

Module 3:

Guidelines for managing air pollution

Part 1: Air pollution control techniques

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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 nearly 150 years, and most of the techniques used today were known by the middle of the twentieth century. The last 50 years have seen further improvements in design and much better predictability of performance.

Key principles

The objective of this part of Module 3 is to introduce the various types of air pollution control techniques that are likely to be encountered in non-scheduled premises. 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.



An old fabric filter in a mining museum

2 Avoidance—cleaner production

The best way to control air pollution is to avoid it in the first place. This may seem like stating the obvious, but it is amazing how often obvious gains can be missed by failing to explore the possibilities for avoidance.

Avoiding pollution and waste is commonly dealt with under the paradigm of ‘cleaner production’. There are no universal rules for pursuing cleaner production. It relies on an attitude of mind which seeks continual improvement and a willingness and ability to innovate.

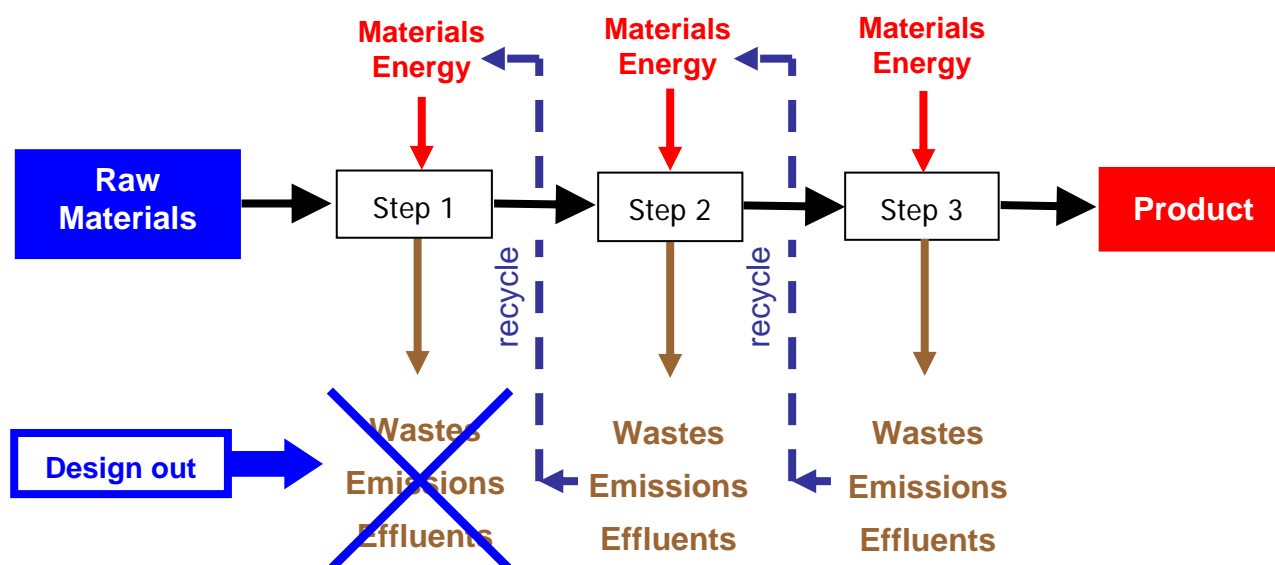
2.1 Tools for cleaner production

Some of the tools which 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.

The diagram below illustrates how a process can be analysed step-by-step or unit-by-unit to document all the inputs and outputs of materials and energy with a view to recycling, reusing and eliminating wastes, including emissions to air.

Cleaner production process analysis



2.2 Case studies

Case studies of successful innovations can also be useful. For example, they can suggest new lines of development for the process under review.

A wealth of case studies and suggested techniques are available from several websites:

www.environment.nsw.gov.au/cleaner_production/index.htm

www.environment.nsw.gov.au/cleaner_production/selfhelptool.htm

www.environment.nsw.gov.au/small_business/index.htm

www.environment.nsw.gov.au/cleaner_production/ipccasestudies.htm

www.deh.gov.au/settlements/industry/corporate/eecp/case-studies/

www.epa.gov/oppt/ppic/ppicdist.htm

(US EPA Pollution Prevention Information Clearinghouse)

2.3 Substituting materials and fuels

Avoiding a problem in the first place can often be done by making a simple change such as substituting materials. For example, the simplest way to overcome a neighbourhood odour problem caused by a surface coating operation might be changing to a less odorous but equally effective solvent. Or, avoiding a particular type of feed in a poultry farm may greatly reduce the otherwise difficult-to-control fugitive odours from growing sheds.

2.4 Involving all staff

Experience shows that suggestions for real advances in cleaner production can come from unexpected quarters. 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, of course, essential for these attitudes to become generally adopted throughout an organisation.

3 Dispersion

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

3.1 Effectiveness of dispersion

The dispersive capacity of the atmosphere is great in most meteorological conditions—much greater than dispersion in the water environment. Dilution of pollutants to the order of one thousand to one (1000:1) is commonly achieved in the atmosphere after less than one kilometre of travel, whereas dilution of the order of ten to one (10:1) is usually only reached after several kilometres of travel in open waters.

Most solutions to air pollution involve some degree of dispersion. Almost all combustion gases, except from gas space heaters, are discharged through stacks of some sort to dilute combustion gases to acceptable levels at the breathing zone.

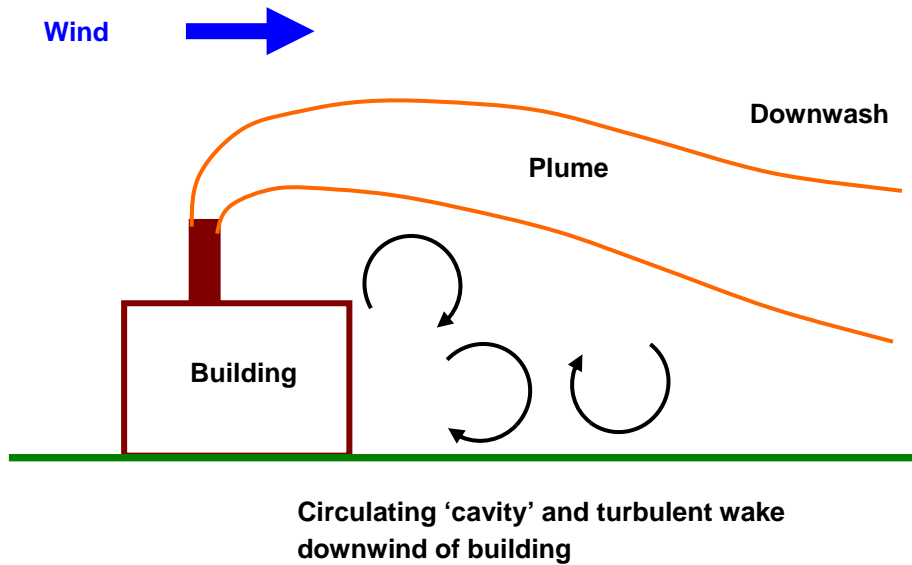
3.2 Stack height and separation

We saw in section 2 of Module 1 that by raising the height of a discharge we can markedly reduce concentrations of pollutants at ground level—doubling the effective stack height can more than halve the ground level concentration. However, the cost of building the stack also increases in more than direct proportion with height.

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 ponds, stock yards and animal runs.

Sizing of stacks

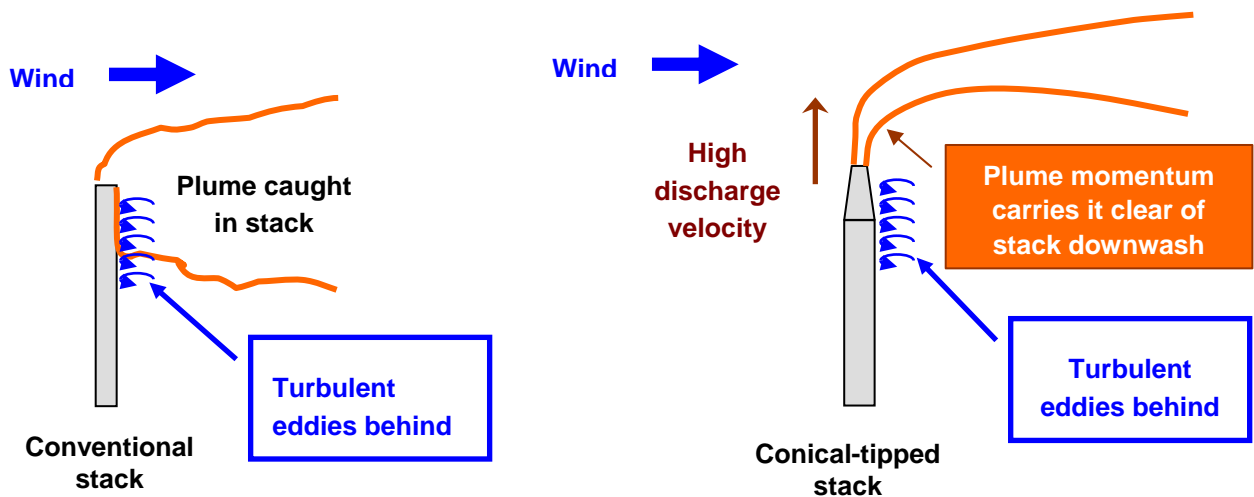
Sizing of stacks where any significant degree of pollution dispersion must be achieved is a specialised exercise. Air dispersion models such as AusPlume are used and interpreted by experts. The DEC *Approved methods for the modelling and dispersion of air pollutants in New South Wales* (2005) should be followed.



Building effects

For many smaller combustion and ventilation sources a short stack will often be effective. In these situations—for example, from small combustion equipment fired with natural gas—it is usually sufficient to require the stack discharge point to be 3 metres above the highest point of the building in which it is located (or of nearby buildings). This avoids building downwash effects (see Module 1 section 2).

Stack effects



To avoid downwash of the plume behind the stack itself, the discharging gases should have a vertical upwards velocity at full rate of operation of 15 metres per second.

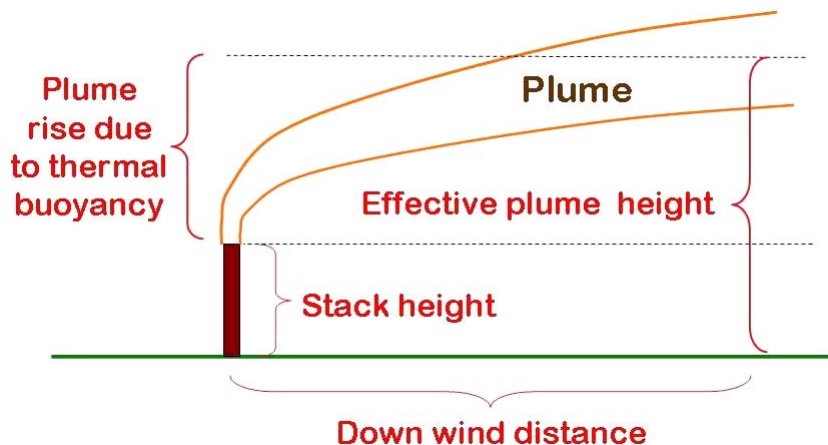
This is the reason why the old fashioned conical cover over the outlet of a stack should be avoided. If some sort of rain protector is needed then types resulting in an upwards discharge should be fitted. Rain almost never falls vertically and so a drainage ‘gutter’ around the inside wall of a stack usually suffices to catch any precipitation entering the stack when the equipment is not operating.

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

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.



The physical momentum of the plume due to its discharge velocity usually adds little to the plume rise. The main effect of a high velocity of discharge from a stack in most situations is to escape the stack’s own downwash, as discussed above.

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 further speeding up will just add to the fan energy and might cause a noise problem.



This sort of stack cover should be avoided as it reduces the plume rise.



This eddy shedding structure on the stack has no real effect on dispersion from the stack.

3.3 Advantages of dispersion for odours

So long as the pollutants being discharged have no toxic impact and are not likely to be cumulative, odours often can 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 to success, then expert modelling skills must be introduced. ‘Hit and miss’ solutions become too expensive if large stacks are needed.

If odour is involved, the DEC *Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW (2001)* should be followed. This will help to ensure that sound practices are followed in reliably assessing the odour source and in applying the dispersion prediction methods.

However, local government officers should be mindful that odour assessments are 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 stack at a cost comparable to the cost of the odour assessment study itself.

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 Module 1, section 2.

Modelling packages available such as AusPlume or TAPM are relatively user-friendly and allow most consultants familiar with software applications to produce ‘answers’. Making the various judgments needed for inputs to the modelling packages about meteorological, topographical and building factors requires some experience, except in the most simple and straightforward cases.

The answers produced by the model are not necessarily correct simply because they come from an accepted modelling package, and can sometimes be misleading in inexperienced hands. As well as checking the credentials and modelling experience of the modeller it is wise to check whether all of the modelling factors appropriately represent the situation of the premises or activity.

3.4 Fugitive odour emissions

Fugitive emissions are those that do not come through the control or dispersion devices.

Fugitive emissions also need to be carefully considered in odour dispersion assessments for two reasons:

Firstly, measurement of emissions from open, smelly surfaces or large, semi-open buildings is far more problematical 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, applying a sampling hood of, say, 0.5 square metres over a small section of a collected garbage surface might give quite misleading results, depending on the extent of sampling. Obviously the different contents of small sections of garbage produce vastly different levels of odour.

