52	6 months of year on treated areas	
Exposure Duration (ED, years)	4	Professional Advice	
Bioaccessibility (B) PBDEs (Br1to9)	12%	See **Section 3.4.1**	
Bioaccessibility (B) DecaBDE	4%	See **Section 3.4.1**	
Averaging Time - Threshold (Atn, days)	1460	ED*365	

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	1.5E-04	1.5E-06
Sum Br1 to Br9 (max)	710.000	NR	3.6E+00	3.6E-02
Sum Br1 to Br9 (mean)	15.0000	NR	7.7E-02	7.7E-04
Sum Br1 to Br9 (95th percentile)	20.0000	NR	1.0E-01	1.0E-03
Sum Br1 to Br9 (median)	0.5000	NR	2.6E-03	2.6E-05
Deca BDE (min)	0.0500	NR	2.6E-05	1.5E-08
Deca BDE (max)	13.0000	NR	6.7E-03	4.0E-06
Deca BDE (mean)	2.0000	NR	1.0E-03	6.2E-07
Deca BDE (95th percentile)	9.0000	NR	4.6E-03	2.8E-06
Deca BDE (median)	1.0000	NR	5.1E-04	3.1E-07
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	2.6E-04	2.6E-06
Sum Br1 to Br9 (max)	710.000	NR	6.1E+00	6.1E-02
Sum Br1 to Br9 (mean)	15.000	NR	1.3E-01	1.3E-03
Sum Br1 to Br9 (95th percentile)	20.000	NR	1.7E-01	1.7E-03
Sum Br1 to Br9 (median)	0.500	NR	4.3E-03	4.3E-05
Deca BDE (min)	0.050	NR	4.3E-04	2.6E-07
Deca BDE (max)	13.000	NR	1.1E-01	6.7E-05
Deca BDE (mean)	2.000	NR	1.7E-02	1.0E-05
Deca BDE (95th percentile)	9.000	NR	7.7E-02	4.6E-05
Deca BDE (median)	1.000	NR	8.5E-03	5.1E-06
Combined				
Sum Br1 to Br9 (min)	0.030	NR	4.1E-04	4.1E-06
Sum Br1 to Br9 (max)	710.000	NR	9.7E+00	9.7E-02
Sum Br1 to Br9 (mean)	15.000	NR	2.1E-01	2.1E-03
Sum Br1 to Br9 (95th percentile)	20.000	NR	2.7E-01	2.7E-03
Sum Br1 to Br9 (median)	0.500	NR	6.8E-03	6.8E-05
Deca BDE (min)	0.050	NR	4.5E-04	2.7E-07
Deca BDE (max)	13.000	NR	1.2E-01	7.1E-05
Deca BDE (mean)	2.000	NR	1.8E-02	1.1E-05
Deca BDE (95th percentile)	9.000	NR	8.2E-02	4.9E-05
Deca BDE (median)	1.000	NR	9.1E-03	5.4E-06

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	5.9E-06	5.9E-08
Sum Br1 to Br9 (max)	27.308	NR	1.4E-01	1.4E-03
Sum Br1 to Br9 (mean)	0.577	NR	3.0E-03	3.0E-05
Sum Br1 to Br9 (95th percentile)	0.769	NR	3.9E-03	3.9E-05
Sum Br1 to Br9 (median)	0.019	NR	9.9E-05	9.9E-07
Deca BDE (min)	0.002	NR	9.9E-07	5.9E-10
Deca BDE (max)	0.500	NR	2.6E-04	1.5E-07
Deca BDE (mean)	0.077	NR	3.9E-05	2.4E-08
Deca BDE (95th percentile)	0.346	NR	1.8E-04	1.1E-07
Deca BDE (median)	0.038	NR	2.0E-05	1.2E-08
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	9.9E-06	9.9E-08
Sum Br1 to Br9 (max)	27.308	NR	2.3E-01	2.3E-03
Sum Br1 to Br9 (mean)	0.577	NR	4.9E-03	4.9E-05
Sum Br1 to Br9 (95th percentile)	0.769	NR	6.6E-03	6.6E-05
Sum Br1 to Br9 (median)	0.019	NR	1.6E-04	1.6E-06
Deca BDE (min)	0.002	NR	1.6E-05	9.9E-09
Deca BDE (max)	0.500	NR	4.3E-03	2.6E-06
Deca BDE (mean)	0.077	NR	6.6E-04	3.9E-07
Deca BDE (95th percentile)	0.346	NR	3.0E-03	1.8E-06
Deca BDE (median)	0.038	NR	3.3E-04	2.0E-07
Combined				
Sum Br1 to Br9 (min)	0.001	NR	1.6E-05	1.6E-07
Sum Br1 to Br9 (max)	27.308	NR	3.7E-01	3.7E-03
Sum Br1 to Br9 (mean)	0.577	NR	7.9E-03	7.9E-05
Sum Br1 to Br9 (95th percentile)	0.769	NR	1.1E-02	1.1E-04
Sum Br1 to Br9 (median)	0.019	NR	2.6E-04	2.6E-06
Deca BDE (min)	0.002	NR	1.7E-05	1.0E-08
Deca BDE (max)	0.500	NR	4.5E-03	2.7E-06
Deca BDE (mean)	0.077	NR	7.0E-04	4.2E-07
Deca BDE (95th percentile)	0.346	NR	3.1E-03	1.9E-06
Deca BDE (median)	0.038	NR	3.5E-04	2.1E-07

Exposure to Chemicals via Ingestion of Milk - Children

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.097	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	4.1E-06		3.0E-07	--	0.0150
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	9.7E-02		7.1E-03	--	355.08
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	2.1E-03		1.5E-04	--	7.50
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	2.7E-03		2.0E-04	--	10.0022
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	6.8E-05		5.0E-06	--	0.2501
Deca BDE (min)		0.007	80%	0.0014	0.05	2.7E-07		2.0E-08	--	0.0000142
Deca BDE (max)		0.007	80%	0.0014	13	7.1E-05		5.2E-06	--	0.003692
Deca BDE (mean)		0.007	80%	0.0014	2	1.1E-05		8.0E-07	--	0.000568
Deca BDE (95th percentile)		0.007	80%	0.0014	9	4.9E-05		3.6E-06	--	0.002556
Deca BDE (median)		0.007	80%	0.0014	1	5.4E-06		4.0E-07	--	0.000284

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	1.6E-07		1.2E-08	--	0.00058
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	3.7E-03		2.7E-04	--	13.66
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	7.9E-05		5.8E-06	--	0.2885
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	1.1E-04		7.7E-06	--	0.3847
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	2.6E-06		1.9E-07	--	0.00961753
Deca BDE (min)		0.007	80%	0.0014	0.002	1.0E-08		7.6E-10	--	0.00000055
Deca BDE (max)		0.007	80%	0.0014	0.500	2.7E-06		2.0E-07	--	0.00014200
Deca BDE (mean)		0.007	80%	0.0014	0.077	4.2E-07		3.1E-08	--	0.00002185
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	1.9E-06		1.4E-07	--	0.00009830
Deca BDE (median)		0.007	80%	0.0014	0.038	2.1E-07		1.5E-08	--	0.00001092

Exposure to Chemicals via Ingestion of Milk - Adults

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.295	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	4.1E-06		7.6E-08	--	0.0038
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	9.7E-02		1.8E-03	--	89.82
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	2.1E-03		3.8E-05	--	1.90
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	2.7E-03		5.1E-05	--	2.53
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	6.8E-05		1.3E-06	--	0.0632548
Deca BDE (min)		0.007	80%	0.0014	0.05	2.7E-07		5.0E-09	--	0.0000036
Deca BDE (max)		0.007	80%	0.0014	13	7.1E-05		1.3E-06	--	0.0009339
Deca BDE (mean)		0.007	80%	0.0014	2	1.1E-05		2.0E-07	--	0.0001437
Deca BDE (95th percentile)		0.007	80%	0.0014	9	4.9E-05		9.1E-07	--	0.0006466
Deca BDE (median)		0.007	80%	0.0014	1	5.4E-06		1.0E-07	--	0.0000718

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0012	1.6E-07		2.9E-09	--	0.000146
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.3077	3.7E-03		6.9E-05	--	3.45
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.5769	7.9E-05		1.5E-06	--	0.0730
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.7692	1.1E-04		1.9E-06	--	0.09731507
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0192	2.6E-06		4.9E-08	--	0.00243288
Deca BDE (min)		0.007	80%	0.0014	0.0019	1.0E-08		1.9E-10	--	0.00000014
Deca BDE (max)		0.007	80%	0.0014	0.5000	2.7E-06		5.0E-08	--	0.00003592
Deca BDE (mean)		0.007	80%	0.0014	0.0769	4.2E-07		7.7E-09	--	0.00000553
Deca BDE (95th percentile)		0.007	80%	0.0014	0.3462	1.9E-06		3.5E-08	--	0.00002487
Deca BDE (median)		0.007	80%	0.0014	0.0385	2.1E-07		3.9E-09	--	0.00000276

Intake of Chemicals by Beef Cattle (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 52 days per year)

$$Daily\ intake_{beef\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Meat to intake ratio =	0.53	0.02	mg/kg (meat) / mg/d

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	100%	Maximum possible
Exposure Frequency (EF, days/year)	52	Maximum possible
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B) PBDEs (Br1to9)	12%	See **Section 3.4.1**
Bioaccessibility (B) DecaBDE	4%	See **Section 3.4.1**
Averaging Time - Threshold (Atn, days)	730	ED*365

values changed

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	1.5E-04	8.2E-05
Sum Br1 to Br9 (max)	710.000	NR	3.6E+00	1.9E+00
Sum Br1 to Br9 (mean)	15.0000	NR	7.7E-02	4.1E-02
Sum Br1 to Br9 (95th percentile)	20.0000	NR	1.0E-01	5.4E-02
Sum Br1 to Br9 (median)	0.5000	NR	2.6E-03	1.4E-03
Deca BDE (min)	0.0500	NR	8.5E-06	1.7E-07
Deca BDE (max)	13.0000	NR	2.2E-03	4.4E-05
Deca BDE (mean)	2.0000	NR	3.4E-04	6.8E-06
Deca BDE (95th percentile)	9.0000	NR	1.5E-03	3.1E-05
Deca BDE (median)	1.0000	NR	1.7E-04	3.4E-06
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	2.6E-04	1.4E-04
Sum Br1 to Br9 (max)	710.000	NR	6.1E+00	3.2E+00
Sum Br1 to Br9 (mean)	15.000	NR	1.3E-01	6.8E-02
Sum Br1 to Br9 (95th percentile)	20.000	NR	1.7E-01	9.1E-02
Sum Br1 to Br9 (median)	0.500	NR	4.3E-03	2.3E-03
Deca BDE (min)	0.050	NR	4.3E-04	8.5E-06
Deca BDE (max)	13.000	NR	1.1E-01	2.2E-03
Deca BDE (mean)	2.000	NR	1.7E-02	3.4E-04
Deca BDE (95th percentile)	9.000	NR	7.7E-02	1.5E-03
Deca BDE (median)	1.000	NR	8.5E-03	1.7E-04
Combined				
Sum Br1 to Br9 (min)	0.0300	NR	4.1E-04	2.2E-04
Sum Br1 to Br9 (max)	710.0000	NR	9.7E+00	5.1E+00
Sum Br1 to Br9 (mean)	15.0000	NR	2.1E-01	1.1E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	2.7E-01	1.4E-01
Sum Br1 to Br9 (median)	0.5000	NR	6.8E-03	3.6E-03
Deca BDE (min)	0.0500	NR	4.4E-04	8.7E-06
Deca BDE (max)	13.0000	NR	1.1E-01	2.3E-03
Deca BDE (mean)	2.0000	NR	1.7E-02	3.5E-04
Deca BDE (95th percentile)	9.0000	NR	7.8E-02	1.6E-03
Deca BDE (median)	1.0000	NR	8.7E-03	1.7E-04

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	5.9E-06	3.1E-06
Sum Br1 to Br9 (max)	27.308	NR	1.4E-01	7.4E-02
Sum Br1 to Br9 (mean)	0.577	NR	3.0E-03	1.6E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	3.9E-03	2.1E-03
Sum Br1 to Br9 (median)	0.019	NR	9.9E-05	5.2E-05
Deca BDE (min)	0.002	NR	3.3E-07	6.6E-09
Deca BDE (max)	0.500	NR	8.5E-05	1.7E-06
Deca BDE (mean)	0.077	NR	1.3E-05	2.6E-07
Deca BDE (95th percentile)	0.346	NR	5.9E-05	1.2E-06
Deca BDE (median)	0.038	NR	6.6E-06	1.3E-07
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	9.9E-06	5.2E-06
Sum Br1 to Br9 (max)	27.308	NR	2.3E-01	1.2E-01
Sum Br1 to Br9 (mean)	0.577	NR	4.9E-03	2.6E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	6.6E-03	3.5E-03
Sum Br1 to Br9 (median)	0.019	NR	1.6E-04	8.7E-05
Deca BDE (min)	0.002	NR	1.6E-05	3.3E-07
Deca BDE (max)	0.500	NR	4.3E-03	8.5E-05
Deca BDE (mean)	0.077	NR	6.6E-04	1.3E-05
Deca BDE (95th percentile)	0.346	NR	3.0E-03	5.9E-05
Deca BDE (median)	0.038	NR	3.3E-04	6.6E-06
Combined				
Sum Br1 to Br9 (min)	0.001	NR	1.6E-05	8.4E-06
Sum Br1 to Br9 (max)	27.308	NR	3.7E-01	2.0E-01
Sum Br1 to Br9 (mean)	0.577	NR	7.9E-03	4.2E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	1.1E-02	5.6E-03
Sum Br1 to Br9 (median)	0.019	NR	2.6E-04	1.4E-04
Deca BDE (min)	0.002	NR	1.7E-05	3.4E-07
Deca BDE (max)	0.500	NR	4.4E-03	8.7E-05
Deca BDE (mean)	0.077	NR	6.7E-04	1.3E-05
Deca BDE (95th percentile)	0.346	NR	3.0E-03	6.0E-05
Deca BDE (median)	0.038	NR	3.4E-04	6.7E-06

Exposure to Chemicals via Ingestion of Meat - Children

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.085	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	2.2E-04		4.3E-07	--	0.02156
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	5.1E+00		1.0E-02	--	510.36590
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	1.1E-01		2.2E-04	--	10.78238
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	1.4E-01		2.9E-04	--	14.37650
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	3.6E-03		7.2E-06	--	0.35941
Deca BDE (min)		0.007	80%	0.0014	0.05	8.7E-06		1.7E-08	--	0.00001
Deca BDE (max)		0.007	80%	0.0014	13	2.3E-03		4.5E-06	--	0.00321
Deca BDE (mean)		0.007	80%	0.0014	2	3.5E-04		6.9E-07	--	0.00049
Deca BDE (95th percentile)		0.007	80%	0.0014	9	1.6E-03		3.1E-06	--	0.00222
Deca BDE (median)		0.007	80%	0.0014	1	1.7E-04		3.5E-07	--	0.00025

