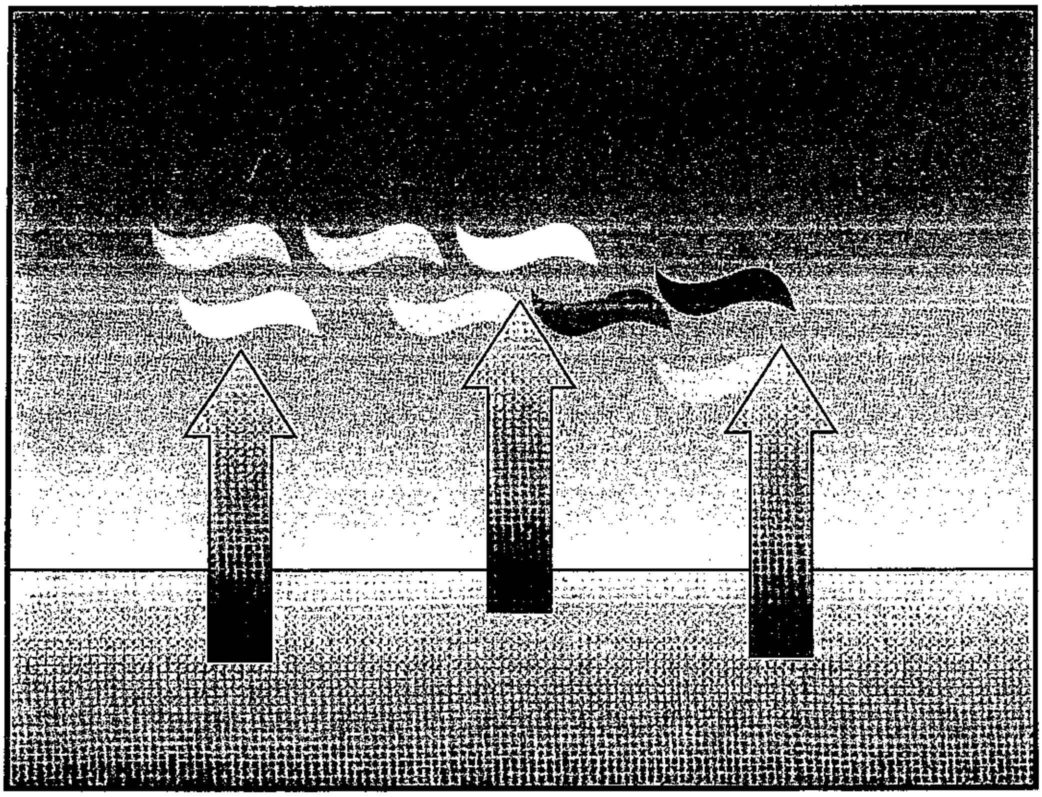
Biofiltration

A Clean Solution for the Australian Rendering Industry



Project M.887
December 1996

Managing odour problems in the meat industry is a costly problem – not only from the traditional methods of treatment, afterburners and chemical scrubbing but also from potential fines incurred from community and environmental complaints.

Some of the volatile organic compounds identified in rendering vapours have been found to include odour with characteristics described as "putrid", "fishy", "chemical-like", "sharp" and "burning". Production of odours such as these can lead to persistent complaints from neighbouring areas.

Penalties for excessive odours have traditionally attracted the heaviest fines under the EPA and local legislation.

With the encroachment of residential and commercial development into areas where rendering plants exist or are likely to be established, the search for a more cost-effective method of odour control has been an objective of the MRC.

Biofilters ... Best Available Technology For Odour Control

Biofilters have been used in a number of countries to treat industry odours and have become increasingly common in Europe, the United States and New Zealand. They control odorous gases from processes such as sewerage treatment plants, anaerobic digesters, refuse composting and pig and poultry farms. Biofilters are now considered the best available control technology in a variety of odour control applications, including rendering industry odours.

Biofilters ... A Lower Cost Option

In addition to being a simple and extremely efficient way to control odours, biofiltration is also a lower cost form of odour control than flame incineration or chemical scrubbing.

Biofilters applications in the meat industry have concentrated in treating rendering odours where large volumes of air are involved, for instance treating outlet air from air dryers. Biofilters can also treat the odours extracted from rendering vessels, raw material bins, processing equipment hoods and even ventilation air from negative pressure processing plants.

Depending on the volume of odorous gas to be treated and the current cost of after burner fuel, the conversion from an afterburner system to installation of a biofilter plant is likely to have a pay back period of 6-18 months.

Cost advantages of the biofilter over flame incineration and chemical scrubbing are lower operating costs and easier monitoring management.

Biofilters ... A Highly Natural Way To Clean The Air

Biofiltration provides an environmentally benign technology that in itself does not create any further pollutants as a result of the process.

Biofilters consist of large beds of compost, peat moss or soil that absorb odorous gaseous compounds which are then broken down through aerobic biological action to non-odorous compounds. In Australia most rendering is conducted in either batch cookers or continuous cookers dry rendering units. The major odour source is the non-condensable gases from the condenser. This odour stream is usually required to be treated through afterburners, which are expensive to operate, require significant maintenance and control, use a non-renewable energy source and are susceptible to failure.

In rendering plants, a number of bins and processing equipment can, at times, generate additional odour. These have been traditionally difficult to control due to the large volumes of air that must be captured and treated. Chemical scrubbing has been used, often with less that successful results. The main problems tend to be monitoring and control of the units, the high cost of chemicals and the generation of liquid wastes.

All these odours can be successfully treated with biofilters in an environmentally sound manner.

Biofilters ... Easier Monitoring And Management Of Odours

In addition to lower capital and operating costs, the advantage of biofiltration over flame incineration and chemical scrubbing is the simple process required for monitoring. The biofilter is virtually maintenance free. Only certain regular checks must be made regarding the moisture content, temperature and pH level of the filter bed.

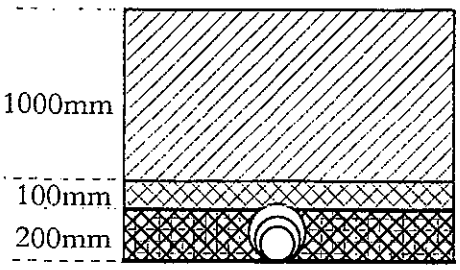
Biofilters ... Specifically Trialed For Australian Rendering Plants

The MRC has conducted two successful projects to develop optimum set up and operating conditions for biofiltration in Australian rendering plants. Initially, a pilot plant was established and run to investigate the variety of organic material suitable for biofilter beds. The project was extended to build a demonstration biofilter which used compost crust material recovered from an anaerobic pond. This biofilter replaced an existing afterburner and ran successfully for two years.

The project also proved that after the biofilter replaced the afterburner, odour reduction rates of better than 90% could be achieved on a concentrated odour sourced from the non-condensable vapour stream off the condenser.

The second project, carried out in conjunction with a rendering plant operator who successfully converted to bio-filtration in December 1995, involved the investigation of optimum monitoring and control of biofilters.

Biofilter Bed Design



As a result of these MRC-sponsored trials, it has been successfully demonstrated that:

- A range of organic materials can be used in the biofilter bed, including recycled abattoir by products, such as composted paunch or crust from anaerobic ponds
- Sensory probes can reliably measure the effect of moisture levels and temperature of the biofiltration process, the monitoring of which are inherent to successful biofilter maintenance. The sensory probe measurement system also proved extremely accurate, easy to operate, with a low-system cost, giving plant managers extremely precise data.

Biofilters ... How They Work

Biofilters are large beds of compost, peat moss, soil or other organic matter constructed above the ground or built below it. They should have a minimum compost depth of 1m.

Fans extract the odour stream. This vapour is then treated with a water mist to assist with the biofilter aerobic reaction, which requires moisture for the microbial activity to take place. The odours are passed through ductwork and fed into the bottom of the biofilter. They are then released into the base of the filter bed.

When odorous gases are passed through the bed, the odour component is absorbed and then broken down through biological action to non-odorous compounds.

Biofilters provide a highly natural way of cleaning the air.

The filter bed is composed of several layers. Immediately on top of the pipes is the base level which is usually comprised of 25mm gravel, and this allows the odours to easily release from the pipes. The intermediate layer contains 10-25mm layer of gravel.