Air sampling above smelly liquid surfaces is also tricky—the sampling process itself may not simulate the evaporative conditions that the liquid surface actually experiences in the open atmosphere. Methods are available (e.g. OHM, US EPA 1986 EPA/600/8-8E/008) but they are difficult and expensive.

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

- Consider the expertise and experience of the testers and modellers.
- Be critical—do not be afraid to ask the experts difficult questions.
- Consider parallel experience elsewhere.

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 ten rather than a factor of two to achieve any significant difference in community perception. **Half a bad smell is still a bad smell!** So, if the fugitive emissions are likely to account for a substantial part of the total odour emission, ten-fold reduction of, say, half the emissions, is effectively negated by the fugitive emission of the other half if it continues uncontrolled.

See Module 1, section 3 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 that workplace occupational health and comfort requirements are met. This can then result in very expensive control equipment or very large ductwork, fans and stacks, or both.

3.5 Limitations to dispersion

Regional limitations

Dilution is not the solution to regional pollution!

Where there are cumulative impacts from the pollutants being dispersed, dispersion is not an adequate solution in itself. So, for example, dilution of nitrogen oxides or volatile organic compounds by discharge through stacks might address **local odour and exposure problems** 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 probably does 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 un-noticed dust is being spread around the neighbourhood from an elevated discharge point. A more costly solution is to fit tribo-electric dust leak monitors.

4 Air pollution control devices

4.1 Simple inertial separators

Devices which 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 emission standards for particles. But, they can 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 quantity that measures inertia for a moving object is its momentum—the product of the object's mass and its velocity.

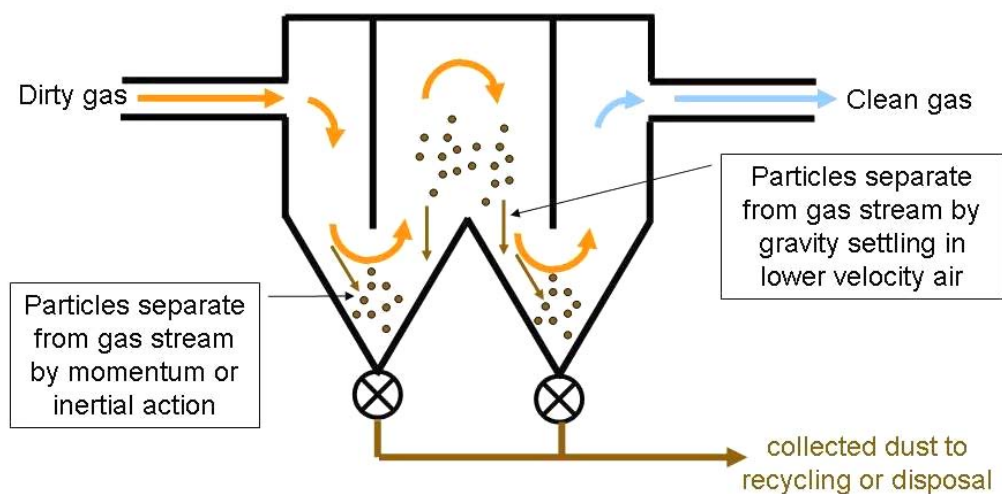
Inertial devices rely on two principles:

- 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 in the time of its travel 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

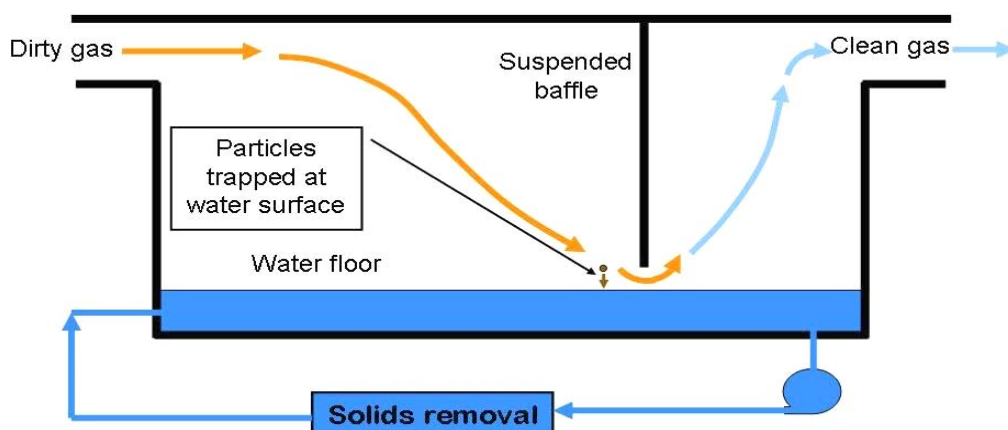
A simple inertial device is shown in the diagram below. This type is rarely used alone nowadays, but it illustrates the two principles of inertia and settling at work.

A simple inertial separator



A device which is sometimes used to supplement this effect is to provide a water floor to the inertial/settling chamber to trap particles moved to the floor by inertial and settling effects.

Simple inertial separator with water floor

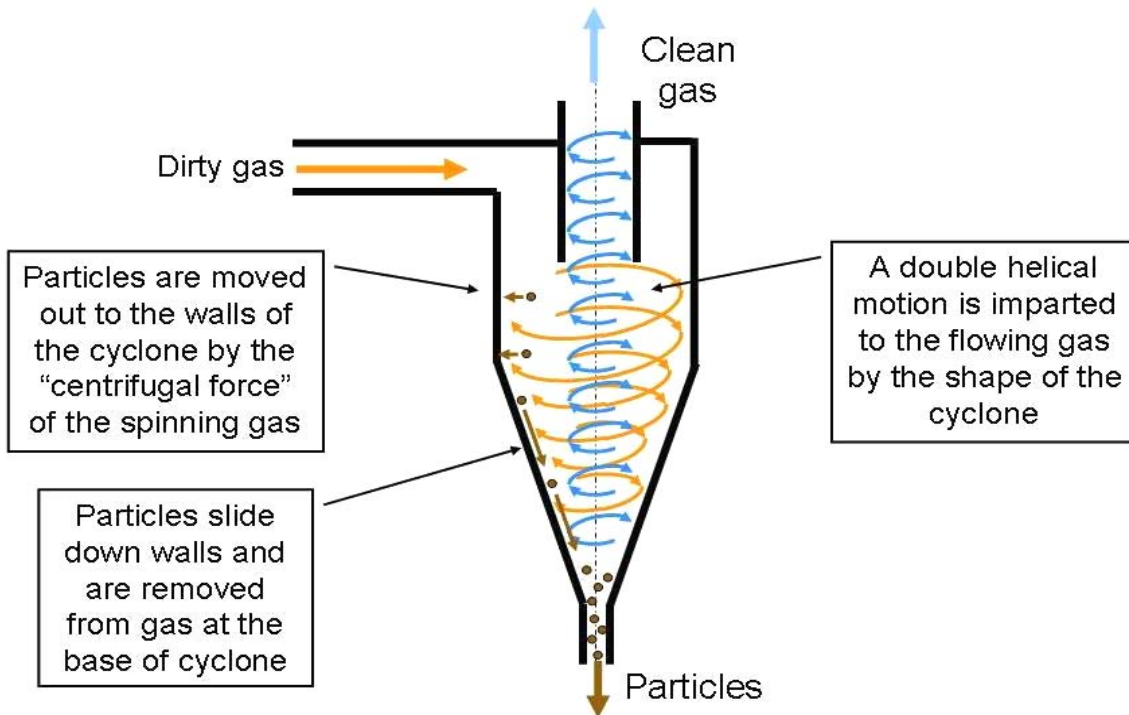


An arrangement based on these principles was common in small, older incinerators. This has largely disappeared as such incinerators have been replaced with cleaner and more efficient disposal methods. Occasionally this principle is still encountered in various types of scrubbing chambers.

4.2 Cyclones

The most familiar inertial device is the cyclone separator, usually a cylindrical vessel with a tapering conical base. The gas enters the cyclone body tangentially and the flow imparts a helical spin to the gas stream.

Cyclone separator

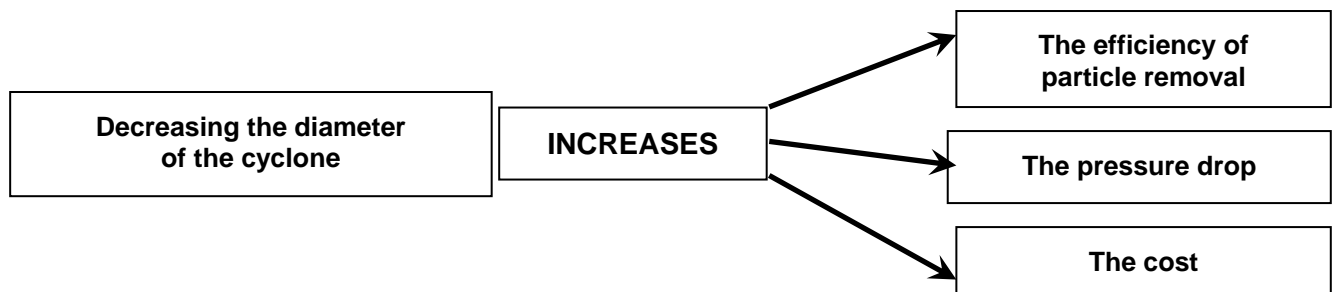


The gas whirls downward, gathering velocity as the diameter of the cone decreases, and then returns in a helical spinning stream up the centre of the outer helix and exits the vessel at the top through an axially placed exit tube. The spinning motion creates a 'centrifugal force' on the particles in the gas stream, causing them to move through the spinning gas outwards 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.

Removal efficiency

The removal efficiency of particles from the gas stream depends on the velocity of flow and the diameter of spin. The pressure loss to be overcome in forcing the spinning air through the device, and hence the power and operating cost incurred, is also related to the velocity and diameter of the cyclone.

In general:



This is an example of the typical trade-off situation which often occurs in air pollution control—for higher efficiency we need to spend more on operational energy.

However, there are limits to the velocity which 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 many

cyclones arranged in parallel—the commonly encountered ‘**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 larger single cyclone.

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

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

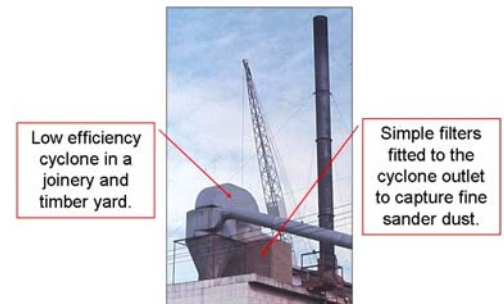
As a general rule, the smaller the diameter of the cyclone the more efficient will be the removal of smaller particles. The following table gives a very rough indication of likely performance. For precise estimation of efficiency for a given application an engineer’s report should be obtained.

Table 1: Rough indication of cyclone performance

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

Cyclones combined with filters

For coarse dusts, such as those encountered in joinery works, low-efficiency cyclones are often used in conjunction with some kind of fabric or fibrous 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 advanced particulate removal is filtration. Filtration has a long history in air pollution control.

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 have been extensively studied and developed. They range from simple woven fabrics, through needle-felted synthetic materials to teflon-coated glass cloths.



Close up of the bag filter from a gold mine

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.

Principle of filtering

The principle of operation 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 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 (mainly in air conditioning systems, occasionally in industry) 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 secondary industry 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 two factors, because all filters, if operated in their recommended range, are capable of delivering gas that is relatively clean of particles after filtering.

The main types of filter media used in industrial applications fall into the categories of woven fabrics 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



Medium-sized baghouses



Small baghouse collecting saw dust from a suburban joinery shop

- resistance to chemical attack
- suitability for washing or other methods of external cleaning
- temperature resistance, and
- life of bags.

Natural and synthetic fibres are used: cotton, polypropylene, polyester, nomex, gortex, 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 gortex bags.

Air-to-cloth ratio

A key factor in determining filter performance is the so called ‘air-to-cloth’ ratio (ACR).

Much useful experience has been accumulated and documented in the early years of air pollution control and consequently the old imperial units of measure are still routinely encountered for this parameter.

The air-to-cloth ratio is the ratio of gas flow in cubic feet per minute to filter area in square feet (cfm/sq ft).

The ratio is equal to the average velocity of gas flow through the filter in feet per minute.

Air-to-cloth ratios usually encountered across the normal spectrum of air pollution control experience range between 1 and 12 feet per minute (discussed further below). The corresponding filtering velocities in metric units are between 0.005 and 0.06 metres per second (m/s).

$$ACR = \frac{\text{volume / time}}{\text{area}}$$

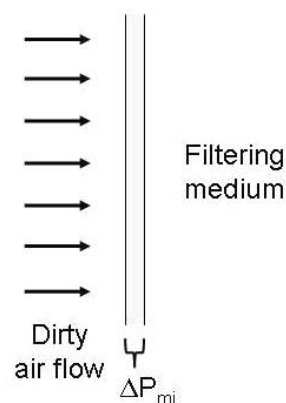
$$\therefore ACR = \text{velocity}$$

Recommendations for the various types of cleaning duties encountered are generally given in terms of an air-to-cloth ratio coupled with a designated cleaning mechanism.