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	8.4E-06		1.7E-08	--	0.000829
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	2.0E-01		3.9E-04	--	19.629458
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	4.2E-03		8.3E-06	--	0.414707
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	5.6E-03		1.1E-05	--	0.552942
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	1.4E-04		2.8E-07	--	0.013824
Deca BDE (min)		0.007	80%	0.0014	0.002	3.4E-07		6.7E-10	--	0.00000048
Deca BDE (max)		0.007	80%	0.0014	0.500	8.7E-05		1.7E-07	--	0.000124
Deca BDE (mean)		0.007	80%	0.0014	0.077	1.3E-05		2.7E-08	--	0.00001900
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	6.0E-05		1.2E-07	--	0.000086
Deca BDE (median)		0.007	80%	0.0014	0.038	6.7E-06		1.3E-08	--	0.00000950

Exposure to Chemicals via Ingestion of Meat - Adults

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.163	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	2.2E-04		1.8E-07	--	0.009
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	5.1E+00		4.2E-03	--	209.722
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	1.1E-01		8.9E-05	--	4.431
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	1.4E-01		1.2E-04	--	5.908
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	3.6E-03		3.0E-06	--	0.148
Deca BDE (min)		0.007	80%	0.0014	0.05	8.7E-06		7.1E-09	--	0.000005
Deca BDE (max)		0.007	80%	0.0014	13	2.3E-03		1.8E-06	--	0.001320
Deca BDE (mean)		0.007	80%	0.0014	2	3.5E-04		2.8E-07	--	0.000203
Deca BDE (95th percentile)		0.007	80%	0.0014	9	1.6E-03		1.3E-06	--	0.000914
Deca BDE (median)		0.007	80%	0.0014	1	1.7E-04		1.4E-07	--	0.000102

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	8.4E-06		6.8E-09	--	0.000341
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	2.0E-01		1.6E-04	--	8.066222
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	4.2E-03		3.4E-06	--	0.170413
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	5.6E-03		4.5E-06	--	0.227218
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	1.4E-04		1.1E-07	--	0.005680
Deca BDE (min)		0.007	80%	0.0014	0.002	3.4E-07		2.7E-10	--	0.000000195
Deca BDE (max)		0.007	80%	0.0014	0.500	8.7E-05		7.1E-08	--	0.000050756
Deca BDE (mean)		0.007	80%	0.0014	0.077	1.3E-05		1.1E-08	--	0.000007809
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	6.0E-05		4.9E-08	--	0.000035139
Deca BDE (median)		0.007	80%	0.0014	0.038	6.7E-06		5.5E-09	--	0.000003904

Updated Exposure Assessment Parameters

Cattle exposed 52 days

Upper Bioaccessibility

Intake of Chemicals by Cows (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 52 days per year)

$$Daily\ intake_{dairy\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{milk} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Milk to intake ratio =	0.01	0.0006	mg/kg (milk) / mg/d

Cattle

Exposure Parameters	Average	Reference	
Cattle water ingestion rate (L/day)	70	ANZECC & ARMCANZ (2000)	values changed
Cattle fodder ingestion rate (kg ww/day)	20	ANZECC & ARMCANZ (2000)	
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)	
CF (dw to ww)	0.15	Assumption 15% dry matter	
Fraction of produce from site in diet (FI)	100%	Maximum possible	
Exposure Frequency (EF, days/year)	52	6 months of year on treated areas	
Exposure Duration (ED, years)	4	Professional Advice	
Bioaccessibility (B) PBDEs (Br1to9)	30%	See **Section 3.4.1**	
Bioaccessibility (B) DecaBDE	15%	See **Section 3.4.1**	
Averaging Time - Threshold (Atn, days)	1460	ED*365	

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	3.8E-04	3.8E-06
Sum Br1 to Br9 (max)	710.000	NR	9.1E+00	9.1E-02
Sum Br1 to Br9 (mean)	15.0000	NR	1.9E-01	1.9E-03
Sum Br1 to Br9 (95th percentile)	20.0000	NR	2.6E-01	2.6E-03
Sum Br1 to Br9 (median)	0.5000	NR	6.4E-03	6.4E-05
Deca BDE (min)	0.0500	NR	6.4E-05	3.8E-08
Deca BDE (max)	13.0000	NR	1.7E-02	1.0E-05
Deca BDE (mean)	2.0000	NR	2.6E-03	1.5E-06
Deca BDE (95th percentile)	9.0000	NR	1.2E-02	6.9E-06
Deca BDE (median)	1.0000	NR	1.3E-03	7.7E-07
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	6.4E-04	6.4E-06
Sum Br1 to Br9 (max)	710.000	NR	1.5E+01	1.5E-01
Sum Br1 to Br9 (mean)	15.000	NR	3.2E-01	3.2E-03
Sum Br1 to Br9 (95th percentile)	20.000	NR	4.3E-01	4.3E-03
Sum Br1 to Br9 (median)	0.500	NR	1.1E-02	1.1E-04
Deca BDE (min)	0.050	NR	1.1E-03	6.4E-07
Deca BDE (max)	13.000	NR	2.8E-01	1.7E-04
Deca BDE (mean)	2.000	NR	4.3E-02	2.6E-05
Deca BDE (95th percentile)	9.000	NR	1.9E-01	1.2E-04
Deca BDE (median)	1.000	NR	2.1E-02	1.3E-05
Combined				
Sum Br1 to Br9 (min)	0.030	NR	1.0E-03	1.0E-05
Sum Br1 to Br9 (max)	710.000	NR	2.4E+01	2.4E-01
Sum Br1 to Br9 (mean)	15.000	NR	5.1E-01	5.1E-03
Sum Br1 to Br9 (95th percentile)	20.000	NR	6.8E-01	6.8E-03
Sum Br1 to Br9 (median)	0.500	NR	1.7E-02	1.7E-04
Deca BDE (min)	0.050	NR	1.1E-03	6.8E-07
Deca BDE (max)	13.000	NR	2.9E-01	1.8E-04
Deca BDE (mean)	2.000	NR	4.5E-02	2.7E-05
Deca BDE (95th percentile)	9.000	NR	2.0E-01	1.2E-04
Deca BDE (median)	1.000	NR	2.3E-02	1.4E-05

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Milk (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	1.5E-05	1.5E-07
Sum Br1 to Br9 (max)	27.308	NR	3.5E-01	3.5E-03
Sum Br1 to Br9 (mean)	0.577	NR	7.4E-03	7.4E-05
Sum Br1 to Br9 (95th percentile)	0.769	NR	9.9E-03	9.9E-05
Sum Br1 to Br9 (median)	0.019	NR	2.5E-04	2.5E-06
Deca BDE (min)	0.002	NR	2.5E-06	1.5E-09
Deca BDE (max)	0.500	NR	6.4E-04	3.8E-07
Deca BDE (mean)	0.077	NR	9.9E-05	5.9E-08
Deca BDE (95th percentile)	0.346	NR	4.4E-04	2.7E-07
Deca BDE (median)	0.038	NR	4.9E-05	3.0E-08
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	2.5E-05	2.5E-07
Sum Br1 to Br9 (max)	27.308	NR	5.8E-01	5.8E-03
Sum Br1 to Br9 (mean)	0.577	NR	1.2E-02	1.2E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	1.6E-02	1.6E-04
Sum Br1 to Br9 (median)	0.019	NR	4.1E-04	4.1E-06
Deca BDE (min)	0.002	NR	4.1E-05	2.5E-08
Deca BDE (max)	0.500	NR	1.1E-02	6.4E-06
Deca BDE (mean)	0.077	NR	1.6E-03	9.9E-07
Deca BDE (95th percentile)	0.346	NR	7.4E-03	4.4E-06
Deca BDE (median)	0.038	NR	8.2E-04	4.9E-07
Combined				
Sum Br1 to Br9 (min)	0.001	NR	3.9E-05	3.9E-07
Sum Br1 to Br9 (max)	27.308	NR	9.3E-01	9.3E-03
Sum Br1 to Br9 (mean)	0.577	NR	2.0E-02	2.0E-04
Sum Br1 to Br9 (95th percentile)	0.769	NR	2.6E-02	2.6E-04
Sum Br1 to Br9 (median)	0.019	NR	6.6E-04	6.6E-06
Deca BDE (min)	0.002	NR	4.4E-05	2.6E-08
Deca BDE (max)	0.500	NR	1.1E-02	6.8E-06
Deca BDE (mean)	0.077	NR	1.7E-03	1.0E-06
Deca BDE (95th percentile)	0.346	NR	7.8E-03	4.7E-06
Deca BDE (median)	0.038	NR	8.7E-04	5.2E-07

Exposure to Chemicals via Ingestion of Milk - Children

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.097	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	1.0E-05		7.5E-07	--	0.0375
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	2.4E-01		1.8E-02	--	887.70
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	5.1E-03		3.8E-04	--	18.75
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	6.8E-03		5.0E-04	--	25.0056
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	1.7E-04		1.3E-05	--	0.6251
Deca BDE (min)		0.007	80%	0.0014	0.05	6.8E-07		5.0E-08	--	0.0000355
Deca BDE (max)		0.007	80%	0.0014	13	1.8E-04		1.3E-05	--	0.009230
Deca BDE (mean)		0.007	80%	0.0014	2	2.7E-05		2.0E-06	--	0.001420
Deca BDE (95th percentile)		0.007	80%	0.0014	9	1.2E-04		8.9E-06	--	0.006390
Deca BDE (median)		0.007	80%	0.0014	1	1.4E-05		9.9E-07	--	0.000710

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	3.9E-07		2.9E-08	--	0.00144
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	9.3E-03		6.8E-04	--	34.14
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	2.0E-04		1.4E-05	--	0.7213
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	2.6E-04		1.9E-05	--	0.9618
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	6.6E-06		4.8E-07	--	0.02404384
Deca BDE (min)		0.007	80%	0.0014	0.002	2.6E-08		1.9E-09	--	0.00000137
Deca BDE (max)		0.007	80%	0.0014	0.500	6.8E-06		5.0E-07	--	0.00035499
Deca BDE (mean)		0.007	80%	0.0014	0.077	1.0E-06		7.6E-08	--	0.00005461
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	4.7E-06		3.4E-07	--	0.00024576
Deca BDE (median)		0.007	80%	0.0014	0.038	5.2E-07		3.8E-08	--	0.00002731

Exposure to Chemicals via Ingestion of Milk - Adults

$$Daily\ Chemical\ Intake_{milk} = C_{milk} \bullet \frac{IR_{milk} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Milk (IR_{milk}, kg/day)	1.295	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Milk Consumed (FHG)	100%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume milk consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	1.0E-05		1.9E-07	--	0.0095
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	2.4E-01		4.5E-03	--	224.55
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	5.1E-03		9.5E-05	--	4.74
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	6.8E-03		1.3E-04	--	6.33
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	1.7E-04		3.2E-06	--	0.1581370
Deca BDE (min)		0.007	80%	0.0014	0.05	6.8E-07		1.3E-08	--	0.0000090
Deca BDE (max)		0.007	80%	0.0014	13	1.8E-04		3.3E-06	--	0.0023348
Deca BDE (mean)		0.007	80%	0.0014	2	2.7E-05		5.0E-07	--	0.0003592
Deca BDE (95th percentile)		0.007	80%	0.0014	9	1.2E-04		2.3E-06	--	0.0016164
Deca BDE (median)		0.007	80%	0.0014	1	1.4E-05		2.5E-07	--	0.0001796

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Milk	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0012	3.9E-07		7.3E-09	--	0.000365
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.3077	9.3E-03		1.7E-04	--	8.64
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.5769	2.0E-04		3.6E-06	--	0.1825
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.7692	2.6E-04		4.9E-06	--	0.24328767
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0192	6.6E-06		1.2E-07	--	0.00608219
Deca BDE (min)		0.007	80%	0.0014	0.0019	2.6E-08		4.8E-10	--	0.00000035
Deca BDE (max)		0.007	80%	0.0014	0.5000	6.8E-06		1.3E-07	--	0.00008980
Deca BDE (mean)		0.007	80%	0.0014	0.0769	1.0E-06		1.9E-08	--	0.00001382
Deca BDE (95th percentile)		0.007	80%	0.0014	0.3462	4.7E-06		8.7E-08	--	0.00006217
Deca BDE (median)		0.007	80%	0.0014	0.0385	5.2E-07		9.7E-09	--	0.00000691

Intake of Chemicals by Beef Cattle (stock watering, fodder watering, fodder soil, soil ingestion)

(Updated Parameter Values with Cattle Present in Paddocks for 52 days per year)

$$Daily\ intake_{beef\ cattle} = \frac{((C_{soil} * IR_{soil}) + (C_{soil} * Transfer\ factor\ (soil\ to\ plant) * IR_{fodder})) * B * EF * ED}{AT} \quad \text{(mg/day)}$$

$$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Water to fodder ratio =	NR	NR	mg/kg (plant) (w/w) / mg/L
Soil to fodder ratio =	0.1	0.01	mg/kg (plant) (d/w) / mg/kg (soil)
Meat to intake ratio =	0.53	0.02	mg/kg (meat) / mg/d

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	100%	Maximum possible
Exposure Frequency (EF, days/year)	52	Maximum possible
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B) PBDEs (Br1to9)	30%	See **Section 3.4.1**
Bioaccessibility (B) DecaBDE	15%	See **Section 3.4.1**
Averaging Time - Threshold (Atn, days)	730	ED*365

values changed

Grazing Land - Overall Dataset - No Dilution

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	3.8E-04	2.0E-04
Sum Br1 to Br9 (max)	710.000	NR	9.1E+00	4.8E+00
Sum Br1 to Br9 (mean)	15.0000	NR	1.9E-01	1.0E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	2.6E-01	1.4E-01
Sum Br1 to Br9 (median)	0.5000	NR	6.4E-03	3.4E-03
Deca BDE (min)	0.0500	NR	3.2E-05	6.4E-07
Deca BDE (max)	13.0000	NR	8.3E-03	1.7E-04
Deca BDE (mean)	2.0000	NR	1.3E-03	2.6E-05
Deca BDE (95th percentile)	9.0000	NR	5.8E-03	1.2E-04
Deca BDE (median)	1.0000	NR	6.4E-04	1.3E-05
Treated soil				
Sum Br1 to Br9 (min)	0.030	NR	6.4E-04	3.4E-04
Sum Br1 to Br9 (max)	710.000	NR	1.5E+01	8.0E+00
Sum Br1 to Br9 (mean)	15.000	NR	3.2E-01	1.7E-01
Sum Br1 to Br9 (95th percentile)	20.000	NR	4.3E-01	2.3E-01
Sum Br1 to Br9 (median)	0.500	NR	1.1E-02	5.7E-03
Deca BDE (min)	0.050	NR	1.1E-03	2.1E-05
Deca BDE (max)	13.000	NR	2.8E-01	5.6E-03
Deca BDE (mean)	2.000	NR	4.3E-02	8.5E-04
Deca BDE (95th percentile)	9.000	NR	1.9E-01	3.8E-03
Deca BDE (median)	1.000	NR	2.1E-02	4.3E-04
Combined				
Sum Br1 to Br9 (min)	0.0300	NR	1.0E-03	5.4E-04
Sum Br1 to Br9 (max)	710.0000	NR	2.4E+01	1.3E+01
Sum Br1 to Br9 (mean)	15.0000	NR	5.1E-01	2.7E-01
Sum Br1 to Br9 (95th percentile)	20.0000	NR	6.8E-01	3.6E-01
Sum Br1 to Br9 (median)	0.5000	NR	1.7E-02	9.1E-03
Deca BDE (min)	0.0500	NR	1.1E-03	2.2E-05
Deca BDE (max)	13.0000	NR	2.9E-01	5.7E-03
Deca BDE (mean)	2.0000	NR	4.4E-02	8.8E-04
Deca BDE (95th percentile)	9.0000	NR	2.0E-01	4.0E-03
Deca BDE (median)	1.0000	NR	2.2E-02	4.4E-04