The top level, known as the biomass is comprised of material which has a significant biological activity and allows for a uniform flow in the bed without stream formation. Stream formation causes odours to bypass the filter media, resulting in failure of the biofilter. The biomass should have a minimum depth of 1 metre.

Two types of media are used in the biomass: compost-based and soil-based.

Compost filters

Compost filters consist of beds of compost material, peat moss or fibrous peat, often mixed with a proportion of other material such as rice husks to assist in establishing an open structured biomass. Garbage compost, mushroom compost, paunch compost, crust from anaerobic ponds and garden compost have been successfully used in biofilters. To ensure an open structure, compost should be well matured and well turned. Constructing a filter with lumpy, immature compost is generally unsuccessful, as this results in streaming of gas through the bed.

The best compost material for biofilters have high surface area, high air and water permeability with high water holding capacity and high microbial population.

Compost containing extensive growth of fungal mycelia is not desirable, as this can lead to non-homogeneous gas flow through the bed and can result in channelling of the air flow through only part of the bed.

Composted paunch material

With a correct composting process, the final product has little resemblance to the initial paunch material and is similar to any other high organic compost such as kitchen waste, garden waste, chicken shed waste, mushroom compost, etc. The odours inherent in raw paunch material resulting from anaerobic digestion in the animal gut are eliminated by appropriate composting.

Composting of paunch is now being used as a disposal method for a number of Australian meatworks. The resultant composted product has been successfully trialed in biofiltration and provides a useful disposal method for a low value abattoir by-product. It also reduces the cost of compost material for the biofilter.

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1.1 ODOUR CONTROL CAN BE COSTLY

Managing odour problems in the meat industry is a costly problem - not only from the traditional methods of treatment, afterburners and chemical scrubbing, but also from the potential fines that incurred from community and environmental complaints.

Some of the volatile organic compounds identified in rendering vapours have been found to include odour with characteristics described as putrid, fishy, chemical-like, sharp and burning. Production of odours such as these can lead to persistent complaints from neighbouring areas.

Penalties for excessive odours have traditionally attracted the heaviest fines under the EPA and local legislation.

With the encroachment of residential and commercial development into areas where rendering plants exist or are likely to be established, the search for a more cost effective method of odour control has been an objective of the MRC.

1.2 BIOFILTERS PROVIDE BEST AVAILABLE TECHNOLOGY FOR ODOUR CONTROL

Biofilters have been used in a number of countries to treat industry odours. In particular they have become increasingly common in Australia, Europe, USA and New Zealand. They control odorous gases from processes such as sewerage treatment plants, anaerobic digesters, refuse composting and pig and poultry farms. Biofilters are now considered best available control technology in a variety of odour control applications including rendering industry odours.

1.3 BIOFILTERS ARE A LOWER COST OPTION

As well as being a simple and extremely efficient way to control odours, biofiltration is also a lower cost form of odour control than flame incineration or chemical scrubbing.

Biofilters applications in the meat industry have concentrated in treating rendering odours, where large volumes of air are involved, for instance treating outlet air from air dryers. Biofilters can also treat the odours extracted from rendering vessels, raw material bins, processing equipment hoods and even ventilation air from negative pressure processing plants.

Depending on the volume of odorous gas to be treated, and the current cost of after burner fuel, the conversion from an afterburner system to installation of a biofilter plant is likely to have a pay back period of 6-18 months. Cost advantages of the biofilter over flame incineration and chemical scrubbing are lower operating costs and easier monitoring management.

1.4 Biofilters Are A Highly Natural Way To Clean The Air

Biofiltration provides an environmentally benign technology that in itself does not create any further pollutants as a result of the process.

Biofilters consist of large beds of compost, peat moss or soil that absorb odorous gaseous compounds which are then broken down through aerobic biological action to non-odorous compounds.

In Australia most rendering is conducted in either batch cookers or continuous cookers dry rendering units. The major odour source is the non condensable gases from the condenser.

This odour stream is usually required to be treated through afterburners, which are expensive to operate, require significant maintenance and control, use a non-renewable energy source and are susceptible to failure.

In rendering plants there are always a number of bins and processing equipment that can at times generate additional odour. These have been traditionally difficult to control due to the large volumes of air that must be captured and treated. Chemical scrubbing has been used, often with less that successful results. The main problems tend to be monitoring and control of the units, the high cost of chemicals and the generation of liquid wastes.

All these odours can be successfully treated with biofilters in an environmentally sound manner.

1.5 Biofilters Allow For Easier Monitoring And Management Of Odours

As well as lower capital and operating costs, the advantage of biofiltration over flame incineration and chemical scrubbing is also the simple process required for monitoring. Although certain regular checks which need to be made regarding the moisture content, temperature and pH level of the filter bed, the biofilter is virtually maintenance free.

1.6 Biofilters Have Been Specifically Trialed In Australian Plants

The MRC has conducted two successful projects to develop optimum set up and operating conditions for biofiltration in Australian rendering plants. Initially, a pilot plant was established and run to investigate the variety of organic material suitable for biofilter beds. The project was extended to build a demonstration biofilter which used compost crust material recovered from an anaerobic pond. This biofilter replaced an existing afterburner and ran successfully for two years.

The project also proved that after the biofilter replaced the afterburner, odour reduction rates of better than 90% could be achieved on a concentrated odour sourced from the non-condensable vapour stream off the condenser.

The second project, carried out in conjunction with a rendering plant operator who successfully converted to biofiltration in December 1995, involved the investigation of optimum monitoring and control of biofilters.

As a result of these MRC sponsored trials, it has been successfully demonstrated that:

- *a range of organic materials can be used in the biofilter bed, including recycled abattoir by products, such as composted paunch or crust from anaerobic ponds.*
- *the use of sensory probes is a reliable way to measure the effect of moisture levels and temperature of the biofiltration process, the monitoring of which are inherent to successful biofilter maintenance. The sensory probe measurement system also proved extremely accurate, easy to operate, with a low system cost, giving plant managers extremely precise data.*

1.7 How Do Biofilters Work?

Biofilters are large beds of compost, peat moss, soil or other organic matter. The beds can be constructed above the ground or built below it. They should have a minimum compost depth of 1m.

Fans extract the odour stream. This vapour is then treated with a water mist to assist with the biofilter aerobic reaction, which requires moisture for the microbial activity to take place. The odours are passed through ductwork and fed into the bottom of the biofilter. They are then released into the base of the filter bed.

When odorous gases are passed through the bed the odour component is absorbed and then broken down through biological action to non-odorous compounds.

Biofilters provide a highly natural way of cleaning the air.

The filter bed is composed of several layers. Immediately on top of the pipes is the base level which is usually made up of 25mm gravel. This allows the odours to easily release from the pipes. The intermediate layer is usually made up of 10 -25mm layer of gravel.

The top level, known as the biomass is comprised of material which has a significant biological activity and allows for a uniform flow in the bed without stream formation. Stream formation causes odours to bypass the filter media, resulting in failure of the biofilter. The biomass should have a minimum depth of 1 metre.

1.8 Selection of Material for the Biomass

There are two types of media used in the biomass, compost based and soil based.

Compost filters consist of beds of compost material, peat moss or fibrous peat, often mixed with a proportion of other material such as rice husks to assist in establishing an open structured biomass . Garbage compost, mushroom compost, paunch compost, crust from anaerobic ponds and garden compost have been successfully used in biofilters. Compost should be well matured and well turned to ensure an open structure. Constructing a filter with lumpy, immature compost is generally unsuccessful as this results in streaming of gas through the bed.

The best compost material for biofilters have high surface area, high air and water permeability with high water holding capacity and high microbial population.

Compost containing extensive growth of fungal mycelia is not desirable as this can lead to non-homogeneous gas flow through the bed. This can result in channelling of the air flow through only part of the bed.

Composted Paunch Material - With a correct composting process the final product has little resemblance to the initial paunch material and is similar to any other high organic compost such as kitchen waste, garden waste, chicken shed waste, mushroom compost, etc. The odours inherent in raw paunch material resulting from anaerobic digestion in the animal gut are eliminated by appropriate composting.

Composting of paunch is now being used as a disposal method for a number of Australian meatworks. The resultant composted product has been successfully trialed in biofiltration and provides a useful disposal method for a low value abattoir by-product. It also reduces the cost of compost material for the biofilter.