Resistance to flow or pressure drop

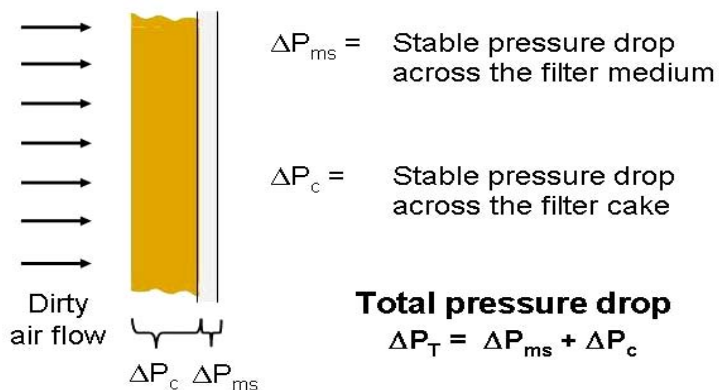
Maintaining pressure drop across the filter at a reasonably low value is the key performance outcome and it depends on the air-to-cloth ratio. This in turn means maintaining the air flow through the filter unit. The pressure loss through the filter medium increases with time as particles embedded in the medium build-up to form a ‘filter cake’.

If the back pressure increases because of inability to effectively clean the filter medium of accumulated dust, then the gas flow will be reduced. Limited flow reduces the normal operating output of the equipment in cases where all the dirty gas generated must pass through the filter (e.g. flue gases from a boiler in a power station).



ΔP_{mj} = Initial pressure drop across the filtering medium

This situation is likely to receive prompt attention from management. But in cases where the dirty gases are fugitive, back pressure will impede flow, reduce capture efficiency and result in increased fugitive emissions, without affecting the ability of the equipment to produce at normal rate. This situation might continue unattended for some time.



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

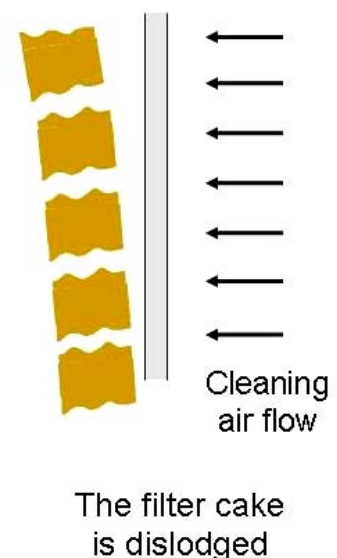
- the pressure loss as the air passes through the filter medium itself
- the pressure loss as the air passes through the filter cake that has accumulated on the filter medium.

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 be either removed and cleaned externally with cleaning agents (for example by washing) or replaced.

Typical pressure losses across fabric filters range between 0.5 and 1.5 kPa (2 to 6 inches water gauge).

The 'inch of water gauge' (or 'inch of water column') is a traditional unit of pressure used in plumbing and ventilation to describe both water and gas pressures. The word 'gauge' after a pressure reading indicates that the pressure stated is actually the difference between the total or absolute pressure and the ambient air pressure at the time of the reading.

One inch of water is approximately equal to 250 Pa or 0.25 kPa

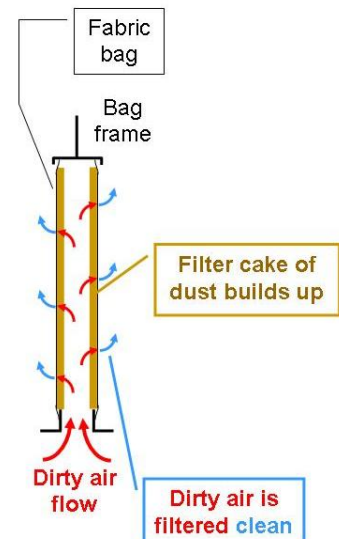


Cleaning techniques for filters

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

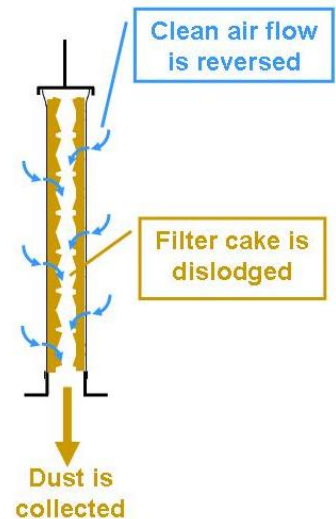
- **reverse air**—ceasing filtration periodically and then reversing a flow of clean air through the filter elements ('bags')
- **shaking**—ceasing filtration periodically and shaking the 'bags'
- **pulse-jet**—directing a pulse of clean compressed air against the flow periodically to expand the 'bags'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



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.

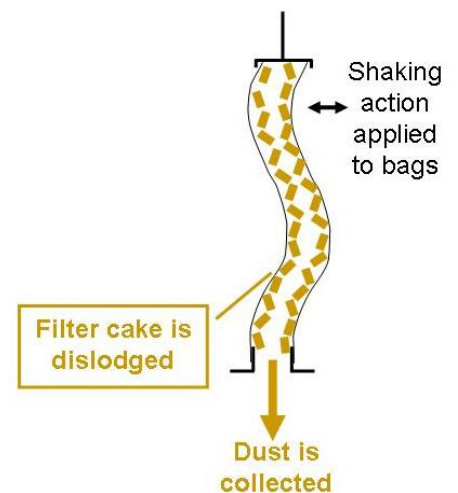
Reverse air flow



Cleaning by shaking

Cleaning by shaking also 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.

Shaking bags



Cleaning by pulse-jet

A rather different cleaning mechanism is applied to baghouses cleaned by pulse-jet. In contrast to the bag filter systems described on the previous page, 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 throat of a venturi 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 dust particles and dislodges much of the deep-seated dust embedded in the medium itself.

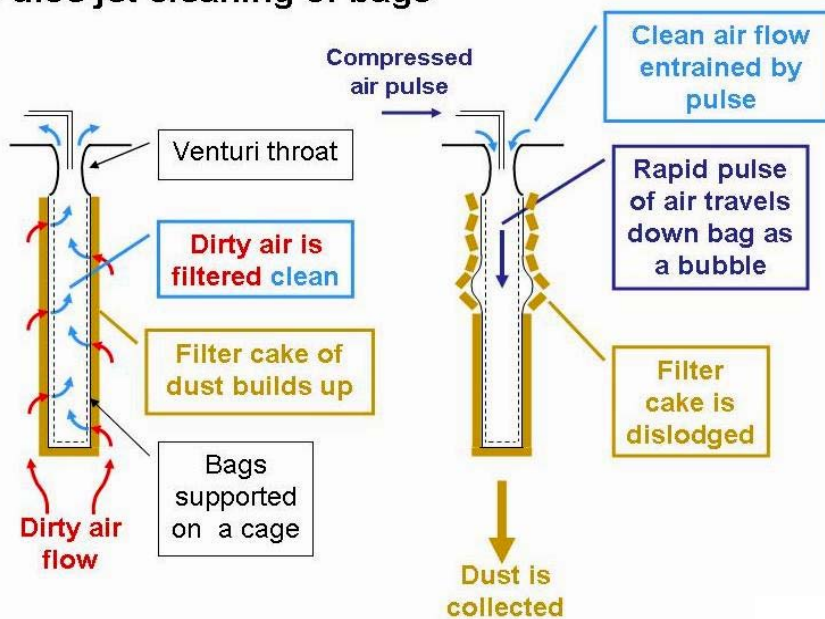


Pulse jet bags on metal frames



Pulse jet bags showing bottom closure

Pulse jet cleaning of bags



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. However, some reverse-air mechanisms are more vigorous than others and can approach pulse-jet performance if used with felted media.

Recommended air-to-cloth ratios

The net effect of the different cleaning techniques is that recommended air-to-cloth ratios for pulse-jet filters are significantly greater than for reverse-air or shaken fabric filters. That is, for the same duty, pulse-jet filters:

- can filter more gas through a given area of bag, or
- require less filter area.

Pulse-jet filters therefore tend to be more compact than the other types. However, they are not proportionately less costly because they operate at higher pressure drops and are more complicated and expensive to build. Each application needs to be weighed on its merits to decide which type of filter to use.

Some recommended air-to-cloth ratios (in imperial and metric units) are given for applications that might be encountered by local government officers:

Table 2: Typical air-to-cloth ratios for various industries

Type of dust/industry	Shaken/woven Reverse-air/woven		Pulse-jet/felted Reverse-air/felted	
	cfm/sq ft	m/s	cfm/sq ft	m/s
Cement	2.0	0.01	8.0	0.04
Clay	2.5	0.0125	9.0	0.045
Feeds, grains	3.5	0.0175	14.0	0.07
Flour	3.0	0.015	12.0	0.06
Fly ash	2.5	0.0125	5.0	0.025
Gypsum	2.0	0.01	10.0	0.05
Leather dust	3.5	0.0175	12.0	0.06
Paper	3.5	0.0175	10.0	0.05
Plastics	2.5	0.0125	7.0	0.035
Rock dust	3.0	0.015	9.0	0.045
Sand	2.5	0.0125	10.0	0.05
Sawdust	3.5	0.0175	12.0	0.06

(From Buonicore & Davis *Air pollution engineering manual*, 3rd edition, p 128.)

These figures are indicative and suitable for local government checking only. For specific design applications advice should be sought from an air pollution engineering specialist.

Performance of fabric filters

Fabric filters are generally capable of reducing particulate concentrations to between 10 and 20 mg/m³ for the type of applications likely to be encountered in local government work. However, bag filters require attentive and consistent maintenance to ensure continued sound performance. Fabrics are, after all, comparatively fragile materials.

Most emissions will be invisible to the naked eye at concentrations up to 100 mg/m³ depending on the size of the dust—fine dust will be more visible—so visible monitoring is not generally adequate for assessing fabric filter performance or detecting minor bag failures. **Monitoring pressure drop across the filters will not indicate small holes in the filters!**

Failure of fabric filters

Failure of fabric filters tends to take three forms:

- The most common is **development of small holes and tears in the bags**. Small leaks result which 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 (there’s nothing like ‘dusty’ employee cars to get some simple maintenance done promptly), or by installing tribo-electric sensors which are sensitive to the presence of small concentrations of particles in the gas stream—lower concentrations than can be reliably detected by conventional optical monitoring techniques (See Module 1).

- **Condensation in the bags and ‘cementation’ of the dust cake in the filter medium** 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 an air flow moving through the baghouse at all times, with heating if necessary.
- **Burning of the bags by exposure to gases above the recommended temperature of operation**. This is usually overcome by bleeding fresh, cooler air into the suction of the ventilation or gas movement system just before the baghouse inlet. A corresponding shut-down of the process is usually essential to avoid excessive pollution.

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 powders before fabric filters can have beneficial impacts on air pollution control:

- **An alkaline material can react with acid gases, removing acidity as well as particles from the emissions**. Common applications of this technique are the addition of alumina to gases containing fluorides in the aluminium smelting industry, or the addition of lime to remove hydrogen chloride. 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 which is more easily removed in the cleaning cycle than the sticky particulate solids in the untreated flow. This practice is generally called ‘pre-conditioning’.

4.4 Scrubbers

Contacting gases with liquids to remove both particles and gaseous impurities has a long history in air pollution control. Using ‘smut collectors’ or simple spray chambers to remove particles from combustion flue gases dates back to the industrial revolution. ‘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 widely 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.

Wet scrubbers and odours

It is a myth that wet scrubbers are generally effective at removing odours. Most odours likely to be encountered by local government officers will **not** be removed by water scrubbing.

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

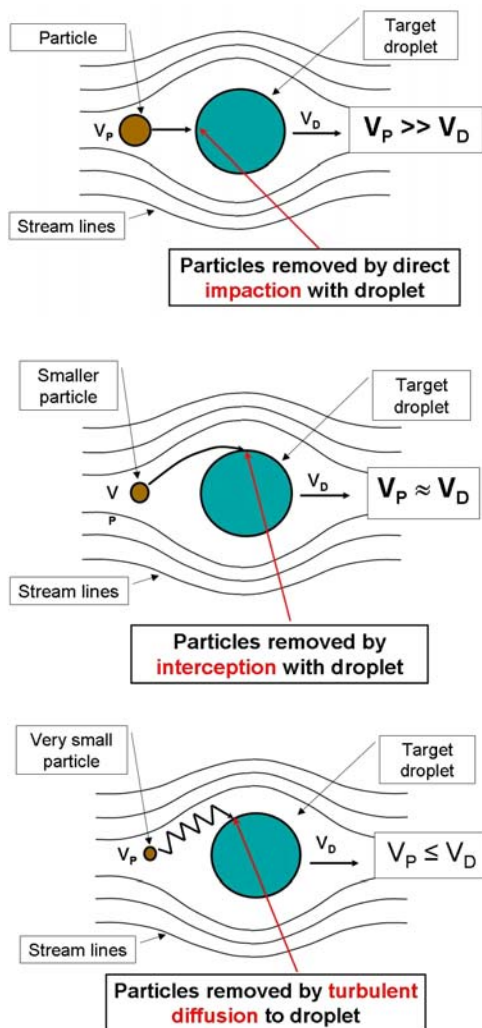
Principles of operation of scrubbers

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

- **imparting high energy** to either or both of the gas and liquid streams, or
- **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 that 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 three modes of contact between a particle and a droplet of scrubbing liquor, contact being essential for removal of the particle:

- impaction
- interception
- diffusion.

Impaction

For impaction to be effective, the velocity of the particle must be considerably greater than the velocity of the droplets; that is, the droplets become targets for the particles. **Impaction is the most effective mode for removal of particles.** There is much greater exposure of target droplets to particles in the gas stream in the throat of some type of venturi scrubber than in a simple spray chamber. This is discussed below, but it shows why the efficiency of high-energy scrubbers is much greater than that of low-energy scrubbers.