Grazing Land - Overall Dataset - Trampled

Scenarios	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/day)	PBDEs in Meat (mg/kg)
Fodder in Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	1.5E-05	7.8E-06
Sum Br1 to Br9 (max)	27.308	NR	3.5E-01	1.9E-01
Sum Br1 to Br9 (mean)	0.577	NR	7.4E-03	3.9E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	9.9E-03	5.2E-03
Sum Br1 to Br9 (median)	0.019	NR	2.5E-04	1.3E-04
Deca BDE (min)	0.002	NR	1.2E-06	2.5E-08
Deca BDE (max)	0.500	NR	3.2E-04	6.4E-06
Deca BDE (mean)	0.077	NR	4.9E-05	9.9E-07
Deca BDE (95th percentile)	0.346	NR	2.2E-04	4.4E-06
Deca BDE (median)	0.038	NR	2.5E-05	4.9E-07
Treated soil				
Sum Br1 to Br9 (min)	0.001	NR	2.5E-05	1.3E-05
Sum Br1 to Br9 (max)	27.308	NR	5.8E-01	3.1E-01
Sum Br1 to Br9 (mean)	0.577	NR	1.2E-02	6.5E-03
Sum Br1 to Br9 (95th percentile)	0.769	NR	1.6E-02	8.7E-03
Sum Br1 to Br9 (median)	0.019	NR	4.1E-04	2.2E-04
Deca BDE (min)	0.002	NR	4.1E-05	8.2E-07
Deca BDE (max)	0.500	NR	1.1E-02	2.1E-04
Deca BDE (mean)	0.077	NR	1.6E-03	3.3E-05
Deca BDE (95th percentile)	0.346	NR	7.4E-03	1.5E-04
Deca BDE (median)	0.038	NR	8.2E-04	1.6E-05
Combined				
Sum Br1 to Br9 (min)	0.001	NR	3.9E-05	2.1E-05
Sum Br1 to Br9 (max)	27.308	NR	9.3E-01	4.9E-01
Sum Br1 to Br9 (mean)	0.577	NR	2.0E-02	1.0E-02
Sum Br1 to Br9 (95th percentile)	0.769	NR	2.6E-02	1.4E-02
Sum Br1 to Br9 (median)	0.019	NR	6.6E-04	3.5E-04
Deca BDE (min)	0.002	NR	4.2E-05	8.5E-07
Deca BDE (max)	0.500	NR	1.1E-02	2.2E-04
Deca BDE (mean)	0.077	NR	1.7E-03	3.4E-05
Deca BDE (95th percentile)	0.346	NR	7.6E-03	1.5E-04
Deca BDE (median)	0.038	NR	8.5E-04	1.7E-05

Exposure to Chemicals via Ingestion of Meat - Children

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.085	Maximum mean value for 2-5 year olds as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	5.4E-04		1.1E-06	--	0.05391
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	1.3E+01		2.6E-02	--	1275.91474
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	2.7E-01		5.4E-04	--	26.95595
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	3.6E-01		7.2E-04	--	35.94126
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	9.1E-03		1.8E-05	--	0.89853
Deca BDE (min)		0.007	80%	0.0014	0.05	2.2E-05		4.4E-08	--	0.00003
Deca BDE (max)		0.007	80%	0.0014	13	5.7E-03		1.1E-05	--	0.00811
Deca BDE (mean)		0.007	80%	0.0014	2	8.8E-04		1.7E-06	--	0.00125
Deca BDE (95th percentile)		0.007	80%	0.0014	9	4.0E-03		7.9E-06	--	0.00561
Deca BDE (median)		0.007	80%	0.0014	1	4.4E-04		8.7E-07	--	0.00062

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	2.1E-05		4.1E-08	--	0.002074
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	4.9E-01		9.8E-04	--	49.073644
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	1.0E-02		2.1E-05	--	1.036767
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	1.4E-02		2.8E-05	--	1.382356
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	3.5E-04		6.9E-07	--	0.034559
Deca BDE (min)		0.007	80%	0.0014	0.002	8.5E-07		1.7E-09	--	0.00000120
Deca BDE (max)		0.007	80%	0.0014	0.500	2.2E-04		4.4E-07	--	0.000312
Deca BDE (mean)		0.007	80%	0.0014	0.077	3.4E-05		6.7E-08	--	0.00004797
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	1.5E-04		3.0E-07	--	0.000216
Deca BDE (median)		0.007	80%	0.0014	0.038	1.7E-05		3.4E-08	--	0.00002399

Exposure to Chemicals via Ingestion of Meat - Adults

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.163	Maximum mean value for >2 years as per FSANZ 2017
Fraction Home-Grown Meat Consumed (FHG)	35%	Assumed relevant for home slaughtered meat
Exposure Frequency (EF, days/year)	365	Assume meat consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Grazing - Overall Dataset - No Dilution

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.03	5.4E-04		4.4E-07	--	0.022
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	710	1.3E+01		1.0E-02	--	524.304
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	15	2.7E-01		2.2E-04	--	11.077
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	20	3.6E-01		3.0E-04	--	14.769
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.5	9.1E-03		7.4E-06	--	0.369
Deca BDE (min)		0.007	80%	0.0014	0.05	2.2E-05		1.8E-08	--	0.000013
Deca BDE (max)		0.007	80%	0.0014	13	5.7E-03		4.7E-06	--	0.003332
Deca BDE (mean)		0.007	80%	0.0014	2	8.8E-04		7.2E-07	--	0.000513
Deca BDE (95th percentile)		0.007	80%	0.0014	9	4.0E-03		3.2E-06	--	0.002306
Deca BDE (median)		0.007	80%	0.0014	1	4.4E-04		3.6E-07	--	0.000256

Grazing - Overall Dataset - Trampled

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.001	2.1E-05		1.7E-08	--	0.000852
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.308	4.9E-01		4.0E-04	--	20.165556
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.577	1.0E-02		8.5E-06	--	0.426033
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.769	1.4E-02		1.1E-05	--	0.568044
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.019	3.5E-04		2.8E-07	--	0.014201
Deca BDE (min)		0.007	80%	0.0014	0.002	8.5E-07		6.9E-10	--	0.000000493
Deca BDE (max)		0.007	80%	0.0014	0.500	2.2E-04		1.8E-07	--	0.000128135
Deca BDE (mean)		0.007	80%	0.0014	0.077	3.4E-05		2.8E-08	--	0.000019713
Deca BDE (95th percentile)		0.007	80%	0.0014	0.346	1.5E-04		1.2E-07	--	0.000088709
Deca BDE (median)		0.007	80%	0.0014	0.038	1.7E-05		1.4E-08	--	0.000009857

Other Types of Home Grown Produce

(Mean Case is shown in highlighted cells on each spreadsheet)

Intake of PBDEs by chickens (treated soil ingestion)

$$Average\ Daily\ intake_{chickens} = C_{soil} * IR_{soil} * B * \frac{EF * ED}{AT}$$ **(mg/day)**

$$C_{eggs} = Daily\ Intake_{chicken}\ x\ Transfer\ Factor$$ **(mg/kg fresh produce)**

TRANSFER FACTORS	PBDE (BR1to9)	DecaBDE	Units
Egg to intake ratio =	10	3	mg/kg edib/d / mg/d

Chicken

Exposure Parameters	Average	Reference
Chicken water ingestion rate (L/day)	0.32	ANZECC & ARMCANZ (2000)
Chicken soil ingestion rate (kg/day)	0.01	OEHHA 2012
Fraction of produce from site in diet (FI)	100%	Maximum possible
Exposure Frequency (EF, days/year)	365	Maximum possible
Exposure Duration (ED, years)	8	Professional Advice
Bioaccessibility (B)	100%	Maximum possible
Averaging Time - Threshold (Atn, days)	2920	ED*365

Incorporated into Soil

Scenario	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Daily intake (chickens) (mg/kg/day)	Concentration in Eggs (mg/kg) ww
Cropping Land - Overall Dataset				
MWOO in Soil - Uptake from Soil				
Sum Br1 to Br9 (min)	0.0003	Not Applicable	3.0E-06	3.1E-05
Sum Br1 to Br9 (max)	5.5000		5.5E-02	5.7E-01
Sum Br1 to Br9 (mean)	0.1000		1.0E-03	1.0E-02
Sum Br1 to Br9 (95th percentile)	0.1500		1.5E-03	1.6E-02
Sum Br1 to Br9 (median)	0.0040		4.0E-05	4.2E-04
Deca BDE (min)	0.0004		4.0E-06	4.2E-05
Deca BDE (max)	0.1000		1.0E-03	1.0E-02
Deca BDE (mean)	0.0200		2.0E-04	2.1E-03
Deca BDE (95th percentile)	0.0700		7.0E-04	7.3E-03
Deca BDE (median)	0.0080		8.0E-05	8.3E-04

Exposure to Chemicals via Ingestion of Eggs from On-Site Hens - Children

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \textbf{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate of Eggs (IR_{eggs}, kg/day)	0.036	P90 FSANZ 2017 2-5 years
Fraction Home-Grown Eggs Consumed (FHG)	100%	Assumed relevant for eggs from backyard
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Cropping Land - Overall Dataset

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Eggs	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0003	3.1E-05		7.5E-08	--	0.0038
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	5.5000	5.7E-01		1.4E-03	--	68.8
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.1000	1.0E-02		2.5E-05	--	1.250
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.1500	1.6E-02		3.8E-05	--	1.8750
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0040	4.2E-04		1.0E-06	--	0.0500
Deca BDE (min)		0.007	80%	0.0014	0.0004	4.2E-05		1.0E-07	--	0.000071
Deca BDE (max)		0.007	80%	0.0014	0.1000	1.0E-02		2.5E-05	--	0.0179
Deca BDE (mean)		0.007	80%	0.0014	0.0200	2.1E-03		5.0E-06	--	0.00357
Deca BDE (95th percentile)		0.007	80%	0.0014	0.0700	7.3E-03		1.8E-05	--	0.01250
Deca BDE (median)		0.007	80%	0.0014	0.0080	8.3E-04		2.0E-06	--	0.00143

Exposure to Chemicals via Ingestion of Eggs from On-Site Hens - Adults

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate of Eggs (IR_{eggs}, kg/day)	0.059	P90 FSANZ 2017 (>2 yrs)
Fraction Home-Grown Eggs Consumed (FHG)	100%	Assumed relevant for eggs from backyard
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Cropping Land - NSW OEH Dataset

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Concentration in Eggs	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0003	3.1E-05		2.6E-08	--	0.0013
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	5.5000	5.7E-01		4.8E-04	--	24
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.1000	1.0E-02		8.8E-06	--	0.43899
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.1500	1.6E-02		1.3E-05	--	0.65848
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0040	4.2E-04		3.5E-07	--	0.01756
Deca BDE (min)		0.007	80%	0.0014	0.0004	4.2E-05		3.5E-08	--	0.000025
Deca BDE (max)		0.007	80%	0.0014	0.1000	1.0E-02		8.8E-06	--	0.00627
Deca BDE (mean)		0.007	80%	0.0014	0.0200	2.1E-03		1.8E-06	--	0.0012543
Deca BDE (95th percentile)		0.007	80%	0.0014	0.0700	7.3E-03		6.1E-06	--	0.0043899
Deca BDE (median)		0.007	80%	0.0014	0.0080	8.3E-04		7.0E-07	--	0.0005017

Calculation of Uptake Factors for Home-Grown Produce

Refined calculation

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	**Log Kow**	**Root Concentration Factor (i.e. below ground portions)** (Briggs et al 1982) (mg/kg in roots dry weight/mg/kg in solution)	**Root Concentration Factor (i.e. below ground portions)** (Briggs et al 1982) (mg/kg in roots wet weight/mg/kg in solution)	**Leaching factor (%)**	**Transfer into below ground portions** (mg/kg in roots/mg/kg in MWOO)
Sum Br1 to Br9 (mean)	6.5	3056	458	0.13%	0.595869517
DecaBDE (maximum)	6.3	2144	322	0.13%	0.418023567

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	**Log Kow**	**Translocation (i.e. above ground portions)** (Travis & Arms 1988) (mg/kg dry weight /mg/kg in soil dry weight)	**Translocation (i.e. above ground portions)** (Travis & Arms 1988) (mg/kg wet weight /mg/kg in soil dry weight)	**Leaching factor (%)**	**Transfer into above ground portions** (mg/kg in roots/mg/kg in MWOO)
Sum Br1 to Br9 (mean)	6.5	0.006776	0.001016	0.13%	1.3214E-06
DecaBDE (maximum)	6.3	0.008843	0.001326	0.13%	1.72439E-06

Exposure to Chemicals via Ingestion of Home-Grown Produce - Children

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \text{(kg/day)}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF incl FHG (kg/d)	
Consumption Rate - Children	0.055	0.017	0.028	0.18		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (min)	1.32E-06	5.96E-01	5.96E-01	1.32E-06	2.68E-02	(mg/kg produce per mg/kg soil)
Deca BDE (median)	1.72E-06	4.18E-01	4.18E-01	1.72E-06	1.88E-02	

Parameters Relevant to Quantification of Exposure to Young Children		
Fraction Home-Grown (FHG)	0.35	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Cropping Land - Overall Dataset

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0003		1.9E-07		0.00939
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	5.5000		3.4E-03		172.06
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.1000		6.3E-05		3.128
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.1500		9.4E-05		4.693
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0040		2.5E-06		0.125
Deca BDE (min)		0.007	80%	0.0014	0.0004		2.5E-07		0.000179
Deca BDE (max)		0.007	80%	0.0014	0.1000		6.3E-05		0.044691
Deca BDE (mean)		0.007	80%	0.0014	0.0200		1.3E-05		0.008938
Deca BDE (95th percentile)		0.007	80%	0.0014	0.0700		4.4E-05		0.031284
Deca BDE (median)		0.007	80%	0.0014	0.0080		5.0E-06		0.003575

