Local Government Air Quality Toolkit

Module 3: Air pollution control techniques

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This resource may contain images or names of deceased persons in photographs or historical content.

The Local Government Air Quality Toolkit has been developed by Department of Climate Change, Energy, the Environment and Water in collaboration with the NSW Environment Protection Authority, the NSW Department of Planning, Housing and Infrastructure, Local Government NSW and local councils.

Cover photo: Dust and storm, Nyngan. DCCEEW image library

Artist and designer Nikita Ridgeway from Aboriginal design agency – Boss Lady Creative Designs, created the People and Community symbol.

Published by:
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ISBN 978-1-923200-61-6
EH 2024/0168 July 2024

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1. Introduction

The types of equipment likely to be encountered by local government officers in the control of air pollution are well understood. Devices to control air pollution have been in use for many years, and most of the techniques used today were known by the middle of the 20th century. Recent decades have seen further improvements in design and much better predictability of performance.

1.1 Purpose

The purpose of this module of the Local Government Air Quality Toolkit is to introduce the various types of air pollution control techniques that are likely to be encountered in premises where non-scheduled activities are carried out within the meaning of the *Protection of the Environment Operations Act 1997* (POEO Act). Most importantly, these sections set out the key principles and factors involved.

If local government officers understand the key principles and factors governing the performance of air pollution control techniques, they will be able to make well-informed judgments about the likely effectiveness of proposals put forward by industry and consultants.

2. Avoidance – cleaner production

The best way to control air pollution is to avoid it in the first place. Avoiding pollution and waste is commonly dealt with under the paradigm of ‘cleaner production’.

2.1 Tools for cleaner production

Some of the tools that will help with a cleaner production management approach are:

- waste audits
- redesign of equipment and processes
- thorough inventories of material and energy flows
- benchmarking of performance against similar industries.

A cleaner production management approach also needs to consider innovation. Useful links can be found in Chapter 6, ‘References and other resources’.

There are links between climate change and air quality, with many actions to tackle climate change also having a positive effect on local and regional air quality. The Local Government Air Quality Toolkit *Climate change impacts affecting air quality guidance note* provides further information.

2.2 Substituting materials and fuels

Avoiding a problem in the first place can often be achieved by making simple changes such as substituting materials. For example, to overcome a neighbourhood odour problem caused by a surface coating operation might involve changing to a less odorous but equally effective solvent (e.g. a water-based paint formulation). Another example is that avoiding a particular type of feed in a poultry farm may greatly reduce the otherwise difficult-to-control fugitive odours from growing sheds.

2.3 Involving all personnel

All the people involved in the process under review need to be briefed about the cleaner production concept and encouraged to participate in the search for cleaner production opportunities. Demonstrated leadership and commitment from senior management is essential for these attitudes to become generally adopted throughout an organisation.

3. Dispersion

The next way to control air pollution problems is by dispersion or dilution of pollutant emissions with the ambient atmosphere.

3.1 Effectiveness of dispersion

Pollutant concentrations are most effectively reduced through the process of dispersion. The more air that is mixed with the emission source, the more diluted (less concentrated) it becomes. The concept of dispersion is discussed in detail in the Local Government Air Quality Toolkit – Module 1, *The science of air quality*.

Emissions via a stack are often more effective, as they usually discharge at speed, at height and at temperatures above ambient, adding to thermal buoyancy. The longer an emission takes to reach the ground the more time it has to disperse (mix with cleaner air) and reduce in concentration.

Most of the plume rise is due to the thermal buoyancy of the gases discharged, that is, the flue gas temperature. The hotter the gas the higher it rises above the top of the stack, and as it travels downwind the greater the dilution at ground level.

3.2 Stack height and separation

The Local Government Air Quality Toolkit – Module 1, Part 1 indicates that raising the height of a discharge stack can markedly reduce concentrations of pollutants at ground level – doubling the effective stack height can more than halve the ground level concentration. However, doubling the height of the stack comes with a considerable increase in costs.

Separation of the source and receptor by distance is also an effective use of atmospheric dispersion, even for sources of pollution released at ground level, such as odours from effluent ponds and feedlots.

Height and size of stacks

The height and sizing of stacks, where any significant degree of pollution dispersion must be achieved, is a specialised exercise usually requiring expert use and interpretation of air dispersion models such as AERMOD and CALPUFF. The *Approved methods for the modelling and assessment of air pollutants in New South Wales* (EPA 2022) should be followed.

Building effects

For many smaller combustion and ventilation sources, a short stack will be effective. In these situations, for example, small combustion equipment fired with natural gas, it is considered good practice to require the stack discharge point to be 3 m above the highest point of the building in which it is located (or of nearby buildings). This avoids building downwash effects (see Local Government Air Quality Toolkit – Module 1, Part 1).

Figure 1 shows building downwash.

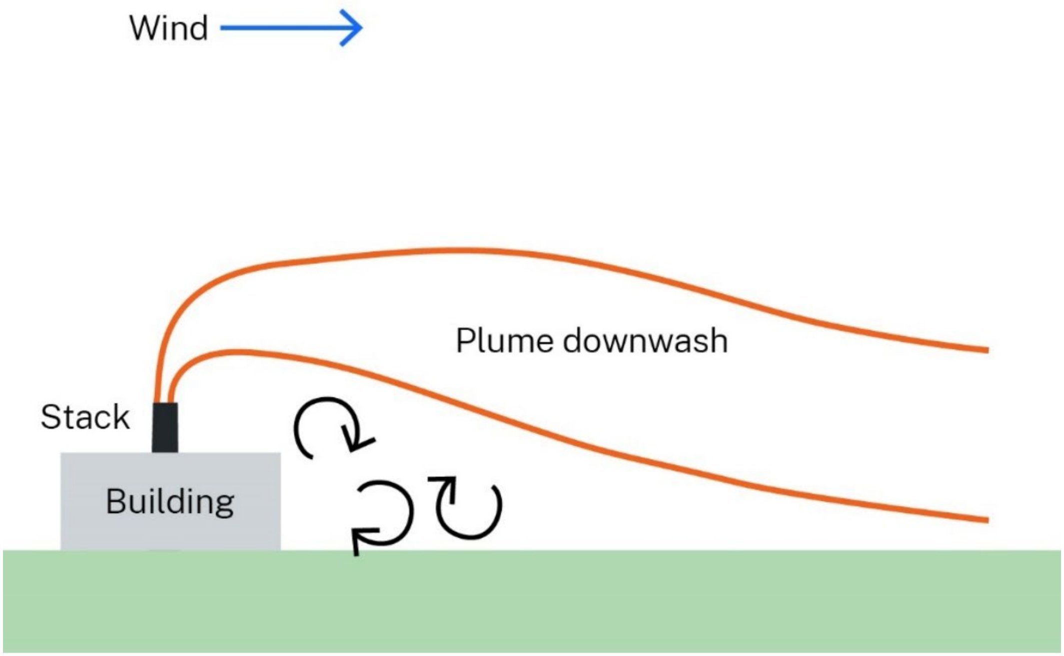


Figure 1 **Building downwash**

Stack effects

The discharging gases need enough vertical upwards velocity to avoid downwash of the plume behind the stack itself. For this reason, rain caps over the outlets of stacks should be avoided (Figure 2). If some sort of rain protector is needed, types resulting in an upwards discharge should be fitted. Rain almost never falls vertically and so a drainage 'gutter' around the inside wall of a stack usually suffices to catch any precipitation entering the stack when the equipment is not operating.

Figure 2 **Example of a rain cap over the outlet of a stack, which should be avoided since it inhibits dispersion**

Source: Damon Roddis/Zephyr Environmental

Sometimes stacks are fitted with eddy shedding devices. These are designed to reduce vibration and noise around the stack in strong winds and have no real effect on dispersion from the stack.

Plume height and stack height

The rise of the gas plume from a stack usually adds significantly to the effective plume / stack height, which in turn determines the downwind ground-level concentrations.

The physical momentum of the plume, which is due to its discharge velocity, usually adds little to the plume rise. The main effect of a high velocity discharge from a stack in most situations is to escape the stack's own downwash, as discussed earlier, and increase the effective stack height (Figure 3).

Speeding up the discharge for a stack that is too low is not a sure 'quick fix' and will not usually solve the problem. If the discharge velocity is already about 15 m/s, then speeding it up further will just add to the fan energy and might cause a noise problem (see Local Government Air Quality Toolkit – Module 1, Part 1).

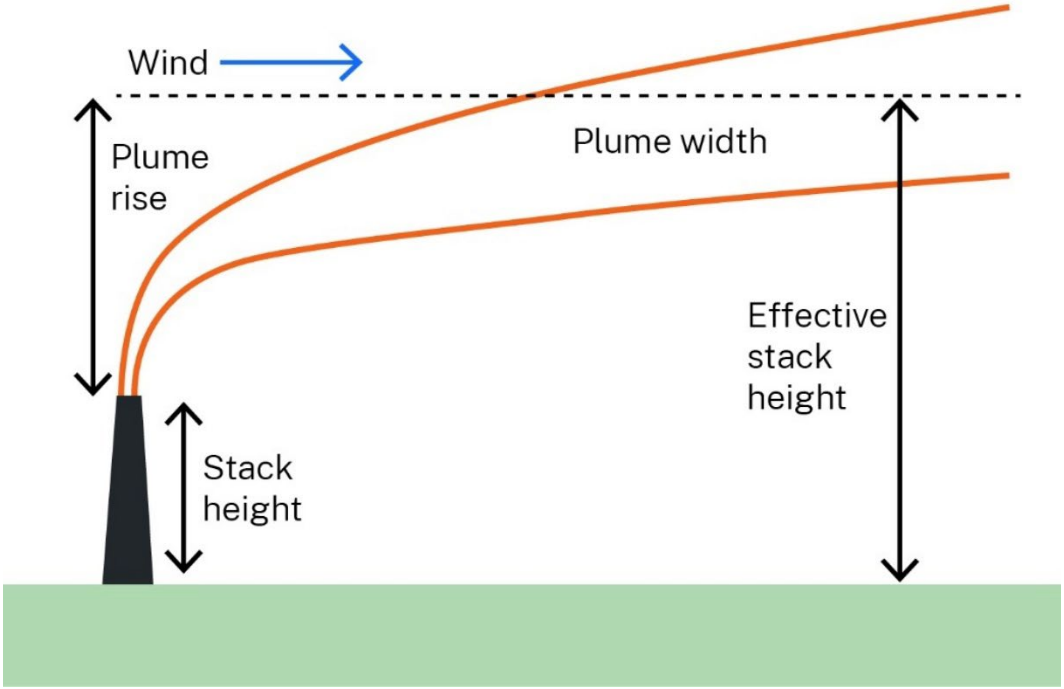


Figure 3 **Plume rise and stack height**

3.3 Advantages of odour dispersion

As long as the pollutants being discharged have no toxic impact and are not likely to be cumulative, odours can often be dealt with by dispersion from a reasonably high stack.

In such situations, clearing the downwash effects of the buildings can be important and a tall stack may be considered. However, the addition of control equipment can lower the required height of the stack.

Measurement and modelling expertise

If dispersion is to be used as the primary means of control, and a large degree of dispersion is essential for success, expert modelling skills should be introduced.

If odour is involved, these documents should be followed:

- *Approved methods for the modelling and assessment of air pollutants in New South Wales* (EPA 2022)
- *Technical Framework: Assessment and management of odour from stationary sources in NSW* (DEC 2006a)
- *Technical Notes: Assessment and management of odour from stationary sources in NSW* (DEC 2006b).

These documents will help ensure sound practices are followed in assessing the odour source and dispersion modelling.

Local government officers should be mindful that odour assessments can be expensive and should not be applied without carefully considering the cost of a solution. A minor problem might be solved by installing control equipment or a modest change in stack height, at a cost comparable to performing an odour assessment study.

If modelling is required, local government officers should carefully check the capability and experience of the modellers undertaking the work. The features of the different modelling approaches are described briefly in the Local Government Air Quality Toolkit – Module 1, Part 5.

