Local Government Air Quality Toolkit

Crematoria emissions guidance note

Information on the cremation process and management measures to reduce emissions from council regulated crematoria

NSW GOVERNMENT

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

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1. Introduction

1.1 Industry overview

This guidance note provides general information on the cremation process, emissions to air from these activities and management measures to reduce air emissions from crematoria. It does not cover waste management or work health and safety.

Crematoria are not a scheduled activity under the *Protection of the Environment Operations Act 1997* (the POEO Act) and so do not require an environment protection licence (EPL). For most crematoria, local government is the appropriate regulatory authority (ARA) for the purposes of the POEO Act and the regulation of environmental and human health impacts. There are a small number of crematoria operated on Crown land, including Sydney Crematorium (managed by Catholic Metropolitan Cemeteries Trust), Western Sydney Crematorium (Rockwood Necropolis Land Manager), and Macquarie Park Crematorium and Eastern Suburbs Memorial Park (Metropolitan Memorial Parks Land Manager). The NSW Environment Protection Authority (EPA) is the ARA for Crown crematoria for the purposes of the POEO Act, as the activities are carried on by the State, per s 6(2)(c) of the POEO Act.

Cemeteries & Crematoria NSW is the regulatory authority for the operation of crematoria under the *Cemeteries and Crematoria Act 2013* and Cemeteries and Crematoria Regulation 2022. Crematoria are required to hold a licence from Cemeteries & Crematoria NSW to operate in New South Wales.

The location, operational status and contact details of crematoria in New South Wales is available on the *Find a cemetery or crematorium* webpage (Cemeteries & Crematoria NSW 2024).

Cremation is a combustion process whereby a casket and human remains (or animal remains in a pet crematorium) are incinerated at a high temperature in a closed chamber. In recent years the industry has experienced growth due to changing funeral customs and preferences, as more people opt for cremation over traditional burial.

The environmental management of emissions to air from crematoria, including the mitigation of any off-site impacts or nuisance caused by those emissions, is the responsibility of the site owner and operator in the first instance.

1.2 Process description

Cremators can vary in age, model and type. Each cremator has a primary and a secondary chamber, which are lined with refractory bricks that can withstand the high temperatures (up to 1,100°C) required for the cremation process, and a cooling tray (Figure 1).

Each combustion chamber is fitted with a burner. Once the temperature in the secondary chamber reaches 300–800°C (after a preheating by the support fuel at 850°C), the primary chamber is heated, reaching a temperature of 300–800°C. The primary chamber may have air lances to break up the main burner and promote combustion. Air lancing removes or cuts away loose material using compressed air and is used to prevent blockages to maintain good airflow. The combustion gases from the primary chamber are then fed into the compartmentalised secondary chamber, which is heated with afterburners and supplied with secondary air to complete combustion. The secondary chamber (also known as the afterburner) incinerates the waste gases from the primary chamber, ensuring that smoke, odour and other air emissions are minimised. The secondary chamber has a typical residence time for the gases of 1–2 seconds (DSEWPAC 2011).