Exposure to Chemicals via Ingestion of Home-Grown Produce - Adult

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \text{(kg/day)}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF incl FHG (kg/d)	
Consumption Rate - Adult	0.1534	0.0468	0.0598	0.14		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (min)	1.32E-06	5.96E-01	5.96E-01	1.32E-06	6.35E-02	(mg/kg produce per mg/kg soil)
Deca BDE (median)	1.72E-06	4.18E-01	4.18E-01	1.72E-06	4.46E-02	

Parameters Relevant to Quantification of Exposure to Adults		
Fraction Home-Grown (FHG)	0.35	Assumed relevant for on-site
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Cropping Land - Overall Dataset

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0003		9.5E-08		0.005
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	5.5000		1.7E-03		87
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.1000		3.2E-05		1.59
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.1500		4.8E-05		2.38
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0040		1.3E-06		0.063520
Deca BDE (min)		0.007	80%	0.0014	0.0004		1.3E-07		0.000091
Deca BDE (max)		0.007	80%	0.0014	0.1000		3.2E-05		0.022686
Deca BDE (mean)		0.007	80%	0.0014	0.0200		6.4E-06		0.004537
Deca BDE (95th percentile)		0.007	80%	0.0014	0.0700		2.2E-05		0.015880
Deca BDE (median)		0.007	80%	0.0014	0.0080		2.5E-06		0.001815

Exposure to Chemicals via Ingestion of Wheat/barley/oats - Children

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

C_{wheat} = Csoil x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.038	2/3rds of bread consumption from FSANZ Total Diet Survey
Fraction Home-Grown (FHG)	35%	Assumed relevant for wheat grown in fields where material is applied
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Cropping - Overall Dataset

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in wheat)/(mg/kg soil)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.1	0.0003		2.7E-08	--	0.00133
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	0.1	5.5		4.9E-04	--	24.383
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.1	0.1		8.9E-06	--	0.4433
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.1	0.15		1.3E-05	--	0.6650
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.1	0.004		3.5E-07	--	0.0177
Deca BDE (min)		0.007	80%	0.0014	0.01	0.0004		3.5E-09	--	0.00000253
Deca BDE (max)		0.007	80%	0.0014	0.01	0.1		8.9E-07	--	0.0006333
Deca BDE (mean)		0.007	80%	0.0014	0.01	0.02		1.8E-07	--	0.0001267
Deca BDE (95th percentile)		0.007	80%	0.0014	0.01	0.07		6.2E-07	--	0.0004433
Deca BDE (median)		0.007	80%	0.0014	0.01	0.008		7.1E-08	--	0.0000507

Exposure to Chemicals via Ingestion of Wheat/barley/oats - Adult

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

C_{wheat} = Csoil x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Adult		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.095	2/3rds of bread consumption from FSANZ Total Diet Survey
Fraction Home-Grown (FHG)	35%	Assumed relevant for wheat grown in fields where material is applied
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Cropping - Overall Dataset

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in wheat)/(mg/kg soil)	Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.1	0.0003		1.4E-08	--	0.00071
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	0.1	5.5		2.6E-04	--	13.063
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.1	0.1		4.8E-06	--	0.2375
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.1	0.15		7.1E-06	--	0.3563
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.1	0.004		1.9E-07	--	0.00950
Deca BDE (min)		0.007	80%	0.0014	0.01	0.0004		1.9E-09	--	0.00000136
Deca BDE (max)		0.007	80%	0.0014	0.01	0.1		4.8E-07	--	0.00033929
Deca BDE (mean)		0.007	80%	0.0014	0.01	0.02		9.5E-08	--	0.00006786
Deca BDE (95th percentile)		0.007	80%	0.0014	0.01	0.07		3.3E-07	--	0.00023750
Deca BDE (median)		0.007	80%	0.0014	0.01	0.008		3.8E-08	--	0.00002714

Cropping Land – Direct Contact

(MWOO incorporated into the soil)

(Mean Case is shown in highlighted cells on each spreadsheet)

Exposure to Chemicals via Incidental Ingestion of Soil - Cropping Land - Overall Dataset

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.000020	0.0003		2.0E-09	--	0.000100
Sum Br1 to Br9 (max)		1.0E-04	80%	0.000020	5.5		3.7E-05	--	1.833
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	0.1		6.7E-07	--	0.03333
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.000020	0.15		1.0E-06	--	0.05000
Sum Br1 to Br9 (median)		1.0E-04	80%	0.000020	0.004		2.7E-08	--	0.00133
Deca BDE (min)		7.0E-03	80%	0.001400	0.0004		2.7E-09	--	0.00000190
Deca BDE (max)		7.0E-03	80%	0.001400	0.1		6.7E-07	--	0.0004762
Deca BDE (mean)		7.0E-03	80%	0.001400	0.02		1.3E-07	--	0.0000952
DecaBDE (95th percentile)		7.0E-03	80%	0.001400	0.07		4.7E-07	--	0.0003333
DecaBDE (median)		7.0E-03	80%	0.001400	0.008		5.3E-08	--	0.0000381

Exposure to Chemicals via Incidental Ingestion of Soil - Cropping Land Overall Dataset

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.000020	0.0003		2.1E-10	--	0.0000107
Sum Br1 to Br9 (max)		1.0E-04	80%	0.000020	5.5		3.9E-06	--	0.1964
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	0.1		7.1E-08	--	0.003571
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.000020	0.15		1.1E-07	--	0.005357
Sum Br1 to Br9 (median)		1.0E-04	80%	0.000020	0.004		2.9E-09	--	0.000143
Deca BDE (min)		7.0E-03	80%	0.001400	0.0004		2.9E-10	--	0.000000204
Deca BDE (max)		7.0E-03	80%	0.001400	0.1		7.1E-08	--	0.0000510
Deca BDE (mean)		7.0E-03	80%	0.001400	0.02		1.4E-08	--	0.0000102
DecaBDE (95th percentile)		7.0E-03	80%	0.001400	0.07		5.0E-08	--	0.0000357
DecaBDE (median)		7.0E-03	80%	0.001400	0.008		5.7E-09	--	0.0000041

Dermal Exposure to Chemicals via Contact with Soil - Cropping Land Overall Dataset

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Surface Area (SAs, cm^2)	2700	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	6	Exposures occur from areas 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.0002		1.1E-09	--	0.000054
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	5.5		3.0E-05	--	1.4850
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.1		5.4E-07	--	0.02700
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	0.15		8.1E-07	--	0.04050
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.004		2.2E-08	--	0.00108
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.0004		2.2E-10	--	0.000000154
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	0.1		5.4E-08	--	0.00003857
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	0.02		1.1E-08	--	0.00000771
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	0.07		3.8E-08	--	0.00002700
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	0.008		4.3E-09	--	0.00000309

Dermal Exposure to Chemicals via Contact with Soil - Cropping Land Overall Dataset

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Surface Area (SAs, cm^2)	2700	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	6	Exposures occur from areas 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.0003		1.6E-09	--	0.000081
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	5.5		3.0E-05	--	1.4850
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.1		5.4E-07	--	0.02700
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	0.15		8.1E-07	--	0.04050
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.004		2.2E-08	--	0.00108
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.0004		2.2E-10	--	0.000000154
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	0.1		5.4E-08	--	0.00003857
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	0.02		1.1E-08	--	0.00000771
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	0.07		3.8E-08	--	0.00002700
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	0.008		4.3E-09	--	0.00000309

Dermal Exposure to Chemicals via Contact with Soil - Cropping Land Overall Dataset

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Surface Area (SAs, cm^2)	6300	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.0003		8.1E-10	--	0.0000405
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	5.5		1.5E-05	--	0.7425
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.1		2.7E-07	--	0.01350
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	0.15		4.1E-07	--	0.02025
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.004		1.1E-08	--	0.000540
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.0004		1.1E-10	--	0.000000077
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	0.1		2.7E-08	--	0.000019286
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	0.02		5.4E-09	--	0.000003857
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	0.07		1.9E-08	--	0.000013500
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	0.008		2.2E-09	--	0.000001543

Soil to Air Particulate Emission Factor (PEF) - Outdoors - Cropping Land

(Reference: USEPA Soil Screening Guidance (1996), Supplemental Guidance (2002))

$$PEF = \frac{Q/C \bullet 3600}{0.036 \bullet (1-V) \bullet (\frac{U_m}{U_t})^3 \bullet F_x}$$

where:

A	area of site (acres)
Q/C =	dispersion factor ($g/m^2/s$ per kg/m^3)
V =	fraction of vegetative cover (unitless)
U_m =	mean annual windspeed (m/s)
U_t =	equivalent threshold value (m/s)
U_t/U_m =	ratio of threshold value to windspeed
F_x =	windspeed distribution function (unitless)

Site Data	Comments
2.50	Area of concern covers approx. 0.1 ha
71.01	Calculated using equations for outdoor worker from US EPA, 2002
0.5	Assume half of the area has vegetation cover
3.6	Mean windspeed from 9am and 3pm readings from Scoresby Research Institute Met Station
11.3	Calculated for a threshold velocity of 1 m/s (US EPA, 1996)
3.1	Ratio
3.91E-02	Value based on Ut/Um ratio, Cowherd (1985)

PEF = 1.13E+10 (m^3/kg)

COPC	Soil Concentration, C_{soil} (mg/kg)	Dust Concentration C_{dust} [=C_{soil}/PEF] (mg/m^3)
Sum Br1 to Br9 (min)	0.0003	2.7E-14
Sum Br1 to Br9 (max)	5.5000	4.9E-10
Sum Br1 to Br9 (mean)	0.1000	8.9E-12
Sum Br1 to Br9 (95th percentile)	0.1500	1.3E-11
Sum Br1 to Br9 (median)	0.0040	3.5E-13
Deca BDE (min)	0.0004	3.5E-14
Deca BDE (max)	0.1000	8.9E-12
Deca BDE (mean)	0.0200	1.8E-12
DecaBDE (95th percentile)	0.0700	6.2E-12
DecaBDE (median)	0.0080	7.1E-13

PEF for fugitive dust emissions considered relevant for the quantification of inhalation exposures by outdoor workers on a residential or commercial/industrial site (including gardening and landscaping activities). However it is noted that the fugitive model may not be relevant for activities and conditions that may result in the generation of potentially high dust emissions such as dry soils (MC<8%), fine soils (high silt or clay content), high annual average winds (>5.3 m/s) and less than 50% vegetative cover.

Inhalation of Dust (derived from Soil Source) - Children and Adults

$$Inhalation\ Exposure\ Conc_P = C_a \bullet \frac{ET \bullet FI \bullet DF \bullet CC \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Parameters Relevant to Quantification of Exposure		
Exposure Time (ET, hr/day)	24	Assumed time spent at the site each day
Exposure Time Indoors (hours/day)	20	ASC NEPM (2013)
Exposure Time Outdoors (hours/day)	4	ASC NEPM (2013)
Fraction Inhaled from Contaminated Source (FI, unitless)	1	Assume all of dust is from site related soil
Deposition Fraction (DF, unitless)	0.75	Assume 75% inhaled dust reaches lungs
Cilliary Clearance (CC, unitless)	0.5	Assume 50% small enough to penetrate deep enough for absorption
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	35	Duration of exposure as young child and adult
Averaging Time - NonThreshold (Atc, hours)	613200	USEPA 2009
Averaging Time - Threshold (Atn, hours)	306600	USEPA 2009

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	in Air (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Sum Br1 to Br9 (min)		0.00035	80%	0.00007	2.7E-14		1.0E-14	--	1.42E-10
Sum Br1 to Br9 (max)		0.00035	80%	0.00007	4.9E-10		1.8E-10	--	2.61E-06
Sum Br1 to Br9 (mean)		0.00035	80%	0.00007	8.9E-12		3.3E-12	--	4.74E-08
Sum Br1 to Br9 (95th percentile)		0.00035	80%	0.00007	1.3E-11		5.0E-12	--	7.12E-08
Sum Br1 to Br9 (median)		0.00035	80%	0.00007	3.5E-13		1.3E-13	--	1.90E-09
Deca BDE (min)		0.02	80%	0.00400	3.5E-14		1.3E-14	--	3.32E-12
Deca BDE (max)		0.02	80%	0.00400	8.9E-12		3.3E-12	--	8.30E-10
Deca BDE (mean)		0.02	80%	0.00400	1.8E-12		6.6E-13	--	1.66E-10
DecaBDE (95th percentile)		0.02	80%	0.00400	6.2E-12		2.3E-12	--	5.81E-10
DecaBDE (median)		0.02	80%	0.00400	7.1E-13		2.7E-13	--	6.64E-11

Grazing Land – Direct Contact

(MWOO not incorporated into the soil)

(Mean Case is shown in highlighted cells on each spreadsheet)

Exposure to Chemicals via Incidental Ingestion of Soil - Grazing Land Overall Dataset

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.000020	0.04		2.7E-07	--	0.0133
Sum Br1 to Br9 (max)		1.0E-04	80%	0.000020	710		4.7E-03	--	237
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	15		1.0E-04	--	5.0
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.000020	20		1.3E-04	--	6.67
Sum Br1 to Br9 (median)		1.0E-04	80%	0.000020	0.5		3.3E-06	--	0.16667
Deca BDE (min)		7.0E-03	80%	0.001400	0.05		3.3E-07	--	0.00024
Deca BDE (max)		7.0E-03	80%	0.001400	13		8.7E-05	--	0.06190
Deca BDE (mean)		7.0E-03	80%	0.001400	2		1.3E-05	--	0.00952
DecaBDE (95th percentile)		7.0E-03	80%	0.001400	9		6.0E-05	--	0.04286
DecaBDE (median)		7.0E-03	80%	0.001400	1		6.7E-06	--	0.00476

Exposure to Chemicals via Incidental Ingestion of Soil - Grazing Land Overall Dataset

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.000020	0.04		2.9E-08	--	0.00143
Sum Br1 to Br9 (max)		1.0E-04	80%	0.000020	710		5.1E-04	--	25.4
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	15		1.1E-05	--	0.54
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.000020	20		1.4E-05	--	0.714286
Sum Br1 to Br9 (median)		1.0E-04	80%	0.000020	0.5		3.6E-07	--	0.017857
Deca BDE (min)		7.0E-03	80%	0.001400	0.05		3.6E-08	--	0.000026
Deca BDE (max)		7.0E-03	80%	0.001400	13		9.3E-06	--	0.006633
Deca BDE (mean)		7.0E-03	80%	0.001400	2		1.4E-06	--	0.001020
DecaBDE (95th percentile)		7.0E-03	80%	0.001400	9		6.4E-06	--	0.004592
DecaBDE (median)		7.0E-03	80%	0.001400	1		7.1E-07	--	0.000510

Dermal Exposure to Chemicals via Contact with Soil - Grazing Land Overall Dataset

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Surface Area (SAs, cm^2)	2700	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	6	Exposures occur from areas 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.04		2.2E-07	--	0.01080
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	710		3.8E-03	--	192
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	15		8.1E-05	--	4.1
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	20		1.1E-04	--	5.400
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.5		2.7E-06	--	0.135
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.05		2.7E-08	--	0.0000193
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	13		7.0E-06	--	0.0050143
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	2		1.1E-06	--	0.0007714
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	9		4.9E-06	--	0.0034714
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	1		5.4E-07	--	0.0003857