Composted Crust from Anaerobic Ponds -Being able to recycle a by-product from the abattoir production process to create a low cost, high performance form of compost material is again the major benefit of using this material.

Soil Based Filters consist of a bed of sandy or loamy soil, or a fine sand layer topped with soil. However, soils vary widely in permeability and microbial activity. The performance of a soil filter depends on the internal pore structure which in turn depends on the type of soil used.

Soil filters tend to be cheaper to construct than compost filters unless there is a ready supply of compost available. However, this is offset by the lower porosity of soil which results in a lower flow rate per cubic metre of volume (ie the bed needs to be proportionately larger) and higher operating pressures (ie increased operating costs). Soil based filters have traditionally been used in waste water odour reduction applications.

The actual make-up of the biomass is not of critical importance so long as the operating conditions for the biofilter are maintained, in particular moisture, temperature and pH.

1.9 Optimum Operating Conditions Of A Biofilter

Basic maintenance of a biofilter is minimal, however if neglected, it will not function optimally -

- Optimum temperature for the filter bed is 35°C. The incoming odour stream should not exceed 45°C.

- The correct balance of moisture content is critical - too dry a bed can cause leaking of the odour stream. Too moist a bed will not allow absorption of odours.

These can be measured by a series of sensory probes situated throughout the filter bed.

Weekly monitoring is essential - or when an odour complaint is received. In addition to temperature and moisture, a satisfactory monitoring record should show -

- Weather conditions - whether fine, overcast or raining
- Wind speed and direction
- Temperature
- Whether any odour exists and whether it is noticeable up 200 metres downwind of biofilter.
- Characteristic of any odour existing
- Location of odour leaks
- Observation of associated equipment - sprinklers, scrubbers, fans, rendering building.
- Action taken

The pH level should be maintained between 7 and 8. If necessary, lime can be added to help maintain this level. The pH of compost beds only needs to be probed occasionally.

1.10 ARE BIOFILTERS SUITABLE FOR YOUR OPERATION?

Biofiltration is a highly viable process for anyone who has a rendering operation and should be considered under any of the following circumstances

- Planned upgrade of a rendering plant
- Planned replacement of current odour control equipment
- Building a new plant
- Unacceptable frequency of odour complaints
- Need for improved environmental performance
- Management looking for a long term cost effective solution to afterburner fuel cost
- Treatment required for high volume odour streams

INTRODUCTION

1. BACKGROUND

Biofilters have been used in a number of countries to treat industry odours, in particular they have become increasingly common in Australia, Europe, USA and New Zealand.

Applications in the meat industry have concentrated in treating rendering odours. In particular attention has focussed on treatment of odours where large volumes of air are involved, especially from direct air driers treating wet rendered solids material and blood coagulant.

In Australia most rendering is conducted in either batch cookers or continuous dry rendering units. A major odour source from these systems is the non condensable gases from the vapour condenser unit. This odour stream is usually required to be treated through an afterburner.

Afterburners are expensive to operate, require significant maintenance and control, use a non-renewable energy source and are susceptible to failure.

In rendering plants there are always a number of bins and units of processing equipment that can at times generate odour. These have been traditionally difficult to control due to the large volumes of air that must be captured and treated.

Chemical scrubbing has been used, often with less that successful results. Problems tend to occur with monitoring and control of the units. Chemical scrubbers of course also consume chemicals and generate their own liquid wastes.

Biofiltration provides an environmentally benign technology that has the potential to overcome these problems.

Biofilters consist of large beds of compost, peat moss or soil, individually or in combination, that absorb odorous gaseous compounds which are then broken down through aerobic biological action to non-odorous compounds.

Although the air stream may pass through the filter medium quickly, the odorous compounds, absorbed by the moisture within the pores of the filter material, may reside in the bed for hours before being degraded by microbial action. The filter medium is thus regenerated by the action of the micro-organisms on the absorbed pollutants.

The biofilter medium can vary significantly depending on the application and the desired end result. If compost is used, it is usually of a fibrous nature. Soil has also been used with success although the different types of soil vary widely in permeability and microbial activity.

Biofilters have been used for the control of odorous gases from processes such as the rendering of animal matter, anaerobic digesters, refuse composting, and pig and poultry farms.

Soil bed biofilters have been installed in a number of countries, including Australia, to control sulphide odours from wastewater treatment plants. These soil beds are a form of biofilter, however they have not been generally applied in industrial installations.

Since the technology is perceptibly simple it is considered that there is also likely to be a number of "home-made" units installed in Australia which work on a "better than nothing" basis.

There are many environmental and operational advantages associated with biofilters, however a number of operational problems have occurred. These have mostly been associated with:

- **Drying** of the bed, principally caused by passing an unsaturated vapour stream through the filter bed.
- **Blinding** of the bed caused by carry over of fat and particulate matter in the gas streams.
- **Cracking and streaming** in the bed, caused by drying and poor filter material selection.
- **High vapour temperatures** causing failure of the microbial mass.

Experience is also beginning to suggest that high ammonia and sulphide levels can cause problems by lowering pH levels and poisoning the filter bed. Careful maintenance and monitoring of the bed overcomes these problems. This is however generally not a problem associated with the treatment of rendering odours.

2. APPLICATION OF BIOFILTRATION TO RENDERING

Application of biofilters has generally been in two areas:

1. Treatment of high volume vapour streams from pneumatic (air) driers including ring driers, rotary kiln driers, disc driers etc.
2. Treatment of fugitive vapour streams either captured in hood and duct systems or from within buildings operated under negative air pressure.

Biofilters have been ideal for these applications because:

- High vapour volumes make flame incineration uneconomic.
- Chemical scrubbers can be unreliable and require constant attention.
- The nature of these streams; less than 40°C; containing high air and moisture content; and containing organic volatiles is suitable for the application of biofilter technology without further treatment.

The application of biofilters is advantageous wherever high volume flows of waste gases have to be cleaned, which contain gaseous and biologically degradable pollutants in relatively low concentrations.

The method is particularly suitable for plants in which the waste gases from processing and auxiliary equipment as well as the building ventilation air need to be treated.

3. INDUSTRY CASE STUDIES

3.1 CASE STUDY 1: BIOFILTER TO TREAT NON CONDENSABLE ODOURS

This installation consisted of an above ground type biofilter with a surface area of 30 square metres. The installation required a cooling module to be fitted on the inlet vapour to ensure that the temperature did not exceed 45 °C. The filter bed comprised 100% composted material from the crust of an anaerobic pond. A roof was installed over the bed.

The design flow-rate was 500m^3/hr, and the odour reduction efficiency measured by olfactometry was better than 90%. There was evidence that although the total odour had reduced by 90% the odour characteristic of the output was also less obnoxious (more an earthy type odour characteristic), and did not appear to travel. More importantly odour complaints from surrounding residents reduced after the commissioning of the biofilter.

The whole installation including the cooling unit had a capital cost in the vicinity of $45,000. This does not include the induction fan which was already in place servicing the flame incinerator. The flame incinerator was left in place at the request of the environmental authorities.

The operating cost for the biofilter is essentially electricity for fan power which is necessary for any odour control system including flame incineration.

The reported fuel cost for the afterburner averaged $60,000 per annum, and required $5,000 per annum repairs and maintenance.

A simple economic analysis looks at the pay-back period for the biofilter to replace the afterburner.

Pay-back Analysis - Case Study 1

Capital Cost Biofilter

Biofilter	$25,000	
Cooling Unit etc	$15,000	
Total		**$40,000**

Annual Savings

Afterburners Fuel	$60,000	
Afterburners R&M	$5,000	
Total		**$65,000**

Pay-back Period

$$= \frac{\text{Capital Cost}}{\text{Annual Savings}} \times 12 \text{ months}$$

$$= \frac{40{,}000}{65{,}000} \times 12 \text{ months}$$

$$= 7.4 \text{ Months}$$

The pay-back on replacing the afterburner with the biofilter in this instance is estimated to be less than 8 months.

In a new installation the advantage of the biofilter is even greater as the capital cost of the afterburner would be at least twice the capital cost of the biofilter.

3.2 CASE STUDY 2: BIOFILTER TO TREAT COMPOSITE RENDERING ODOURS

This installation consisted of an above ground type biofilter with a surface area of 350 square metres. The odours treated included non condensable vapour from the rendering vessels, direct vented areas in the blood processing area and from sumps, and general rendering building ventilation air.