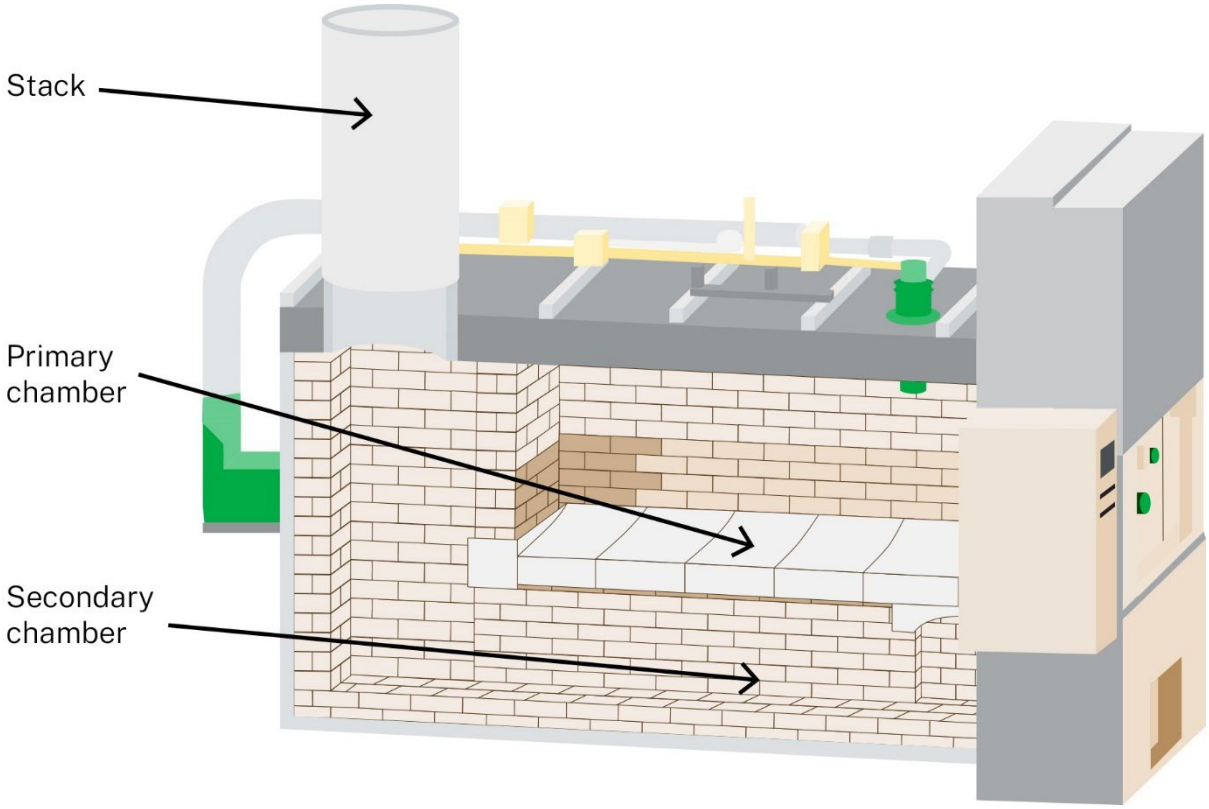

Figure 1 **Typical configuration of a crematory system**

Figure 2 shows the movement of gases through a cremation system.

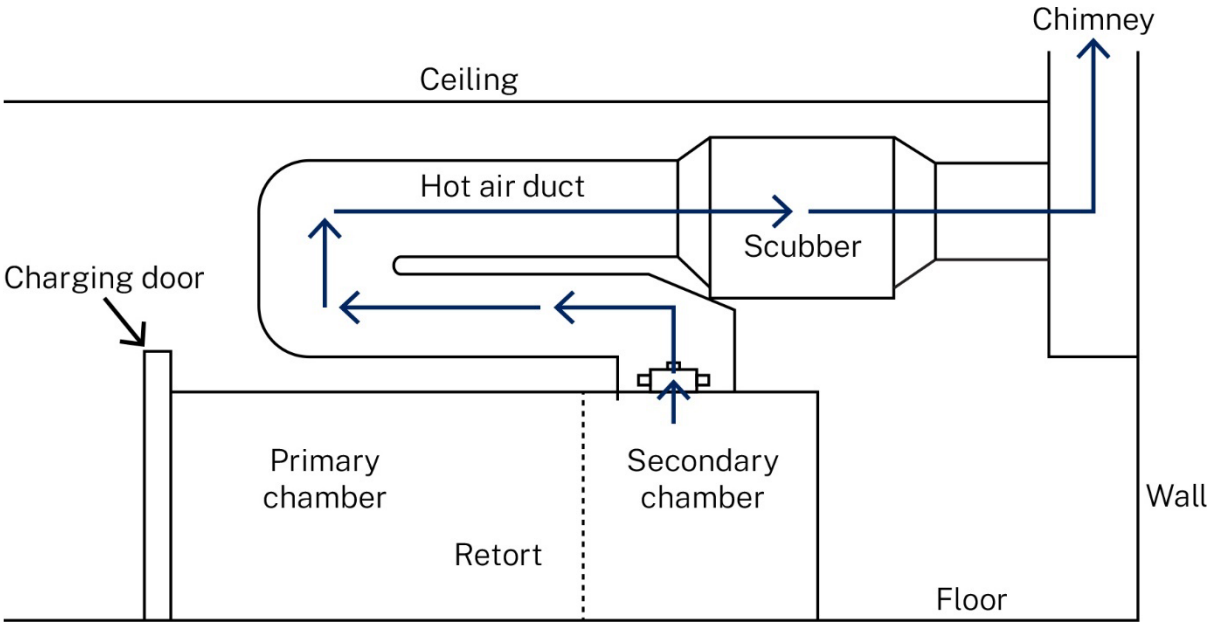

Figure 2 **Schematic diagram of a cremator showing flow of gases**

Cremation is a batch (rather than a continuous) process consisting of the following steps (UK DEFRA 2012). Indicative cremation times are shown in brackets:

1. a brief flash caused by volatilisation of the veneer on the outside of the coffin (1 minute)
2. burning of the coffin (20 minutes)

3. after the coffin breaks open, further burning of the coffin and cremation of the body (40 minutes)
4. calcination of the remains (30 minutes)
5. ashing (2 minutes).

Total cremation times vary considerably, ranging from as little as 50 minutes up to more than 2 hours depending on factors such as body mass, bone density and the materials from which the coffin is manufactured. The average time for an adult cremation is typically 90 minutes at 800–1,000°C. For larger pets (horses or large dogs), the average cremation time will be similar to that of adult humans. For small pets, the average cremation time will be much quicker, typically no more than 45 minutes. An out of coffin cremation is also possible and NSW Health is the regulator for that aspect.

The main fuels used in crematoria are:

- natural gas
- liquid petroleum gas (LPG)
- diesel
- petroleum products.

Cremators can also be electrically heated, which is less environmentally harmful and more energy efficient than gas fired cremators.

There are 2 types of cremators – abated and unabated. The operation of cremators without abatement in New South Wales would not meet the requirements of the POEO Act and therefore it is expected that all cremators in New South Wales are abated. The operation of unabated cremators would also not meet the requirements of the POEO (Clean Air) Regulation 2022, as the typical unabated concentration limit for cremators for total particulate matter is 160 mg/m^3, whereas the concentration limit prescribed in Schedule 2 Part 3 of the POEO (Clean Air) Regulation 2022 is 100 mg/m^3.

Alternatives to traditional heat/air cremation include alkaline hydrolysis and the use of liquid nitrogen. However, due to the economics of the sector these options have not been widely adopted. These methods also have issues with emissions, waste water and safe handling/storage concerns for the chemicals used.

Abatement of cremators

An abated cremator has additional equipment to remove dangerous and noxious contaminants from its emissions before they are released into the atmosphere. Emission control technologies such as scrubbers can be installed to reduce particulates (DSEWPAC 2011).

2. Potential emissions to air

All air pollutants should be considered during the planning process and addressed within consent conditions, where relevant. The site operator must comply with all consent conditions.

Potential emissions to air from cremation are those associated with combustion and include:

- carbon monoxide (CO)
- nitrogen oxides (NOx)
- sulphur dioxide (SO_2)
- particulate matter (PM_{10} and $PM_{2.5}$)
- volatile organic compounds (VOCs)
- polychlorinated dioxins and furans (PCDDs/PCDFs)
- polycyclic aromatic hydrocarbons (PAHs)
- polychlorinated biphenyls (PCBs)
- heavy metals including mercury, lead and cadmium
- hydrogen chloride
- hydrogen fluoride.

The pollutant composition and emission rates may vary depending on the fuel composition, fuel consumption, cremator design and the emission control devices in use.

There is the potential for odour to be emitted from the cremation process, however this should be prevented by good combustion and the operation of a secondary combustion zone. Modern cremators include as standard a primary and secondary combustion zone and if cremation equipment is operating efficiently then no odours should be emitted (ACCA 2009).

Air emissions from crematoria are typically released through a controlled point source or stack.

There is the potential for fugitive emissions from the volatilisation of vapour from storage and open vessels but this is less of a concern than the point source emissions.

Mercury can be present in the human body, usually in the form of fillings made with dental amalgam. During the cremation process, if fillings are present, these will volatilise and can release mercury to the atmosphere.

Studies in the United Kingdom have shown that an average of 3 g of mercury are emitted for each body cremated. The NSW Government has acknowledged that cremation is a contributor to mercury emissions, however this is small compared to other sources (ISF 2021). A South Australian report has also shown that the lower rates of dental fillings with amalgam containing mercury amongst the Australian population means that this is less of a concern in Australia than in the United Kingdom (SA EPA 2016).