Dermal Exposure to Chemicals via Contact with Soil - Grazing Land Overall Dataset

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Surface Area (SAs, cm^2)	6300	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.04		1.1E-07	--	0.00540
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	710		1.9E-03	--	96
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	15		4.1E-05	--	2.03
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	20		5.4E-05	--	2.7000
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.5		1.4E-06	--	0.0675
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.05		1.4E-08	--	0.00000964
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	13		3.5E-06	--	0.002507
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	2		5.4E-07	--	0.000386
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	9		2.4E-06	--	0.001736
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	1		2.7E-07	--	0.000193

Soil to Air Particulate Emission Factor (PEF) - Outdoors - Grazing Land Overall Dataset

(Reference: USEPA Soil Screening Guidance (1996), Supplemental Guidance (2002))

$$PEF = \frac{Q/C \bullet 3600}{0.036 \bullet (1-V) \bullet (\frac{U_m}{U_t})^3 \bullet F_x}$$

where:

A	area of site (acres)
Q/C =	dispersion factor ($g/m^2/s$ per kg/m^3)
V =	fraction of vegetative cover (unitless)
U_m =	mean annual windspeed (m/s)
U_t =	equivalent threshold value (m/s)
U_t/U_m =	ratio of threshold value to windspeed
F_x =	windspeed distribution function (unitless)

Site Data	Comments
2.50	Area of concern covers approx. 0.1 ha
71.01	Calculated using equations for outdoor worker from US EPA, 2002
0.5	Assume half of the area has vegetation cover
3.6	Mean windspeed from 9am and 3pm readings from Scoresby Research Institute Met Station
11.3	Calculated for a threshold velocity of 1 m/s (US EPA, 1996)
3.1	Ratio
3.91E-02	Value based on Ut/Um ratio, Cowherd (1985)

PEF = 1.13E+10 (m^3/kg)

COPC	Soil Concentration, C_{soil} (mg/kg)	Dust Concentration C_{dust} [=C_{soil}/PEF] (mg/m^3)
Sum Br1 to Br9 (min)	0.0400	3.5E-12
Sum Br1 to Br9 (max)	710.0000	6.3E-08
Sum Br1 to Br9 (mean)	15.0000	1.3E-09
Sum Br1 to Br9 (95th percentile)	20.0000	1.8E-09
Sum Br1 to Br9 (median)	0.5000	4.4E-11
Deca BDE (min)	0.0500	4.4E-12
Deca BDE (max)	13.0000	1.2E-09
Deca BDE (mean)	2.0000	1.8E-10
DecaBDE (95th percentile)	9.0000	8.0E-10
DecaBDE (median)	1.0000	8.9E-11

PEF for fugitive dust emissions considered relevant for the quantification of inhalation exposures by outdoor workers on a residential or commercial/industrial site (including gardening and landscaping activities). However it is noted that the fugitive model may not be relevant for activities and conditions that may result in the generation of potentially high dust emissions such as dry soils (MC<8%), fine soils (high silt or clay content), high annual average winds (>5.3 m/s) and less than 50% vegetative cover.

Inhalation of Dust (derived from Soil Source) - Children and Adults

$$Inhalation\ Exposure\ Conc_P = C_a \bullet \frac{ET \bullet FI \bullet DF \bullet CC \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Parameters Relevant to Quantification of Exposure		
Exposure Time (ET, hr/day)	24	Assumed time spent at the site each day
Exposure Time Indoors (hours/day)	20	ASC NEPM (2013)
Exposure Time Outdoors (hours/day)	4	ASC NEPM (2013)
Fraction Inhaled from Contaminated Source (FI, unitless)	1	Assume all of dust is from site related soil
Deposition Fraction (DF, unitless)	0.75	Assume 75% inhaled dust reaches lungs
Cilliary Clearance (CC, unitless)	0.5	Assume 50% small enough to penetrate deep enough for absorption
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	35	Duration of exposure as young child and adult
Averaging Time - NonThreshold (Atc, hours)	613200	USEPA 2009
Averaging Time - Threshold (Atn, hours)	306600	USEPA 2009

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	in Air (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Sum Br1 to Br9 (min)		0.00035	80%	0.00007	3.5E-12		1.3E-12	--	1.90E-08
Sum Br1 to Br9 (max)		0.00035	80%	0.00007	6.3E-08		2.4E-08	--	3.37E-04
Sum Br1 to Br9 (mean)		0.00035	80%	0.00007	1.3E-09		5.0E-10	--	7.12E-06
Sum Br1 to Br9 (95th percentile)		0.00035	80%	0.00007	1.8E-09		6.6E-10	--	9.49E-06
Sum Br1 to Br9 (median)		0.00035	80%	0.00007	4.4E-11		1.7E-11	--	2.37E-07
Deca BDE (min)		0.02	80%	0.00400	4.4E-12		1.7E-12	--	4.15E-10
Deca BDE (max)		0.02	80%	0.00400	1.2E-09		4.3E-10	--	1.08E-07
Deca BDE (mean)		0.02	80%	0.00400	1.8E-10		6.6E-11	--	1.66E-08
DecaBDE (95th percentile)		0.02	80%	0.00400	8.0E-10		3.0E-10	--	7.47E-08
DecaBDE (median)		0.02	80%	0.00400	8.9E-11		3.3E-11	--	8.30E-09

Grazing Land – Direct Contact

(MWOO trampled into the soil)

(Mean Case is shown in highlighted cells on each spreadsheet)

Exposure to Chemicals via Incidental Ingestion of Soil - Grazing Land Overall Dataset (Trampled)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.000020	0.002		1.0E-08	--	0.000513
Sum Br1 to Br9 (max)		1.0E-04	80%	0.000020	27		1.8E-04	--	9.103
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	0.6		3.8E-06	--	0.192
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.000020	0.8		5.1E-06	--	0.2564
Sum Br1 to Br9 (median)		1.0E-04	80%	0.000020	0.02		1.3E-07	--	0.00641
Deca BDE (min)		7.0E-03	80%	0.001400	0.002		1.3E-08	--	0.00000916
Deca BDE (max)		7.0E-03	80%	0.001400	0.5		3.3E-06	--	0.00238
Deca BDE (mean)		7.0E-03	80%	0.001400	0.08		5.1E-07	--	0.000366
DecaBDE (95th percentile)		7.0E-03	80%	0.001400	0.35		2.3E-06	--	0.00165
DecaBDE (median)		7.0E-03	80%	0.001400	0.04		2.6E-07	--	0.000183

Exposure to Chemicals via Incidental Ingestion of Soil - Grazing Land Overall Dataset (Trampled)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.000020	0.002		1.1E-09	--	0.000055
Sum Br1 to Br9 (max)		1.0E-04	80%	0.000020	27		2.0E-05	--	0.9753
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.000020	0.6		4.1E-07	--	0.0206
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.000020	0.8		5.5E-07	--	0.0274725
Sum Br1 to Br9 (median)		1.0E-04	80%	0.000020	0.02		1.4E-08	--	0.0006868
Deca BDE (min)		7.0E-03	80%	0.001400	0.002		1.4E-09	--	0.0000010
Deca BDE (max)		7.0E-03	80%	0.001400	0.500		3.6E-07	--	0.0002551
Deca BDE (mean)		7.0E-03	80%	0.001400	0.08		5.5E-08	--	0.0000392
DecaBDE (95th percentile)		7.0E-03	80%	0.001400	0.35		2.5E-07	--	0.0001766
DecaBDE (median)		7.0E-03	80%	0.001400	0.04		2.7E-08	--	0.0000196

Dermal Exposure to Chemicals via Contact with Soil - Grazing Land Overall Dataset (Trampled)

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Surface Area (SAs, cm^2)	2700	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	6	Exposures occur from areas 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.002		8.3E-09	--	0.00042
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	27		1.5E-04	--	7.37308
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.6		3.1E-06	--	0.15577
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	0.8		4.2E-06	--	0.20769
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.02		1.0E-07	--	0.00519
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.002		1.0E-09	--	0.00000074
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	0.5		2.7E-07	--	0.00019286
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	0.08		4.2E-08	--	0.00002967
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	0.3		1.9E-07	--	0.00013352
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	0.04		2.1E-08	--	0.00001484

Dermal Exposure to Chemicals via Contact with Soil - Grazing Land Overall Dataset (Trampled)

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Surface Area (SAs, cm^2)	6300	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Key Chemical	Toxicity Data					Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)		Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		1.0E-04	80%	0.00002	0.1	0.002		4.2E-09	--	0.000208
Sum Br1 to Br9 (max)		1.0E-04	80%	0.00002	0.1	27		7.4E-05	--	3.687
Sum Br1 to Br9 (mean)		1.0E-04	80%	0.00002	0.1	0.6		1.6E-06	--	0.0779
Sum Br1 to Br9 (95th percentile)		1.0E-04	80%	0.00002	0.1	0.8		2.1E-06	--	0.1038
Sum Br1 to Br9 (median)		1.0E-04	80%	0.00002	0.1	0.02		5.2E-08	--	0.00260
Deca BDE (min)		7.0E-03	80%	0.00140	0.01	0.002		5.2E-10	--	0.000000371
Deca BDE (max)		7.0E-03	80%	0.00140	0.01	0.5		1.4E-07	--	0.0000964
Deca BDE (mean)		7.0E-03	80%	0.00140	0.01	0.08		2.1E-08	--	0.0000148
DecaBDE (95th percentile)		7.0E-03	80%	0.00140	0.01	0.3		9.3E-08	--	0.0000668
DecaBDE (median)		7.0E-03	80%	0.00140	0.01	0.04		1.0E-08	--	0.000007418

Soil to Air Particulate Emission Factor (PEF) - Outdoors - Grazing Land (Trampled)
Overall Dataset

(Reference: USEPA Soil Screening Guidance (1996), Supplemental Guidance (2002))

$$PEF = \frac{Q/C \bullet 3600}{0.036 \bullet (1-V) \bullet (\frac{U_m}{U_t})^3 \bullet F_x}$$

where:

A	area of site (acres)
Q/C =	dispersion factor ($g/m^2/s$ per kg/m^3)
V =	fraction of vegetative cover (unitless)
U_m =	mean annual windspeed (m/s)
U_t =	equivalent threshold value (m/s)
U_t/U_m =	ratio of threshold value to windspeed
F_x =	windspeed distribution function (unitless)

Site Data	Comments
2.50	Area of concern covers approx. 0.1 ha
71.01	Calculated using equations for outdoor worker from US EPA, 2002
0.5	Assume half of the area has vegetation cover
3.6	Mean windspeed from 9am and 3pm readings from Scoresby Research Institute Met Station
11.3	Calculated for a threshold velocity of 1 m/s (US EPA, 1996)
3.1	Ratio
3.91E-02	Value based on Ut/Um ratio, Cowherd (1985)

PEF = 1.13E+10 (m^3/kg)

COPC	Soil Concentration, C_{soil} (mg/kg)	Dust Concentration C_{dust} [=C_{soil}/PEF] (mg/m^3)
Sum Br1 to Br9 (min)	0.0015	1.4E-13
Sum Br1 to Br9 (max)	27.3077	2.4E-09
Sum Br1 to Br9 (mean)	0.5769	5.1E-11
Sum Br1 to Br9 (95th percentile)	0.7692	6.8E-11
Sum Br1 to Br9 (median)	0.0192	1.7E-12
Deca BDE (min)	0.0019	1.7E-13
Deca BDE (max)	0.5000	4.4E-11
Deca BDE (mean)	0.0769	6.8E-12
DecaBDE (95th percentile)	0.3462	3.1E-11
DecaBDE (median)	0.0385	3.4E-12

PEF for fugitive dust emissions considered relevant for the quantification of inhalation exposures by outdoor workers on a residential or commercial/industrial site (including gardening and landscaping activities). However it is noted that the fugitive model may not be relevant for activities and conditions that may result in the generation of potentially high dust emissions such as dry soils (MC<8%), fine soils (high silt or clay content), high annual average winds (>5.3 m/s) and less than 50% vegetative cover.

Inhalation of Dust (derived from Soil Source) - Children and Adults

$$Inhalation\ Exposure\ Conc_P = C_a \bullet \frac{ET \bullet FI \bullet DF \bullet CC \bullet EF \bullet ED}{AT} \quad (mg/m^3)$$

Parameters Relevant to Quantification of Exposure		
Exposure Time (ET, hr/day)	24	Assumed time spent at the site each day
Exposure Time Indoors (hours/day)	20	ASC NEPM (2013)
Exposure Time Outdoors (hours/day)	4	ASC NEPM (2013)
Fraction Inhaled from Contaminated Source (FI, unitless)	1	Assume all of dust is from site related soil
Deposition Fraction (DF, unitless)	0.75	Assume 75% inhaled dust reaches lungs
Cilliary Clearance (CC, unitless)	0.5	Assume 50% small enough to penetrate deep enough for absorption
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	35	Duration of exposure as young child and adult
Averaging Time - NonThreshold (Atc, hours)	613200	USEPA 2009
Averaging Time - Threshold (Atn, hours)	306600	USEPA 2009

Key Chemical	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk $(mg/m^3)^{-1}$	Chronic TC air (mg/m^3)	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background) (mg/m^3)	in Air (Ca) (mg/m^3)	Inhalation Exposure Concentration - NonThreshold (mg/m^3)	Inhalation Exposure Concentration - Threshold (mg/m^3)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Sum Br1 to Br9 (min)		0.00035	80%	0.00007	1.4E-13		5.1E-14	--	7.30E-10
Sum Br1 to Br9 (max)		0.00035	80%	0.00007	2.4E-09		9.1E-10	--	1.30E-05
Sum Br1 to Br9 (mean)		0.00035	80%	0.00007	5.1E-11		1.9E-11	--	2.74E-07
Sum Br1 to Br9 (95th percentile)		0.00035	80%	0.00007	6.8E-11		2.6E-11	--	3.65E-07
Sum Br1 to Br9 (median)		0.00035	80%	0.00007	1.7E-12		6.4E-13	--	9.12E-09
Deca BDE (min)		0.02	80%	0.00400	1.7E-13		6.4E-14	--	1.60E-11
Deca BDE (max)		0.02	80%	0.00400	4.4E-11		1.7E-11	--	4.15E-09
Deca BDE (mean)		0.02	80%	0.00400	6.8E-12		2.6E-12	--	6.39E-10
DecaBDE (95th percentile)		0.02	80%	0.00400	3.1E-11		1.1E-11	--	2.87E-09
DecaBDE (median)		0.02	80%	0.00400	3.4E-12		1.3E-12	--	3.19E-10

Appendix G UPDATED Risk Calculations – PFAS

Exposure to Chemicals via Incidental Ingestion of Soil - Overall Dataset (Incorporated into Soil)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Maximum Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.001		6.7E-09	--	0.000370
PFOA		1.6E-04	10%	0.000144	0.005		3.3E-08	--	0.0002315