The installation required a wet scrubbing module to be fitted on the non condensable vapour stream and a spray mister fitted into the duct-work to ensure humidity levels better than 95%. Since the majority of the vapour to be treated was plant ventilation air there was no need for specific temperature control.

The filter bed comprised 66% composted paunch material and 33% rice hulls.

The design flow-rate was 33,000m^3/hr. The local council reported reduced odour complaints from surrounding residents after the commissioning of the biofilter.

The whole installation including full stainless steel had a capital cost in the vicinity of $230,000. The flame incinerator was left in place at the request of the environmental authorities.

The operating cost for the biofilter is essentially electricity for fan power. The cost would be some $4,500 per annum.

The reported fuel cost for the afterburner averaged $100,000 per annum, and required $8,000 per annum repairs and maintenance. Due to other changes at the plant it would have been necessary to replace and upgrade the afterburner at a capital cost of around $80,000.

A simple economic analysis looks at the pay-back period for the biofilter to replace the afterburner.

Pay-back Analysis - Case Study 2

Capital Cost Biofilter		
Biofilter total	$230,000	
Afterburner	$ 80,000	
	Nett	**$150,000**
Annual Savings		
Afterburners Fuel	$100,000	
Afterburners R&M	$8,000	
Minus Fan electricity cost	$5,000	
	Total	**$103,000**

Pay-back Period

$$= \frac{\text{Nett Capital Cost}}{\text{Annual Savings}} \times 12 \text{ months}$$

$$= \frac{150{,}000}{103{,}000} \times 12 \text{ months}$$

= **17.4 Months**

The pay-back on replacing the afterburner with the biofilter in this instance is estimated to be less than 18 months and the supplementary benefit is that the biofilter is also treating the other significant odour streams including plant ventilation air, which would not be able to be treated in an afterburner.

4. REFERENCES

The principal documents sourced during the study and an abstract of each is provided in Appendix 1. Appendix 2 lists a number of biofilters in Australia.

1. ENVIRONMENTAL RESPONSIBILITIES

Government controls on industry are usually of two types - governing land use and control of the release of pollutants to the environment.

Variations exist between states within Australia with regard to government controls, but each state requires within its environmental protection legislation -

- licences to operate
- approvals for new developments and extensions
- work to be done or operations to be modified to prevent or minimise pollution of the environment
- limitation of pollutant and waste releases
- approvals for land use
- development & building approvals

Severe penalties can be incurred and a much greater responsibility on individual managers and directors is in place to ensure that environmental law is not breached . As a consequence many companies have put in place environmental management systems and auditing procedures to monitor their impact in these areas.

1.1 ODOUR MANAGEMENT REQUIREMENTS

Odours can be generated at many points in a meat processing operation: stock holding yards, raw offal and blood handling; offal cooking; meal and blood handling; tallow and fat processing; dried meal processing and packing; waste water treatment; waste disposal; and sludge disposal. Odours are probably the greatest environmental problem faced by rendering plants.

There is a diverse array of odour laws across the Australian States.

1.1.1 Victoria

In Victoria the Environment Protection Act requires odours which are objectionable in the judgment of an officer to be controlled. The Victorian State Environment Protection Policy for the Air Environment sets several more detailed requirements for rendering plants -

- materials to be rendered to be processed as soon as possible after slaughter
- cooking and pressing vapour from existing plants to be vented to odour removal equipment
- solid rendered material to be conveyed in enclosed equipment
- all new continuous high temperature cooker plants to be totally enclosed and the extracted ventilation air to be treated in odour removal equipment

- enclosure of raw material and cooker/drier equipment
- no visible emissions except water vapour
- odour level after the control equipment not to exceed 200 odour units
- the odour removal equipment to be a condenser, and incinerator or chemical scrubber or equivalent
- building ventilation air to be brought to a single point for control
- odour suspension to be calculated in accordance with the Victorian dispersion method (Ausplume)
- sampling and testing to be in accordance with Victorian method
- a recommended buffer zone of 1 kilometre

1.1.2 New South Wales

The Clean Air Act has required since 1975 that no odours detectable by an authorised officer relying solely on his sense of smell be allowed to travel beyond the premises boundary, irrespective of objectionableness. In practice the NSW EPA mainly pursues this section with factories which cause complaints.

NSW has also recently adopted a design standard of one odour unit at the recognition threshold (averaged over the response time of the human nose of one second) not to be exceeded more than 1% of the time at he boundary or sensitive receptor. In practice, this corresponds to 0.1 odour units averaged over three minutes.

Conditions similar to those specified in the Victorian EPA may be specified by the NSW EPA as licence conditions. It is common for equipment-based operation conditions to be attached to EPA licences for rendering plants.

1.1.3 Queensland

There is an Interim Environment Protection Policy under the new Environment Protection Act which specifies a design ambient standard for odour of 0.5 odour units for stack emissions and 2.5 odour units for non-stack emissions, expressed as three-minute averages calculated by an approved dispersion model.

The odour test method adopted by the Department of Environment and Heritage is slightly different to the method used by NSW and consequently the standards are not directly comparable. This requirement applies to rendering plants along with other specified industries.

1.1.4 South Australia

There are as yet no formal regulations or policy governing control of rendering plants in South Australia. The criterion used by the SA Environment Protection Authority is to design for 0.1 odour units for an emission from a chimney based on a ten minute average. A series of practical operation conditions are also applied to rendering plants which must be licensed.

1.1.5 Western Australia

Western Australia is also at the point of developing a policy for odour and is generally following the Queensland model.

1.1.6 Other States and Territories

Tasmania, the Northern Territory and the ACT do not have formal policies or regulations for odours and apply best practicable requirements on an 'as needs' basis in response to complaints.

2. ODOUR MANAGEMENT OVERVIEW

2.1 IDENTIFICATION OF ODOUR SOURCES

The first step is to identify all the potential sources of odour in a plant and rate them on a scale of significance. It is useful to include all the potential sources at this stage, no matter how low on the priority scale they might seem to be.

A checklist of sources to consider includes:

raw materials handling
- receiving hoppers
- transfer conveyors
- contra-shear screens and save-all pit
- cleaning equipment

batch cookers
- charging emissions
- non-condensable odour from cooking
- venting to reduce pressure
- discharging to drop-out troughs or percolator pans
- condensate

continuous cookers
- feed hoppers and conveyors
- non-condensable from cooking
- leakages from seals
- venting vapours off hot meal from the cooker
- condensate

presses
- feed hoppers and conveyors
- fumes from the press discharge point
- product conveyors
- decanters
- hot oil storage tanks
- hot oil loading

batch driers
- charging emissions
- non-condensable from drying
- discharging to drop-out troughs
- condensate

continuous driers
- feed hoppers
- non-condensable
- leakages from seals
- condensate

blood coagulation and ring driers
- raw blood handling
- ring drier emissions
- stick water
- materials handling
- odours associated with dust emissions from bins, conveyors, bagging, loading out, etc.
- odours from deteriorating, spoiled finished product

general plant areas
- waste water treatment system
- save-all pit
- dissolved air flotation plant
- anaerobic treatment pond
- aerobic treatment ponds
- stabilisation and holding dams
- spray irrigation
- stockyards

1.1 Quantifying the Sources

Priority odour sources can often be quantified from experience. Some previous measurements of odour generation rates from the various unit processes in a rendering operation have been recorded in the air pollution control literature (see Appendix 1), however, for high priority sources some measurement may be desirable. Usually this will involve fugitive and diffuse odour sources. These are the most difficult to measure since collection hoods usually need to be built to capture and allow assessment of odour strength.

Measurement of odours from exposed surfaces such as cattle feedlots or waste water treatment processes is particularly difficult with some controversy continuing over the use of static or ventilated hoods for odour capture.

Modern odour intensity testing requires olfactometric assessment. Measurements are expressed in odour units, where one odour unit is defined as the quantity of odour in a cubic metre of air sufficient for 50% of a panel to just detect it. There is much current debate in Australia and New Zealand as to the appropriate methodology to use for measurement.

The key variants in the tests centre around the number and selection of the olfactory panel; the method of presentation of the odour sample; the method of panel response (forced choice or yes/no); the end point (detection or recognition); and the method of calibration.