In Australia, our population has had better dental hygiene from an earlier age than some other countries, with the addition of fluoride to drinking water and higher abundance of quality fresh foods. The members of the population with the highest amalgam pollution potential from tooth fillings have already died.

3. Managing air pollution

3.1 Management options

The practical management of crematoria emissions begins by following the '3 Ts' of good combustion:

- temperature
- time (residence)
- turbulence.

Temperature

Sustaining an effective temperature range plays a major role in the operation and efficiency of cremation equipment. The correct furnace temperature can maximise the reduction of toxic chemicals during combustion. It is recommended that the main chamber temperature is between 650°C and 900°C, with the insertion and operating temperature being at 760°C. The insertion into the secondary chamber is optimum when between 850°C and 1,200°C and should be maintained at this temperature for the entire cremation process.

Time (residence)

Total cremation times vary considerably, ranging from as little as 50 minutes up to more than 2 hours. The residence time is essentially fixed at the time required by the design and construction of the cremation system, as it is a number based on the volume of the secondary chamber and flow rate of gases from the primary chamber. The residence time refers to the amount of time the gases are exposed to the specific temperature with the aim of ensuring total combustion of the air emissions from the exhaust gas before it leaves the stack.

The weight of the body, the ratio of body fat to muscle mass, the functionality of the cremation equipment utilised, the operating temperature of the cremation chamber, and the kind of casket in which the body is placed are all factors that affect the cremation time.

Turbulence

Turbulence refers to how much the air is mixed up inside the cremation equipment. This is created by the presence of baffle walls and restrictions in the path of the exhaust gases. Without turbulence, time and temperature will be of little help and total combustion will not occur.

> If any one of the 3 Ts is not present or is insufficient, an air pollution issue is likely to occur.

Operational suggestions and devices

Where recommended emission standards for crematorium furnace facilities are not met (see ACCA 2009 for standards), the Australasian Cemeteries and Crematoria Association (ACCA) has the following operational suggestions that may help in meeting these standards and preventing smouldering, odour, high quantities of particulate emissions, acid gases and dark smoke, as well as a variety of potentially hazardous emissions:

- efficient cremation furnace operation and monitoring
- the correct furnace temperature (a suitably high temperature in the secondary chamber throughout the combustion process with adequate excess air will optimise reduction of potentially hazardous compounds)
- an appropriate residence time (the time required for gases in the chamber to travel from the ignition source to the point of exit); 1.5 seconds at 850°C is usually sufficient
- automated chamber loading mechanisms interlocked to temperature
- main chamber temperature between 650°C and 900°C
- main chamber optimum insertion and operation temperature at 760°C
- automatic control of additional air to the main chamber
- automatic control of secondary air (this may also include oxygen monitoring at the base of each individual cremation stack)
- 2 or more cremations feeding into one stack are difficult to control and generally unadvisable
- at initial insertion and throughout the cremation the secondary chamber should be maintained at a minimum temperature of 850°C and can withstand in excess of 1,200°C for sustained periods
- the burner in the secondary chamber must have modulating fire rate control (rather than high–low control)
- a turbulent path of well mixed gases in the secondary chamber with the addition of excess oxygen as needed to ensure proper combustion of volatiles
- air supplied at the inlet or into the secondary (and/or tertiary) chamber to provide a level of oxygen at the outlet of the cremator of not less than 6% to ensure oxidising conditions are maintained throughout the process
- measurement of oxygen levels or smoke obscuration levels (measured by a device located in the flue stack)
- wet scrubber devices should only be used when absolutely necessary due to the additional waste stream they introduce, as well as their cost. Modern well-maintained cremators do not require wet scrubbers.

Where crematoria furnaces do not meet air emission standards, the following devices may be fitted, as recommended by ACCA (2009):

- gas conditioning devices to reduce flue gas temperatures
- wet or dry scrubbers to remove acid gases
- fabric filters or electrostatic precipitators to remove fine particulates
- mechanical collectors
- addition of secondary chamber afterburners where none are fitted.