Average Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.0008		5.3E-09	--	0.0002963
PFOA		1.6E-04	10%	0.000144	0.0009		6.0E-09	--	0.0000417

95th Percentile

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.0008		5.3E-09	--	0.000296
PFOA		1.6E-04	10%	0.000144	0.002		1.3E-08	--	0.0000926

Median

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.0008		5.3E-09	--	0.000296
PFOA		1.6E-04	10%	0.000144	0.0008		5.3E-09	--	0.0000370

Exposure to Chemicals via Incidental Ingestion of Soil - Overall Dataset (Incorporated into Soil)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Maximum Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.001		7.1E-10	--	0.0000397
PFOA		1.6E-04	10%	0.000144	0.005		3.6E-09	--	0.00002480

Average Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.0008		5.7E-10	--	0.00003175
PFOA		1.6E-04	10%	0.000144	0.0009		6.4E-10	--	0.00000446

95th Percentile

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.0008		5.7E-10	--	0.0000317
PFOA		1.6E-04	10%	0.000144	0.002		1.4E-09	--	0.00000992

Median

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.0008		5.7E-10	--	0.0000317
PFOA		1.6E-04	10%	0.000144	0.0008		5.7E-10	--	0.00000397

Uptake of PFAS into Plants

Overall Data

C_{plant} = Csoil x Transfer Factor **(mg/kg fresh produce)**

Incorporated into Soil

Maximum Case

Key Chemical	Concentration in MWOO (C) (mg/kg)	Concentration in Soil when incorporated (Cs) (mg/kg)	Transfer Factor = (mg/kg in plant ww/dw)/(mg/kg soil)	Conversion Factor (dw to ww)	Concentration in Plant (mg/kg) wet weight
PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)	0.13	0.0010	2.2	0.15	0.0003300
Root Vegetables (based on wet weight)	0.13	0.0010	0.05	not required	0.0000500
Tuber Vegetables (based on wet weight)	0.13	0.0010	0.04	not required	0.0000400
Tree Fruit (incl Blueberries) (based on dry weight)	0.13	0.0010	0.07	0.15	0.0000105
Wheat (Cereals) (based on dry weight)	0.13	0.0010	0.5	0.15	0.0000750
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)	0.64	0.005	1.5	0.15	0.001108
Root Vegetables (based on wet weight)	0.64	0.005	0.05	not required	0.000246
Tuber Vegetables (based on wet weight)	0.64	0.005	0.1	not required	0.000492
Tree Fruit (incl Blueberries) (based on dry weight)	0.64	0.005	0.03	0.15	0.000022
Wheat (Cereals) (based on dry weight)	0.64	0.005	3.2	0.15	0.002363

Average Case

PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)	0.1	0.0008	2.2	0.15	0.0002538
Root Vegetables (based on wet weight)	0.1	0.0008	0.05	not required	0.0000385
Tuber Vegetables (based on wet weight)	0.1	0.0008	0.04	not required	0.00003077
Tree Fruit (incl Blueberries) (based on dry weight)	0.1	0.0008	0.07	0.15	0.00000808
Wheat (Cereals) (based on dry weight)	0.1	0.0008	0.5	0.15	0.0000577
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)	0.12	0.0009	1.5	0.15	0.0002077
Root Vegetables (based on wet weight)	0.12	0.0009	0.05	not required	0.0000462
Tuber Vegetables (based on wet weight)	0.12	0.0009	0.1	not required	0.0000923
Tree Fruit (incl Blueberries) (based on dry weight)	0.12	0.0009	0.03	0.15	0.00000415
Wheat (Cereals) (based on dry weight)	0.12	0.0009	3.2	0.15	0.000443

95th Percentile

PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)	0.11	0.0008	2.2	0.15	0.0002792
Root Vegetables (based on wet weight)	0.11	0.0008	0.05	not required	0.0000423
Tuber Vegetables (based on wet weight)	0.11	0.0008	0.04	not required	0.0000338
Tree Fruit (incl Blueberries) (based on dry weight)	0.11	0.0008	0.07	0.15	0.00000888
Wheat (Cereals) (based on dry weight)	0.11	0.0008	0.5	0.15	0.0000635
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)	0.3	0.002	1.5	0.15	0.000519
Root Vegetables (based on wet weight)	0.3	0.002	0.05	not required	0.000115
Tuber Vegetables (based on wet weight)	0.3	0.002	0.1	not required	0.000231
Tree Fruit (incl Blueberries) (based on dry weight)	0.3	0.002	0.03	0.15	0.000010
Wheat (Cereals) (based on dry weight)	0.3	0.002	3.2	0.15	0.001108

Median

PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)	0.1	0.0008	2.2	0.15	0.0002538
Root Vegetables (based on wet weight)	0.1	0.0008	0.05	not required	0.0000385
Tuber Vegetables (based on wet weight)	0.1	0.0008	0.04	not required	0.0000308
Tree Fruit (incl Blueberries) (based on dry weight)	0.1	0.0008	0.07	0.15	0.00000808
Wheat (Cereals) (based on dry weight)	0.1	0.0008	0.5	0.15	0.0000577
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)	0.1	0.001	1.5	0.15	0.000173
Root Vegetables (based on wet weight)	0.1	0.001	0.05	not required	0.000038
Tuber Vegetables (based on wet weight)	0.1	0.001	0.1	not required	0.000077
Tree Fruit (incl Blueberries) (based on dry weight)	0.1	0.001	0.03	0.15	0.000003
Wheat (Cereals) (based on dry weight)	0.1	0.001	3.2	0.15	0.000369

Intake of PFAS by chickens (treated soil ingestion)

Overall Data

$$Intake_{chicken} = \frac{C \; x \; IR \; x \; FI \; x \; B \; x \; EF \; x \; ED}{BW \; x \; AT}$$ (mg/kg/day)

$$C_{eggs} = Daily\ Intake_{chicken} \; x \; Transfer\ Factor$$ (mg/kg fresh produce)

	PFOS	PFOA	Units
Adjusted Egg to intake ratio =	37.5	17.1925	mg/kg edib/d / mg/kg bw-d
Egg to intake ratio as per study =	1	0.46	mg/edible egg-d / mg/d

Average weight of bird = 2 kg ; and average weight of egg without shell = 56g -d

Chicken

Exposure Parameters	Average	Reference
Chicken water ingestion rate (L/day)	0.32	ANZECC & ARMCANZ (2000)
Chicken soil ingestion rate (kg/day)	0.01	AECOM (2017)
Fraction of produce from site in diet (FI)	100%	Maximum possible
Exposure Frequency (EF, days/year)	365	Maximum possible
Exposure Duration (ED, years)	8	Professional Advice
Body Weight (BW, kg)	2	AECOM (2017)
Bioaccessibility (B)	100%	Maximum possible
Averaging Time - Threshold (Atn, days)	2920	ED*365
Laying Rate	0.96	

Incorporated into Soil

Scenario	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Daily intake (chickens) (mg/kg/day)	Ceggs (mg/kg) ww
Maximum Case				
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.001	**Not Applicable**	5.0E-06	2.0E-04
PFOA (PFOA + other acids like PFOA)	0.005		2.5E-05	4.5E-04
Average Case				
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.0008	**Not Applicable**	4.0E-06	1.6E-04
PFOA (PFOA + other acids like PFOA)	0.0009		4.5E-06	8.1E-05
95th Percentile				
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.0008	**Not Applicable**	4.0E-06	1.6E-04
PFOA (PFOA + other acids like PFOA)	0.002		1.0E-05	1.8E-04
Median				
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.0008	**Not Applicable**	3.8E-06	1.5E-04
PFOA (PFOA + other acids like PFOA)	0.0008		3.8E-06	6.9E-05

Exposure to PFAS in Produce - Children - Incorporated into Soil - Overall Data

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
green vegetables	0.055	as per PBDE assessment
root vegetables	0.017	as per PBDE assessment
tuber vegetables	0.028	as per PBDE assessment
tree fruit	0.18	as per PBDE assessment
wheat/oats/barley	0.038	as per PBDE assessment
eggs	0.036	as per PBDE assessment
Fraction Home-Grown Eggs (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Fruit, Wheat/Oats, Vegetables (FH	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.000330		4.2E-07	--	0.02353
Root Vegetables		2.0E-05	10%	0.000018	0.0000500		2.0E-08	--	0.001102
Tuber Vegetables		2.0E-05	10%	0.000018	0.0000400		2.6E-08	--	0.001452
Tree Fruit		2.0E-05	10%	0.000018	0.00001050		4.4E-08	--	0.00245
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000750		6.7E-08	--	0.00369
Eggs		2.0E-05	10%	0.000018	0.00019531		4.7E-07	--	0.02604
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.0011077		1.4E-06	--	0.009872
Root Vegetables		1.6E-04	10%	0.000144	0.0002462		9.8E-08	--	0.0006781
Tuber Vegetables		1.6E-04	10%	0.000144	0.0004923		3.2E-07	--	0.002234
Tree Fruit		1.6E-04	10%	0.000144	0.00002215		9.3E-08	--	0.0006462
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.002363		2.1E-06	--	0.01455
Eggs		1.6E-04	10%	0.000144	0.00044772		1.1E-06	--	0.0074620

Average Case

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.0002538		3.3E-07	--	0.01810
Root Vegetables		2.0E-05	10%	0.000018	0.0000385		1.5E-08	--	0.000848
Tuber Vegetables		2.0E-05	10%	0.000018	0.00003077		2.0E-08	--	0.001117
Tree Fruit		2.0E-05	10%	0.000018	0.00000808		3.4E-08	--	0.001885
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000577		5.1E-08	--	0.00284
Eggs		2.0E-05	10%	0.000018	0.00015625		3.8E-07	--	0.020833
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.00020769		2.4E-07	--	0.001635
Root Vegetables		1.6E-04	10%	0.000144	0.00004615		1.8E-08	--	0.000127
Tuber Vegetables		1.6E-04	10%	0.000144	0.00009231		6.0E-08	--	0.000419
Tree Fruit		1.6E-04	10%	0.000144	0.00000415		1.7E-08	--	0.000121
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.00044308		3.9E-07	--	0.00273
Eggs		1.6E-04	10%	0.000144	0.00008059		1.9E-07	--	0.001343

95th Percentile

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.0002792		3.6E-07	--	0.01991
Root Vegetables		2.0E-05	10%	0.000018	0.0000423		1.7E-08	--	0.000932
Tuber Vegetables		2.0E-05	10%	0.000018	0.0000338		2.2E-08	--	0.001228
Tree Fruit		2.0E-05	10%	0.000018	0.00000888		3.7E-08	--	0.002073
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000635		5.6E-08	--	0.00313
Eggs		2.0E-05	10%	0.000018	0.00015625		3.8E-07	--	0.020833
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.00051923		2.1E-07	--	0.001430
Root Vegetables		1.6E-04	10%	0.000144	0.00011538		4.6E-08	--	0.000318
Tuber Vegetables		1.6E-04	10%	0.000144	0.00023077		1.5E-07	--	0.00105
Tree Fruit		1.6E-04	10%	0.000144	0.00001038		4.4E-08	--	0.000303
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.00110769		9.8E-07	--	0.0068
Eggs		1.6E-04	10%	0.000144	0.00006888		1.7E-07	--	0.001148

Median

Key Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold TDI (mg/kg/day)	Toxicity Data: Background Intake (% TDI)	Toxicity Data: TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	Daily Intake: NonThreshold (mg/kg/day)	Daily Intake: Threshold (mg/kg/day)	Calculated Risk: Non-Threshold Risk (unitless)	Calculated Risk: Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.0002538		3.3E-07	--	0.0181
Root Vegetables		2.0E-05	10%	0.000018	0.0000385		1.5E-08	--	0.000848
Tuber Vegetables		2.0E-05	10%	0.000018	0.0000308		2.0E-08	--	0.00112
Tree Fruit		2.0E-05	10%	0.000018	0.0000081		3.4E-08	--	0.00188
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000577		5.1E-08	--	0.00284
Eggs		2.0E-05	10%	0.000018	0.0001502		3.6E-07	--	0.0200
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.00017308		6.9E-08	--	0.000477
Root Vegetables		1.6E-04	10%	0.000144	0.00003846		1.5E-08	--	0.000106
Tuber Vegetables		1.6E-04	10%	0.000144	0.00007692		5.0E-08	--	0.000349
Tree Fruit		1.6E-04	10%	0.000144	0.00000346		1.5E-08	--	0.000101
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.00036923		3.3E-07	--	0.00227
Eggs		1.6E-04	10%	0.000144	0.00006888		1.7E-07	--	0.00115

Exposure to PFAS in Produce - Adult - Incorporated into Soil - Overall Dataset

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure for Adults		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
green vegetables	0.15	as per PBDE assessment
root vegetables	0.05	as per PBDE assessment
tuber vegetables	0.06	as per PBDE assessment
tree fruit	0.14	as per PBDE assessment
wheat/oats/barley	0.095	as per PBDE assessment
eggs	0.059	as per PBDE assessment
Fraction Home-Grown Eggs (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Fruit, Wheat/Oats, Vegetables (FH	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.000330		2.5E-07	--	0.01375
Root Vegetables		2.0E-05	10%	0.000018	0.0000500		1.3E-08	--	0.000694
Tuber Vegetables		2.0E-05	10%	0.000018	0.0000400		1.2E-08	--	0.000667
Tree Fruit		2.0E-05	10%	0.000018	0.00001050		7.4E-09	--	0.00041
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000750		3.6E-08	--	0.00198
Eggs		2.0E-05	10%	0.000018	0.00019531		1.6E-07	--	0.00915
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.0011077		8.3E-07	--	0.005769
Root Vegetables		1.6E-04	10%	0.000144	0.0002462		6.2E-08	--	0.0004274
Tuber Vegetables		1.6E-04	10%	0.000144	0.0004923		1.5E-07	--	0.001026
Tree Fruit		1.6E-04	10%	0.000144	0.00002215		1.6E-08	--	0.0001077
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.002363		1.1E-06	--	0.00779
Eggs		1.6E-04	10%	0.000144	0.00044772		3.8E-07	--	0.0026206

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.0002538		1.9E-07	--	0.01058
Root Vegetables		2.0E-05	10%	0.000018	0.0000385		9.6E-09	--	0.000534
Tuber Vegetables		2.0E-05	10%	0.000018	0.00003077		9.2E-09	--	0.000513
Tree Fruit		2.0E-05	10%	0.000018	0.00000808		5.7E-09	--	0.0003141
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000577		7.8E-08	--	0.00435
Eggs		2.0E-05	10%	0.000018	0.00015625		1.3E-07	--	0.007316
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.00020769		1.5E-07	--	0.00103
Root Vegetables		1.6E-04	10%	0.000144	0.00004615		1.2E-08	--	0.0000801
Tuber Vegetables		1.6E-04	10%	0.000144	0.00009231		2.8E-08	--	0.0001923
Tree Fruit		1.6E-04	10%	0.000144	0.00000415		2.9E-09	--	0.0000202
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.00044308		6.0E-07	--	0.00418
Eggs		1.6E-04	10%	0.000144	0.00008059		6.8E-08	--	0.0004717