Before going to the expense of olfactometric testing it is advisable to approach the state regulatory agency to determine which method they require and whether the laboratory undertaking the test needs to be certified.

Due to the expense and problematic nature of odour measurement, it is advisable to limit testing only to those areas judged to be particularly significant and on which no odour data is already available.

1.2 Dispersion Modelling

Once odour source strengths have been determined, spread of odours in the vicinity of the plant can be predicted using atmospheric dispersion models. The model gaining most acceptance is Ausplume developed by the Victorian EPA. In order to run the models local meteorology must be known, especially in light wind conditions, when local topography can strongly influence wind direction and odour transport.

There is debate among modellers over the appropriate model for odour prediction, since the response time of the human nose, in the order of seconds, is not the usual period predicted by the models, ie. 10 minutes to an hour.

There is therefore some uncertainty in the results predicted by the models and expert modellers and meteorologists are generally required to produce realistic predictions of odour nuisance.

1.3 ASSESSMENT OF ODOUR IMPACT

Once odour strength and frequency around a plant has been predicted the likelihood of complaints needs to be assessed.

An occasional whiff of a slight odour is not likely to cause complaint, whereas frequent exposure to strong unpleasant odours is almost certain to bring complaints.

There is no agreement as to these assessment in Australia. In New South Wales the test has tended to be merely the occurrence of detectable odour. In practice only objectionable odours have been pursued.

In other states and territories the FIDO factors have been applied. FIDO factors involve taking Frequency, Intensity, Duration and Objectionableness into account.

1.4 MINIMISING ODOURS

Some broad choices need to be made in designing odour control systems for new plants or for retro-fitting to existing plants.

A range of control equipment has been used to eliminate or reduce odours.

The efficiency of capture is as important as the efficiency of odour removal in the final control equipment. As an example, 99% efficiency of removal will mean little if the odour capture efficiency is only 70%.

Control equipment for non-condensable odours has traditionally been by incineration at 760°C with a half or third of a second residence time. This ensures complete destruction of this highly odorous stream, but the volume of air to be incinerated is relatively small compared to other significant sources. Both separate incineration and burning in the boiler are in common practice. Incineration is usually impractical for the larger volumes of secondary air from many of the sources.

Wet scrubbers are sometimes used to control odours; however, chemicals must be added to the scrubbing liquid to effectively remove the hundreds of odorous compounds present, many of which are not soluble in water. Often both an oxidising and acid stage will be needed in chemical scrubbing of rendering odours to ensure removal of all odours. If whole building ventilation is adopted then wet scrubbing presents an effective control system. However, a factor to consider is the disposal of the waste chemicals arising from wet chemical scrubbing. Disposal to the local sewer system is an easy solution if the effluent is acceptable to the authorities. But often this will not be available and the long term consequences of disposing of chlorinated liquors to land should be carefully considered. A chemical scrubber is a sophisticated piece of process plant which should be operated with modern control to achieve effective performance.

Biofilters have therefore become popular in recent years in the rendering industry. When well designed they are both effective and easy to operate. They generally require large areas of land to be available, especially for the treatment of large secondary air volumes, and care must be taken to control temperature and humidity.

In some circumstances dispersion of collected odours through a tall stack might be possible. Stacks are simple devices and require no skill or special instrumentation to operate. They are also relatively inexpensive, with low long term operating costs. However, the meteorology and dispersion predictions need to be very carefully designed to ensure effective elimination or minimisation of odours. Usually the intensity of non-condensable odours will preclude the use of stacks of modest height. Incineration of non-condensables and dispersion of secondary odours may be an option in some cases. However, the difficulty in predicting plume movements in hilly terrain usually means that stacks generally cannot be used in these situations.

A further option is to establish large buffer zones around rendering plants and rely on the dilution of odours with spread. Again a combination of dispersion for secondary sources with control of the higher strength odours by incineration or biofiltration can provide an acceptable common option.

1.5 COLLECTION AND CONTAINMENT

The completeness of collection needed from a rendering operation will depend on two factors, the proximity of sensitive neighbours and the size and strength of the emissions.

Where residences are close and the operation is of medium to large size there will usually be little option but to totally enclose the building and evacuate all the building air through control equipment. The background odours associated with rendering, no matter how good the housekeeping, will be sufficient to mandate total treatment.

Total enclosure eases the need for extensive ducting within the plant to capture emissions at source in the process and leads to a more open and uncluttered plant design. However, industrial hygiene requirements mandate that large volumes of air must be circulated making the cost of fan operation and the size and cost of control equipment large. Typically 15 air changes per hour would be a minimum requirement. Operating conditions will generally be less comfortable for operators both because of the odours at the work station and humidity and heat.

Where a reasonable buffer zone exists it is usually possible to design local collection hoods and extraction points to efficiently capture odours from the process. This requires more complexity in ductwork and great care in hooding design, but results in considerably lesser air volumes than for total building enclosure with consequent smaller size and cost of control equipment.

With buoyant steam plumes it is important to ensure ample hood size to avoid loss through billowing. Ducting should be designed with an eye to ease of cleaning. Stainless steel is recommended due to the corrosive nature of rendering fumes. Provision should also be made for condensation and removal of vapour in primary cooking emissions and some secondary collection emissions.

1.6 ODOUR COMPOUNDS & CHARACTERISTICS

Volatile organic compounds identified in rendering vapours have been found by Van langenhove et al to include:

Compound	Present in			Sensory evaluation odour character	Compound	Present in			Sensory evaluation odour character
	a	b	c			a	b	c	
dichlorodifluoromethane	x				chlorobenzene	x		x	
2-methylpropane	x				ethylbenzene	x	x	x	
1-butene	x	x	x		dimethylthiophene			x	
butene	x	x	x		m,p-xylene	x	x	x	
methanethoil	x		x	putrid, bad	nonene	x		x	
trimethylamine	x	x	x	fishy, ammonia	styrene	x		x	
2-methylbutane	x				nonane	x	x	x	
trichlorofluoromethane	x	x	x		o-xylene	x	x	x	
pentene	x		x		heptanal	x	x	x	fatty
pentane	x	x	x		α-thujene	x			
2-propanone	x	x	x	acetone	propylcyclohexane	x			
diethylether	x		x	ether	methyl propyl disulfide	x			putrid
dimethyl sulfide	x	x	x	putrid	α-pinene	x	x	x	fir
propanal	x	x	x	sharp	terpene (mol wt 136)	x			fresh
carbon disulfide	x		x		camphene	x		x	
dichloromethane	x		x	sweet, ethereal	benzaldehyde			x	
2,3-dimethylbutane	x				propylbenzene isomer	x	x	x	
2-methylpropanal	x	x	x	malty	methylethylbenzene isomer	x	x	x	
2-methylpentane	x	x	x		methylethylbenzene isomer	x	x	x	
3-methylpentane	x	x	x		sabinene	x			
hexene	x		x		dimethyl trisulfide	x			putrid
hexene	x	x	x		β-pinene	x	x	x	
butanal	x		x	malty, burnt	2-pentylfuran	x	x	x	
2-butanone			x	solvent	decane	x	x	x	
trichloromethane	x		x	ethereal	trimethylbenzene isomer	x	x	x	
methylcyclopentane	x	x	x		α-phellandrene	x			
ethyl acetate	x			fruity	octanal	x	x	x	faaty,oily
tetrahydrofuran	x		x		Δ^3-carene	x		x	
trichloroethane		x	x	sweet	butylbenzene isomer	x		x	
3-methylbutanal	x	x	x	buttery	butylbenzene isomer	x		x	
cyclohexane		x	x		o-dichlorobenzene	x	x	x	sanitary
thiophene			x		tetramethylbenzene	x	x	x	
tetrachloromethane	x		x		limonene	x	x	x	lemon
benzene	x	x	x		m-dichlorobenzene	x	x	x	sanitary
2-methylbutanal	x	x	x	aldehydic	tetramethylbenzene isomer	x	x	x	
3-methylhexane		x	x		terpene (mol wt 136)	x			
2,2,4-trimethylpentane	x		x		undecane	x	x	x	
heptene	x		x		nonanal	x	x	x	fatty, oily
heptane	x	x	x		tetramethylbenzene isomer	x	x	x	
pentanal	x	x	x	fatty, pungent	dodecane	x	x	x	
trichloroethylene	x	x	x		naphthalene	x	x	x	naphthalene
methylcyclohexane	x	x	x		tridecane	x		x	
dimethyl disulfide	x	x	x	putrid	decanal		x		citrus fruit
toluene	x	x	x		methylnaphthalene	x		x	
octene	x		x		terpene (mol wt 136)	x			
methylthiophene			x		tetradecane	x		x	
octane	x		x		terpene (mol wt 136)	x			
hexanal	x	x	x	fatty, green	pentadecene	x		x	
pentanol		x			pentadecane	x		x	
tetrachloroethylene	x	x	x						
octadiene	x								

Key: **a,** scrubber outlet samples; **b**, air sampled in factory buildings; **c**, ambient air samples

These volatile organics are considered to be a family which can be appropriately treated with biofiltration.