The following suggestions may significantly reduce air emissions prior to combustion, as recommended by ACCA (2009):

- remove PVC plastics (these chlorinated materials produce hazardous end products such as PCDDs, PCDFs and PCBs)
- use water-based adhesive products wherever possible
- reduce unnecessary use of synthetic fibres for lining and/or trimming caskets
- reduce the use of paint and/or lacquer finishes and replace with water-based products wherever possible
- caskets should be constructed of wood or wood by-products which, when subjected to the cremation process, are easily combustible and do not emit smoke, give off toxic gas or leave any retardant smears or drips after final combustion

- use of metal fittings should be limited unless these are removed prior to the cremation process
- use of polyurethane paints should be avoided wherever possible
- products containing polystyrene foams should not be used
- pitch, bitumen or similar products should not be used as a sealing material.

3.2 Stack/flue design

The *Environmental guidelines for crematoria and cremators* (ACCA 2009) provide clear guidance on stack/flue design which is summarised below.

The furnace stack design and construction must be capable of withstanding the temperature of gases leaving the secondary chamber. The design of the stack must be based on the maximum gas temperatures expected and the maximum rate of operation.

When stack fans are used, the system design must enable the continued discharge of a lower-than-normal flow during a system failure (e.g. a power cut). Stack dilution inlets must be designed and placed so as not to create a hazard inside or outside the building. Thus, a flue system using a fan must be designed in a way that combustion gases are discharged safely during a power failure, without damaging the stack fan.

If dilution inlets are not designed and placed correctly then in the event of flue fan power failure hot (e.g. 850°C) flue gases could be discharged inside the building.

Provision for weather protection should not interfere with free upward vertical discharge of gases and vapours (i.e. rain caps should not be fitted at the outlet). The stack outlet should be designed to allow for flows of at least 8 m^3/s.

The stack must be no less than 3 m above the peak of the roof (Figure 3). Eddy or wake effects will not generally occur if the effective stack height is greater than 2.5 times the building height or width (whichever is the lesser), or if the stack is 10 times the building height or width (again, whichever is the lesser), away from the building.

Figure 3 **A well-designed stack with good height and conforming visually with the surrounding buildings**
Source: Jane Barnett/Zephyr Environmental

In some circumstances greater stack heights may be required to meet the criteria for design ground level concentrations. It may be necessary to optimise stack heights / exit parameters using atmospheric dispersion modelling techniques.

3.3 Emission controls

There are control techniques available to reduce emissions from crematoria. These are discussed below.

Process control

One of the best ways to control emissions is to measure properties (such as temperature, opacity, CO and oxygen) and adjust to meet desired parameters (reflecting optimal combustion).

Wet scrubbers

These scrubbers collect gases that are exhausted from the cremator unit. The air is sprayed with water to remove emissions from the gas stream and the water droplets gather at the bottom of the wet scrubber and are drained out. The stream is then taken to a holding tank where the heavy particles settle out. The water can then be reused in the wet scrubber or can be disposed of safely and under the relevant environmental regulations regarding wastewater.

As noted above, due to the additional (water) waste stream that is introduced, the use of wet scrubbers within crematoria is not considered best practice.

Baghouses

Similar to a wet scrubber, air is directed from the cremator to a baghouse filter. The size of the filter bags depends on the emission concentration in the air stream as well as the airflow from the cremator. The bags usually have mechanical arms to shake free the collected material when the bags need to be cleaned. The dust is collected at the bottom of the baghouse and is then disposed of. Unclaimed cremated remains may be disposed of within the grounds of the crematorium. Where additional absorbent material is injected / collected for pollution control (e.g. activated carbon) and this material falls within the definition of ‘hazardous waste’ then this baghouse waste should be disposed of within a hazardous waste landfill.

Crematoria that have a baghouse to reduce their emissions need to install a cooling system to cool the air stream before it reaches the baghouse.

Catalytic filters

Some modern crematoria also have honeycomb catalytic chimney filters (typically a selenium catalyst) that significantly reduce the amount of mercury vapour released into the atmosphere and can have the co-benefit of reducing dioxin and NOx emissions.

3.4 Minimisation of persistent organic pollutants

Studies have established that PCDD/PCDF generation is greatest during the combustion of the coffin. They are also generated from the combustion of the body. Temperature control is needed during the whole cremation time. In other words, raising the temperature in the secondary chamber is the only measure to prevent PCDD/PCDF emissions (SA EPA 2016).