Interception

Some particles are also removed by interception when the path of particles and droplet intersect at about the same velocity.

Diffusion

Finally some particles contact water droplets as a result of turbulent motion or diffusion at the same or lower velocities than the particles.

Turbulent diffusion is important in gas-liquid contact for removal of gaseous pollutants. It is greater in high-energy than low-energy scrubbers.

Wetting of particles

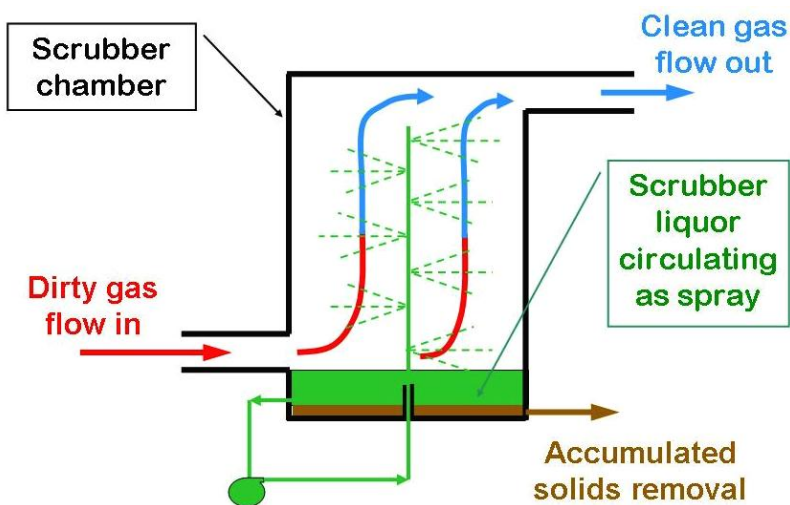
For some particles, the ability of the scrubbing liquid to 'wet' the particles can influence the efficiency of removal. In general the easier the wetting the less energy input required to ensure the particles are adequately wet to be collected in the liquid.

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.

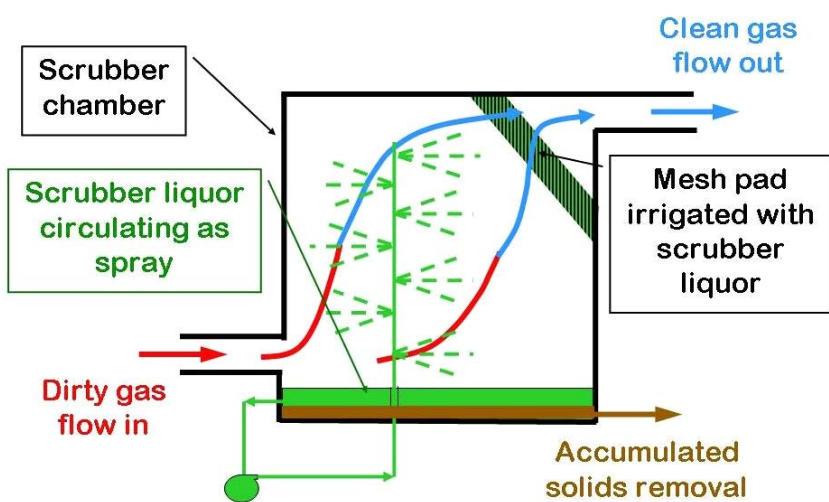
4.5 Low-energy particulate scrubbers



The pressure drop or energy requirement is small and the efficiency of collection is low. Low-energy scrubbers are generally only useful for removing coarse particles.

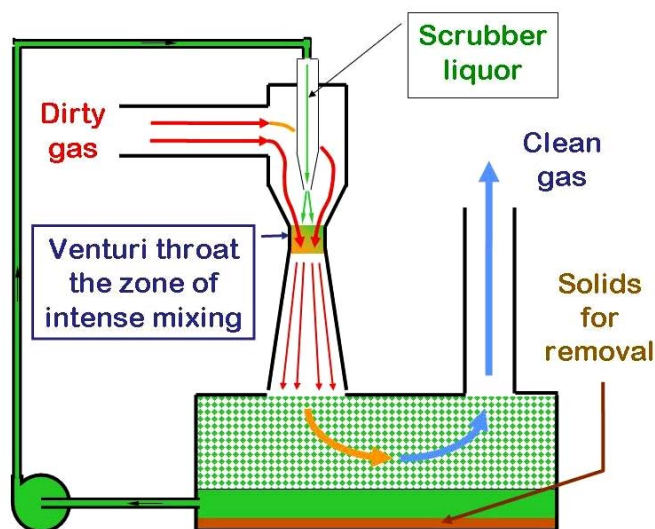
Low-energy scrubbers are usually chambers in which the dirty gas passes through a spray of scrubber liquor. The chamber may take many forms: cylindrical, cubic, oblong 'boxes', and so on.

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 to 1 kPa (1 to 4 inches water gauge). Particle removal efficiencies are typically less than 50% for all except quite coarse particles (50 to 100 μm).

4.6 High-energy particulate scrubbers



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.

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



Venturi scrubber for metallic fume

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 water pollution generated.

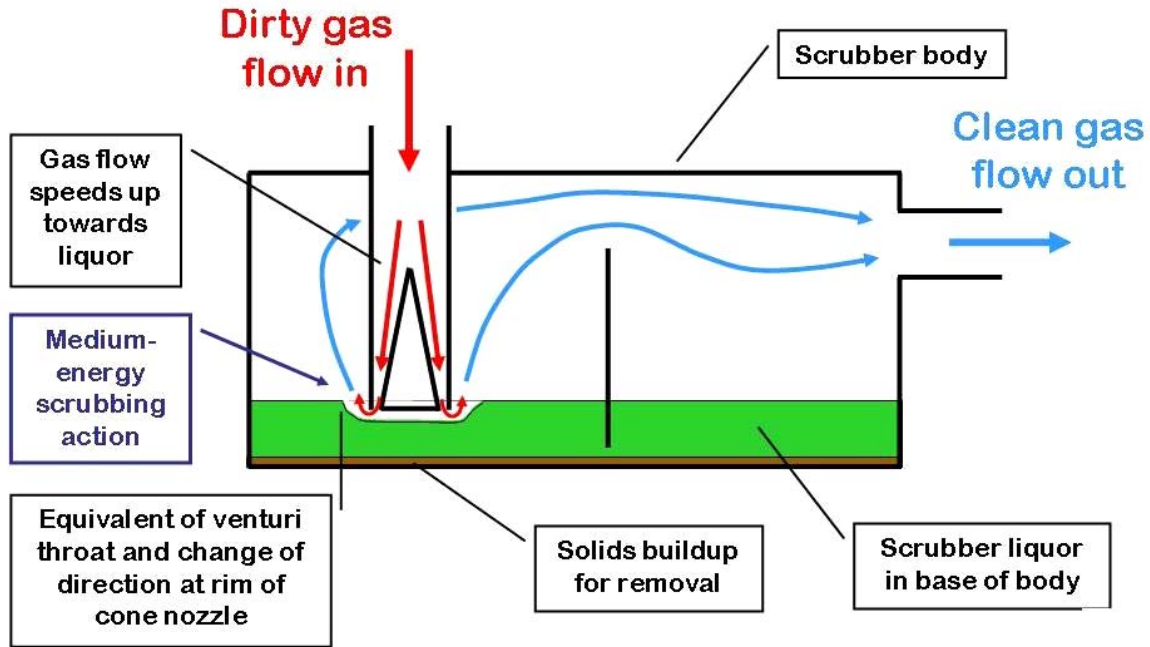
The gas is discharged after the particles have been removed.

The pressure losses across venturi scrubbers range from 4 to 15 kPa (16 to 60 inches water gauge). Efficiencies of 98% and better can typically be achieved for 10 μm particles.

Venturi scrubbers also 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.

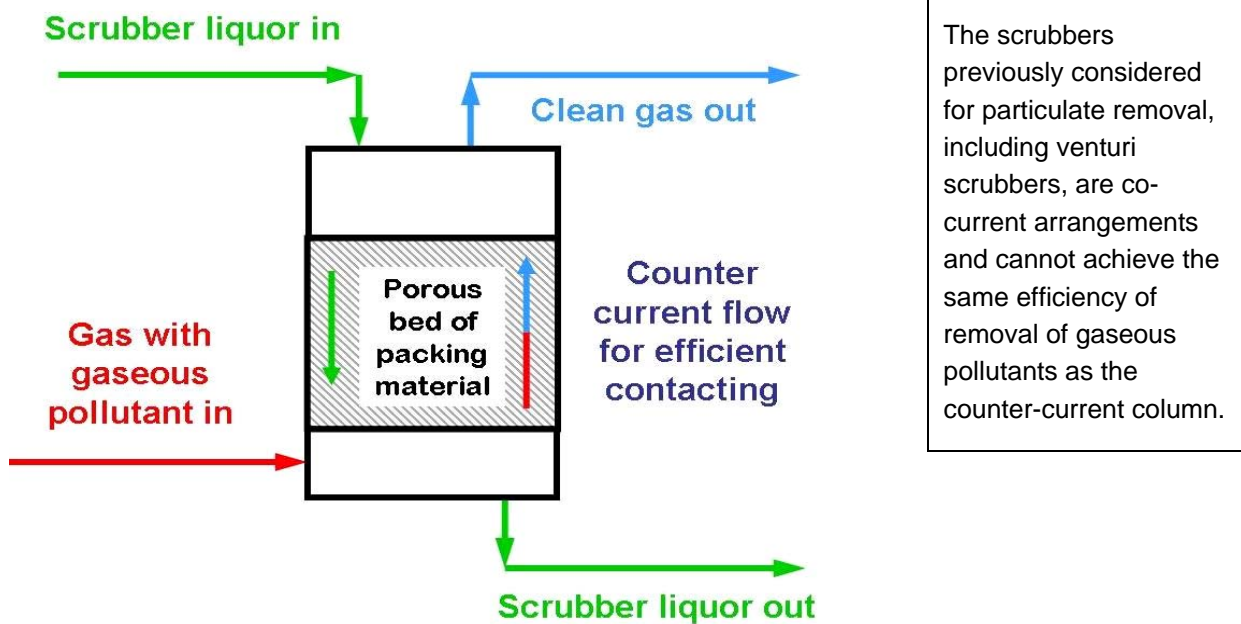
4.7 Medium-energy particulate scrubbers

Many varieties of wet scrubbers have been developed to operate at medium pressure losses, typically between 1.5 and 4 kPa (6 to 16 inches water gauge). 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. A set of nozzles or equivalent operating in close proximity to the scrubbing liquor surface is the principle involved; the configurations can take many forms.

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 as shown above. 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.

Methods to increase contact between the gas and scrubbing liquor

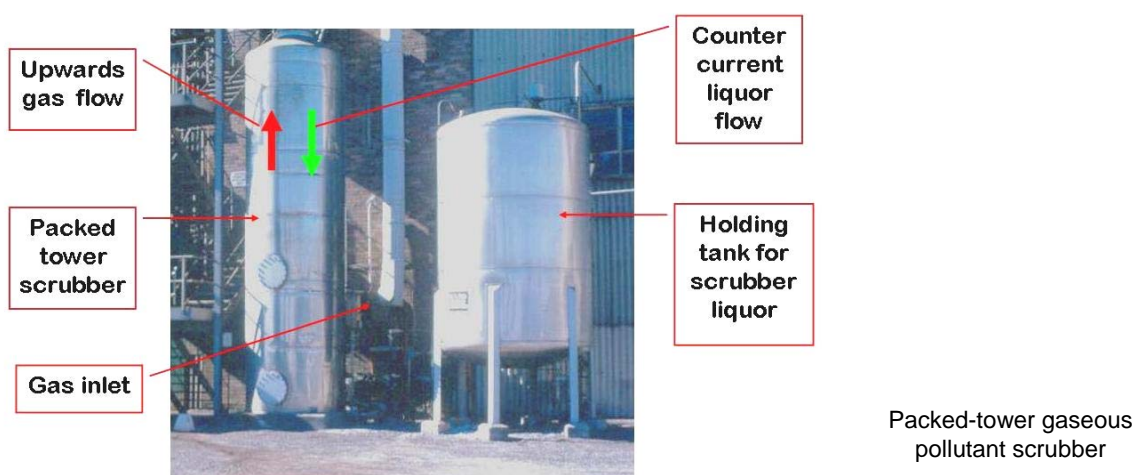
A common method for increasing the contact between the gas and the liquid, allowing the diffusion of gaseous pollutants from the air stream into the liquid to proceed, is to provide a large porous surface area by packing the column with various types of specially designed scrubbing media. Examples of this are Rashig 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 which promote intimate contact (through frothing and foaming) between the counter-flowing gas and liquid. Examples of this are bubble-cap plates or sieve plates.

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.

Operating scrubbers for gaseous pollutants



The pressure loss across scrubbers for gaseous pollutants is moderate (0.5 to 2.5 kPa or 2 to 10 inches water gauge) but the removal efficiency is 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.