1. PRINCIPLES

Biofilters are large beds of compost, peat moss soil or other organic matter arranged in such a way that when odorous gaseous compounds are passed through the bed the odour component is absorbed and then broken down through biological action to non-odorous compounds.

The vapour stream passes through the filter medium quickly, however, the odorous compounds are absorbed within the structure of the filter bed material and may reside in the bed for hours before being degraded by microbial action. The filter medium is continually regenerated by the action of the micro-organisms on the absorbed pollutants.

The active section of a biofilter consists of a layer of organic material (compost, mixtures of fibrous peat and other materials). The waste gas components are absorbed by the filter material or by its surrounding liquid film. These components are then metabolised by the microbes (bacteria, yeasts, fungi - biomass) living on the filter material. The microbes utilise the filtered substances for their nutrition and cell construction. Materials which are useless to them will be captured in the filter bed or released with the waste gas flow.

Micro-organisms are available in such great variety that all kinds of organic and inorganic pollutants can be removed. For most pollutants, there will be either a species suitable for degrading the particular compound or a suitable species will adapt through the natural process of biological evolution. As aerobic microbial activity only occurs to any degree in solution, the pollutants and oxygen must be transferred to the very thin film of water that adheres to the surface of the solid material in the biofilter medium.

As polar compounds tend to be more easily absorbed, they are more readily biodegradable. Soil has been reported as having the capacity to absorb a wide range of both organic and inorganic pollutants including sulphur dioxide, hydrogen sulphide, methyl mercaptan, carbon monoxide and polynuclear organic material.

Is not necessary, to administer specific populations of microbes to the filter material, however a sufficient supply of oxygen and humidity and acceptable ranges of the temperature and the pH-value in the filter environment are absolutely necessary for their survival.

There are two principal groups of micro-organisms suitable for the treatment of odorous gases; autotrophic and heterotrophic bacteria. Autotrophic bacteria obtain their carbon requirements solely from carbon dioxide and their energy requirements from the oxidation of a range of inorganic compounds including molecular hydrogen, ammonia, nitrite, thiosulphate, hydrogen sulphide and sulphur.

Heterotrophic bacteria gain their nutrients and energy by the oxidation of organic compounds which makes them well suited for the conversion of organic pollutants. This process is much faster than the oxidation of inorganic compounds by autotrophic bacteria, but requires aerobic conditions.

The filter bed material supports both the absorption effects and the biomass:

- it is the living space of the microbes
- it acts as a humidity reservoir
- it provides the mechanical support for the maintenance of the internal structure of the biomass.
- it provides a maximum effective filter surface (large pore volume) and a minimum pressure drop in the filter layer.

The filter bed material should not itself have a distinct specific odour that may cause its own odour nuisance.

Mixtures of paunch compost and rice hulls provide a suitable filter medium with many advantages. It is appropriate as a reserve substratum for the nutrition of the microflora during plant shutdowns because it contains a high amount of cellulose. The internal structure of the filter layer is also preserved for a long time due to the high lignin content, which is resistant to microbial decomposition .

Thus, important characteristics of biofilter beds is that they have:

- a high pore volume,
- a low flow resistance (approx 10-15mm water gauge per meter height of the filter bed), and
- a service life of better than five years at maximum operation temperatures of about 35° to 40°C. Higher temperatures can lead to a more rapid rotting process, a thickening of the filter material and higher pressure drops.

For sound operation of filters with mixed materials, the components should be mixed as thoroughly as possible for even composition and packing density.

Adequate and homogeneous humidity in the filter layer is imperative. This can be achieved during continuous operation with the waste gas being saturated with water vapour in a spray scrubber or mister upstream of the biofilter.

The best cleaning efficiency is achieved with those components which can be easily adsorbed/absorbed by the carrier material and which are biologically/biochemically easily degradable. Bearing this in mind, alcohols, aldehydes, ketones, carboxylic acids and esters (including phosphoric esters) furans, organic sulphides and polysulphides, basic nitrogen compounds etc. can easily be degraded to a good extent. This applies also to hydrogen sulfide and ammonia.

The worst efficiency is achieved with aliphatic, aromatic and halogenated hydrocarbons. This is attributable to their apolarity (low water solubility) and their chemical stability.

Biofilters have been mainly used to prevent odour annoyance in plants whose emissions consist of a large variety of mostly odorous gaseous degradation products from animal and plant material.

The Table presents a survey of the applications which proved successful in pilot plants and in industrial practice.

Table 1: Plants equipped with Biofilters

TYPE OF PLANT	RAW GAS TEMP °C	PRE-SCRUBBED DUE TO	MAIN GASEOUS COMPONENTS
Rendering plant (complete)	20 to 35	fatty aerosols, dust	basic N-compounds, fatty acids, aldehydes, organic sulphides
Food production for pets	80	fine dust	amines, ammonia, aldehydes
Yeast production (drier)	90	dust	aromatics, fatty acid esters, alcohols
Oil mill (conditioning, hexane extraction)	70	fine dust	hexane (800 mg/m^3, reduced to 50%), iso-butanols, pentene nitrile, butyric esters
Slaughterhouse (storage and waste processing)	20 to 35	fatty aerosols, dust	basic N-compounds, fatty acids, aldehydes, organic sulphides

Since the early 1980's biofilters have been used in rendering facilities in a number of countries including Germany, Netherlands, USA and NZ. Application of the biofilters has generally been in two areas:

1. Treatment of high volume vapour streams from pneumatic (air) driers including ring driers, rotary kiln driers, disc driers etc.
2. Treatment of fugitive vapour streams either captured in hood and duct systems or from within buildings operating under negative air pressure.

Biofilters have been ideal for these applications because:

- High vapour volumes make flame incineration uneconomic.
- Chemical scrubbers can be unreliable and require constant attention.
- The nature of these streams; less than 40°C; containing high air and moisture content; and containing organic volatiles is suitable for the application of biofilter technology without further treatment.

2. PROCESS ENGINEERING ASPECTS

All biofilters have in common that they comprise one or several waste-air fans which push the exhaust air to be cleaned into an air distributing system below the filter bed. If necessary, a dust separator is installed upstream of the fans or between them. In addition, all biofilter systems have to be equipped with a moistening devices to moisten the filter bed homogeneously whenever necessary.

In-rendering plants, any fat particles in the waste air should be removed by suitable equipment before the waste air enters into the filter layer, otherwise the filter may blind and cause high back pressures after some time in operation.

2.1 PHYSICO-CHEMICAL ASPECTS

Activity of micro-organisms can be compared with a chemical reaction, the rate of which is a function of

- concentration of the pollutants
- water concentration (humidity)
- density of micro-organisms, and
- temperature

As decomposition rates are comparatively slow, the absorption phase may generally be ignored.

The reduction of the pollutants in the biofilter bed therefore depends on the reaction rate (decomposition), on the height of the filter bed, on the flow velocity through the bed, and on the concentration of pollutants.

Retention time in the biofilter is determined by the height of bed, the void fraction of the filter material and the flow velocity.