Commentary around selecting a consultant can be found in Chapter 9 of the Local Government Air Quality Toolkit – Module 4, and an assessment and dispersion modelling checklist is provided in Chapter 6 of the Local Government Air Quality Toolkit – *Resource pack*.

3.4 Fugitive odour emissions

Fugitive emissions are those emissions that are not controlled via a vent or stack. Rather, they escape from leaky buildings or are generated directly from surfaces such as effluent ponds.

Fugitive emissions also need to be carefully considered in odour dispersion assessments, for 2 reasons.

Firstly, measurement of emissions from open, odorous surfaces or large, semi-open buildings is far more problematic than measurement and modelling of emissions from stacks.

If it is suspected that much of the strength of an odour source comes from fugitive emissions, considerable care must be used to assess the reliability of any measurement methods and their application to the modelling process.

For example, diffuse odour sampling by applying a flux sampling hood of, say, 0.5 m^2 over a small section of a collected refuse waste surface might give quite misleading results, depending on the extent of sampling. The different contents of small sections of refuse waste may produce very different odour characters and concentrations.

Air sampling above odorous liquid surfaces is also difficult as the sampling process itself may not simulate the evaporative conditions that the liquid surface experiences in the open atmosphere.

Advice for local government officers involved in assessments of fugitive odours:

- Consider the expertise and experience of the samplers and modellers.
- Be critical – ask the experts questions.
- Consider relevant and successful case studies.

Secondly, the human response to odour is exponential. In practical terms this means, typically, that an odour source needs to be reduced by a factor of 10 rather than a factor of 2 to achieve any significant difference in community perception.

See Local Government Air Quality Toolkit – Module 1, Part 4 for a discussion of the human perception of odour and odour measurement methods.

The big obstacle here is that most fugitive emissions are difficult to capture. When captured effectively they often require large air flows to ensure workplace occupational health and safety requirements are met. This can then result in very expensive control equipment or very large ductwork, fans and stacks, or both. Where possible it is best to minimise odour producing sources. A relatively inexpensive solution for fugitive and diffuse sources could be to install a misting system, which deploys a fine mist, usually of water and a neutralising liquor, in the areas that are odorous. The misting system acts like a scrubber for odours, it may also be effective for the suppression of dust.

3.5 Limitations to dispersion

Regional limitations

Where there are cumulative impacts from the pollutants being dispersed, dispersion is not an adequate solution. For example, dilution of nitrogen oxides or volatile organic compounds (VOCs) by discharge through stacks might address local air quality impacts but will have no effect on the regional potential of these precursor compounds to contribute to ozone formation by photochemical reaction.

Local limitations

In a few situations, dispersion might be undesirable even in the local context. An example would be the common practice of ducting the exhaust from fabric filters serving pneumatic conveying systems back to ground level within the premises rather than up stacks. Provided the filters are efficient, the exhaust gas may not present a health problem. However, if a filter develops a leak, dust will be deposited within the premises. This is more likely to be fixed promptly than if a fine layer of particulate is being spread around the neighbourhood from an elevated discharge point. A more costly solution is to fit electrodynamic dust leak monitors. These monitors are used to provide an early alert related to breaks or tears in filter bags by detecting solid particles with diameters less than 100 μm.

4. Air pollution control devices

4.1 Simple inertial separators

Devices that rely on inertial separation to remove particles or droplets from a gas stream are the oldest, simplest and most reliable types of air pollution control equipment (within their limitations).

Inertial separators are useful for removing coarse dusts from gas streams and less effective for finer particles. Since air pollution practices have been improved in recent years, inertial separators are now used less frequently because they cannot by themselves attain today's stringent emissions standards for particles, nor effectively reduce the PM_{10} size fraction. They can, however, still be useful in removing coarse particles and droplets before more efficient equipment is used to achieve the lower limits now specified.

Principles of inertial separators

Inertia is the tendency of all matter to continue moving in a straight line. The measure of inertia for a moving object is its momentum – the object's mass times its velocity.

Inertial devices rely on 2 principles:

- Particles in a gas stream have greater inertia or momentum than the carrying gas (usually air or flue gas). Consequently, when there is a change in the direction of the stream, the particles tend to keep going in the original direction while the gas turns. This allows the physical separation of the solids or droplets from the carrying gas.
- The gas flow velocity needs to be slow enough for the particles to settle out from the gas stream during its journey through the device. For effective settling to be achieved it is essential that the gas velocity is reduced by enlarging the cross-section of the flow area.

Inertia and settling

A simple inertial device is shown in Figure 4. This type is rarely used in isolation nowadays, but it illustrates the 2 principles of inertia and settling at work.

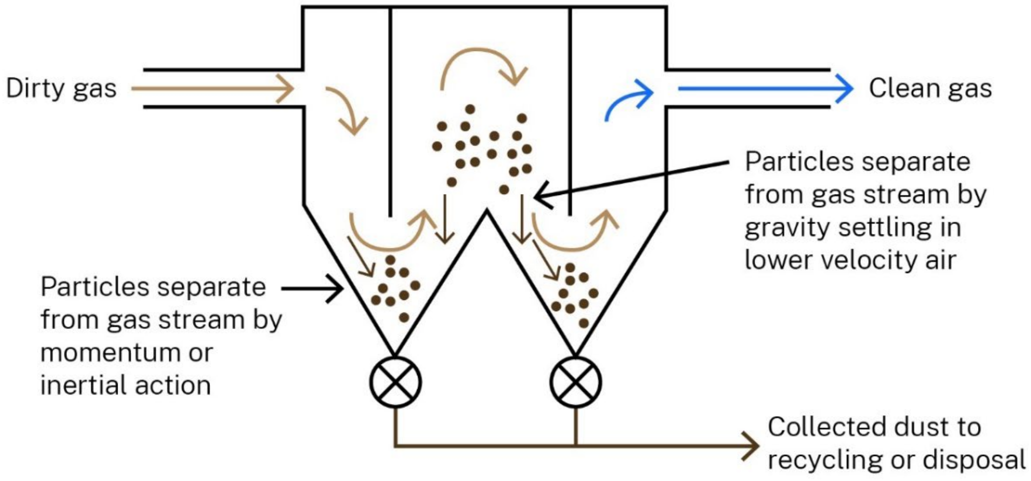


Figure 4 **A simple inertial separator**

A device used to supplement this effect is a water floor in the inertial/settling chamber to trap particles moved to the floor by inertial and settling effects. This is shown in Figure 5.

Occasionally this principle is still encountered in various types of scrubbing chambers.

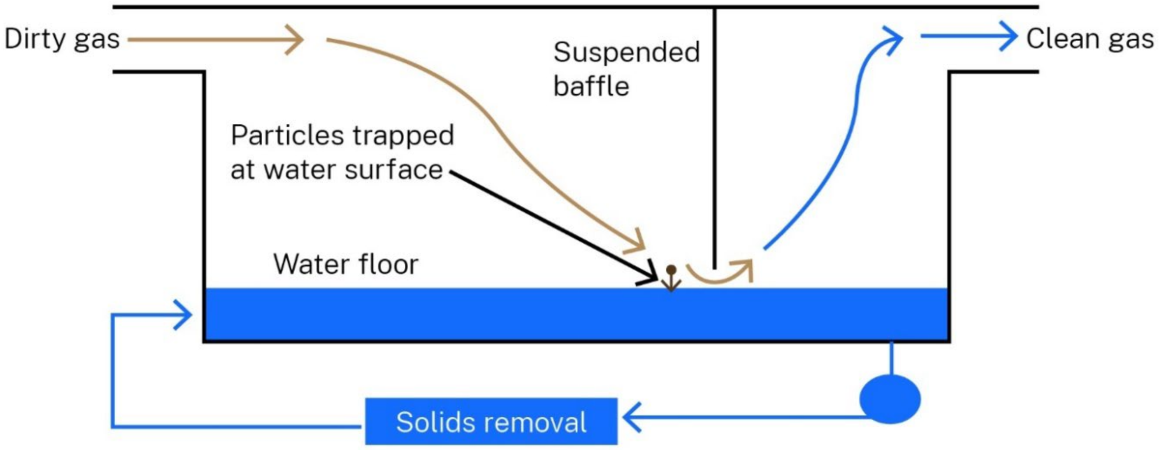


Figure 5 **Simple inertial separator with water floor**

4.2 Cyclones

The most familiar inertial device currently used is the cyclone separator, usually a cylindrical vessel with a tapering conical base. As shown in Figure 6 the gas flows into the device such that the air stream is spun in ever decreasing circles down the cyclone body.

The gas circulates rapidly downward, gathering velocity as the diameter of the cone decreases, and then returns in a helical spinning stream up the centre of the outer helix and exits the vessel at the top through an axially placed exit tube. The spinning motion creates a ‘centrifugal force’ on the particles in the gas stream, causing them to move outwards through the spinning air to the walls of the vessel. They collect on the walls and then slide down towards the conical base, from where they are removed through some kind of air lock – commonly a rotating gas valve.

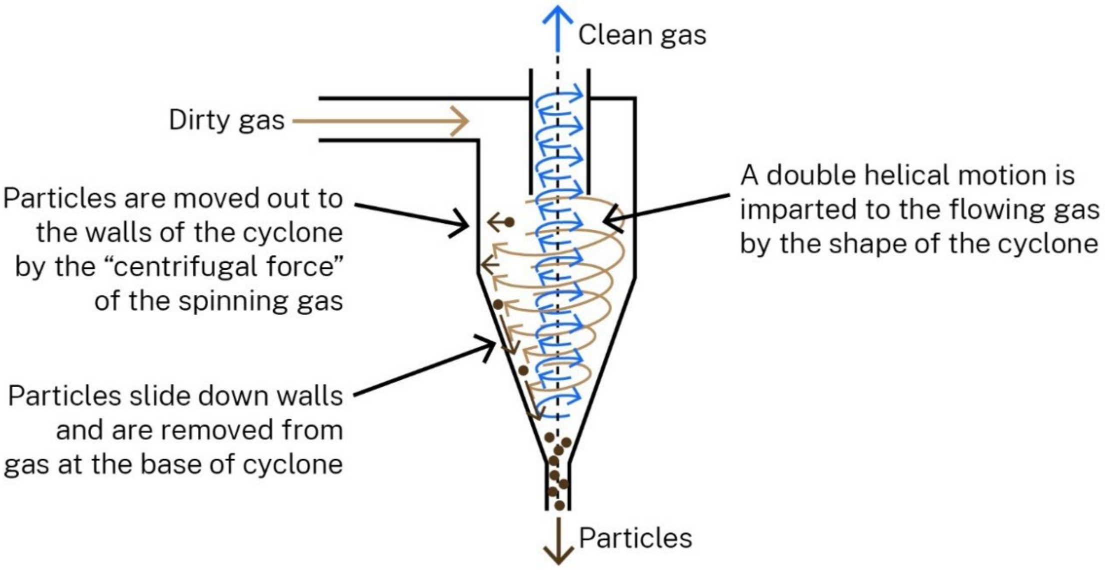


Figure 6 **Cyclone separator**

Removal efficiency

The removal efficiency of particles from the air stream depends on the velocity of flow and the diameter of spin. There is a pressure loss to be overcome in forcing the spinning air through the device, which is related to the velocity and diameter of the cyclone. This can lead to a higher power consumption and operating cost. In general, decreasing the diameter of the cyclone causes an increase in the:

- efficiency of particle removal
- pressure drop
- cost.

This is an example of the typical trade-off situation that often occurs in air pollution control. To achieve higher control efficiencies, more is spent on operational energy.

There are, however, limits to the velocity that can be forced through small-diameter cyclonic vessels. If higher efficiency is to be achieved, it becomes necessary to split the gas flow and use several cyclones arranged in parallel, known as a 'multicyclone'. This in turn pushes up the capital cost of the equipment as more material is needed in a more complex arrangement to achieve a flow of gas equivalent to that of a single, larger cyclone.