4.9 General scrubbing considerations

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

The advice given earlier is repeated here: **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

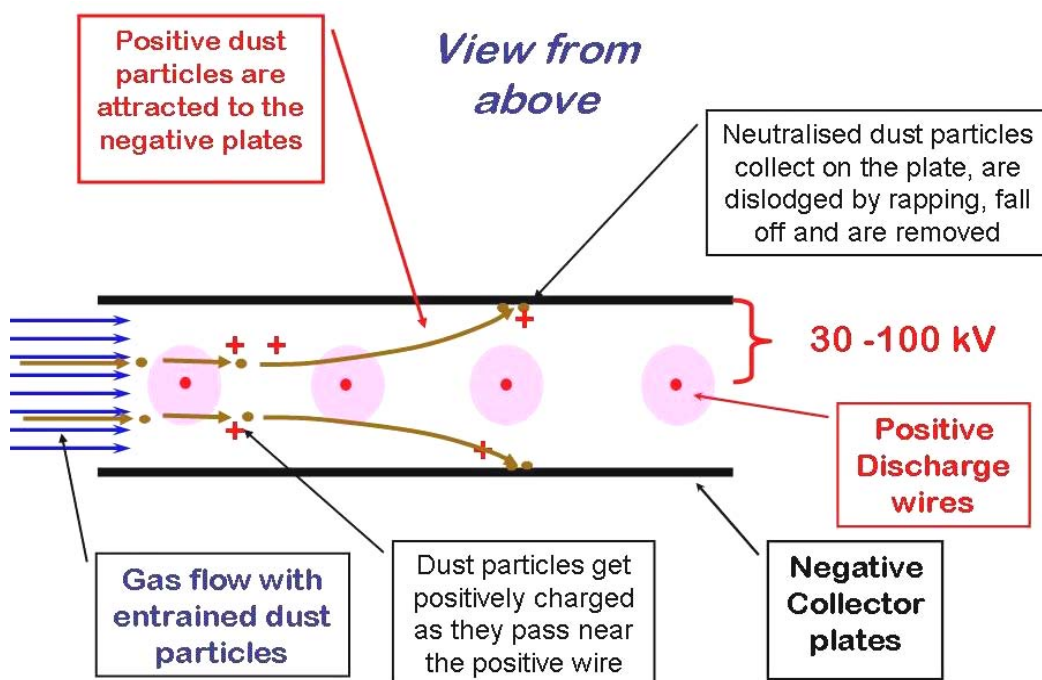
Finally, removing the solid collected from the scrubber liquor and disposing of or recycling the liquor back into the process need to be carefully considered. The separation process is sometimes difficult and corrosion can also be a factor, for both the scrubber and the separation equipment.

4.10 Electrostatic precipitators

Electrostatic precipitation has had a role in air pollution control over many years, but has tended to be a rather 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 from emissions, but not as frequently as inertial devices, filters and scrubbers.

Electrostatic precipitator



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. (Auxiliary equipment is needed to convert the precipitator's electrical supply from AC to DC.)

The diagram above illustrates the following process:

- A set of electrode wires hang between electrode plates; the wires and plates are oppositely charged.
- A high DC voltage is applied between the wires and plate, sufficient to ionize the gas near the wires—this is called a coronal discharge.
- Dust particles passing near the wires pick up a small electrostatic charge from the ionized gas.
- The charged dust particles are then attracted across the flowing gas stream to the oppositely charged plates.
- The charge on the dust particles is then neutralized at the plates and the particles are retained on the plates.
- 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 which 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.

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 in recent times 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.

The low sulfur content of Australian coals has meant that fly ash from boilers burning these coals has tended to have high resistivity. Consequently, power stations burning Australian coals need precipitators that are larger than those typical in North America or Europe. This is part of the reason for the switch from precipitators to fabric filters in this application.

Lack of suitability for gaseous pollutants

Electrostatic precipitators are not really suitable for gaseous pollutants—they cannot remove pollutants such as odours. However, they are sometimes used in food preparation applications to remove aerosol fats and oils from discharges to air. While this does not remove odours as such, it removes the aerosols which evaporate after release to the atmosphere—the evaporation causes slow release of odours before they settle out. 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. Because the amounts of material causing the odours in air are usually only tiny, they 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.

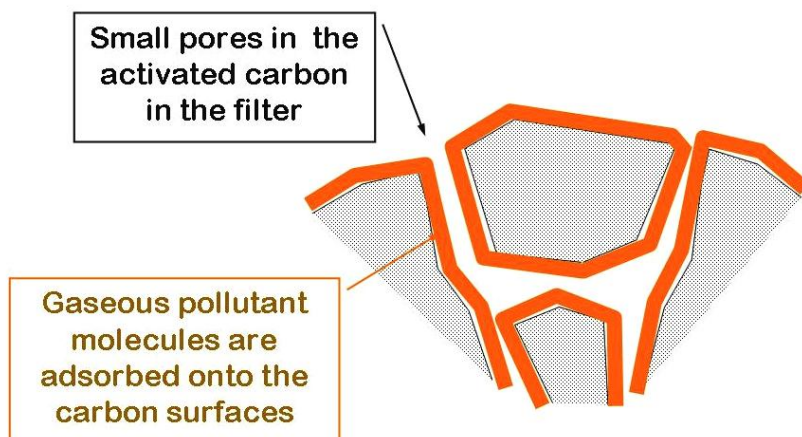
Adsorbers are compact, mostly easy to install, relatively inexpensive and the disposal of waste adsorbent is not usually difficult.

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

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.

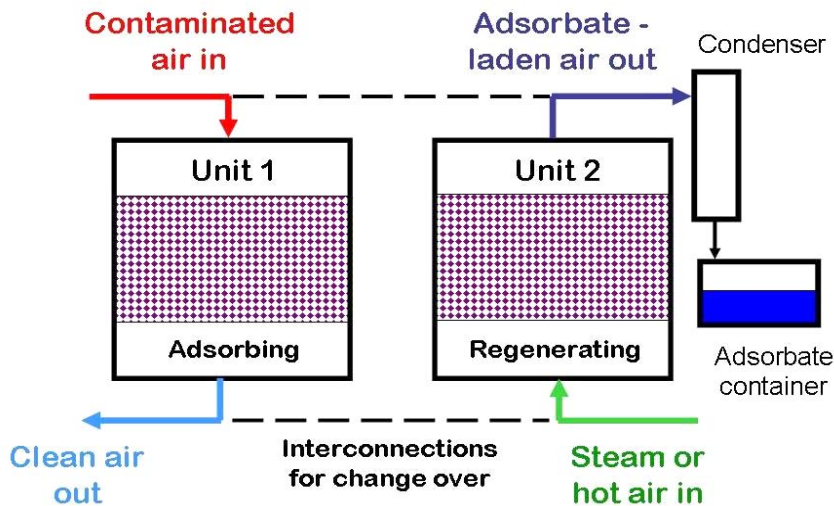


The gas penetrates these pores, with sufficient time for exposure and diffusion, and the pollutants are retained on the surfaces.

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.

Types of adsorbers



For an adsorber to be effective it is essential that the capacity of the adsorbent is not exhausted.

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



Dual adsorbers for capturing petrol vapours

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.

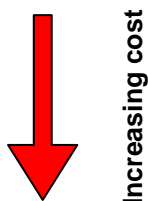
If the material adsorbed is an odorous compound the adsorbent may be disposed of to landfill, although for a continuous duty a dual unit may still be required.

Performance of adsorbents

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

Adsorbents commonly in use are:

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

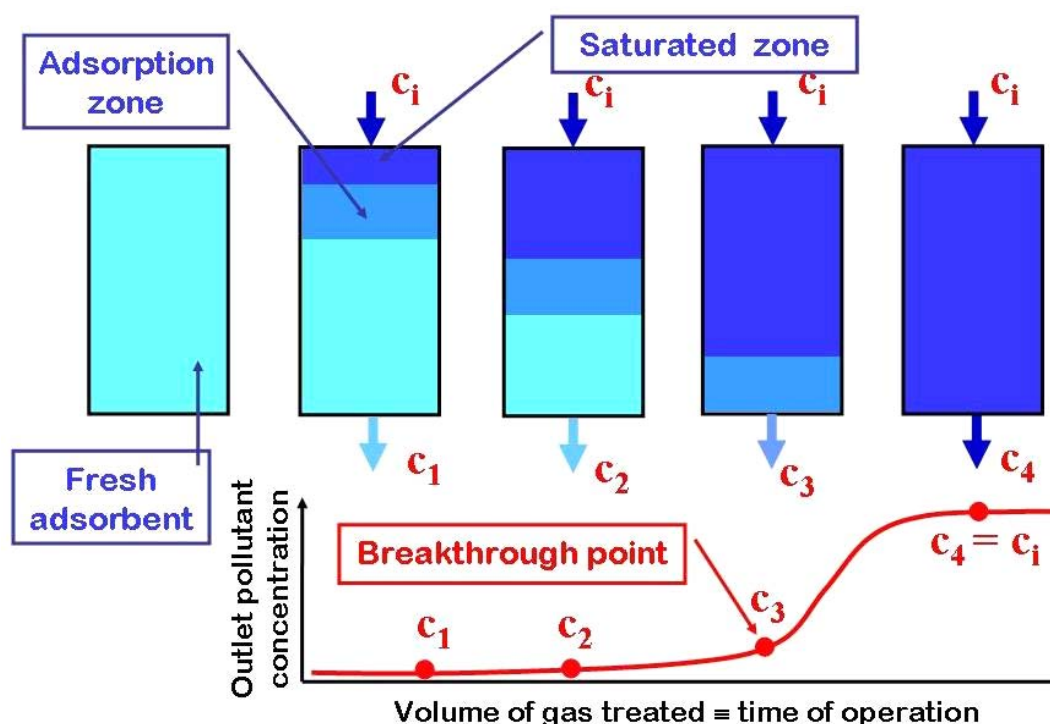


The cost and capability of these adsorbents increases down the list. Activated carbon is the adsorbent most likely to be applied to problems encountered in local government work. Information about suitability for particular types of duty and the appropriate type of treatment for activation should be 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. An initially effective installation can fall 'out of sight' and become ineffective. **Unfortunately, in the control of odours, a sniff test 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. Some independent assessment is needed to establish a reliable changeover pattern.

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.



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 these do not become clogged or blocked. If there are heavy loading of particulates and 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 another technique than adsorption, for example, incineration.



Shell and tube condensers for wet rendering gases before incineration

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.

In most situations managed by local government this is unlikely to be the case. 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

The condensation phenomenon 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 can also cause significant emissions of both odours and VOCs (precursors to photochemical air pollution).

DECC regulations are in place to govern petroleum product handling, with strict requirements based on the vapour pressure of the materials handled and stored.

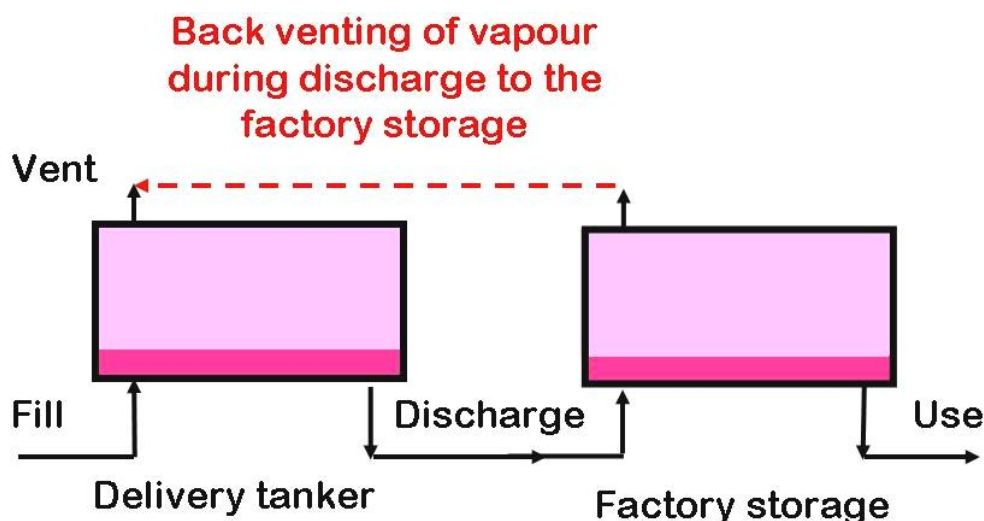
Whenever a volatile liquid is transferred there is the possibility that a volume of air saturated with the vapour will be emitted with every transfer:

- 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 practiced 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 smelly solvents and monomers such as acrylates, styrene monomer and some solvents.

‘Breathing losses’ are another source of emissions from storage, 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

A method now enjoying greater application for air pollution control is biofiltration, especially for the removal of odours. Since biofilters occupy large areas the technique is commonly applied in rural or semi-rural situations where space is not usually restricted.

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, wastewater treatment, and so on. In recent years there have been some applications in non-food related industrial processes.

The principle of biofiltration

If 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 which are 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 in the bed are maintained.

The temperature and moisture of the biomass bed need to be maintained nearly continuously and long periods of inactivity 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.



This photograph well illustrates the large area and preparatory ground work needed for effective biofiltration.

The inlet containing the odorous gases is the narrow pipe running diagonally in front of the white tanks at the end of the building.

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 and mushroom compost. 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 be disappointing in performance.

4.14 Fume and gaseous incinerators

Incineration of gaseous pollutants is a well-tried and effective concept. If organic materials can be completely burned they are reduced to carbon dioxide, sulfur dioxide, nitrogen oxides and water vapour. The first three combustion products are pollutants in their own right, but at the concentrations generated from the incineration of more troublesome organic air pollutants, these residuals are relatively innocuous.

Gaseous incineration or **thermal oxidation** has been widely practiced 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 and foundries.