It is recommended that any cremation is undertaken in the presence of excess oxygen while the secondary chambers are held at a temperature of 850°C for a residence time of at least 2 seconds for the entire cremation.

3.5 Minimisation of mercury

Mercury abatement equipment, such as activated carbon and carbon–selenium filters, scrubbers and technologies that bind or precipitate mercury are effective at reducing mercury emissions.

Removal of mercury at source by the removal of dental amalgams prior to cremation can be both cost and environmentally effective; however, it is less socially acceptable, and difficult to impose.

Generally, potential mercury emissions from the crematoria sector are not considered to be high-risk because the use of mercury amalgam fillings in the dental industry is being phased out.

4. Considerations for local councils

4.1 Scheduled or non-scheduled activity

As mentioned in Chapter 1, crematoria are not scheduled activities under the POEO Act, and therefore do not require an EPL.

Non-scheduled activities such as crematoria are therefore regulated by local government.

Existing problems can be addressed using 2 sets of regulatory tools:

- orders requiring compliance with consent conditions under the *Environmental Planning and Assessment Act 1979* (the EP&A Act)
- environment protection notices under Chapter 4 of the POEO Act (see Local Government Air Quality Toolkit – Module 2 and Module 4), including:
  - a prevention notice or series of notices, where the ARA suspects the activity is being carried out in an environmentally unsatisfactory manner
  - a clean-up notice where there is a pollution incident within the meaning of the POEO Act
  - both a prevention notice and a clean-up notice.

If issues are identified, the following tools are available in the Local Government Air Quality Toolkit – *Resource pack*:

- Chapter 3 – checklists for investigating odour, fallout or other complaints
- Chapter 6 – checklists for reviewing air quality assessments and dispersion modelling.

Under the POEO notice provisions, local councils are empowered to direct a recipient to take clean-up action or preventative action, including calling for studies to be carried out by the operation's management. Time spent making sure the brief for any investigation is thorough and covers all the relevant aspects raised in this guideline, is time well spent – for the management, for the local council and for the neighbours and wider community.

4.2 Assessment and dispersion modelling

There are a few important aspects for local government to consider when overseeing external consultants' air quality assessment and dispersion modelling studies, to make sure the best outcome is achieved. These are included in Chapter 6 of the Local Government Air Quality Toolkit – *Resource pack*.

It should also be noted that dispersion modelling only applies to projects during the development and approvals stage. Once a facility is operational, odour surveys can be a more useful tool for addressing complaints. The methodology for conducting an odour survey is provided in Chapter 3 of the Local Government Air Quality Toolkit – *Resource pack*.

4.3 Operational and control recommendations

Consideration should be given to appropriate operational procedures to control and limit air emissions. Chapter 7 of the Local Government Air Quality Toolkit – *Resource pack* lists several operational measures that are helpful in reducing emissions and impacts from crematoria.

The local council may be required to conduct a site inspection to investigate current management practices. Chapter 2 of the Local Government Air Quality Toolkit – *Resource pack* provides helpful information for council officers prior to these inspections, including a checklist.

Before going on site for an inspection, council officers should be aware of whether scheduled or non-scheduled activities are being carried out at the premises and should review any previous reports (including diagrams, photographs and maps).

Case study

Note that this case study is for illustrative purposes only. It does not indicate a procedure that ARAs, authorised officers and enforcement officers should follow in all cases and does not constitute legal advice. Readers should seek their own legal advice in relation to their specific circumstances.

Issue: Council received a complaint from a commercial office property next to a pet crematorium. The complainant alleged that smoke and strong odours were being experienced at the property and black particles were settling on surfaces inside the property. This was occurring at varying times, usually when a burn took place. Thick white and grey smoke had been visible and the odours were so strong and offensive that staff had to leave the office at times.

Background: The commercial office property was about 20 m from the discharge stack of the cremation chamber. Despite the proximity to other properties, the issue was not reported by other surrounding users; however, that did not mean other users were not affected.

Response: Initial investigation confirmed that appropriate development consent was in place for the use of the property. Conditions of consent included operational controls of the cremation system. The zoning of the area permitted varying uses including light industry and commercial, with surrounding residential blocks.