As a general rule, the smaller the diameter of the cyclone the more efficient the removal of the smaller particles. Table 1 gives a rough indication of likely performance. An engineer's report should be sought for precise estimation of efficiency for a given application.

Table 1 Rough indication of cyclone performance

Cyclone type	Cyclone diameter	Particle size (μm)	Removal efficiency (%)	Pressure drop (kPa)
High efficiency	150–200 mm	15–20	95 or better	1–2
Low efficiency	1–5 m	40 or larger	up to 95	0.5–1

The kilopascal (kPa) is the metric unit of pressure.

The pressure of one standard atmosphere is defined as 101.325 kPa, so the pressure differences in cyclones are about 0.5–2% of normal atmospheric pressure.

Cyclones combined with filters

For coarse particles, such as those encountered in sawmills, surface preparation, and joinery works, low-efficiency cyclones are often used in conjunction with some kind of fabric filter fitted to the air outlet from the cyclone. This effectively removes the coarse material, such as shavings and large sawdust, relieving the dust load on the filter so that it can then handle the fine dust from operations such as sanding.

4.3 Filters

The most common method of particulate removal is filtration. Filters of some description are commonly seen at premises like sawmills, food outlets and spray painting.

Filtration equipment comes in all sizes, from small package units installed at dusty locations in small workshops to huge installations on large metallurgical plant. Filter media range from simple woven fabrics, through needle-felted synthetic materials, to Teflon-coated glass cloths.

Baghouses

The filter elements are usually arranged in tubes or cartridges mounted in banks inside a containing chamber. The term 'bag filter' or 'baghouse' used to describe these units derives from this aspect of their construction. An example is shown in Figure 7.

Principle of filtering

The operating principle of filtering is straightforward: the particle-laden gas stream is forced through a filter medium. The particles are trapped on the medium while the gas passes through.

A porous layer of trapped particles builds up on the filter medium (the 'filter cake') and this accumulated layer also acts to trap and filter out particles.

Filtration and cleaning

Periodically the filter needs to be replaced or the medium needs to be 'cleaned' by dislodging the layer of trapped particles from the surface.

Some filters, including those in air conditioning systems and some industrial processes such as spray painting, consist of disposable fibrous cartridges that are replaced when the filtered dust load builds up to the point of imposing too much back pressure on the ventilation system.

The method more commonly used in processing, manufacturing and construction industries involves periodically cleaning a woven cloth or felted, fibrous filter medium. The style of filter medium and method of cleaning generally determine suitability for a specific purpose, capital cost and energy requirements.

The efficiency of dust removal depends less on these last 2 factors, because all filters, if operated in their recommended range, can deliver gas that is relatively free of particles after filtering.

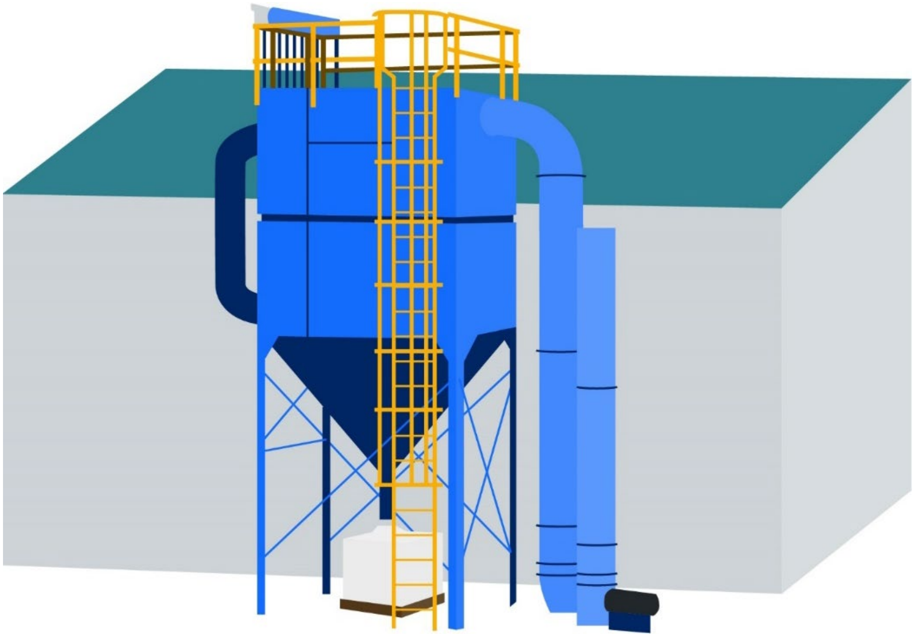


Figure 7 **Baghouse**

The main types of filter media used in industrial applications are either woven or non-woven (felted) fabrics. Felted fabrics are often needle-punched during manufacture to improve bonding of the layers incorporated into the fabrics.

Fabric filters

There are many varieties of fabric types and materials, with differing performance in terms of:

- resistance to flow (pressure drop and air-to-cloth ratio)
- ability to remove fine particles (filtration capability)
- resistance to abrasive wear
- resistance to chemical attack
- suitability for washing or other methods of external cleaning
- temperature resistance
- life span of bags.

Natural and synthetic fibres are used: cotton, polypropylene, polyester, Nomex, Gore-Tex, Teflon and fibreglass all have applications depending on conditions. For some high-temperature applications glass fibres with Teflon or other coatings are used. Local government officers would typically encounter applications using cotton, polyester or Gore-Tex bags.

Resistance to flow or pressure drop

Maintaining pressure drop across the filter at a reasonably low value is key to performance for bag filtration. The pressure loss through the filter medium increases with time as particles embedded in the medium build up to form a ‘filter cake’.

If the back pressure increases because of the inability to effectively clean the filter medium of accumulated dust, the gas flow will be reduced.

When the filter is operating there are 2 components to the resistance to flow of the air passing through the filter:

- pressure loss as the air passes through the filter medium itself
- pressure loss as the air passes through the filter cake that has accumulated on the filter medium.

When automatic cleaning is carried out, for example by a reverse pulse of air flow, the pressure loss through the filter cake is reduced. A point can be reached when the pressure loss through the filter medium becomes too high and the filter medium must either be removed and cleaned externally with cleaning agents (e.g. by washing), or replaced.

Cleaning techniques for filters

The cleaning technique used in industrial filtration is fundamentally important in determining the filtration capability and hence the size and cost of the filter required for specific applications.

The 3 common methods of cleaning fabric filters to dislodge the accumulated dust are:

- shaking – ceasing filtration periodically and shaking the filter elements (‘bags’) to dislodge the filter cake
- reverse air – ceasing filtration periodically and reversing a flow of clean air through the ‘bags’ to dislodge the filter cake
- pulse jet – directing a pulse of clean compressed air against the flow periodically to expand the ‘bags’ and break up and dislodge the filter cake.

Figure 8 shows these 3 methods of cleaning fabric filters.

Cleaning by shaking

Cleaning by mechanical shaking requires the dirty air flow to be stopped. A sectional arrangement, similar to that used in reverse air units, is also built into shaking-type baghouses.

Reverse air cleaning

As the name suggests 'reverse air cleaning' is an occasional reversing of the flow direction through the filter with clean rather than dirty air. Fabric filter units are arranged in sections so that one section at a time can be closed automatically to dirty air and the cleaning cycle carried out with reverse flow. The capacity of the unit must be sufficient to allow for one section to be out of service for this periodic cleaning.

Cleaning by pulse jet

A different cleaning mechanism is applied to baghouses cleaned by pulse jet. In contrast to the bag filter systems, the normal air flow in this system is from outside to inside of the filtration bags or tubes, so the bags must be supported on a wire frame to avoid collapsing when the cleaning flow pressure is applied.

The filter medium used also tends to be different, namely needle felted media. When the cleaning cycle falls due for a section of bags – usually a row of bags – an automatic pulse of compressed air is delivered into the venturi 'throat' section at the top of each filter bag. This blast of high-pressure air suddenly entrains larger flows of clean air and directs them rapidly down the inside of the bags. Under the sudden pressure and flow surge the bags expand and a 'bubble' travels down each bag. The flexing of the filter medium dislodges the accumulated filter cake of particles and dislodges much of the deep-seated dust embedded in the medium itself.

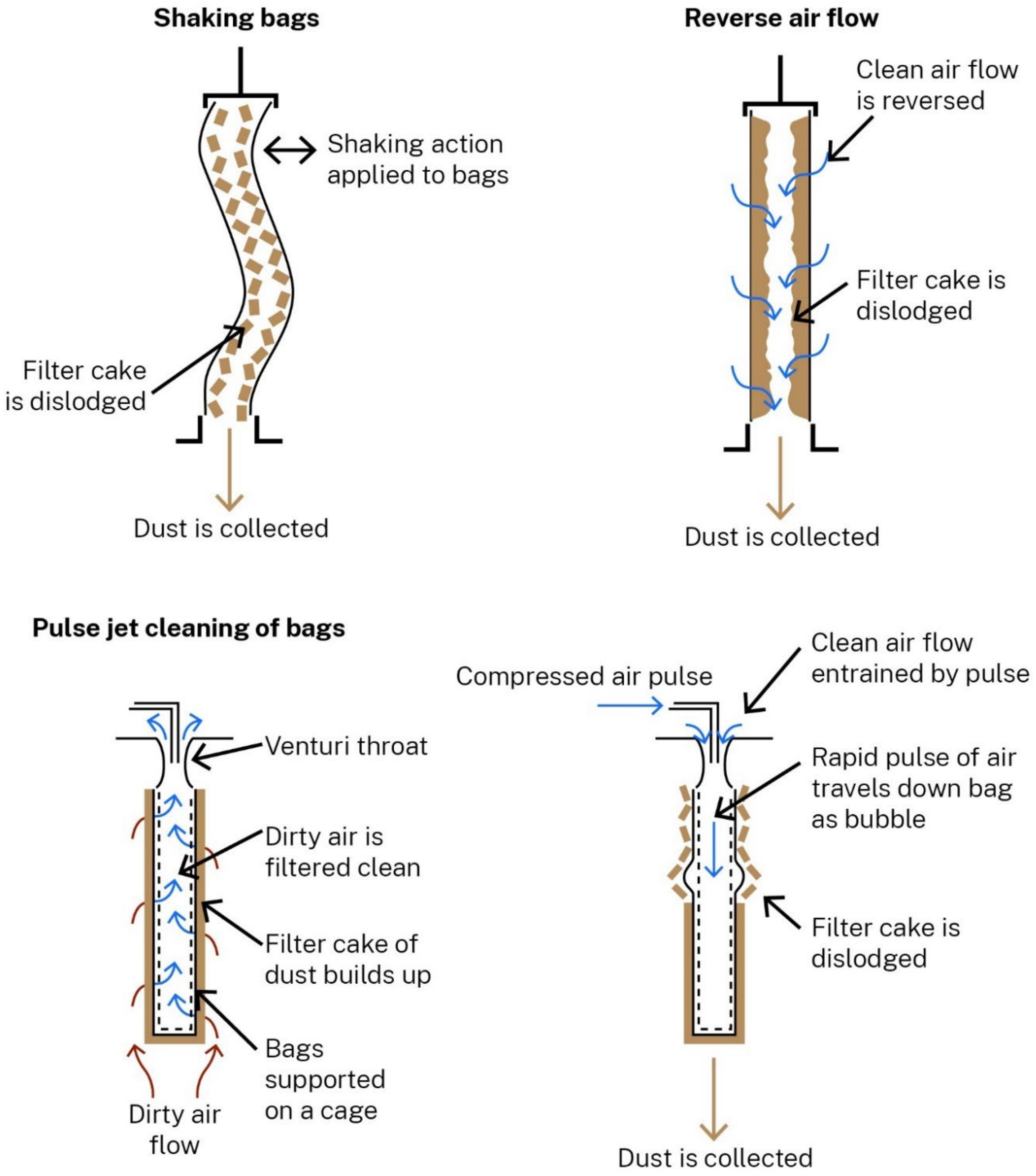
> Venturi is a system for speeding the flow of the fluid by constricting it in a cone-shaped tube.