2.2 FILTER MATERIAL

To maintain the efficiency of the biofilter it is necessary to use a filter material which can provide the micro-organisms with sufficient nutrients. Generally this requirement is met by using

- peat moulds and their by-products (eg fibrous peat)
- compost (garbage, paunch material, etc)
- humus soils

When choosing filter media, the following criteria are important:

1. void fraction (pressure loss across filter bed)
2. surface of the carrier substance (determines micro-organism population)
3. water retaining capacity (humidity balance)
4. structure (filter uniformity)
5. pH-value of the filter medium

6. organic substance content (filter life)
7. weight per volume unit
8. specific odour
9. capital cost and maintenance expenditure

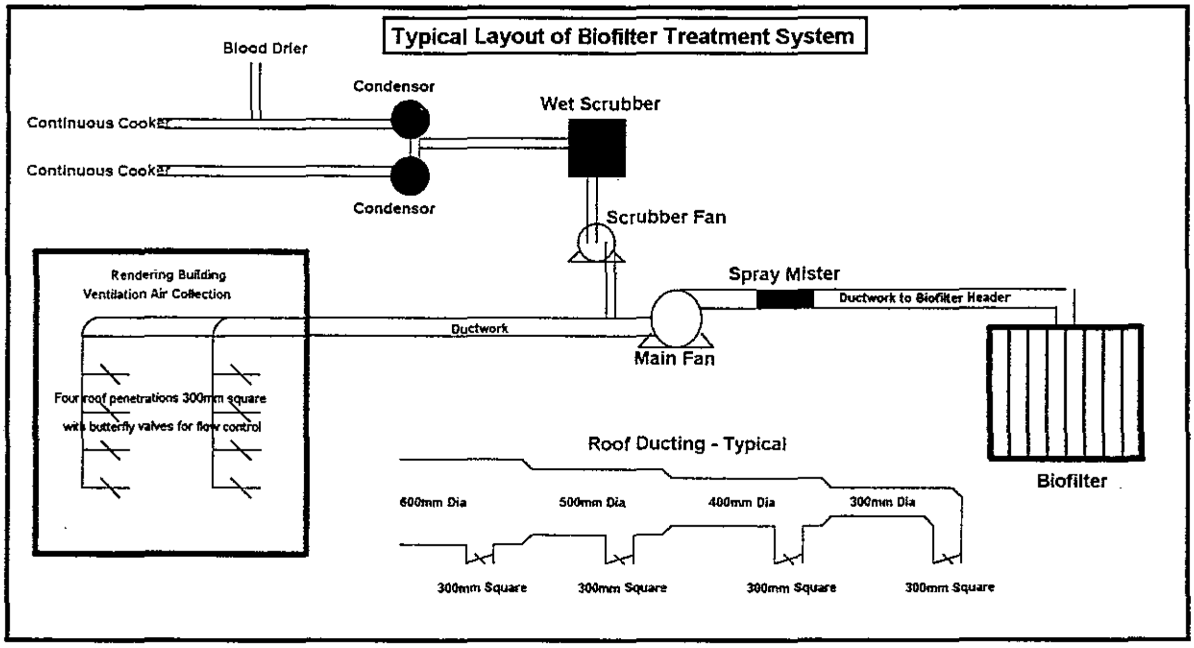
3. BIOFILTER SYSTEM OVERVIEW

A biofilter system contains five basic elements:

1. Vapour collection
2. Duct system
3. Vapour conditioning
4. Vapour conveying
5. Biofilter

The following sketch provides a general arrangement of a typical biofilter system.

Figure 1: Typical Layout of Biofilter Treatment System



3.1 VAPOUR COLLECTION AND HANDLING

The material of the ducts, the scrubber and the fans should be resistant to corrosion, heat and ageing, ideally stainless steel.

3.2 DUCT SYSTEM

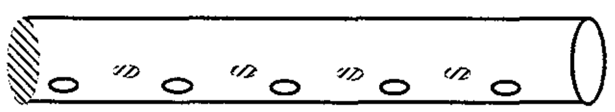
It is desirable that all ductwork including the header into the biofilter be 304 stainless steel of appropriate gauge and constructed with swept bends.

The odour distribution network in the bottom of the biofilter can be constructed from PVC pipe, so long as they can withstand the weight of machinery that may be used to fill or maintain the filter bed material.

The distribution network pipes should contain holes drilled in the bottom (see figure) in order to allow the vapour flow to disperse up through the biomass, and to reduce the chances of the overlaying gravel filling the pipe work. This arrangement also allows easy drainage of any water carried over from the vapour conditioning units.

Figure 2: Hole Configuration

Outlet Hole Configuration for Distribution Network



3.3 VAPOUR CONDITIONING

In a wet scrubber particles, such as dust and fat droplets, can be separated because they might impair the filter functioning by blinding the bottom layer of the filter bed.

When the raw gas temperature is higher than desirable, a scrubber or a simple spray chamber may be used to provide a cooling function. The water may be recycled, any deficit being replaced by fresh water supply. If it is necessary to waste water from the system it needs to be released into the plant effluent system.

In the water scrubber or spray chamber, the waste gas will be moistened to a relative humidity of more than 95%, which is desirable so that the filter bed does not dry out.

3.4 VAPOUR CONVEYING

The fan power will depend on the ductwork and system design but should be capable of compensating for a total pressure drop in the order of 5/mbar (50-150 mm water gauge). This design should include a reserve for increased flow resistance resulting from extreme weather conditions and ageing of the filter material.

4. BASIC BIOFILTER DESIGN PRINCIPLES

In contrast to processes with clear reaction ratios and conditions, little is known of the characteristic of the degradation kinetics in the biofilter, neither with regard to the various combinations of carrier materials including the inherent microflora nor with regard to the numerous types of waste gases. Therefore, the required biofilter dimensions are normally determined empirically.

It is common to conduct pilot trials where a partial flow of the gas to be cleaned is conveyed through a testing plant with a filter area of $1m^2$. It is important for the assessment of the separation efficiency to allow for a sufficient adaptation period and to have temperatures corresponding to those of the projected filter.

Table 2 provides a list of techniques for measuring characteristics required to determine the dimensions of a biofilter.

Table 2 Measurement Methods

PARAMETERS	MEASURING METHODS
Concentrations of:	
– individual components	Gas-chromatography/mass spectroscopy
– odorants	Olfactometry
Waste gas volume flow	Thermistor/Fan wheel anemometer
Waste gas temperature	Resistance thermometer
Relative waste gas humidity	Capacitive hygrometer
Filter resistance	U tube manometer

Experience has shown that as a guide values for the specific filter area load vary over an interval from 80 to 150 $m^3/(m^2h)$. Based on a height of the filter layer of 1m, this corresponds to a residence time of the waste gas to be cleaning of 45 to 25s.

A full range of design parameters is supplied in Appendix 4.

4.1 DESIGN CONSIDERATIONS

There are three basic construction styles adopted for biofilters. They include the above ground style, the plenum chamber style and the in ground style.

Outlines of these types are provided in the following sketches.