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.0002792		2.1E-07	--	0.01163
Root Vegetables		2.0E-05	10%	0.000018	0.0000423		1.1E-08	--	0.000588
Tuber Vegetables		2.0E-05	10%	0.000018	0.0000338		1.0E-08	--	0.000564
Tree Fruit		2.0E-05	10%	0.000018	0.00000888		6.2E-09	--	0.000346
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000635		8.6E-08	--	0.00478
Eggs		2.0E-05	10%	0.000018	0.00015625		1.3E-07	--	0.007316
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.00051923		5.9E-11	--	0.0000004121
Root Vegetables		1.6E-04	10%	0.000144	0.00011538		1.3E-11	--	0.0000000916
Tuber Vegetables		1.6E-04	10%	0.000144	0.00023077		3.2E-11	--	0.0000002198
Tree Fruit		1.6E-04	10%	0.000144	0.00001038		3.3E-12	--	0.0000000231
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.00110769		1.5E-06	--	0.0104
Eggs		1.6E-04	10%	0.000144	0.00006888		5.8E-08	--	0.000403

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Green Vegetables		2.0E-05	10%	0.000018	0.0002538		1.9E-07	--	0.01058
Root Vegetables		2.0E-05	10%	0.000018	0.0000385		9.6E-09	--	0.000534
Tuber Vegetables		2.0E-05	10%	0.000018	0.0000308		9.2E-09	--	0.000513
Tree Fruit		2.0E-05	10%	0.000018	0.00000808		5.7E-09	--	0.000314
Wheat/Oats/Barley		2.0E-05	10%	0.000018	0.0000577		7.8E-08	--	0.00435
Eggs		2.0E-05	10%	0.000018	0.0001502		1.3E-07	--	0.007035
PFOA (PFOA + other acids like PFOA)									
Green Vegetables		1.6E-04	10%	0.000144	0.0001731		2.0E-11	--	0.0000001374
Root Vegetables		1.6E-04	10%	0.000144	0.00003846		4.4E-12	--	0.0000000305
Tuber Vegetables		1.6E-04	10%	0.000144	0.00007692		1.1E-11	--	0.0000000733
Tree Fruit		1.6E-04	10%	0.000144	0.00000346		1.1E-12	--	0.0000000077
Wheat/Oats/Barley		1.6E-04	10%	0.000144	0.00036923		5.0E-07	--	0.00348
Eggs		1.6E-04	10%	0.000144	0.00006888		5.8E-08	--	0.000403

Exposure to Chemicals via Incidental Ingestion of Soil - Overall Dataset (Unincorporated)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Maximum Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.13		8.7E-07	--	0.0481
PFOA		1.6E-04	10%	0.000144	0.64		4.3E-06	--	0.02963

Average Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.1		6.7E-07	--	0.0370
PFOA		1.6E-04	10%	0.000144	0.12		8.0E-07	--	0.00556

95th Percentile

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.11		7.3E-07	--	0.0407
PFOA		1.6E-04	10%	0.000144	0.3		2.0E-06	--	0.01389

Median

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.1		6.7E-07	--	0.0370
PFOA		1.6E-04	10%	0.000144	0.1		6.7E-07	--	0.00463

Exposure to Chemicals via Incidental Ingestion of Soil - Overall Dataset (Unincorporated)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Maximum Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.13		9.3E-08	--	0.00516
PFOA		1.6E-04	10%	0.000144	0.64		4.6E-07	--	0.003175

Average Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.1		7.1E-08	--	0.00397
PFOA		1.6E-04	10%	0.000144	0.12		8.6E-08	--	0.000595

95th Percentile

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.11		7.9E-08	--	0.00437
PFOA		1.6E-04	10%	0.000144	0.3		2.1E-07	--	0.001488

Median

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.1		7.1E-08	--	0.00397
PFOA		1.6E-04	10%	0.000144	0.1		7.1E-08	--	0.000496

Exposure to Chemicals via Incidental Ingestion of Soil - Overall Dataset (Trampled)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

Maximum Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.005		3.3E-08	--	0.0019
PFOA		1.6E-04	10%	0.000144	0.025		1.6E-07	--	0.00114

Average Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.004		2.6E-08	--	0.0014
PFOA		1.6E-04	10%	0.000144	0.005		3.1E-08	--	0.00021

95th Percentile

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.004		2.8E-08	--	0.0016
PFOA		1.6E-04	10%	0.000144	0.01		7.7E-08	--	0.00053

Median

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.004		2.6E-08	--	0.0014
PFOA		1.6E-04	10%	0.000144	0.004		2.6E-08	--	0.00018

Exposure to Chemicals via Incidental Ingestion of Soil - Overall Dataset (Trampled)

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults		
Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

Maximum Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.005		3.6E-09	--	0.0001984
PFOA		1.6E-04	10%	0.000144	0.025		1.8E-08	--	0.0001221

Average Case

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.004		2.7E-09	--	0.0001526
PFOA		1.6E-04	10%	0.000144	0.005		3.3E-09	--	0.0000229

95th Perecentile

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.004		3.0E-09	--	0.0001679
PFOA		1.6E-04	10%	0.000144	0.012		8.2E-09	--	0.0000572

Median

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS + PFHxS		2.0E-05	10%	0.000018	0.004		2.7E-09	--	0.0001526
PFOA		1.6E-04	10%	0.000144	0.004		2.7E-09	--	0.0000191

Intake of Chemicals by Dairy Cows (fodder grown in treated soil, treated soil ingestion)

Overall Data - 183 days per year present in treated area

$$Intake_{dairy\,cow} = \frac{C \times IR \times FI \times B \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

$$C_{milk} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

	PFOS	PFOA	Units
Water to fodder ratio =	3.5	3.5	mg/kg (plant) (ww) / mg/L (water)
Soil to fodder ratio =	0.5	3.2	mg/kg (plant) (dw) / mg/kg dw (soil)
Milk to intake ratio =	8.5	0.04	mg/kg (milk) / mg/kg bw-d (intake of cow)

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	70	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	1	Maximum possible
Exposure Frequency (EF, days/year)	183	Maximum possible
Exposure Duration (ED, years)	4	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B)	1	Maximum possible
Averaging Time - Threshold (Atn, days)	1460	ED*365

Unincorporated - No Dilution

Calculations for PFOS+PFHxS, PFOA	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in milk (mg/kg)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	2.0E-04	1.7E-03
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	6.2E-03	2.5E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	6.5E-05	5.5E-04
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	3.2E-04	1.3E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)				2.2E-03
PFOA (PFOA + other acids like PFOA)				2.6E-04
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.5E-04	1.3E-03
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	1.2E-03	4.6E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	5.0E-05	4.3E-04
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	6.0E-05	2.4E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)			2.0E-04	1.7E-03
PFOA (PFOA + other acids like PFOA)			1.2E-03	4.9E-05
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	1.7E-04	1.4E-03
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	2.9E-03	1.2E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	5.5E-05	4.7E-04
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	1.5E-04	6.0E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				1.9E-03
PFOA (PFOA + other acids like PFOA)				1.2E-04
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.5E-04	1.3E-03
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	9.6E-04	3.9E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	5.0E-05	4.3E-04
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	5.0E-05	2.0E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				1.7E-03
PFOA (PFOA + other acids like PFOA)				4.1E-05

Unincorporated - Trampled

Calculations for PFOS+PFHxS, PFOA	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in milk (mg/kg)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	7.5E-06	6.4E-05
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	1.9E-04	7.7E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	2.5E-06	2.1E-05
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	1.0E-05	4.0E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				8.5E-05
PFOA (PFOA + other acids like PFOA)				8.1E-06
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	6.0E-06	5.1E-05
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	4.8E-05	1.9E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	2.0E-06	1.7E-05
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	2.5E-06	1.0E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)			8.0E-06	6.8E-05
PFOA (PFOA + other acids like PFOA)			5.1E-05	2.0E-06
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	6.0E-06	5.1E-05
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	9.6E-05	3.9E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	2.0E-06	1.7E-05
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	5.0E-06	2.0E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				6.8E-05
PFOA (PFOA + other acids like PFOA)				4.1E-06
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	6.0E-06	5.1E-05
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	3.9E-05	1.5E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	2.0E-06	1.7E-05
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	2.0E-06	8.0E-08
Combined				
PFOS (PFOS + other sulfonates like PFOS)				6.8E-05
PFOA (PFOA + other acids like PFOA)				1.6E-06

Intake of Chemicals by Dairy Cows (fodder grown in treated soil, treated soil ingestion)

Overall Data - 52 days per year in treated area

$$Intake_{dairy\,cow} = \frac{C \times IR \times FI \times B \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

$$C_{milk} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

	PFOS	PFOA	Units
Water to fodder ratio =	3.5	3.5	mg/kg (plant) (ww) / mg/L (water)
Soil to fodder ratio =	0.5	3.2	mg/kg (plant) (dw) / mg/kg dw (soil)
Milk to intake ratio =	8.5	0.04	mg/kg (milk) / mg/kg bw-d (intake of cow)

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	70	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	1	Maximum possible
Exposure Frequency (EF, days/year)	52	Maximum possible
Exposure Duration (ED, years)	4	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B)	1	Maximum possible
Averaging Time - Threshold (Atn, days)	1460	ED*365

Unincorporated - No Dilution

Calculations for PFOS+PFHxS, PFOA	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in milk (mg/kg)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	5.6E-05	4.7E-04
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	1.8E-03	7.0E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	1.9E-05	1.6E-04
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	9.1E-05	3.6E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				6.3E-04
PFOA (PFOA + other acids like PFOA)				7.4E-05
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	4.3E-05	3.6E-04
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	3.3E-04	1.3E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.4E-05	1.2E-04
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	1.7E-05	6.8E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)			5.7E-05	4.8E-04
PFOA (PFOA + other acids like PFOA)			3.5E-04	1.4E-05
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	4.7E-05	4.0E-04
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	8.2E-04	3.3E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	1.6E-05	1.3E-04
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	4.3E-05	1.7E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				5.3E-04
PFOA (PFOA + other acids like PFOA)				3.5E-05
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	4.3E-05	3.6E-04
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	2.7E-04	1.1E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.4E-05	1.2E-04
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	1.4E-05	5.7E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				4.8E-04
PFOA (PFOA + other acids like PFOA)				1.2E-05

Unincorporated - Trampled

Calculations for PFOS+PFHxS, PFOA	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in milk (mg/kg)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	2.1E-06	1.8E-05
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	5.5E-05	2.2E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	7.1E-07	6.1E-06
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	2.8E-06	1.1E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				2.4E-05
PFOA (PFOA + other acids like PFOA)				2.3E-06
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	1.7E-06	1.5E-05
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	1.4E-05	5.5E-07
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	5.7E-07	4.8E-06
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	7.1E-07	2.8E-08
Combined				
PFOS (PFOS + other sulfonates like PFOS)			2.3E-06	1.9E-05
PFOA (PFOA + other acids like PFOA)			1.4E-05	5.8E-07
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	1.7E-06	1.5E-05
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	2.7E-05	1.1E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	5.7E-07	4.8E-06
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	1.4E-06	5.7E-08
Combined				
PFOS (PFOS + other sulfonates like PFOS)				1.9E-05
PFOA (PFOA + other acids like PFOA)				1.2E-06
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	1.7E-06	1.5E-05
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	1.1E-05	4.4E-07
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	5.7E-07	4.8E-06
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	5.7E-07	2.3E-08
Combined				
PFOS (PFOS + other sulfonates like PFOS)				1.9E-05
PFOA (PFOA + other acids like PFOA)				4.6E-07

Intake of Chemicals by Cattle (fodder grown in treated soil, treated soil ingestion)

Overall Data - 183 days per year present in treated area

$$Intake_{beef\ cattle} = \frac{C \times IR \times FI \times B \times EF \times ED}{BW \times AT} \quad \text{(mg/kg/day)}$$

$$C_{meat} = (DailyIntake)_{cattle} \bullet (TransferFactor)$$

	PFOS	PFOA	Units
Water to fodder ratio =	3.5	3.5	mg/kg (plant) (ww) / mg/L (water)
Soil to fodder ratio =	0.5	3.2	mg/kg (plant) (dw) / mg/kg dw (soil)
Meat to intake ratio =	41	0.3	mg/kg ww (meat) / mg/kg bw-d (intake of cattle)

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	1	Maximum possible
Exposure Frequency (EF, days/year)	183	Maximum possible
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B)	1	Maximum possible
Averaging Time - Threshold (Atn, days)	730	ED*365

Unincorporated - No Dilution

Scenario	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in meat (mg/kg ww)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	2.0E-04	8.0E-03
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	6.2E-03	1.8E-03
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	6.5E-05	2.7E-03
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	3.2E-04	9.6E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)				1.1E-02
PFOA (PFOA + other acids like PFOA)				1.9E-03
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.5E-04	6.2E-03
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	1.2E-03	3.5E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	5.0E-05	2.1E-03
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	6.0E-05	1.8E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)			2.0E-04	8.2E-03
PFOA (PFOA + other acids like PFOA)			1.2E-03	3.6E-04
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	1.7E-04	6.8E-03
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	2.9E-03	8.7E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	5.5E-05	2.3E-03
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	1.5E-04	4.5E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)				9.0E-03
PFOA (PFOA + other acids like PFOA)				9.1E-04
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.5E-04	6.2E-03
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	9.6E-04	2.9E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	5.0E-05	2.1E-03
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	5.0E-05	1.5E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)				8.2E-03
PFOA (PFOA + other acids like PFOA)				3.0E-04

Unincorporated - Trampled

Scenario	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in meat (mg/kg ww)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	7.5E-06	3.1E-04
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	1.9E-04	5.8E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	2.5E-06	1.0E-04
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	1.0E-05	3.0E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				4.1E-04
PFOA (PFOA + other acids like PFOA)				6.1E-05
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	6.0E-06	2.5E-04
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	4.8E-05	1.4E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	2.0E-06	8.2E-05
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	2.5E-06	7.5E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)			8.0E-06	3.3E-04
PFOA (PFOA + other acids like PFOA)			5.1E-05	1.5E-05
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	6.0E-06	2.5E-04
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	9.6E-05	2.9E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	2.0E-06	8.2E-05
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	5.0E-06	1.5E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				3.3E-04
PFOA (PFOA + other acids like PFOA)				3.0E-05
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	6.0E-06	2.5E-04
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	3.9E-05	1.2E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	2.0E-06	8.2E-05
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	2.0E-06	6.0E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				3.3E-04
PFOA (PFOA + other acids like PFOA)				1.2E-05

Intake of Chemicals by Cattle (fodder grown in treated soil, treated soil ingestion)