In reverse air and shaken filters there is some cleaning of particles embedded in the filter medium itself, but there are limitations to the capacity of these relatively gentle cleaning techniques to dislodge the embedded dust. The pulse jet mechanism is more vigorous and achieves a greater measure of cleaning of the filter medium. For this reason, pulse jet cleaning is the most common mechanism adopted in modern baghouse arrangements.

Performance of fabric filters

Fabric filters are generally capable of reducing particulate concentrations to between 10 and 20 mg/m^3 for the types of applications likely to be encountered by local government officers. However, bag filters require attentive and consistent maintenance to ensure continued sound performance.

Most emissions will be invisible to the naked eye at concentrations up to 100 mg/m^3 depending on the size of the dust – so visible monitoring is not generally adequate for assessing fabric filter performance or detecting minor bag failures.


Shaking bags

Reverse air flow

Pulse jet cleaning of bags

Figure 8 **Methods for cleaning fabric filters**

Failure of fabric filters

Failure of fabric filters tends to take 3 forms:

- development of small holes and tears in the bags – this is the most common. Small leaks can account for significant emissions if the inlet dust loading is high. Leaks mostly occur where the bags are attached to the frame or at joints and sharp corners in the supporting ‘cage’ for pulse jet type filter bags. The constant movement of the bags during cleaning results in wear of the fabric or filter medium at these points. If the gas stream is innocuous these leaks can be monitored by ducting the fabric filter outlets to ground level within the premises. Alternatively, electrodynamic particle sensors can be installed that are sensitive to the presence of small concentrations of particles in the gas stream and can alert the operator that the equipment requires maintenance

- condensation in the bags and ‘cementation’ of the dust cake in the filter medium – this can occur when the process is shut down and the baghouse is not in operation. This depends to some extent on the nature of the dust, with hygroscopic (moisture attracting) dusts presenting the greatest difficulty. This problem is overcome by keeping the air constantly moving through the baghouse, with heating if necessary
- burning of the bags by exposure to gases above the recommended temperature of operation – this is usually overcome by introducing fresh, cooler air into the suction of the ventilation or gas movement system just before the baghouse inlet.

Condensation and cementation in filter bags and burning of bags are all directly observable and do not require special monitoring.

Other applications with fabric filters

In some processes, treating gas streams by adding material before the fabric filters can have beneficial impacts on air pollution control:

- An alkaline material, such as lime, can react with acid gases, removing acidity from the emissions. This practice is generally called ‘dry scrubbing’.
- It is unlikely that local government officers will encounter this practice often, but if they do, specialist engineering and chemical advice should be sought since such systems need to be carefully designed for effective performance.
- Additions of absorbent solids as a powder can help the filtration process where difficult materials such as grease or tar mists are present in the dirty gas stream. The adsorbent will form a layer on the filter medium that is more easily removed in the cleaning cycle than the sticky particulate solids in the untreated flow. This practice is generally called ‘pre-conditioning’.
- Injection of activated carbon prior to the baghouse is another absorption technique for the control of air toxics such as dioxins / furans and VOCs. Given this technique is generally used to control toxic air pollutants, it is unlikely that council officers will see this in the industries they regulate.

4.4 Scrubbers

Contacting gases with liquids to remove both particles and gaseous impurities has a long history in air pollution control. ‘Scrubbers’ for removing soluble gaseous materials from gas streams have been used for many years in the chemical and process industries, usually in the form of packed towers. Wet scrubbing is still used in air pollution control but is now not quite as popular as previously. This may be in part because of the restrictions applied to disposal of waste waters, including the contaminated waters from wet scrubbers.

Using wet scrubbing techniques usually means that while an atmospheric waste stream is removed, a liquid waste stream is created.

Wet scrubbers and odours

Many odorous compounds from agricultural activities, food preparation and waste decomposition are insoluble in water under typical wet scrubber conditions. With the introduction of reactive chemicals to the scrubbing process, this method can be effective in odour control, but such scrubbing systems are both complex and costly, needing careful design. Further, they can be difficult to operate effectively.

Wet scrubbers are not always effective at removing odours. Most odours likely to be encountered by local government officers will not be removed by wet scrubbing.

Principles of operation of scrubbers

The key concept underlying all scrubbing is the promotion of contact between the gaseous and liquid streams. Gas–liquid contact is promoted by either:

- imparting high energy to either or both the gas and liquid streams
- providing a large surface area on which contact between the gas and liquid streams can occur.

For particle removal, imparted energy is usually the most important consideration. For gaseous removal, surface area of contact between the pollutant and scrubbing liquor, and residence time are usually most important.

'Residence time' is simply the time the gas stream containing the pollutant is in the scrubber.

Particulate scrubbing

The importance of high energy for particle scrubbing is best appreciated by considering the 3 modes of contact between a particle and a droplet of scrubbing liquor (typically water or other liquid). Contact is essential for removal of the particle.

The 3 possible mechanisms depend on the velocities involved, and are:

- impaction – particles are removed when the velocity of the particle is considerably greater than the velocity of the droplets
- interception – particles are removed when the paths of the particles and droplets intersect at around the same velocity
- diffusion – some particles contact water droplets that are in turbulent motion or diffusion at the same or lower velocities than the particles.

Wetting of particles

For some particles, the ability of the scrubbing liquid to 'wet' the particles can influence the efficiency of removal. In general, the easier the wetting the less energy input required to ensure the particles are wet enough to be collected in the liquid.

One advantage scrubbers have over fabric filters is their ability to cool gases and to survive sudden surges in temperature.

Efficiency may drop momentarily, but the equipment is not damaged except in the case of very high temperatures; for example, greater than 600°C.

Most fabric filters commonly used are severely damaged at temperatures of greater than 250°C.

4.5 Low-energy particulate scrubbers

Low-energy scrubbers are usually chambers in which the dirty gas passes through a spray of scrubber liquor. The chamber may take many forms: cylindrical, cubic, oblong ‘boxes’, and so on.

In low-energy scrubbers the pressure drop or energy requirement is small but the efficiency of collection is low. They are generally only useful for removing coarse particles.

Simple inertial separation, described above, may achieve the same performance but without the liquid handling requirements.

Sometimes the contact between the gas and scrubbing liquor is assisted by installing an irrigated mesh pad in the chamber across the gas path. There are many configurations of this basic arrangement.

Pressure drop (energy consumption) for gases passing through low-energy scrubbers is typically only 0.25–1 kPa. Particle removal efficiencies may be less than 50% for all except quite coarse particles (50–100 μm).

4.6 Medium-energy particulate scrubbers

Many varieties of wet scrubbers have been developed to operate at medium pressure losses, typically between 1.5 and 4 kPa. These medium-energy particulate scrubbers seek to capture some of the efficiency of high-energy scrubbers, without the extreme energy requirements.

Medium-energy particulate scrubbers are usually also more compact in design. The principle is a set of nozzles or equivalent, operating in close proximity to the scrubbing liquor surface.

4.7 High-energy particulate scrubbers

High-energy scrubbers consist of venturi scrubbers or some variation on the venturi concept. Particulate-laden gas is forced under pressure through a conical-shaped ‘throat’ (venturi). The gas velocity increases, and turbulence becomes intense in the throat.

The high-pressure drop across the venturi is the key to good removal efficiency.

A ‘venturi’ throat is simply a narrow section of the tube in which a liquid or gas is flowing.

The scrubbing liquor is introduced into the throat, often under high pressure. An atomised mist is formed, promoting intimate contact between the particles entrained in the gas stream and the multitude of scrubbing droplets formed.

The velocity of the gas is then reduced as it leaves the narrow throat and the droplets containing the dust particles are removed as the scrubber liquor. This liquor is usually treated for removal of solids, for recycling to the scrubbing process. Occasionally ‘once-through’ scrubbing liquor is used, but this is inefficient in terms of liquor usage and the wastewater generated.

The gas is discharged after the particles have been removed. The pressure losses across venturi scrubbers range from 4–15 kPa. Removal efficiencies of 98% and better can typically be achieved for 10 µm particles.

Venturi scrubbers have reasonable capacity for removing gaseous pollutants that are soluble in or can react with the scrubber liquor. However, when there are no particles present with the gaseous pollutants, it is usually more efficient to scrub purely gaseous pollutants using a packed tower as the contacting device, as discussed below.

4.8 Gaseous pollutant scrubbers

Removal of purely gaseous pollutants from a gas stream is most efficiently accomplished in a scrubbing tower or column containing or promoting a large contacting surface between the gas and the scrubbing liquor.

The flow of gas and liquid is commonly arranged in a counter-current fashion. Gas enters at the base of the column and flows upwards while liquid enters at the top and flows downwards. This arrangement produces the most efficient removal and can achieve much smaller outlet concentrations of pollutant in the clean gas discharged than a co-current arrangement.

The scrubbers previously considered for particulate removal, including venturi scrubbers, are co-current arrangements and cannot achieve the same efficiency of removal of gaseous pollutants as the counter-current column.

Methods to increase contact between the gas and scrubbing liquor

A common method for increasing the contact between the gas and the liquid is to provide a large porous surface area by packing the column with various types of specially designed scrubbing media.

Examples of this are Raschig rings, Lessing rings, Berl saddles and structured packing with corrugated plates. Another technique, requiring a slightly higher pressure drop, is to install a series of plates in the column that promote contact (through frothing and foaming) between the counter-flowing gas and liquid. Examples of this are bubble cap trays (Figure 9) or sieve plates (Figure 10).

The principle of this method of removal is the solubility of the gaseous pollutant in the scrubber liquor. By adding a chemical to the scrubbing liquid to react with the gaseous pollutants, the necessary degree of removal might be achieved in a co-current arrangement such as a medium-energy scrubber or venturi scrubber.

If chemicals are used fouling, and clogging of the scrubber packings, can be a problem. Solid products of the reaction, especially those from surface coating activities, can be sticky and adhesive.