Principles of incineration

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, with the exception of hydrogen chloride, are considered less noxious than the starting pollutants to be 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 Three T's—time, temperature and turbulence—are satisfied in the combustion chamber(s) and adequate combustion air is provided to maintain oxidising conditions.

Three T's for effective combustion:

Time
Temperature
Turbulence

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. 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 400°C to 250°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.

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

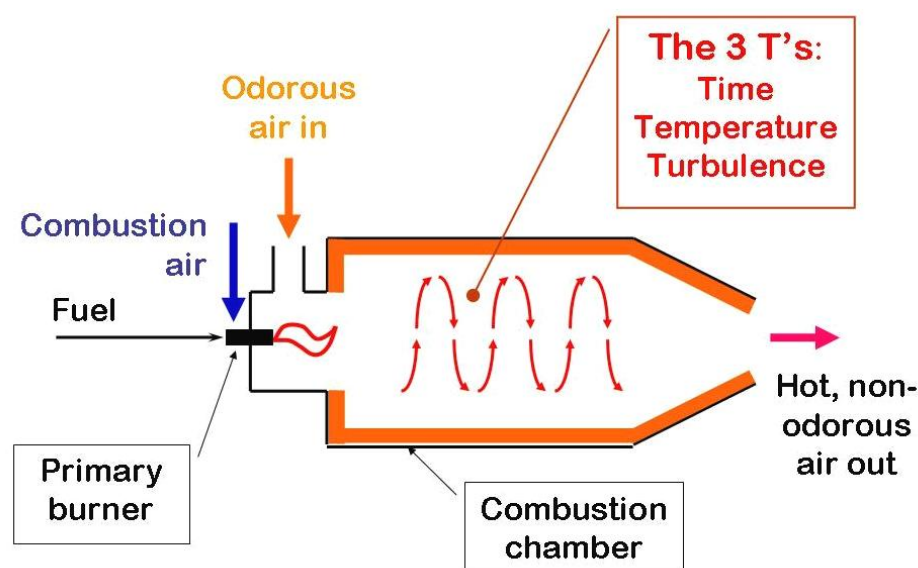
- **residence time** in the combustion zone is adequate—0.5 seconds for most applications
- **adequate oxygen** is provided at all times to maintain oxidising conditions—typically with a minimum of 15% excess air
- **flame impingement** is avoided
- **the burners achieve efficient atomisation** where liquid fuels are used (visible ‘sparks’ in the flame are a tell-tale of poor atomisation)
- **corrosive conditions are accommodated** by appropriate choice of construction materials
- **flue gases are cooled rapidly** through the ‘dioxin formation window’ of 400°C to 250°C.

‘**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.

The simplest form of combustion chamber is a cylindrical refractory-lined chamber as in the diagram below.

Simple 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, as for instance for the odorous non-condensable gases from meat rendering shown in the right-hand photo below.



Fume incinerator for building materials



A small afterburner for rendering odours

Heat recovery

In many cases extensive heat recovery is practiced 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.

Thermal oxidisers should be designed by experts in combustion and air pollution engineering. As a minimum requirement the Three T’s should be met (see above).

Performance of combustion equipment

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

$$DRE = 100 \times (W_{in} - W_{out}) / W_{in}$$

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% (‘six 9’s’) are called for. Higher temperatures and residence times are needed to achieve these levels, depending on the compounds involved.

Monitoring to avoid deficient performance

Dioxin emissions cannot be reliably measured continuously.

An isokinetic stack test is always required to determine emission rates. The cost of these tests is considerable.

Effective monitoring of hydrocarbons, carbon monoxide, temperature profiles and oxygen concentrations in the flue gases guards against deficient performance.

The **dioxin standard** which should be met for all equipment is 0.1 (TEQ) ng/m³ at 11% oxygen and standard temperature and pressure (0°C, 101.3 kPa).

'TEQ' (toxic equivalent) appearing after a dioxin measurement means that the many dioxin isomers (chemical variations) measured have been converted to a common standard of toxicity against the most toxic isomer, 2,3,7,8, tetrachloro dibenzo-*p*-dioxin. This is the standard method of expressing dioxins.

If 'TEQ' is absent from a quoted concentration the result should be questioned because much higher values are possible without the conversion.

This is recognised as best practice worldwide and is written into various NSW regulations for scheduled industries. There are no formal standards for non-scheduled industries.

Provided chlorine is low in the material fed to an incinerator and the 'dioxin formation window' temperature is avoided, dioxin emissions should be able to meet the standard requirements.

Material or waste that is already contaminated with dioxins or furans above trace quantities should not be incinerated.

Note that partial incineration of odorous organics can sometimes result in worse odours. Following the Three T's and providing excess oxygen should ensure that partial incineration is avoided.

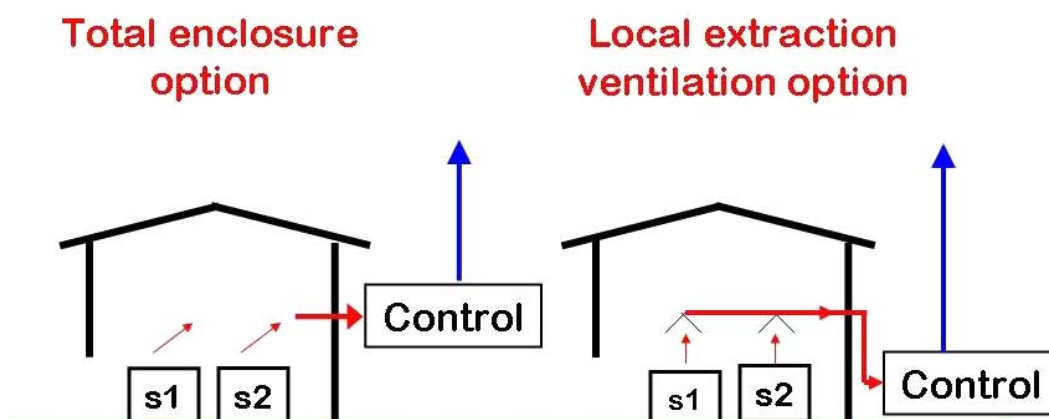
4.15 Capture and fugitive emissions

The controls applied to the emissions from a plant 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 basically two approaches to capture:

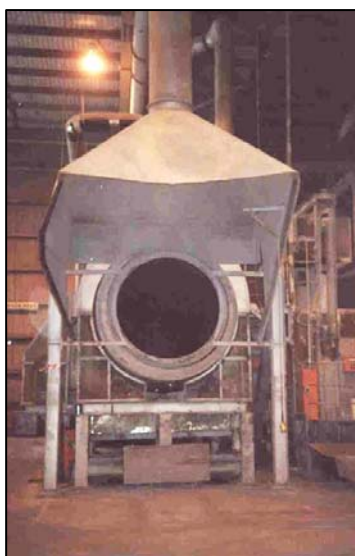
- **total capture**, where the whole building is enclosed and ventilated through controls, and
- **local extraction ventilation (LEV)** at the individual sources of emission within a plant.



The advantages and disadvantages of the two approaches are set out in the following table:

Table 3: Two approaches to capture

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.	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.	There is a smaller gas flow to achieve 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.



LEV capture hood for a rotary furnace discharge point

Design of local extraction ventilation systems

LEV systems require considerable expertise in hood design—configurations and face-capture velocities. As a general 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.

LEV hood design is a specialist skill and specialist help from an experienced practitioner should be sought. An example of an experimental capture hood for a buoyant fugitive emission is shown below. Smoke is being used to test its efficiency.

Smoke test for the efficiency of an experimental LEV capture hood for discharge inside premises



Proper management of many of the air pollution techniques described in Module 3 may require a local government officer to ask the owner or operator of premises to obtain specialist advice, testing and reports. Part 2 of this Module—‘Practical regulation of air pollution sources’—includes suggestions for how local government officers can effectively manage expert advice.

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 surface mining.

The principles of dust suppression

Several principles apply to dust suppression activities:

- **avoiding exposure of loose dust particles to winds** of sufficient velocity to 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.

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.

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.

Spraying increases moisture content and bonding, and, even on drying, wind entrainment will be minimised by the weak cementation or ‘crusting’ which results. This is distinctly noticeable in stockpiles of coal and some other loose materials.

Practical measures to control dust blow-off

Most of these measures are common sense. However, a systematic approach and effective management are needed if neighbours are not to be subject to heavy dust fallout every time a wind storm passes.

Some common techniques include:

- **minimising the extent of disturbed land surface exposed at any one time**; this requires that the natural land cover, usually grasses and bushes, be retained for as long as possible before construction, mining or agriculture commences at that point; **only the minimum amount of clearing should be allowed**



If unsealed roads are watered (as in mining or quarrying) there is usually a spin-off benefit in that tyre wear is reduced by regular surface watering.



- **using water sprays to moisten dusty surfaces** on a systematic basis to maintain a minimum moisture content at the potentially dusty surface
- **re-stabilising dusty surfaces** by undertaking vegetative-cover planting, mine rehabilitation or sealing as soon as possible after the work requiring the disturbance has been completed
- **designing and installing wind breaks, wind barriers and enclosures** at key points, such as truck unloading stations and transfer points in conveying systems, to avoid falling dusty material being exposed to external winds
- **maintaining a minimum moisture content** in solid material being transported or conveyed wherever possible
- **using water suppression sprays at transfer points** in solid-material conveying systems and solids unloading or loading stations to minimise fugitive dust

- **applying fixed water sprays to stockpiles of dusty materials** to thoroughly wet and crust the stockpile surfaces for storage
- **using careful design** to ensure that wetting and agglomeration is adequate at sensitive entrainment points, such as the tops of stockpiles
- **using agglomerating and stabilising agents in water sprays** where the degree of movement is intense or the materials are particularly dusty or dry
- **providing a mobile water spray vehicle** to ensure surfaces not reached by fixed sprays can be kept moist; for surfaces unreachable by vehicles, hand-held watering can be used
- **avoiding driving on stockpile surfaces in rubber-tired vehicles**; tracked vehicles or mechanical stacking equipment should be used for emplacement and recovery at stockpiles
- **minimising the free-fall distance** to the emplacement point from the end of stacking conveyors, drag lines or grab unloaders in non-enclosed situations
- ensuring **engine exhausts from all heavy moving machinery** are not directed onto stockpile or road surfaces
- **ceasing operations such as bulk storage loading and unloading, drag-line operations and surface grading during strong wind conditions**; an average wind speed of over 15 m/s is commonly used as the trigger for stopping certain operations, and where this is the case, a recording and alarmed anemometer should be installed, maintained and records kept
- **practising thorough truck washing, especially washing of tyres, to prevent the tracking of dusty materials** in a wet condition onto sealed roadways; once deposited on roads these materials dry out and are further reduced in size by abrasion due to multiple tyre contact, and are resuspended by tyres and local winds
- **covering loads of dusty material** transported by road or rail in open-topped trucks.



4.17 Open burning

‘Open burning’ is combustion of materials without any containing combustion chamber. For the purposes of the POEO Act, ‘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. Although overhead flares do not make use of a chimney, it is not an offence under the open burning prescriptions in the Clean Air Regulation to burn air impurities by flaring, provided the flare is designed, maintained and operated so as to prevent or minimise air pollution.

Open burning is severely restricted in the more densely settled areas of NSW. In general, open burning is allowed for hazard reduction and valid agricultural purposes only.

Suspended particles (including large amounts of PM₁₀), black smoke, fumes, carbon monoxide, nitrogen oxides and VOCs are some of the emissions from this form of uncontrolled combustion.

Polyaromatic hydrocarbons (PAHs) and polychlorinated dioxins and furans (collectively referred to as ‘dioxins’) are also formed during open burning.

Principles of managing emissions from open burning

The pollutants formed in open burning result from inadequately controlled combustion. The time, temperature and turbulence and the oxygen-to-fuel proportions cannot be controlled in this form of combustion.

In addition to this, **some dioxins are formed** because enough chlorine is present in most vegetation as salt to combine with partly burnt hydrocarbons to form traces of the toxic material in the ‘dioxin formation window’ of 250°C to 400°C.

It is estimated that two-thirds of all dioxins emitted to the atmosphere in Australia are from uncontrolled combustion, including bushfires. (Bawden, Ormerod, Starke and Zeise 2004, *Australian Inventory of Dioxin Emissions*, National Dioxins Program Technical Report No. 3, Australian Government Department of the Environment and Heritage, Canberra).

Competing needs of hazard reduction and pollution control

There is a conflict between the needs of hazard reduction burning to manage bushfire potential and the need to protect air quality:

- Conditions that are good for dispersion—strong winds—are generally adverse for controlling fires.
- Conditions that are good for hazard reduction burning—still, mild spring days—are generally poor for dispersion.

Some windows of opportunity exist when the needs of both hazard control and air quality are reasonably met, but these do not represent a large part of the year. Good forecasting is needed to make sure the best use is made of these opportunities when they arise.

A system of bans and advisory periods under both the bushfire and the environmental legislation indicates whether burning is allowed on a regional basis. Other factors such as topography, likely wind directions and sensitive receptors come into the determination at the local level.

Some practical options for open burning

Uncontrolled combustion cannot become controlled combustion. The most effective way to avoid the impacts of open burning is to avoid it. Modern agricultural practice is moving towards tillage and composting of crop residuals, rather than the older practice of burning.

However, some burning will probably always be necessary, so it should be carried out at a time and in a way which minimises potential impacts on neighbours and townships. Times of poor dispersion, such as still nights, should be avoided. (Atmospheric dispersion is described in Module 1.)