Overall Data - 52 days per year in treated area

$$Intake_{beef\ cattle} = \frac{C\ x\ IR\ x\ FI\ x\ B\ x\ EF\ x\ ED}{BW\ x\ AT} \quad \text{(mg/kg/day)}$$

$$C_{meat} = (DailyIntake)_{cattle} \bullet (TransferFactor)$$

	PFOS	PFOA	Units
Water to fodder ratio =	3.5	3.5	mg/kg (plant) (ww) / mg/L (water)
Soil to fodder ratio =	0.5	3.2	mg/kg (plant) (dw) / mg/kg dw (soil)
Meat to intake ratio =	41	0.3	mg/kg ww (meat) / mg/kg bw-d (intake of cattle)

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC & ARMCANZ (2000)
Cattle fodder ingestion rate (kg/day)	20	ANZECC & ARMCANZ (2000)
Cattle soil ingestion rate (kg/day)	0.5	USEPA (2005)
CF (dw to ww)	0.15	Assumption 15% dry matter
Fraction of produce from site in diet (FI)	1	Maximum possible
Exposure Frequency (EF, days/year)	52	Maximum possible
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B)	1	Maximum possible
Averaging Time - Threshold (Atn, days)	730	ED*365

Unincorporated - No Dilution

Scenario	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in meat (mg/kg ww)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	5.6E-05	2.3E-03
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	1.8E-03	5.3E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.130	Not Relevant	1.9E-05	7.6E-04
PFOA (PFOA + other acids like PFOA)	0.640	Not Relevant	9.1E-05	2.7E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)				3.0E-03
PFOA (PFOA + other acids like PFOA)				5.5E-04
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	4.3E-05	1.8E-03
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	3.3E-04	9.8E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.4E-05	5.8E-04
PFOA (PFOA + other acids like PFOA)	0.120	Not Relevant	1.7E-05	5.1E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)			5.7E-05	2.3E-03
PFOA (PFOA + other acids like PFOA)			3.5E-04	1.0E-04
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	4.7E-05	1.9E-03
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	8.2E-04	2.5E-04
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.110	Not Relevant	1.6E-05	6.4E-04
PFOA (PFOA + other acids like PFOA)	0.300	Not Relevant	4.3E-05	1.3E-05
Combined				
PFOS (PFOS + other sulfonates like PFOS)				2.6E-03
PFOA (PFOA + other acids like PFOA)				2.6E-04
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	4.3E-05	1.8E-03
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	2.7E-04	8.2E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.100	Not Relevant	1.4E-05	5.8E-04
PFOA (PFOA + other acids like PFOA)	0.100	Not Relevant	1.4E-05	4.3E-06
Combined				
PFOS (PFOS + other sulfonates like PFOS)				2.3E-03
PFOA (PFOA + other acids like PFOA)				8.6E-05

Unincorporated - Trampled

Scenario	Concentration in soil (mg/kg)	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in meat (mg/kg ww)
Maximum Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	2.1E-06	8.8E-05
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	5.5E-05	1.6E-05
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.005	Not Relevant	7.1E-07	2.9E-05
PFOA (PFOA + other acids like PFOA)	0.020	Not Relevant	2.8E-06	8.5E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				1.2E-04
PFOA (PFOA + other acids like PFOA)				1.7E-05
Average Case				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	1.7E-06	7.0E-05
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	1.4E-05	4.1E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	5.7E-07	2.3E-05
PFOA (PFOA + other acids like PFOA)	0.005	Not Relevant	7.1E-07	2.1E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)			2.3E-06	9.3E-05
PFOA (PFOA + other acids like PFOA)			1.4E-05	4.3E-06
95th Percentile				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	1.7E-06	7.0E-05
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	2.7E-05	8.2E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	5.7E-07	2.3E-05
PFOA (PFOA + other acids like PFOA)	0.010	Not Relevant	1.4E-06	4.3E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				9.3E-05
PFOA (PFOA + other acids like PFOA)				8.6E-06
Median				
MWOO in Soil - Uptake from Fodder				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	1.7E-06	7.0E-05
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	1.1E-05	3.3E-06
MWOO in Soil - Uptake from Soil				
PFOS (PFOS + other sulfonates like PFOS)	0.004	Not Relevant	5.7E-07	2.3E-05
PFOA (PFOA + other acids like PFOA)	0.004	Not Relevant	5.7E-07	1.7E-07
Combined				
PFOS (PFOS + other sulfonates like PFOS)				9.3E-05
PFOA (PFOA + other acids like PFOA)				3.5E-06

Exposure to PFAS in Produce - Children - Unincorporated - Overall Data (Cattle Present on treated area 183 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.097	as per PBDE assessment
meat	0.085	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00222		1.6E-04	--	9.00
Meat		2.0E-05	10%	0.000018	0.01069		2.1E-05	--	1.178
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0002593		1.9E-05	--	0.1317
Meat		1.6E-04	10%	0.000144	0.001945		3.9E-06	--	0.02678

Average Case

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00170		1.2E-04	--	6.93
Meat		2.0E-05	10%	0.000018	0.00822		1.6E-05	--	0.906
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000486		3.6E-06	--	0.0247
Meat		1.6E-04	10%	0.000144	0.000365		7.2E-07	--	0.00502

95th Percentile

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00188		1.4E-04	--	7.62
Meat		2.0E-05	10%	0.000018	0.00904		1.8E-05	--	0.997
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0001215		8.9E-06	--	0.0617
Meat		1.6E-04	10%	0.000144	0.000911		1.8E-06	--	0.0126

Median

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	Concentration in Produce (mg/kg ww)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00170		1.2E-04	--	6.93
Meat		2.0E-05	10%	0.000018	0.00822		1.6E-05	--	0.906
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000405		3.0E-06	--	0.0206
Meat		1.6E-04	10%	0.000144	0.000304		6.0E-07	--	0.00418

Exposure to PFAS in Produce - Children - Unincorporated - Overall Data (Cattle Present on treated area 52 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.097	as per PBDE assessment
meat	0.085	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000630		4.6E-05	--	2.56
Meat		2.0E-05	10%	0.000018	0.00304		6.0E-06	--	0.335
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000737		5.4E-06	--	0.0374
Meat		1.6E-04	10%	0.000144	0.000553		1.1E-06	--	0.00761

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000484		3.5E-05	--	1.97
Meat		2.0E-05	10%	0.000018	0.00234		4.6E-06	--	0.257
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000138		1.0E-06	--	0.00702
Meat		1.6E-04	10%	0.000144	0.0001036		2.1E-07	--	0.001427

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000533		3.9E-05	--	2.16
Meat		2.0E-05	10%	0.000018	0.00257		5.1E-06	--	0.283
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000345		2.5E-06	--	0.0175
Meat		1.6E-04	10%	0.000144	0.000259		5.1E-07	--	0.0036

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000484		3.5E-05	--	1.97
Meat		2.0E-05	10%	0.000018	0.00234		4.6E-06	--	0.257
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000115		8.4E-07	--	0.00585
Meat		1.6E-04	10%	0.000144	0.0000863		1.7E-07	--	0.001189

Exposure to PFAS in Produce - Adult - Unincorporated - Overall Dataset (Cattle Present on treated area 183 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

Parameters Relevant to Quantification of Exposure for Adults		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.295	as per PBDE assessment
meat	0.163	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00222		4.1E-05	--	2.28
Meat		2.0E-05	10%	0.000018	0.01069		8.7E-06	--	0.484
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0002593		4.8E-06	--	0.03331
Meat		1.6E-04	10%	0.000144	0.001945		1.6E-06	--	0.011005

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00170		3.2E-05	--	1.75
Meat		2.0E-05	10%	0.000018	0.00822		6.7E-06	--	0.372
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000486		9.0E-07	--	0.006245
Meat		1.6E-04	10%	0.000144	0.000365		3.0E-07	--	0.002064

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00188		3.5E-05	--	1.93
Meat		2.0E-05	10%	0.000018	0.00904		7.4E-06	--	0.410
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0001215		2.2E-06	--	0.01561
Meat		1.6E-04	10%	0.000144	0.000911		7.4E-07	--	0.005159

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.00170		3.2E-05	--	1.75
Meat		2.0E-05	10%	0.000018	0.00822		6.7E-06	--	0.372
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000405		7.5E-07	--	0.00520
Meat		1.6E-04	10%	0.000144	0.000304		2.5E-07	--	0.00172

Exposure to PFAS in Produce - Adult - Unincorporated - Overall Dataset (Cattle Present on treated area 52 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

Parameters Relevant to Quantification of Exposure for Adults		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.295	as per PBDE assessment
meat	0.163	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000630		1.2E-05	--	0.647
Meat		2.0E-05	10%	0.000018	0.00304		2.5E-06	--	0.1375
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000737		1.4E-06	--	0.00946
Meat		1.6E-04	10%	0.000144	0.0005525		4.5E-07	--	0.003127

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000484		9.0E-06	--	0.4978
Meat		2.0E-05	10%	0.000018	0.00234		1.9E-06	--	0.1058
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000138		2.6E-07	--	0.001775
Meat		1.6E-04	10%	0.000144	0.0001036		8.4E-08	--	0.000586

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000533		9.9E-06	--	0.5476
Meat		2.0E-05	10%	0.000018	0.00257		2.1E-06	--	0.1164
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000345		6.4E-07	--	0.00444
Meat		1.6E-04	10%	0.000144	0.0002590		2.1E-07	--	0.001466

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000484		9.0E-06	--	0.4978
Meat		2.0E-05	10%	0.000018	0.00234		1.9E-06	--	0.1058
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.0000115		2.1E-07	--	0.00148
Meat		1.6E-04	10%	0.000144	0.0000863		7.0E-08	--	0.00049

Exposure to PFAS in Produce - Children - Overall Dataset (Trampled - Cattle Present on treated area 183 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.097	as per PBDE assessment
meat	0.085	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000085		6.2E-06	--	0.346298
Meat		2.0E-05	10%	0.000018	0.000411		8.2E-07	--	0.045300
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000810		5.9E-07	--	0.004115
Meat		1.6E-04	10%	0.000144	0.0000608		1.2E-07	--	0.000837

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000682		5.0E-06	--	0.27704
Meat		2.0E-05	10%	0.000018	0.000329		6.5E-07	--	0.03624
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.000002026		1.5E-07	--	0.00103
Meat		1.6E-04	10%	0.000144	0.00001519		3.0E-08	--	0.0002092

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000682		5.0E-06	--	0.2770
Meat		2.0E-05	10%	0.000018	0.000329		6.5E-07	--	0.0362
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000405		3.0E-07	--	0.00206
Meat		1.6E-04	10%	0.000144	0.0000304		6.0E-08	--	0.000418

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000682		5.0E-06	--	0.2770
Meat		2.0E-05	10%	0.000018	0.000329		6.5E-07	--	0.0362
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000162		1.2E-07	--	0.00082
Meat		1.6E-04	10%	0.000144	0.0000122		2.4E-08	--	0.000167

Exposure to PFAS in Produce - Children - Overall Dataset (Trampled - Cattle Present on treated area 52 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.097	as per PBDE assessment
meat	0.085	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000242		1.8E-06	--	0.098402
Meat		2.0E-05	10%	0.000018	0.0001168		2.3E-07	--	0.012872
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000230		1.7E-07	--	0.001169
Meat		1.6E-04	10%	0.000144	0.0000173		3.4E-08	--	0.000238

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000194		1.4E-06	--	0.07872
Meat		2.0E-05	10%	0.000018	0.0000935		1.9E-07	--	0.01030
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.000000576		4.2E-08	--	0.000292
Meat		1.6E-04	10%	0.000144	0.000004317		8.6E-09	--	0.0000595

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000194		1.4E-06	--	0.0787
Meat		2.0E-05	10%	0.000018	0.0000935		1.9E-07	--	0.0103
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000115		8.4E-08	--	0.00058
Meat		1.6E-04	10%	0.000144	0.00000863		1.7E-08	--	0.000119

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000194		1.4E-06	--	0.0787
Meat		2.0E-05	10%	0.000018	0.0000935		1.9E-07	--	0.0103
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.000000460		3.4E-08	--	0.00023
Meat		1.6E-04	10%	0.000144	0.00000345		6.8E-09	--	0.000048

Exposure to PFAS in Produce - Adult - Overall Dataset (Trampled - Cattle Present on treated area 183 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

Parameters Relevant to Quantification of Exposure for Adults		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.295	as per PBDE assessment
meat	0.163	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.000085		1.6E-06	--	0.08760
Meat		2.0E-05	10%	0.000018	0.000411		3.4E-07	--	0.01861
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000810		1.5E-07	--	0.0010409
Meat		1.6E-04	10%	0.000144	0.0000608		5.0E-08	--	0.0003439

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000682		1.3E-06	--	0.0701
Meat		2.0E-05	10%	0.000018	0.000329		2.7E-07	--	0.0149
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.000002026		3.7E-08	--	0.000260
Meat		1.6E-04	10%	0.000144	0.00001519		1.2E-08	--	0.0000860

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000682		1.3E-06	--	0.0701
Meat		2.0E-05	10%	0.000018	0.000329		2.7E-07	--	0.0149
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000405		7.5E-08	--	0.00052
Meat		1.6E-04	10%	0.000144	0.0000304		2.5E-08	--	0.000172

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000682		1.3E-06	--	0.0701
Meat		2.0E-05	10%	0.000018	0.000329		2.7E-07	--	0.0149
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000162		3.0E-08	--	0.000208
Meat		1.6E-04	10%	0.000144	0.0000122		9.9E-09	--	0.0000688

Exposure to PFAS in Produce - Adult - Overall Dataset (Trampled - Cattle Present on treated area 52 days per year)

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ **(mg/kg/day)**

Parameters Relevant to Quantification of Exposure for Adults		
Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
milk	1.295	as per PBDE assessment
meat	0.163	as per PBDE assessment
Fraction Home-Grown Milk (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Meat (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000242		4.5E-07	--	0.02489
Meat		2.0E-05	10%	0.000018	0.0001168		9.5E-08	--	0.00529
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000230		4.3E-08	--	0.0002958
Meat		1.6E-04	10%	0.000144	0.00001727		1.4E-08	--	0.0000977

Average Case

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000194		3.6E-07	--	0.0199
Meat		2.0E-05	10%	0.000018	0.0000935		7.6E-08	--	0.00423
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.000000576		1.1E-08	--	0.0000739
Meat		1.6E-04	10%	0.000144	0.00000432		3.5E-09	--	0.0000244

95th Percentile

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000194		3.6E-07	--	0.0199
Meat		2.0E-05	10%	0.000018	0.0000935		7.6E-08	--	0.00423
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.00000115		2.1E-08	--	0.000148
Meat		1.6E-04	10%	0.000144	0.00000863		7.0E-09	--	0.0000489

Median

Key Chemical	Toxicity Data				Concentration in Produce	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Milk		2.0E-05	10%	0.000018	0.0000194		3.6E-07	--	0.0199
Meat		2.0E-05	10%	0.000018	0.0000935		7.6E-08	--	0.00423
PFOA (PFOA + other acids like PFOA)									
Milk		1.6E-04	10%	0.000144	0.000000460		8.5E-09	--	0.0000592
Meat		1.6E-04	10%	0.000144	0.000003453		2.8E-09	--	0.0000195