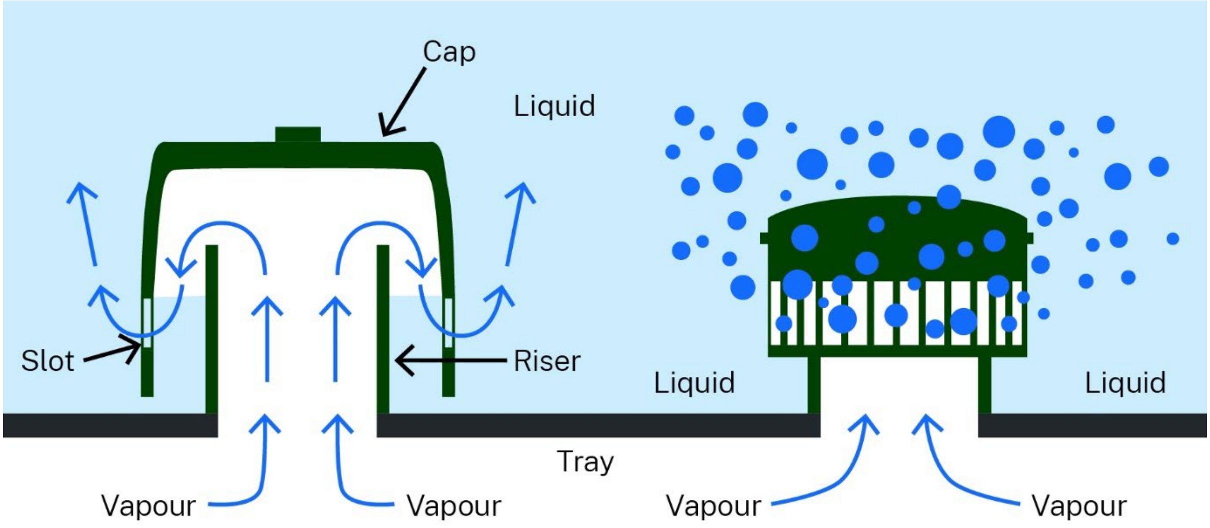


Figure 9 **Bubble cap tray**

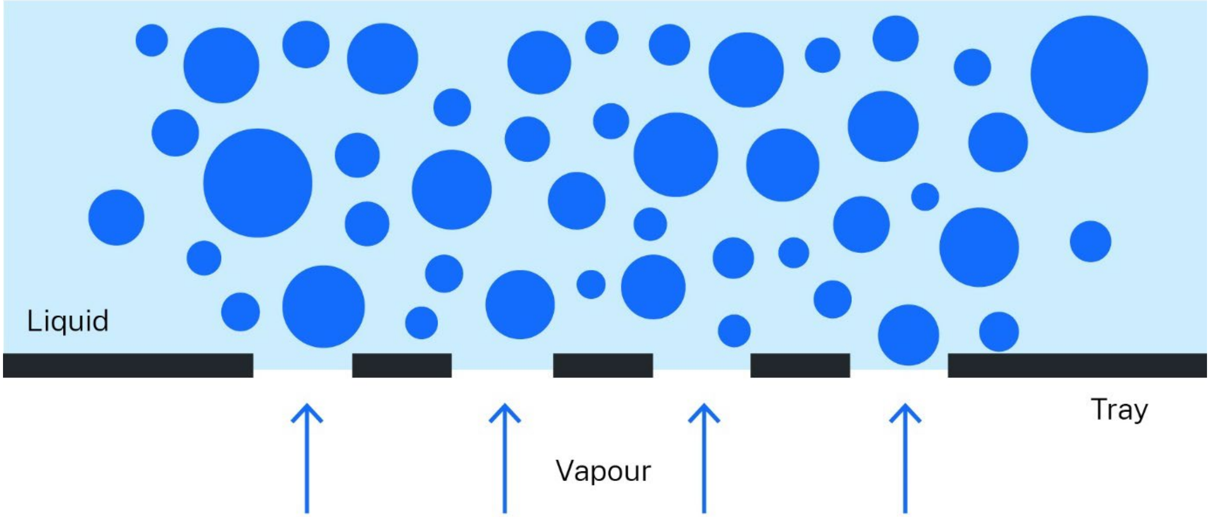


Figure 10 **Sieve plate**

Operating scrubbers for gaseous pollutants

The pressure loss across scrubbers for gaseous pollutants is moderate (0.5–2.5 kPa) but the removal efficiency is typically very high. However, they are relatively costly devices, they require careful design by a chemical engineer, and they can be difficult to operate properly outside the process industries. If a gaseous pollutant scrubber is not operated carefully, flooding and by-passing can occur. This results in upset operating conditions and wide fluctuations in the outlet pollutant concentration. Figure 11 shows a packed-tower gaseous pollutant scrubber.

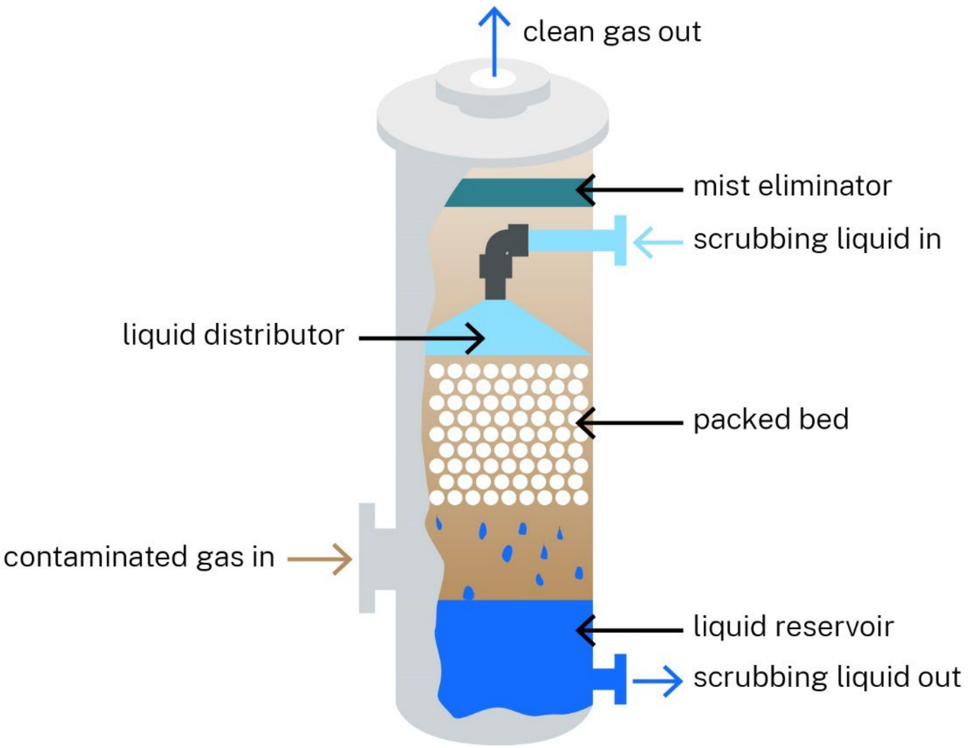


Figure 11 **Packed-tower gaseous pollutant scrubber**

4.9 General scrubbing considerations

Decisions about effective scrubbing devices are complicated by the many configurations and arrangements that have been developed. Local government officers should seek advice on the effectiveness of any proposed solution unless it has a well-proven record for the application.

Scrubbing remains an effective and robust means of removing particles from emissions, especially when high temperatures and variability are characteristic of the processes in which it is used.

Scrubbing with water has mixed effectiveness in the removal of odours – the application for which it is frequently proposed.

Steam plumes

An important aspect to consider is that a visible steam plume is frequently formed when the gases being scrubbed are hot.

Disposal of scrubbing liquor

Finally, removing the solid collected from the scrubber liquor and disposing of or recycling the liquor back into the process need to be carefully considered. The separation process is sometimes difficult, and corrosion can also be a factor, for both the scrubber and the separation equipment.

4.10 Electrostatic precipitators

Electrostatic precipitation has had a role in air pollution control over many years but has been a specialised technique restricted to industries such as metallurgy and coal-fired power generation.

Special forms of electrostatic precipitation are used in large conditioning systems, but these tend to find only limited application for pollution control. Local government officers will occasionally encounter electrostatic precipitators for removal of particles, but not as frequently as inertial devices, filters and scrubbers. For example, where a solution cannot be achieved at a food outlet using basic measures, more advanced control techniques like electrostatic precipitators can be used.

Principle of electrostatic precipitators

An electrostatic precipitator works by imparting an electrostatic charge to a dust particle and then using that charge to draw the particle out of the gas stream to an oppositely charged electrode. The charge is removed, and the particle retained for collection.

Figure 12 illustrates the following process:

1. A set of electrode wires hang between electrode plates; the wires and plates are oppositely charged.
2. A high DC voltage is applied between the wires and plate, sufficient to ionise the gas near the wires (coronal discharge).
3. Dust particles passing near the wires pick up a small electrostatic charge from the ionised gas.
4. The charged dust particles are attracted across the flowing gas stream to the oppositely charged plates.
5. The charge on the dust particles is neutralised at the plates and the particles are retained on the plates.
6. The plates are periodically struck with hammer mechanisms (or ‘rapped’) and the accumulated particles are dislodged in clumps or sheets that fall into hoppers below for removal.

Types of electrostatic precipitators

The basic mechanism of charge and discharge in a high voltage field has many variations in different applications:

- The collecting electrode plates are usually arranged inside large housings in sections that can be electrically isolated for maintenance purposes.
- In some industrial situations, instead of plates the collecting electrodes are tubes inside which the discharge wires hang.
- In other applications the collected particles are removed by periodic washing, with the power disconnected.
- Where electrostatic precipitation is used in air conditioning work, the lower concentration of dust can mean that cleaning is needed less frequently.

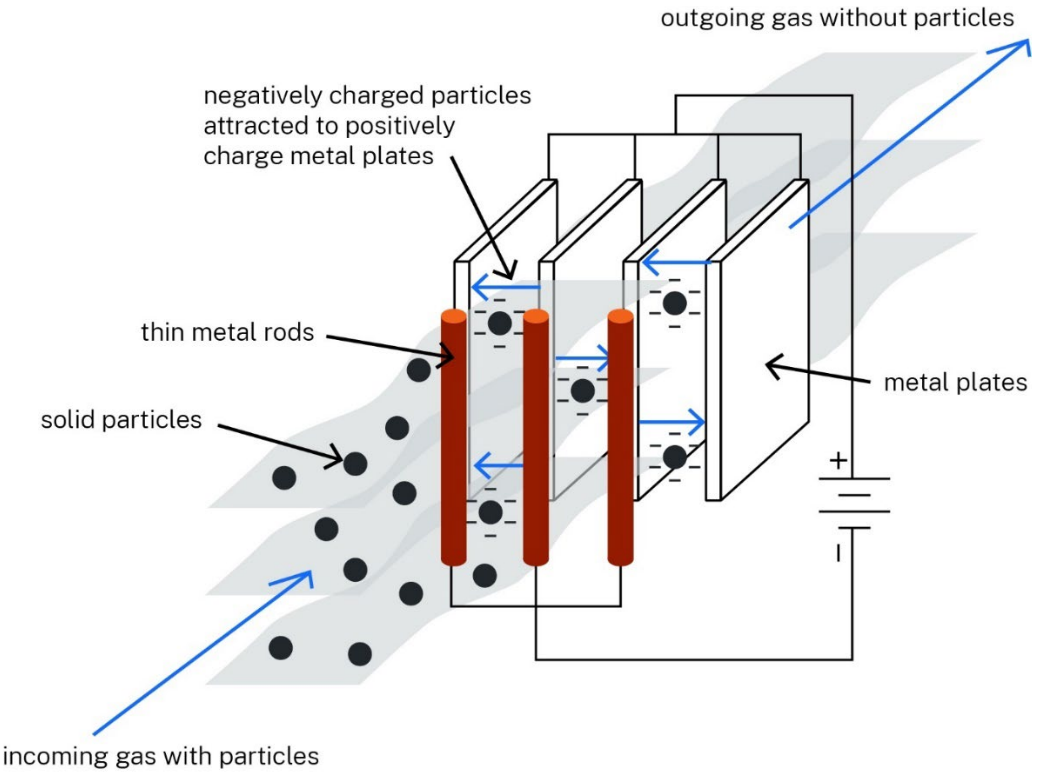


Figure 12 **Electrostatic precipitator**

Performance of electrostatic precipitators

Electrostatic precipitator performance depends on both the electrical and aerodynamic properties of the gases being cleaned, and the particles being collected.

If the electrical resistivity of the particulate material is high, this tends to impede collection. A technique sometimes used to overcome this is to ‘condition’ the dirty gas before it enters the precipitator by adding an acid or alkali spray to the stream to reduce the resistivity of the dust.

Electrostatic precipitators can operate at higher temperatures than fabric filters and this has been one of the traditional reasons for using this type of equipment in the metallurgical and power generation industries, where high temperature combustion is encountered.

The units tend to be more robust to occasional over-temperature episodes (within limits) as compared to fabric filters. However, with improved process control and reliable cooling techniques, the trend has been for fabric filters to replace electrostatic precipitators even in these industries.

For optimal performance, electrostatic precipitators need continual maintenance and careful adjustment. The discharge wires tend to break, causing an electrical short to whole sections of the precipitator, thereby substantially reducing the overall gas cleaning performance. Corrosion of the plates and wires can also be significant problems in some industries.

Lack of suitability for gaseous pollutants

Electrostatic precipitators tend not to be suitable for gaseous pollutants as they cannot remove pollutants such as odour. They are sometimes used in food preparation applications to remove aerosol fats and oils from discharges to air. While this does not remove odour as such, it removes the aerosols, which evaporate after release to the atmosphere. The effectiveness of this form of control for odour reduction is problematic.