Some practical measures to minimise impacts on air quality from open burning include:

- **Avoid the burning altogether.** Consider other options. Is mechanical clearing possible? Is vegetation destruction essential?
- If open burning cannot be avoided, **choose weather likely to be favourable** for both fire control and pollution dispersion.
- Ensure there is appropriate **fire-fighting capacity** and the ability to extinguish the burn at nightfall is adequate for all circumstances.
- Take special care if **persistent pesticides** have been applied to the biomass to be burned. If they have been applied then persons downwind of the likely fire should be notified.
- Ensure the **vegetation has dried out sufficiently** to avoid smouldering combustion. Unfortunately this is likely to occur during the season of greatest fire hazard.



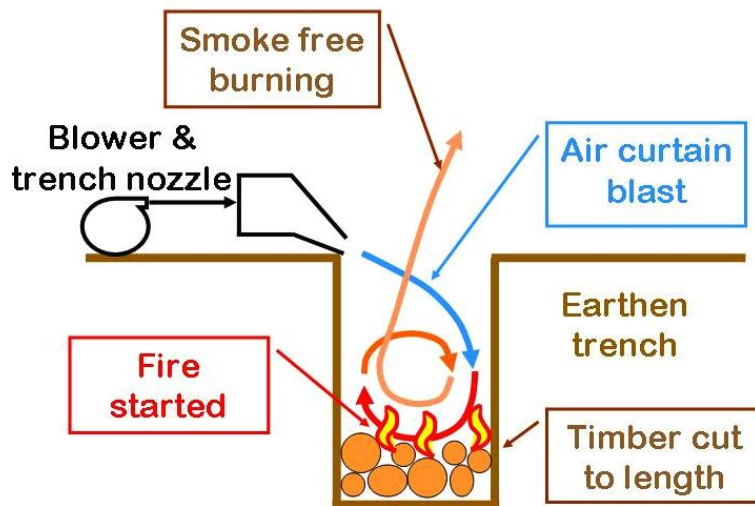
Trench burning

Where other options are not possible, a technique which can minimise emissions from open burning is the ‘**trench burner**’. This is generally applied to one-off activities such as clearing partially wooded land for other development, and where the impacts of burning are likely to be sensitive. **Trench burning is not accepted as a substitute form of incineration for routine disposal of waste.**

A deep trench is cut into the earth at the point of disposal. A specially shaped nozzle and blower is placed at one side of the pit, and a blast of cold air directed into the pit approximately as shown in the following diagram. The partial air curtain, the turbulence and the refractory effects of the pit walls bring a measure of control to the combustion.

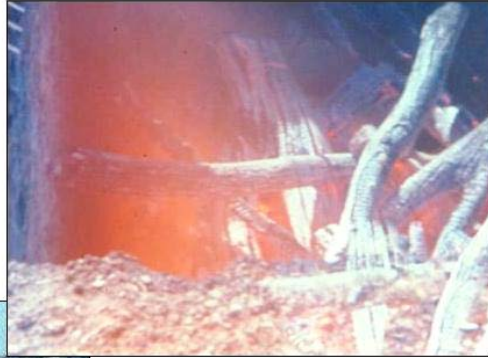
Trench burning will only be applicable in some circumstances.

Using the trench results in better combustion than burning an open pile of timber. However, there is an added expense in preparing the timber to fit into the trench, and the overall burning process is relatively slow, since the trench should be not fully filled to gain the environmental benefits of this form of combustion.



Trench burning

The intense fire of trench burning compared to the 'lazy' flame of open burning



Tests on trench burners have demonstrated real reductions in emissions, but they are not able to comply with the strict emission requirements for regular combustion equipment.

Trench burning should not be confused with **open-pit burning** as practiced at some older sawmills. In pit burners sawdust and off-cuts merely smoulder slowly in a large, open pit with little combustion control. Pit burners are not recommended.

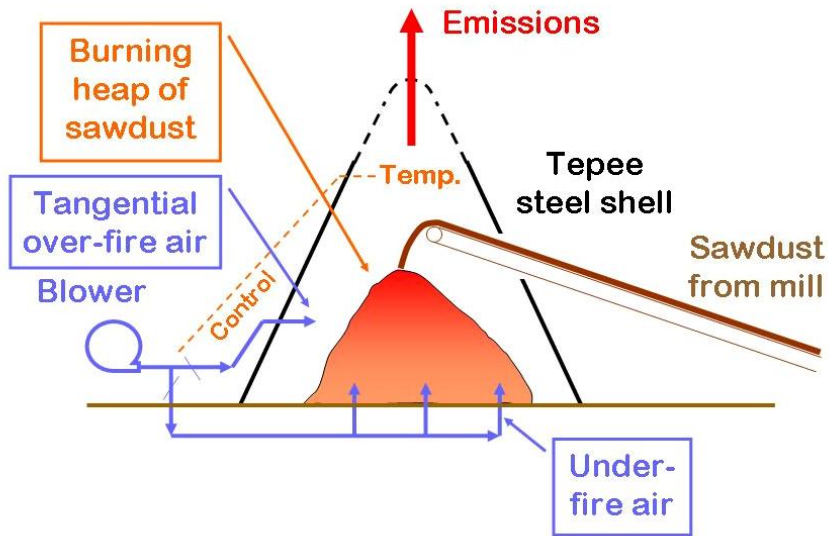
Sawmill combustion in 'tepee' burners

Another form of combustion sometimes encountered in sawmills are so-called 'tepee' burners.

A truncated conical metal housing is constructed around a heaped fire which is fed continuously with mill waste. This brings a measure of control to combustion, but still tends to result in smouldering and fumes at the margins of the fire. White smoke and extensive fallout are common with these units.

Improved 'tepee' burners with regulated under-fire and over-fire air and temperature controls result in much improved combustion.

Teepee burner



Such controlled teepee burners probably comply with emission limits for existing non-scheduled premises, but it is unlikely they would comply with the new limits for fuel burning equipment on non-scheduled premises. There have been no recent tests on teepee burners in NSW.

5 Air pollution and agricultural industries

The characteristics of air pollution from agricultural industries mostly differ from those from secondary industry. This section deals briefly with air pollution from intensive agricultural industries and how to manage it.

The main air pollutants from intensive agricultural industries are:

- dust
- odours
- methane, and
- agricultural chemicals.

5.1 Air pollutants

Dust

Dust in agricultural industries arises from the movement of soil, dried animal and crop wastes and exposure of unconsolidated surfaces to wind. The intensity of animal stocking can also contribute to dust generation. Most of the dust is in the coarse range—larger than $PM_{2.5}$.

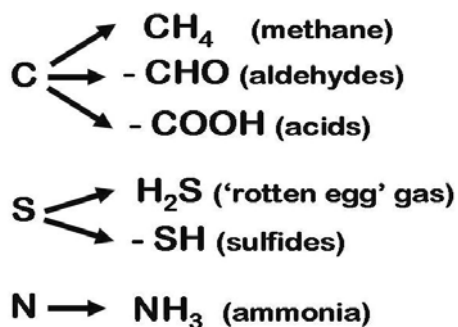
Odours and methane

Odours and **methane** come from the anaerobic breakdown of biological matter. From a chemical viewpoint, anaerobic breakdown occurs mainly under reducing conditions.

In anaerobic decomposition the carbon, sulfur and nitrogen naturally occurring in biological matter form volatile gases, generally in the reduced form that have strong odour potential, except for methane. These gases include methane, organic acids and aldehydes from carbon, sulfides and mercaptans (thiols) from sulfur and ammonia from nitrogen.

'Anaerobic' means 'in the absence of oxygen'. It is the usual means of breakdown of biological material in nature.

Anaerobic air pollutants



Odours and methane generated in anaerobic breakdown are formed in animal digestive systems, solid agricultural wastes, composting, wastewaters, various types of treatment systems and decaying carcasses.

Odour problems in intensive agricultural industries are frequently exacerbated by the exposure of large surfaces of smelly liquids or solids to the atmosphere.

Methane is a powerful greenhouse gas, but its emission control is not further considered in the context of this Toolkit.

Agricultural chemicals

Agricultural chemicals as air pollutants arise from aerial application, which does not come under the jurisdiction of local government.

Dust, gases and odours are **transported** by winds. During transport they are diluted and removed by deposition and reaction.

5.2 Managing air pollutants

Dust suppression

In intensive animal industries, dust impacts are managed by:

- making sure there is a substantial separation distance between the point of dust generation and sensitive receptors
- reducing the extent of exposed surfaces of unconsolidated soil and other solid materials, such as manure
- treating dusty surfaces so as to reduce the mobility of the dust particles, e.g. water sprays
- reducing stocking rates
- providing enclosures to contain dusty operations and to filter ventilation air as required.

It is best to ensure the operation is well removed from sensitive receptors. For new installations experts can predict dust impacts using air dispersion models—see section 5.3 ‘Dispersion’ below.

Initial siting is usually the most important decision relating to air quality management for intensive agricultural industries.

Some measures for consolidating dusty surfaces to avoid wind entrainment are outlined in section 4.16 ‘Dust suppression’. A technique well-suited to agricultural situations is encouraging vegetation growth (pasture) on disturbed surfaces as soon as possible.

Windbreaks, wind barriers and enclosures using conventional measures (mentioned in section 4.16) can be applied to bulk handling of materials and wastes in some circumstances. But the contribution of such measures in agricultural situations is usually small compared to the larger problem arising from extensive, windswept, dusty surfaces.

Odour

Because of the nature of biological matter and the chemistry of anaerobic decomposition, **unpleasant odours are inevitable in the biological processes which occur in all agricultural activities and waste management.**

Techniques used to manage and control odours normally used in agricultural industries include:

- dispersion by distance separation from sensitive receptors
- modified operation of agricultural processes to reduce or restrict odour release
- modified operation of anaerobic or aerobic wastewater treatment processes to minimise the release of anaerobic gases
- disposal of solid and liquid wastes to land
- control of decomposition processes by composting
- treatment of odorous shed and digestion gases, and
- combustion of digestion gases to destroy odours (and generate energy).

5.3 Dispersion

As outlined in section 2 of Module 1 and in section 3 of this Module, the atmosphere is a very effective in diluting air pollutants.

Where there are regional problems of cumulative impacts or the emissions are toxic, dispersion may not be effective in reducing concentrations to acceptable levels. But where the air pollutants are not toxic (most odours) and there is no cumulative impact problem (most agricultural areas), a perfectly acceptable solution is dispersion to a concentration below detection at the nearest sensitive receptor.

In Australia cumulative odour impacts from agricultural activities are encountered only occasionally. This is in contrast to some intensively farmed regions of Europe (e.g. in some eastern parts of the Netherlands) where the odours from agricultural manure tend to be all-pervasive.

Dilution by separation of source and receptor is a desirable solution to potential odour problems, provided cumulative impacts are unlikely.

Dilution is usually a viable solution in Australia. This is achieved initially by locating industries with odour potential where the necessary separation from neighbours is achievable. Atmospheric dispersion modelling at the development approval stage can be used to predict acceptability of separation distances.

Modelling experts undertaking air quality assessment studies should follow the methods set out in two DEC publications:

- *Approved methods for the modelling and dispersion of air pollutants in New South Wales*, and
- *Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW*.

AusPlume or other equivalent continuous-source dispersion models (e.g. US EPA's ISC model) should be adequate for most assessments.

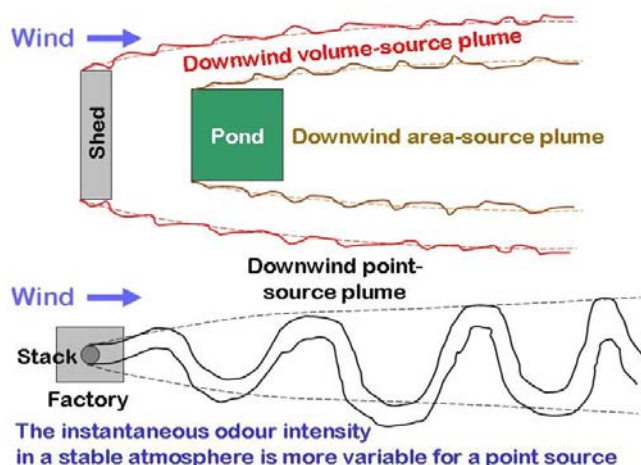
If more accurate predictions of short-term odour impacts are needed, then one of the puff models may be required. However, this will rarely be the case for agricultural industries with large-area, ground-level releases, as distinct from the high-stack releases of industry.

Areas of complex topography or with frequent temperature inversions and sea breezes may warrant using a 'puff' model.

Dispersion from intensive agricultural activities usually involves modelling ground-level emissions from area sources (pond or lot surfaces) or volume sources (sheds). Also, there is usually only minimal if any thermal buoyancy in the plume of dispersing odour. This has several consequences for modelling predictions:

- Topography becomes critically important, with plumes being more prone to following slopes and valleys in stable conditions than plumes from high stack emissions.
- Short-term peaks are less significant—the wide odorous plumes generated by agricultural activities are less subject to the meandering effect that point-source plumes encounter in stable conditions.
- Model predictions are slightly less reliable for area and volume sources (compared with point sources) but this usually has only a marginal influence on assessing overall impact.

Dispersion in agriculture



Considerations for modelling

Some points to consider in any modelling assessment for intensive agricultural industries are:

Local topography

- Is high ground or are pronounced valleys involved? They will strongly influence night time drainage flows and could make it difficult to model dispersion.