The investigating officer attended the property to gather further information including gaining an understanding of the location, the types of land use, building structures and to potentially observe the issue. During the initial site inspection, no odours were detected. However, the black particulate matter was observed on surfaces including internal windowsills, desks, benches and paper.

The council officer provided the complainant with a detailed odour diary and requested that they call the council as soon as the odours and smoke were noticed. When a call was made about odour, the officer immediately attended the site to gather evidence. Upon arrival, a strong offensive odour was detected and a plume of smoke was visible that was confirmed to be coming from the stack on the roof of the cremator unit.

Standard evidence was obtained including time, date, place and observations. Video and photo evidence was obtained of the smoke and surrounding location.

The council officer tried unsuccessfully to speak with the crematorium operator while on site. The business's contact details were obtained from council's records and a meeting was scheduled with the business owner / representative.

Regulatory action and/or mitigation method: A prevention notice under the POEO Act was prepared. The terms of the prevention notice and outcome are detailed below.

An alternative to this could have been to issue a compliance order under the EP&A Act if there had been a failure of the cremator operator to comply with conditions of the relevant development consent. However, the POEO Act is typically preferred over the EP&A Act where an activity has been or is being carried out in an environmentally unsatisfactory manner.

The terms of the prevention notice required the cremator operator to engage the services of a suitably qualified and experienced environmental consultant to prepare a detailed air quality assessment, to council's satisfaction and in accordance with the *NSW EPA Approved methods for the modelling and assessment of air*

pollutants in NSW (EPA 2022) and the *Technical framework: Assessment and management of odour from stationary sources in NSW* (DEC 2006) and provide recommendations to control odours from the use of the cremator. It also required a copy of the report be provided to council and any recommendations made in this report be implemented. Further, council was to be notified for a further inspection upon completion.

Outcome: A qualified consultant was engaged to perform an assessment. The assessment identified that there was no maintenance program, ineffective training of the cremator operator, no operational monitoring program and these issues were likely the cause of ineffective incineration due to incorrect processes and temperatures of the chambers.

Recommendations based on the findings of the investigation study were:

- The set point for the primary and secondary incineration chambers should always be operated at or above 750°C and 970°C, respectively, prior to commencement and during cremation activities.
- The cremator operator should maintain a record of all maintenance works on the primary and secondary incineration system to ensure it is always operating in optimum condition.
- The primary and secondary incineration chamber temperatures should be regularly recorded during normal cremator operations. Monitoring records should be stored both in hard-copy and digital formats.

A variation to the prevention notice was then issued after the findings and recommendations of the air quality assessment were received by council. The prevention notice, as varied, required the cremator operator to engage the services of a suitably qualified and experienced environmental consultant/engineer to develop an air quality and odour management plan (AQOMP) in accordance with the best available technology and practice, including for the AQOMP to:

- be prepared by a suitably qualified and experienced person and submitted to the council
- on approval by council, be signed and dated by the site manager and displayed for review by employees, contractors, visitors and customers
- establish a commitment to the protection of the environment and the prevention of pollution
- document all operations and activities
- include the following (at a minimum):
  - identification of all potential emission sources
  - the engineering controls and management practices in place to control the undesirable release of air pollutants
  - the standard operating procedures for the set point temperatures of the incinerator chambers
  - written procedures for:
    - continuous monitoring of the set point temperatures of the incinerator chambers and corrective action where critical limits are not achieved
    - reporting of non-conformances to management
    - management of internal audits of the procedures and monitoring
    - external audits, including frequency
    - maintenance program/s to assess the operation of plant equipment
    - staff training and education programs
    - an odour complaints policy.

The AQOMP was adopted, and an on-site audit performed confirming compliance with the AQOMP. The business was issued with a further prevention notice to ensure future compliance. It should be noted that the business was extremely compliant throughout the process and no enforcement other than the prevention notices was required.

The eventual outcome was a compliant business able to operate with processes, procedures and systems in place to monitor, manage and report on emission performance.

Figure 4 **Double chamber incinerator**
Source: Ryan Moore/Hornsby Shire Council

Figure 5 **Crematorium stack**
Source: Ryan Moore/Hornsby Shire Council

5. References and other resources

All documents and webpages that are part of the Local Government Air Quality Toolkit are available from the EPA website.

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