4.11 Adsorbers

Adsorption using activated carbon has become more popular as low-level odour problems have come to the fore in air quality management. For example, adsorbers may be included to reduce odorous emissions from food outlets, sawmills and spray-painting operations. The amounts of material causing odour in the air are usually small and can be retained on the adsorbent surfaces for relatively long periods before the capacity of the surfaces is exhausted and the adsorbent needs to be regenerated or replaced.

Figure 13 shows an activated carbon filter for leachate.

Figure 13 **Activated carbon filter for leachate**

Source: Jane Barnett/Zephyr Environmental

Adsorbers are compact, usually easy to install, relatively inexpensive and the disposal of waste adsorbent is not usually difficult.

The principle of adsorption

The molecules of some polluting substances can be held to the surfaces of some solids by surface forces. Effective adsorbents have a large surface area for a small mass or volume of material. The high relative surface area results from the myriad of pores and micropores in the adsorbent material.

The waste gas stream penetrates these pores, with sufficient time for exposure and diffusion, and the pollutants are retained on the surfaces. If the adsorbent is chemically pre-treated to enhance the surface-holding forces, the adsorbent is said to be ‘activated’.

In some circumstances when heat or steam is applied to the adsorbent, the materials adsorbed (the adsorbate) can be removed. This allows the adsorbent to be 'regenerated' for use again and the adsorbate recovered if this is warranted.

Adsorption is the formation of a layer of foreign substance on an impermeable surface.

Absorption is the dissolution of a pollutant in a scrubbing liquid.

Types of adsorbers

Adsorbents such as activated carbon are usually in a porous granular form that allows the dirty gases to flow through beds of the adsorbent. If regeneration is to be incorporated, a dual adsorber can be arranged so that one 'lung' of the unit can be on adsorption duty while the other is undergoing regeneration.

Regeneration is usually applied when solvents or volatile hydrocarbon emissions are being retained, since the amounts of adsorbate are large and able to be recycled back into the process.

If the material adsorbed is an odorous compound the adsorbent may be disposed of to an appropriately licensed landfill, although for continuous duty a dual unit may still be required. Figure 14 shows the adsorber process.

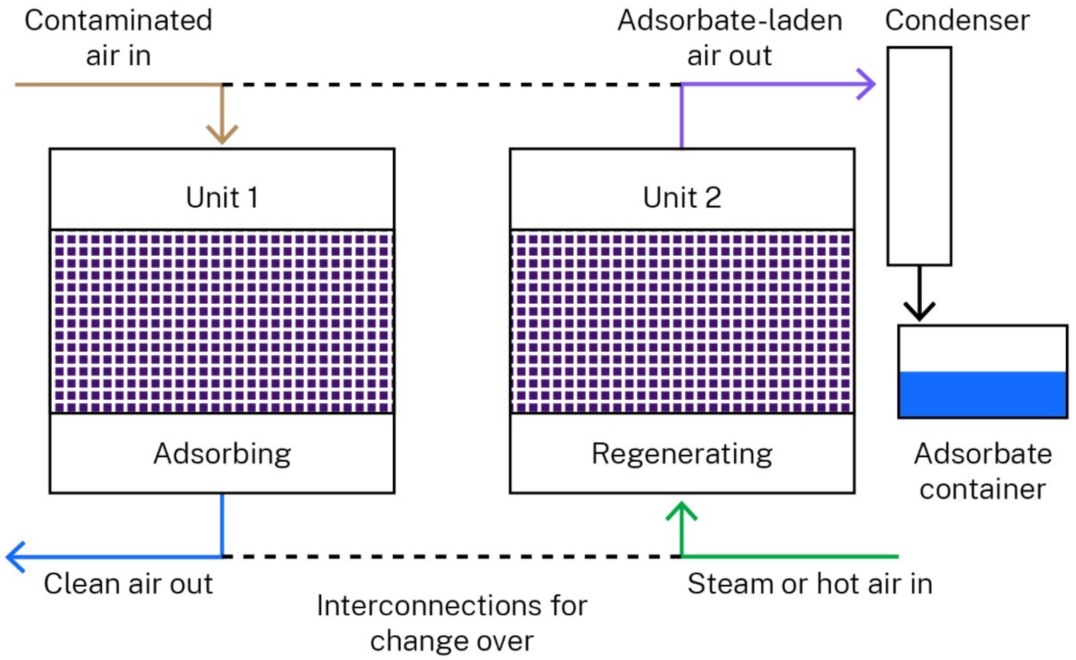


Figure 14 **Absorber process**

For an adsorber to be effective it is essential the capacity of the adsorbent is not exhausted. When the capacity of the adsorbent is exhausted, this is known as 'breakthrough'.

Breakthrough is the point at which the activated carbon has reached saturation and cannot absorb any further VOCs.

Performance of adsorbers

Adsorbers are not universally applicable to any solvent recovery or odour reduction problem. The combination of gas and pollutant type need to be matched to the capability of various adsorbent types. Adsorbents commonly in use are:

- activated carbon
- activated alumina
- silica gel
- molecular sieves.

The cost and capability of these adsorbents increases down the list. Activated carbon is the adsorbent most likely to be applied to problems encountered in local government work. Information about suitability for types of duty and the appropriate type of treatment for activation should be provided by the adsorbent supplier.

The need to monitor the adsorber

A common error made by operators is to install an adsorber and then neglect to monitor the exhaust to determine if the capacity to control has been exhausted, and breakthrough has occurred. In the control of odours, an odour survey by the operator is not effective for determining when the adsorbent should be changed or regenerated. Operators become accustomed to the smells of their operation and literally cannot smell the odours. An independent assessment is needed to establish a reliable changeover pattern. Figure 15 shows the adsorption zone and breakthrough point.

Testing after first installation of the adsorber can be used to determine the breakthrough pattern in relation to the operational patterns. Timing for changeover of the adsorbent bed can then be established.

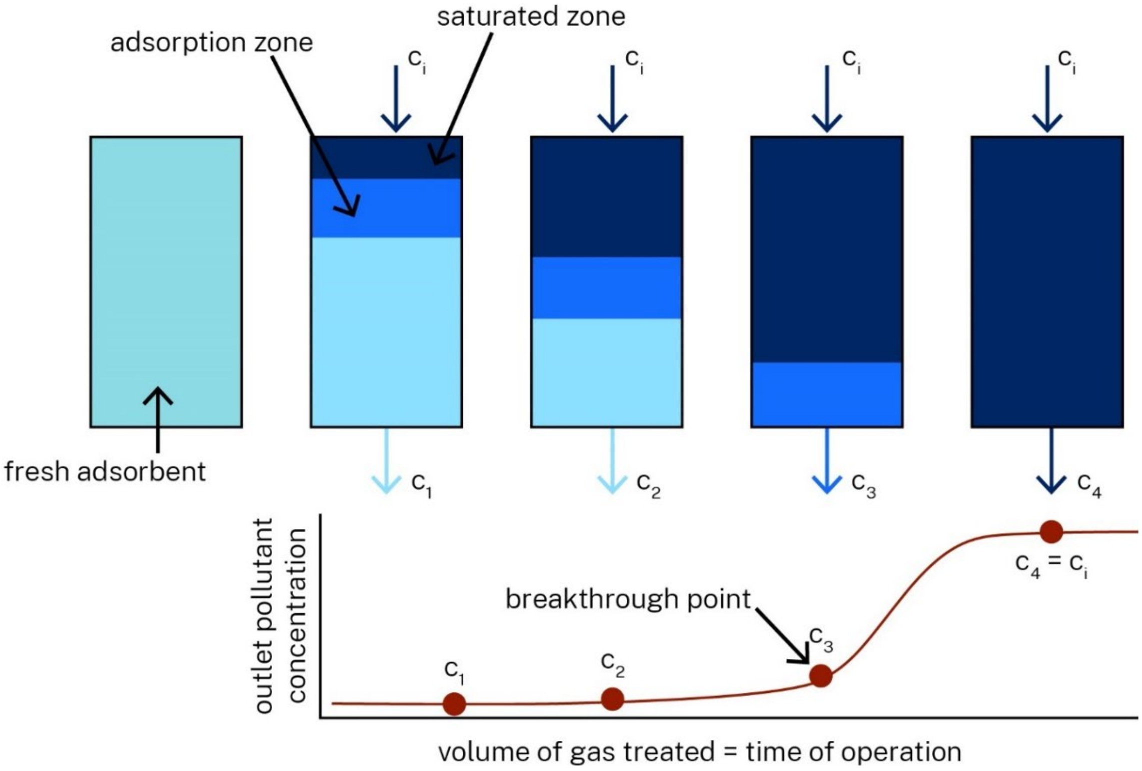


Figure 15 **Adsorption and breakthrough point**

Another important aspect is using the breakthrough point as the signal for the need to change or regenerate the adsorbent, not the saturation capacity as provided by the adsorbent supplier. Significant pollutant discharge through the adsorber commences when the ‘wave’ of adsorbate reaches the end of the bed and this occurs before the capacity of the adsorbent is fully utilised.

Particulates and sticky material

Since adsorption of gaseous pollutants relies on the air carrying them being able to penetrate the pores of the adsorbent, it is important that the adsorbers do not become clogged or blocked. If there is heavy loading of particulates or sticky materials present in the air or gas streams, these need to be removed by some other technique (such as filtration or scrubbing) before the adsorption stage. Alternatively, the presence of other difficult pollutants may warrant the use of a technique other than adsorption.

4.12 Condensation and vapour emissions

For some vapour emissions, direct condensation and recovery of the vapour may be feasible. This is the case for captured petroleum and gasoline vapours in the handling of petrol and some solvents, but it is unlikely in most situations regulated by local government.

> The exception to this may be in the craft brewing industry. Where odorous emissions from a brewery boil kettle cannot be adequately mitigated using dispersion (i.e. amendments to stack exit parameters), a condenser may be considered. The downside of using a condenser in this application is the significant capital and operational costs involved, as well as the creation of a wastewater stream.

Condensation of small concentrations of a condensable vapour, such as a solvent, from a non-condensable gas, such as air, is not usually an efficient process unless very low cooling temperatures involving refrigeration are used.

Condensation

Condensation will usually be encountered in direct contact condensers such as venturi scrubbers; however, the limitations noted under that type of equipment, especially solubility and condensability of the gases involved, also apply to this type of condensation.

In some situations, such as emissions from a rendering plant, large amounts of water vapour are present in an odorous stream. In this case it is first necessary to condense this vapour so the energy requirements for burning the non-condensable gases can be held to a minimum.

Steam plumes

Where a steam plume is encountered because of a scrubber, condensation is not a viable technique. If a scrubber must be used on a hot process, the preferred means of avoiding a steam plume is to reheat the plume to avoid visible condensation in the atmosphere before dispersion. However, this is an energy-inefficient approach unless a source of waste heat is available in the process for the re-heating.

Vapour emissions

Condensable vapours are commonly emitted from handling and storage activities. Petroleum or gasoline is the most notable example of this. Solvents used in a wide range of processes and industries (including construction sites, sawmills and spray painting and surface coating activities) can also cause significant emissions of both odour and VOCs.

The Protection of the Environment Operations (Clean Air) Regulation 2022 (POEO Regulation) provides requirements for tanks and loading plant (Part 6) and large tanker trucks (Part 7) handling volatile organic liquids. Additionally, Part 8 of the POEO Regulation deals with the vapour pressure and Stage 1 and 2 vapour recovery requirements for petrol. More information about vapour recovery can be found on the *Vapour recovery at service stations* webpage (EPA 2023).

Information on the storing and handling liquids is available in the *Storing and handling liquids: Environmental protection participant's manual* (DEC 2007). Other requirements that apply to correct storage and handling such as SafeWork NSW or Australian Standards should also be a consideration.

Whenever a volatile liquid is transferred there is the possibility that a volume of air saturated with the vapour will be emitted with the transfer:

- As a container is filled, the saturated vapour above the liquid is expelled.
- As the container is emptied of liquid, air is aspirated into the vessel and this in turn becomes saturated with the vapour.
- This vapour in turn will be expelled on the next filling.