Local meteorology

- Is data available for the local situation or has it been transferred from another location?
- Are there unique features which influence the local meteorology, e.g. the presence of a large body of water nearby?

Reliability of source strength measurements

- Have measurements of emissions been made on an equivalent process?
- Has an allowance been made in the modelling for variability in the odour emission rate? Biological processes are inherently variable.
- What method of sample collection has been used to determine odour flux rates for area sources? Odour flux rate measurements can be very dependent on the method of measurement.
- Are there other odour sources in the region?
- What measurement method has been used to determine the odour concentrations? (See section 3.5 in Module 1.)

Credibility of experts

- Has the modelling expert had practical experience in rural situations?
- Has the emissions expert had practical experience with the activities involved?
- How do the odour flux rates used compare with published values?
- See Part 2 of this Module, 'Practical regulation of air pollution sources', sections 5 and 6.

Proposals occasionally suggest installing short ventilation stacks on intensive agricultural sheds, or orienting horizontal ventilation discharges from sheds away from sensitive receptors, or installing wind baffles to change flow patterns over volume sources such as sheds.

While there may be merit in such proposals in certain circumstances, they are only likely to have marginal impacts in reducing odours from agricultural operations.

5.4 Modifying operations to reduce or restrict odours

Odours from agricultural industries are normally the result of biological processes. In some cases odour potential can strongly depend on small variations in the process.

Some of the variations which can be explored in intensive agricultural processes are:

Variations in feed and supplement materials

Aspects of animal and bird digestion and excretion can change significantly with some dietary changes, altering the odour emission pattern. For example:

- barley-based rations may produce fewer odours at some feedlots than sorghum-based rations
- acidifying additives can reduce ammonia emissions.

Scientific understanding of these changes is limited and they are not presently recommended as the principal means of control.

Variations in moisture content

The moisture level of litter and other surfaces in animal and bird pens can directly affect biological reaction rates in decomposing droppings, altering the odour emission pattern.

- In enclosed holding areas the moisture content of litter can be directly varied with water sprays.

- In some pens and enclosures the moisture content can also be controlled by the rate of manure and urine removal.

Dry litter and pen surfaces are better for reducing odour, but some moisture is needed to control dust.

Variations in temperature

Temperature also has an effect on odour generation rate. The temperature in enclosed buildings and pens can be controlled using combinations of water sprays, ventilation and heating.

Variations in the timing of certain operations

Where litter must be periodically removed from buildings that house animals or birds, or where treatment ponds are de-sludged, solid materials in anaerobic conditions are disturbed. This causes the short-term release of very odorous gases trapped in the solids.

Where possible, litter removal operations should only be carried out when atmospheric conditions are favourable to good dispersion. Their timing should avoid conditions such as atmospheric stability.

5.5 Modifying wastewater treatment processes

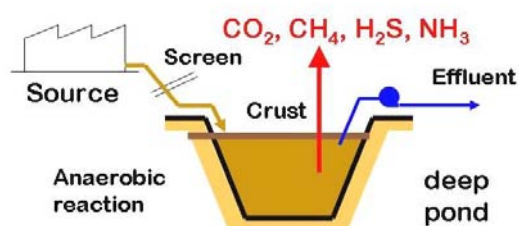
In intensive agricultural processes where large amounts of liquid effluent are generated, such as piggeries and dairies, wastewater holding and treatment ponds can become large odour sources. The waste liquid is high in organic content and will naturally decompose anaerobically if held in ponds. The decomposition generates off-gases, mainly methane and carbon dioxide, but containing many odorous compounds such as organic acids, aldehydes, hydrogen sulfide, reduced organic sulfides, mercaptans, reduced nitrogen organics and ammonia.

Wastewater treatment

Wastewater treatment in agricultural industries follows a general pattern:

- screening to remove coarse solids
- skimming to remove finer solids, fats and greases (optional—usually only where slaughter is also practiced on site)
- anaerobic treatment in deep ponds
- aerobic treatment in shallow ponds (often with aerators)
- stabilisation in shallow ponds, and
- land application for pasture and crops.

Anaerobic treatment - high strength



Waste strength: 2,000 - 40,000 mg/L BOD

Effluent strength: 200 - 300 mg/L BOD

Minimising odour from waste liquids

Several techniques are used to minimise anaerobic odours from waste liquids.

Anaerobic ponds

Waste liquids can be treated in anaerobic ponds, with appropriate crusts, covers or process conditions to minimise odour emissions.

- **Thick crusts carrying vegetative growth** can act as effective mini-biofilters over anaerobic ponds. Odour emissions are minimal. But thick crusts capable of sustaining vegetative growth usually require large amounts of animal fats.
- An alternative that has been used in some piggeries, involves forming an **artificial floating cover on the ponds** using straw, sugar cane waste, or similar fibrous materials. A crude biofilter effect can also be developed with these permeable covers.
- **Impermeable covers** can be installed on anaerobic ponds to collect digestion gases, which have fuel value. The gases can be burned to produce process heat, thereby destroying the odorous compounds, provided combustion conditions are adequate.

There are several problems with using impermeable covers:

- keeping the covers (usually supported plastic film) in place and anchored during all weather conditions
- collecting and managing any rainwater on the surface of the covers, and
- incorporating a system for de-sludging the pond.

- The design of an anaerobic pond should be **sufficient to allow relatively complete digestion**— large enough volume and adequate depth, i.e. 7 metres or more. If high-strength anaerobic liquid flows relatively untreated from the anaerobic ponds to the aerobic ponds, odours will be dispersed extensively into the atmosphere.
- An overloaded pond will have **visible gaseous bubbling and blackish sludge on the surface**. A pond performing within its capacity will often have a pink colour (for piggeries) indicating bacterial activity.
- Allowance for **periodic de-sludging** is essential to make sure the ponds do not become overloaded.

- **Specially developed additives** can be added to anaerobic ponds to improve digestion and reduce odours, but performance is generally not readily predictable in scientific terms. Trials to assess effectiveness should be carefully designed and conducted if the use of additives is proposed.

Digester vessels

Anaerobic treatment can be carried out in large, enclosed digester vessels. Control of the process is possible with this arrangement, including:

- **complete capture of digestion gases** for energy recovery by combustion
- close control of the **quality of digested solids** for reuse and disposal, and
- close control of the quality of **liquid effluent** from the digestion process.

However, the cost of this type of treatment means it is not usually feasible for small intensive agricultural industries.

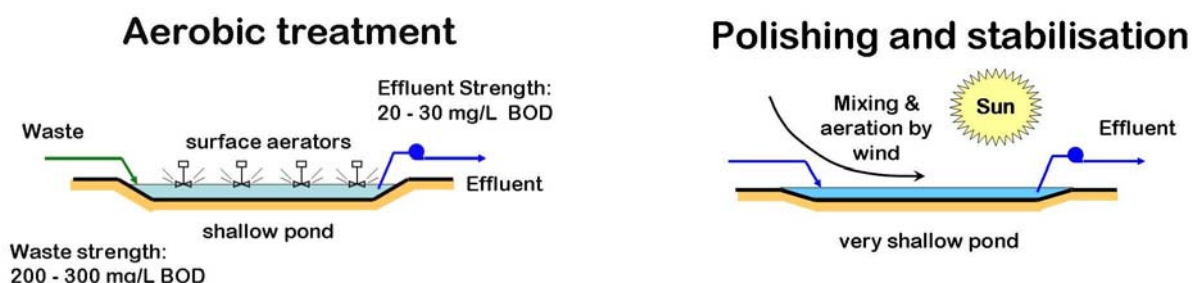


At a 15,000-animal piggyery in Berrybank, Victoria, there is an internationally-recognised example of the use of a digester vessel.

Note that the 'cut-off' for piggyeries under local government control is 2000 animals.

Aerobic ponds

Treatment in aerobic ponds can follow anaerobic treatment when the organic loading has been reduced:



- Odour emissions from these large water surfaces will be avoided if the entering liquid does not contain sufficient un-decomposed organic matter to overwhelm the aeration capacity of the aerators.
- If aerobic ponds become anaerobic they have great capacity to spread odours into the environment.
- Polishing ponds, also aerobic, may follow the aerobic ponds.

Treated waste for irrigation

Treated waste effluent can be used to irrigate land under controlled conditions which protect ground and surface waters. If treatment is not adequate odours can arise from the irrigation.

5.6 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 following advantages. It:

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

Marketing compost

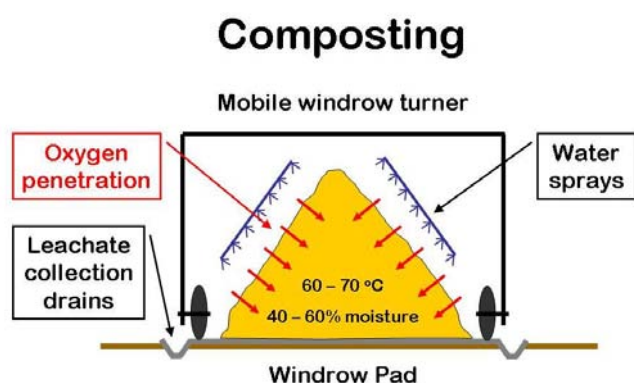
If the compost is to be marketed commercially it should comply with Australian Standard AS 4454–1997 which specifies physical and chemical requirements for composts, soil conditioners and mulches. It also prescribes methods for testing the various characteristics.

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, and
- control of drainage from the composting operation.



There are several practical composting methods:

- passive windrowing
- turned (active) windrowing
- aerated static piles
- in-vessel composting.

Table 4 summaries the key features of a composting operation.

Table 4: Four main composting methods

	Passive windrow	Turned windrow	Aerated static pile	In-vessel channel
General	Low technology. Quality problems.	Most common on farms.	Effective for farm and municipal use.	Large-scale systems for commercial applications.
Labour	Minimal labour required.	Increases with aeration frequency and poor planning.	System design and planning important. Monitoring required.	Requires consistent management of product flow to be cost-efficient.
Site	Requires large land areas.	Can require large land areas.	Less land required given faster rates and effective pile volumes.	Very limited land required, due to rapid rates and continuous operations.
Bulking agent	Less flexible. Must be porous.	Flexible.	Less flexible. Must be porous.	Flexible.
Active period	6–12 months	21–40 days	21–40 days	21–35 days
Curing	Not applicable	30 + days	30 + days	30 + days
Size: height width length	1–4 metres 3–7 metres Variable	1–2.8 metres 3–6 metres Variable	3–4 5 metres Variable Variable	Depends on bay design Variable Variable
Aeration system	Natural convection only.	Mechanical turning and natural convection.	Forced positive and negative air flow through pile.	Extensive mechanical turning and aeration.
Control required	Initial mix only.	Initial mix. Turning.	Initial mix. Aeration, temperature control and/or time control.	Initial mix. Aeration, temperature control and/or time control. Turning.
Odour factors	Odour from the windrow will occur. The larger the windrow the greater the odours.	From surface area of windrow. Turning can create odours during initial weeks.	Odour can occur, but controls can be used such as pile insulation and filters on air system.	Odour can occur. Often due to equipment failure or system design limitations.

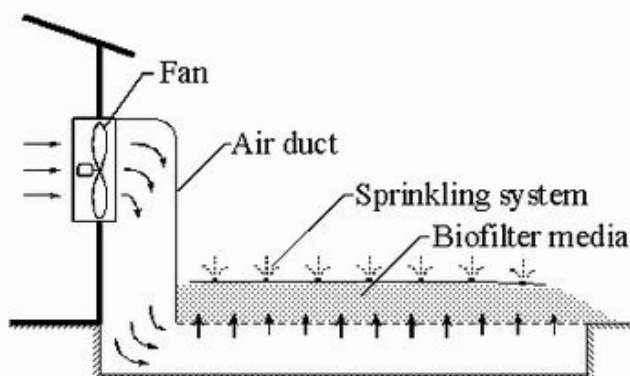
(From DECC Resource Management Branch.)

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.



5.7 Treating odorous shed and digestion gases

Biofilters are capable of removing the types of odours generated in sheds housing large numbers of animals and birds (refer to section 4.13). However, to treat the relatively large ventilation volumes needed to maintain the necessary operating conditions in these sheds, the biofilters may need to be too large to be feasible for most smaller intensive animal industries.



Biofilters have been used to control piggery shed odours in some large European operations, but different climate conditions require operating techniques which are relevant to Australia.

Biofilters in Australia have generally only been feasible for relatively concentrated odorous streams, such as the non-condensable gases from rendering slaughtering by-products.

5.8 Combustion of anaerobic gases to destroy odours

Complete combustion is an effective means of destroying odours in gases (refer to section 4.14). 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 impact of methane emissions (methane has 21 times the greenhouse impact of carbon dioxide).

However, there is usually no match between the volumes of air which are required for ventilation and the volumes of odorous gas which can be handled. (This is the same as the situation which applies for biofilters. Note the relatively small size of the inlet stack carrying the odorous gas compared to the size of the biofilter in the photograph in section 4.13.)

5.9 Other techniques

Occasionally **'masking' or allegedly 'counteractive'** agents are offered to operators with odour problems as a 'cheap fix'. 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 for permanent solutions. However they can be useful if there has been an emergency or short-term one-off odour release.

The scientific principles which 'masking' and 'counteractive' agents are based on are not adequately quantified and they have not been adequately proven as solutions.

For most neighbours of smelly operations a sweet smell is little less acceptable than a foul smell, and, if the two alternate, as sometimes occurs when masking agents are used, the nuisance effect can be exacerbated.