Several losses of vapour, each equal to the volume of the transferred liquid, can occur from bulk storage, through delivery and process storage, to usage.

Managing vapour emissions

Techniques such as adsorption and incineration can be used to control vapour emissions, but the best way is to institute a system of back venting so that the saturated vapour is transferred back to the delivery vessel with each transfer, thereby avoiding the aspiration of a new air parcel on each emptying.

> The extent to which vapour control needs to be practised is indicated by the volatility of the liquids being handled. In general, if the volatility is comparable to that of petrol, then some form of vapour control is needed.
>
> Another driver for this type of control can be particularly odorous solvents and monomers such as acrylates, styrene monomer and some solvents.

'Breathing losses' are another source of emissions from storage tanks, but these can be limited by appropriate setting of pressure relief valves on storage tanks for high volatility liquids. Small canisters containing activated carbon as an adsorber can also be fitted to tank vents to control breathing losses, as is the case for vehicle petrol tanks.

4.13 Biofiltration

Biofiltration can be used for the removal of odours. The method has largely been developed for and applied to agricultural and food processing activities such as odours from starch making, rendering, intensive animal farming, composting and wastewater treatment. Biofiltration has since become a popular method of odour control for the solid waste / recycling industries.

The principle of biofiltration

In biofiltration an odorous air stream is exposed to an active biomass. The micro-organisms in the biomass will take up, as food, some of the organic material constituting the odour. There is also some adsorption of odorous compounds on the active surfaces of the biomass. Some residual odour of the biomass bed itself is common with biofiltration, but this odour is usually much less intense and extensive than the odours being treated. Some liquid material is also produced and this leachate from the biomass bed must be collected and managed.

Since the process relies on living organisms, it is important that strict conditions of temperature and moisture are maintained in the bed.

The temperature and moisture of the biomass bed need to be maintained nearly continuously and long periods of inactivity need to be avoided. However, overnight shut down does not reduce the effectiveness of most biofilters provided they are dried out by continuous dry gas flow.

The operation of biofilters

Large beds are laid out and supplied with a gas distribution system for the flow of odorous gases upwards through the biofilter.

Filtration velocities must be kept quite low to allow time for sufficient contact between the gases and the biomass. Typical substrate materials for biofilters are mixtures of bark. Some synthetic support materials have also been used.

While biofilters may seem like simple devices, to achieve odour and pollution control objectives careful design by experts is required. If temperature, moisture, pH and bioactivity are not properly accounted for, biofilters can perform poorly.

Figure 16 shows an active biofilter.

Figure 16 **Active biofilter**

Source: Jane Barnett/Zephyr Environmental

4.14 Thermal oxidation

Thermal oxidation (effectively, incineration) of gaseous pollutants is a well-tried and effective concept. If organic materials can be completely oxidised they are reduced to carbon dioxide, sulfur dioxide, nitrogen oxides and water vapour. The first 3 combustion products are pollutants, but at the concentrations generated from the incineration of more troublesome organic air pollutants, these residuals are relatively innocuous.

Thermal oxidation has been widely practised in the petroleum refining and chemical industries, food and food-related industries, waste treatment, wastewater treatment, building materials manufacture, surface coating applications, the printing industry, foundries and at coffee roasters.

Principles of thermal oxidation

The principle of thermal oxidation is complete combustion of organic materials, whether in gaseous, liquid or solid form, to the end products of oxidation as follows:

carbon → carbon dioxide

hydrogen → water vapour

nitrogen → nitrogen oxides

sulfur → sulfur dioxide

chlorine → hydrogen chloride

These end products, except for hydrogen chloride, are considered less noxious than the starting pollutants that are destroyed by the oxidation process.

If combustion is incomplete, the products may be more noxious or odorous than the original pollutants. The focus is therefore on completeness of combustion.

As a general principle, combustion is likely to be complete if the 3Ts ((residence) time, temperature and turbulence) are satisfied in the combustion chamber(s) and adequate combustion air is provided to maintain oxidising conditions.

The use of a simple ‘afterburner’ to mitigate odour emissions from coffee roasters in urban areas is a proven thermal oxidation solution for this activity.

Avoiding chloro compounds

A further important principle has come to light in recent years: avoiding the formation of (new) chlorodioxins and chlorofurans when chlorine is present in the gaseous pollutants to be burned (e.g. removal of PVC from the fuel mix at an energy from waste facility). This result is generally avoided by minimising the inputs of chlorine to the combustion process and ‘quenching’ or cooling flue gases rapidly through the temperature range of 250–400°C, the ‘dioxin formation window’. Alternatively, the gas temperature could be kept above 500°C until discharge to the atmosphere, but this creates significant waste energy. Injection of activated carbon and collection within baghouse filter cake has proved effective in dioxin control.

Thermal oxidisers and fume incinerators

The furnaces in which gaseous pollutants are incinerated take many forms. Some key design requirements are to ensure:

- adequate turbulence is promoted in the combustion zone
- adequate temperature is maintained, 800˚C for most organics, but higher for some organic compounds
- residence time in the combustion zone is adequate, 0.5 seconds for most applications
- adequate oxygen is always provided to maintain oxidising conditions, typically with a minimum of 15% excess air
- flame impingement is avoided
- the burners achieve efficient atomisation where liquid fuels are used (visible ‘sparks’ in the flame are a tell-tale sign of poor atomisation)
- corrosive conditions are accommodated by appropriate choice of construction materials.

‘Flame impingement’ occurs when the primary zone of the combustion process (this is generally the ‘visible’ flame) coincides with a solid surface (usually a refractory brick or tile).

It can result from either the misalignment or the inappropriate location of a burner.

It interferes with the combustion process and produces soot and carbon monoxide.

Simple combustion chamber

The simplest form of combustion chamber is a cylindrical refractory-lined chamber (Figure 17).

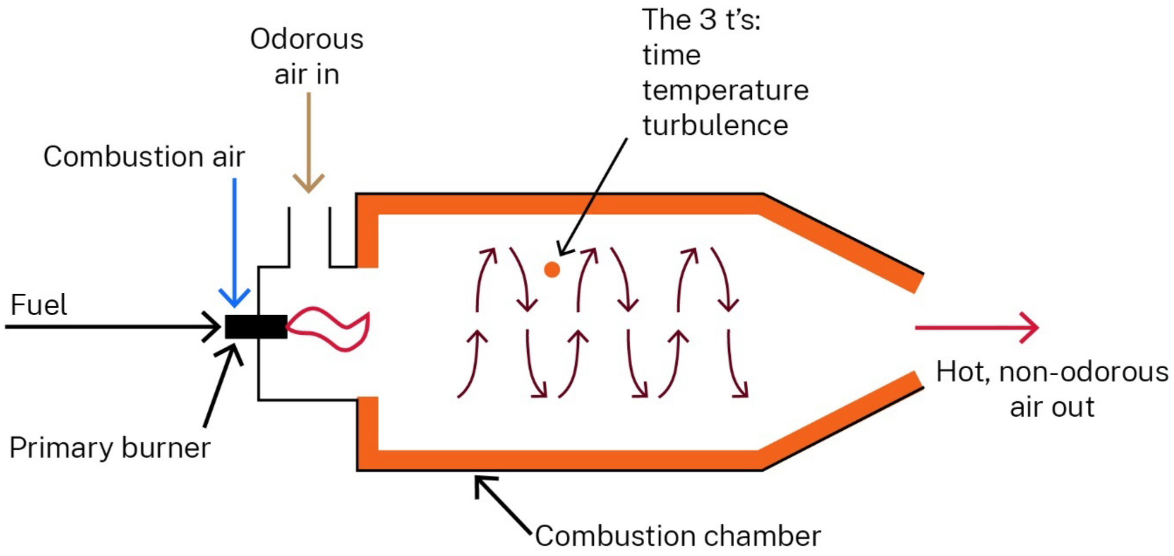


Figure 17 **Cylindrical refractory-lined combustion chamber**

Occasionally larger furnaces will be needed where some organic particulate matter needs to be burned out before discharge. In other situations very small and compact oxidisers are adequate.

Heat recovery

In many cases extensive heat recovery is practised by exchanging heat between combustion products and incoming fumes, minimising energy requirements. However, heat recovery requires extra care if chlorine is present in the fumes because the 'dioxin formation window' is likely to sit within the heat recovery temperatures.

The temperatures of combustion can be substantially reduced, and energy saved if catalytic combustion is possible. The usual catalyst type is platinum on a ceramic substrate.

Care should be taken if the material being thermally oxidised is thought to contain chlorine or other halogenated compounds, since this can lead to dioxin formation. In such instances, council should seek expert advice from either the NSW Environment Protection Authority (EPA) or a specialist air quality consultant.

> Thermal oxidisers should be designed by experts in combustion and air pollution engineering.
>
> As a minimum requirement the 3Ts should be met.

Performance of combustion equipment

Performance of combustion equipment is usually expressed as destruction and removal efficiency (DRE), as a percentage.

DRE = 100 x (W in – W out) / W in

where W is the mass flow rate of the pollutant being assessed, both in and out of the unit.

Typical DREs for efficient and effective thermal oxidation are at least 99.99%. For some hazardous materials DREs of 99.9999% are called for. Higher temperatures and residence times are needed to achieve these levels, depending on the compounds involved.

4.15 Capture of fugitive emissions

The controls applied to the emissions from an activity are only as good as the capture efficiency for emissions from the process.

If fugitive emissions are substantial the control effort in achieving a removal efficiency of 98% or 99% might be largely wasted.

There are 2 basic approaches to capture (see Figure 18):

- total capture, where the whole building is enclosed and ventilated through controls
- local extraction ventilation at the individual sources of emissions within a facility.

The features of the 2 approaches are set out in Table 2.

Design of local extraction ventilation systems

Local extraction ventilation systems require considerable expertise in hood design. As a rule for partially enclosing hoods, all face-capture velocities should be above 0.5 m/s. Where emissions are hot or side-hood capture is proposed, much higher capture velocities may be necessary, sometimes up to 4 m/s. Hood design is a specialist skill and help from an experienced practitioner should be sought.

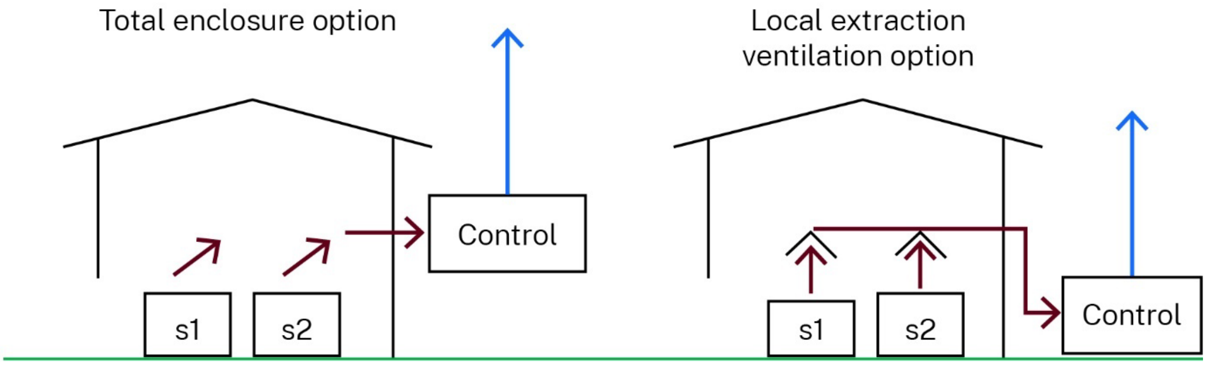


Figure 18 Options for capture of fugitive emissions

Table 2 Features of total enclosure versus local extraction ventilation

Total enclosure	Local extraction ventilation
High rates of flow are mandated by occupational and health requirements	No restrictions on natural ventilation of the buildings
Access to building must be limited and doors kept closed / whole building kept under negative pressure	Access to building is not limited; for example, large openings for truck entrance are unimpeded
Access to machinery is easy	Access to hooded machinery is restricted
A large gas flow is necessary to control fugitive emissions / maintain negative pressure	There is a smaller gas flow to achieve a high degree of capture
The overall capture efficiency is higher and the risk of fugitive pollution is decreased	The overall capture efficiency is lower and the risk of fugitive pollution is increased

Proper management of many of the air pollution control techniques described in this module may require a local government officer to ask the owner or operator of premises to obtain specialist advice, testing and reports.

4.16 Dust suppression

Many activities disturb land surfaces. Wind-blown dust is a common and troublesome air pollutant associated with construction activities, large-scale agriculture, and quarrying.

Wind of sufficient velocity in contact with surface or suspended particles will entrain them if the wind drag forces are greater than the gravity and cohesive forces on the particles.

The principles of dust suppression

Several principles apply to dust suppression activities:

- avoiding exposure of loose dust particles to winds that can lift the particles from the surface they are resting on
- minimising the unnecessary formation of dusty materials through abrasion and crushing of solids due to moving and handling equipment
- avoiding unnecessary disturbance of surfaces that might generate dust particles
- avoiding free dusty material falling through air, where it can be exposed to cross currents of wind
- using water sprays to achieve a simple scrubbing action on particles already suspended in enclosed or semi-enclosed spaces
- maintaining sufficient moisture in dusty materials to keep surface forces strong enough to resist wind entrainment
- promoting bonding of dust particles to the surfaces on which they rest
- using matting or another type of covering over surfaces likely to generate dust
- revegetating surfaces likely to generate dust.

Wetting dusty surfaces

Wetting often results in a degree of agglomeration and weak cementation of loose particles in an unconsolidated surface, with or without the addition of chemicals to promote such bonding.

Water spraying increases moisture content and bonding and wind entrainment will be minimised by the weak cementation or ‘crusting’ that results. This is distinctly noticeable in stockpiles of coal and other loose materials.

Practical measures to prevent wind-blown dust

For detail on techniques to suppress dust refer to the Local Government Air Quality Toolkit visual guides, *Dust from construction sites* and *Dust from small quarries*, the *Construction sites guidance note*, and the *Resource pack*, which provide examples of dust generating activities and dust suppression measures, and site inspection checklists.

4.17 Open burning

‘Open burning’ is combustion of materials without any containing combustion chamber. For the purposes of the POEO Act, an ‘open fire’ or ‘fire in the open’ means any fire in which the products of combustion are not directed to the open air by a stack or chimney. Part 3 and Schedule 1 of the POEO Regulation, set out where open burning of prescribed matter is prohibited and permitted.

For information specific to backyard burning, see the Local Government Air Quality Toolkit, *Neighbourhood smoke guidance note*. For information specific to agricultural burning, see the *Agricultural burning guidance note* and for information specific to trench burning, see the *Small-scale sawmills guidance note*.

5. Air pollution and agricultural industries

5.1 Overview

The characteristics of air pollution from agricultural industries mostly differ from those from secondary industry. The Local Government Air Quality Toolkit guidance notes provide information on a range of agricultural industries, including:

- beef cattle feedlots
- dairies
- egg production
- meat chicken production
- piggeries.

The guidance notes on the above each provide an industry overview, plus details on potential emissions to air and air pollutants, air quality management measures and considerations for local councils.

5.2 Controlling decomposition processes by composting

Intensive agricultural industries produce large amounts of solid organic waste – manure from animals and birds, pen or shed litter and pond sludge.

Advantages of composting

Composting has the advantage that it:

- reduces odour from wastes that would otherwise degrade anaerobically
- converts a waste into a potentially useful produce – for sale or for use on the farm
- destroys pathogens in the waste
- produces a stable and relatively odour-free material that can be stored
- overcomes a waste problem.

To be effective composting must be done in a controlled manner. A composting system should be designed by experts with experience in agricultural composting.

Composting and the POEO Act Schedule 1

Composting on site is permitted, providing there is development consent for this activity and relevant guidelines, protocols and legislation are complied with. For example, responsibilities under biosecurity legislation are met and composting ensures adequate pasteurisation to manage pathogen and weed risks.

Compost generated exclusively from on-site organics does not trigger the licensing thresholds for the scheduled activity of ‘composting’ under clause 12 of Schedule 1 of the POEO Act. This includes disposal of carcasses generated exclusively on site via alternative methods not captured under Schedule 1, such as pit burial.

Receipt of carcasses from off site for burial, composting or similar that are above prescribed thresholds would trigger licensing requirements.

Licensing requirements for composting are only triggered when the organic materials are received from off site and are above the thresholds set out in Schedule 1 clause 12 of the POEO Act.

The composting thresholds may vary depending on the location of the receiving site and whether the organics received are classified as putrescible or non-putrescible. For further details please refer to clause 12 of Schedule 1 of the POEO Act (excerpt below) and clause 50 of Schedule 1 of the POEO Act for definitions of the terms ‘organics’ (including ‘putrescible organics’ and ‘non-putrescible organics’) and ‘regulated area’.

Schedule 1, Part 1, clause 12 – Composting

1. This clause applies to composting, meaning the aerobic or anaerobic biological conversion of organics into humus-like products —
    a. by methods such as bioconversion, biodigestion or vermiculture, or
    b. by size reduction of organics by shredding, chipping, mulching or grinding.
2. The activity to which this clause applies is declared to be a scheduled activity if –
    a. where it takes place inside the regulated area, or takes place outside the regulated area but receives organics from inside the regulated area (whether or not it also receives organics from outside the regulated area) —
        i. it has on site at any time more than 200 tonnes of organics received from off site, or
        ii. it receives from off site more than 5,000 tonnes per year of non-putrescible organics or more than 200 tonnes per year of putrescible organics, or
    b. where it takes place outside the regulated area and does not receive organics from inside the regulated area —
        i. it has on site at any time more than 2,000 tonnes of organics received from off site, or
        ii. it receives from off site more than 5,000 tonnes per year of non-putrescible organics or more than 200 tonnes per year of putrescible organics.
3. For the purposes of this clause, 1 cubic metre of organics is taken to weigh 0.5 tonnes.

Consideration should be given to existing non-scheduled activities that may be approaching the production limits outlined above.

Composts containing animal carcasses cannot be supplied for use off site (i.e. outside the premises where the compost was generated) unless a site has obtained a specific resource recovery order and resource recovery exemption from the EPA that covers that particular waste type. The EPA’s order for compost (the compost order; EPA 2016) defines compost as any combination of mulch, garden organics, food waste, manure and paunch that has undergone composting. It was not developed for composting carcasses and does not apply to composting dead stock or animal parts.

‘Paunch’ is defined in the compost order as the undigested food contained in the stomach of ruminant animals. This is generally considered to include partially digested grass, hay and other feed products such as grain.

Any person proposing to produce/supply compost should give careful consideration to the intended use and all relevant regulatory requirements before determining whether to include animal parts or carcasses in the process.

While carcasses are not an allowed input under the existing compost order, a specific order and exemption can be sought by making a submission to the EPA under the Resource Recovery Framework. Supporting evidence is needed to show that the final compost generated is beneficial or fit for purpose and poses minimal risk of harm to the environment and human health. Information on applying for a specific exemption is available on the EPA's *Apply for an order and exemption* webpage (EPA 2018).

Marketing compost

If the compost is to be marketed commercially it should comply with Australian Standard AS 4454-2003, which specifies physical and chemical requirements for composts, soil conditioners and mulches. It also prescribes methods for testing the various characteristics.

Effective composting

Effective composting involves cost, operational input, equipment and land.

Composting is primarily an aerobic decomposition process. The temperature rises to between 60˚C and 70˚C at the peak of the decomposition process. The key to effective composting is maintaining appropriate conditions throughout the process, including:

- carbon to nitrogen ratio in the composting materials
- moisture content
- temperature
- adequate oxygen supply throughout the reacting body of materials; permeability to air may require the admixture of bulky permeable materials (e.g. wood shavings, straw or shredded paper) to ensure adequate porosity
- effective mixing of the composting materials
- control of drainage from the composting operation.

There are several practical composting methods:

- passive windrowing (low technology) (Figure 19)
- turned (active) windrowing (common on farms and increases aeration frequency) (Figure 20)
- aerated static piles (effective for farm and municipal operations; pile insulation and filters can be used) (Figure 21)
- in-vessel composting (large-scale systems for commercial operations).

Composting can involve strong odours, especially at the time of turning or agitating the windrows to ensure oxygen penetration to the decomposing material. However, the advantage is that odour generation can be controlled during the process and if the resultant material is to be spread 'on farm' it replaces an otherwise odorous process over a wide area.

Figure 19 **Passive windrows**
Source: Tucker et al. 2015

Figure 20 **Aerial view of active windrows**
Source: Nearmap aerial image

Figure 21 **Aerated static piles**
Source: Nearmap aerial image

5.3 Treating odorous shed and digestion gases

Biofilters can remove the types of odours generated in sheds housing large numbers of animals and birds (refer to Section 4.13 above). They are also commonly used for composting facilities where odorous processes such as waste separation and maturation are taking place. The size of the biofilter needs to be proportional to the volumes of air requiring treatment. Figure 22 presents an aerial view of a biofilter.

Figure 22 **Aerial view of a biofilter treating odour ducted from a building**

Source: Nearmap aerial image

5.4 Combustion of anaerobic gases to destroy odours

Complete combustion is an effective means of destroying odours in gases (refer to Section 4.14 above). Some intensive agricultural industries require heat inputs, especially if slaughtering facilities are also installed on the site. The combustion of odorous gases is feasible in these facilities.

If digestion gas is collected from either covered ponds or enclosed digesters, the methane in the gas can be a useful fuel supplement; both replacing fossil fuel usage and substantially reducing the greenhouse gas impact of methane emissions. Methane has 28 times the greenhouse gas impact of carbon dioxide, so converting methane to carbon dioxide via combustion reduces the carbon footprint.

5.5 Other techniques

Occasionally ‘masking’ or allegedly ‘counteractive’ agents are offered to operators with odour problems as a cheaper option. The principle involved is to subject the olfactory senses to a stronger smell than that of the unpleasant odour. A measure of neutralisation or counteraction is theoretically possible, but the effect is not well understood, and the consequences cannot be scientifically predicted.

These are rarely effective as permanent solutions; however, they can be useful if there has been an emergency or short-term one-off odour release.

The scientific principles that ‘masking’ and ‘counteractive’ agents are based on are not well quantified and they have not been adequately proven as solutions.

In most cases, introduction of an odorous ‘masking agent’ will either shift the odour problem, or exacerbate it by introducing additional odours of a different character.

6. References and other resources

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

DEC (Department of Environment and Conservation) (2006a) *Technical Framework: Assessment and management of odour from stationary sources in NSW*, NSW Department of Environment and Conservation, Sydney South NSW, www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/air/20060440framework.pdf [PDF 259 KB].

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DEC (2007) *Storing and handling liquids: Environmental protection participant's manual*, NSW Department of Environment and Conservation, Parramatta NSW, www.epa.nsw.gov.au/licensing-and-regulation/licensing/environment-protection-licences/compliance-audit-program/storing-and-handling-liquids-trainers-manual.

EPA (2016) *Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014: The compost order 2016*, NSW Environment Protection Authority, Parramatta NSW, www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/wastegrants/rro16-compost.pdf [PDF 128 KB]

EPA (2018) *Apply for an order and exemption*, NSW Environment Protection Authority, Parramatta NSW, www.epa.nsw.gov.au/your-environment/recycling-and-reuse/resource-recovery-framework/apply-for-an-order-and-exemption.

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Tucker R, McDonald S, O'Keefe M, Craddock T and Galloway J (2015) *Beef cattle feedlots: waste management and utilisation*, Meat and Livestock Australia Ltd, North Sydney NSW, www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/feeding-finishing-and-nutrition/manure-handbook/beef-cattle-feedlots---waste-management-and-utilisation.pdf [PDF 10.2 MB]