Figure 3: Above Ground Biofilter

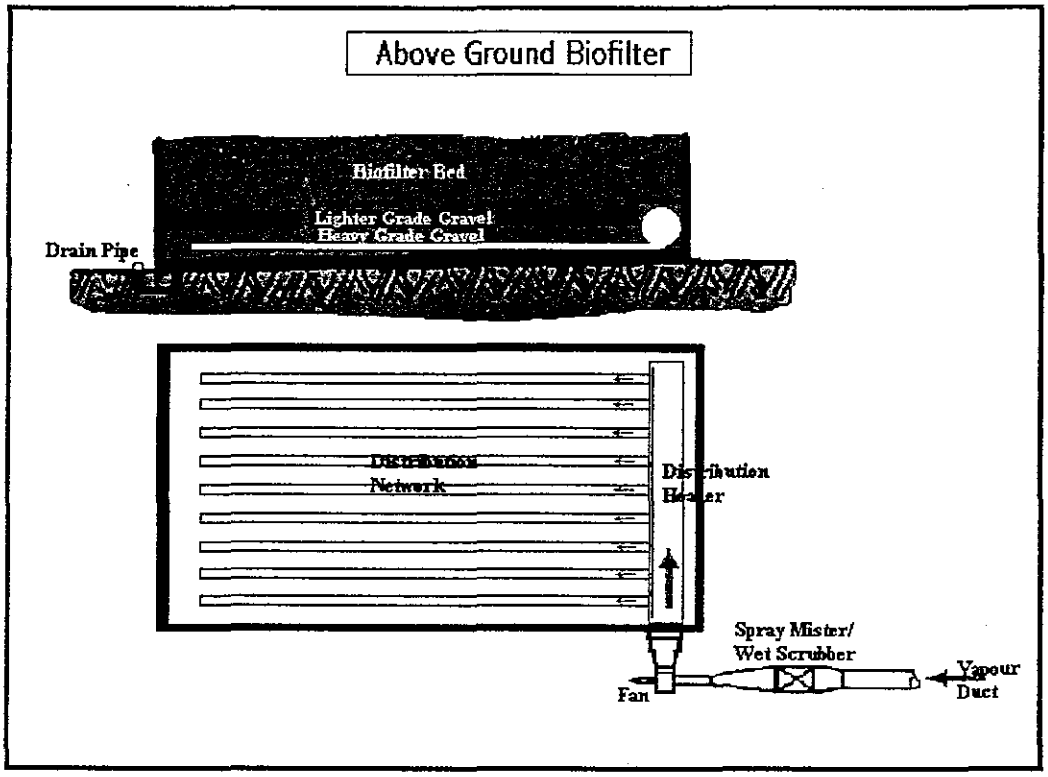


Figure 4: Cross Sectional Details of Above Ground Biofilter

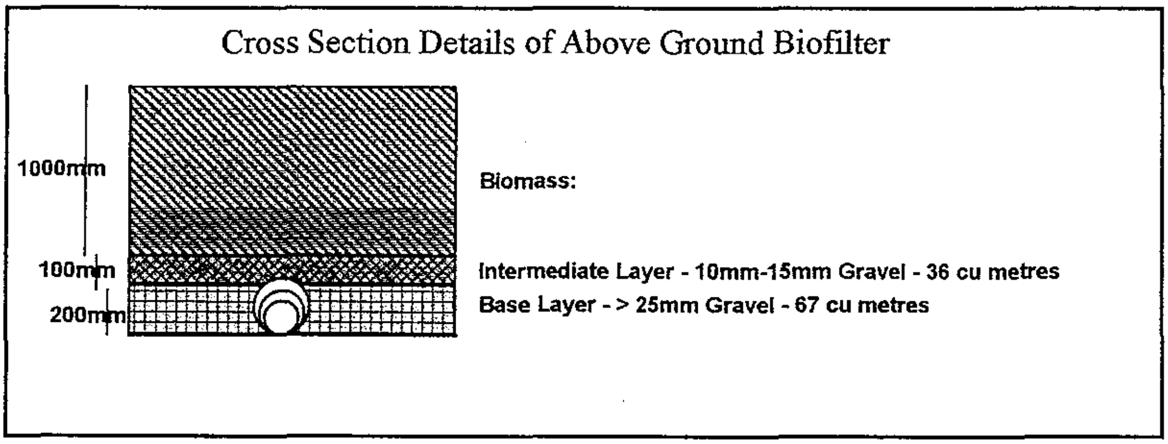


Figure 5: Plenum Chamber Biofilter

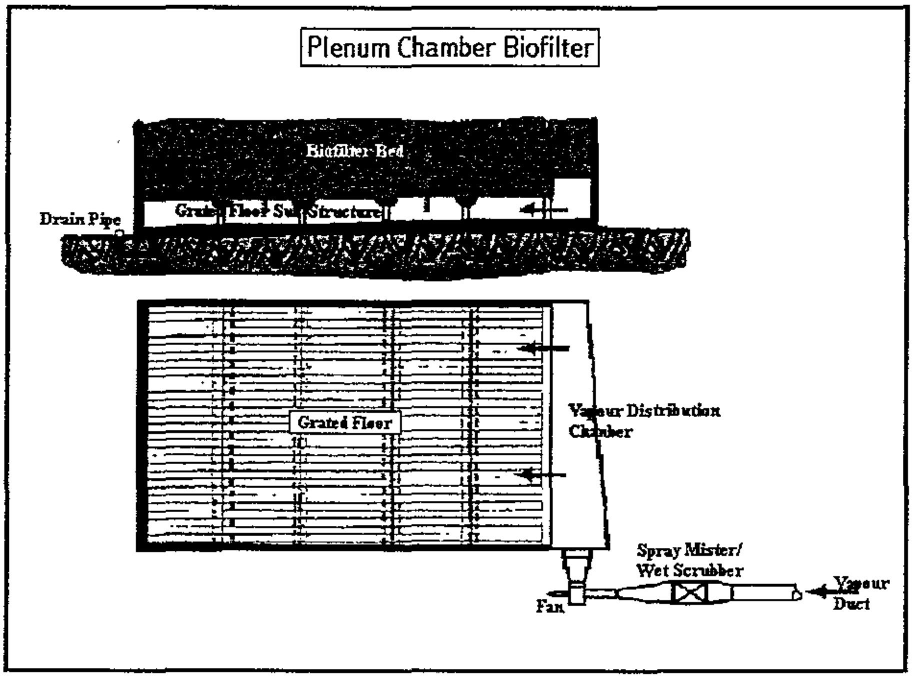
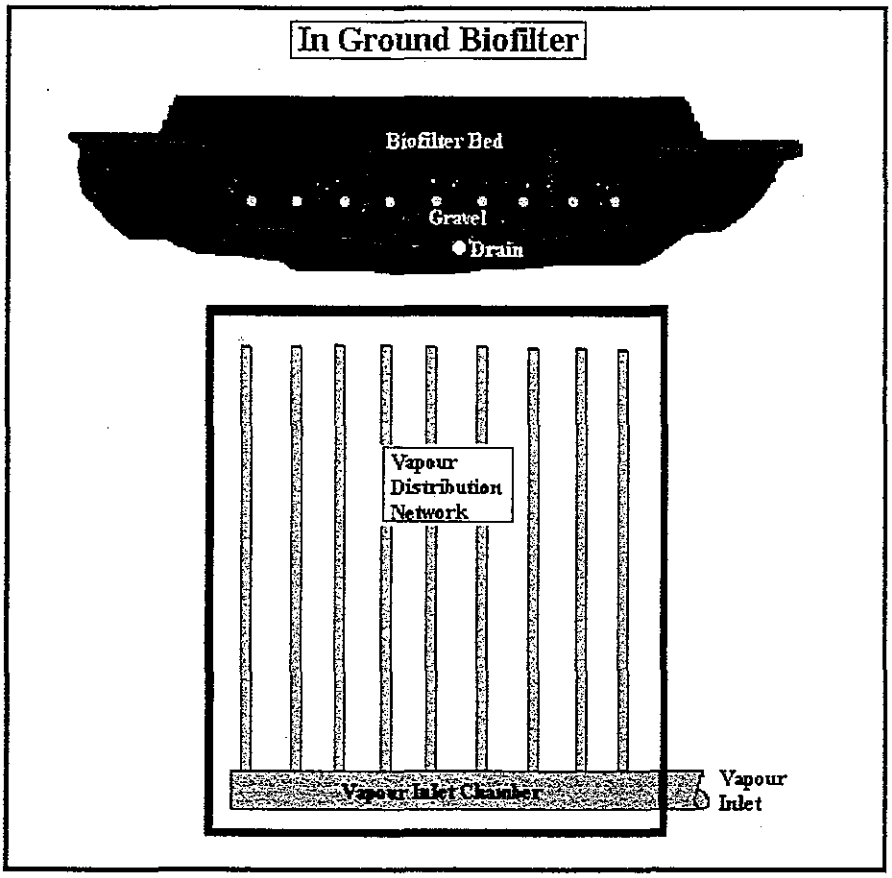


Figure 6: In Ground Biofilter



4.1.1 Civil Engineering (Above Ground Style)

It is desirable that the biofilter pad be at least a 75mm reinforced concrete pad with perimeter reinforcement tied to reinforcing steel in concrete block-work.

The floor of the pad should have a minimum 1:100 fall towards a corner drain to allow excess water to drain. The outlet needs to be fitted to a trap and connected to the trade waste sump.

Concrete work should be minimum 25MPa concrete with thickening (200 mm) around the edge of the pad to form a foundation for the block wall.

The surrounding concrete block wall can be some 1.5 to 1.8 metres high made from concrete blocks laid in stretcher bond and reinforced with steel and concrete fill at a minimum of 1.8 metre centres. It is desirable that the top edge of the wall is to be formed into a bond-beam with 2x12mm reinforcing rods and concrete fill.

Construction of a roof is optional. If desired typical construction would consist of a sloping shade roof with lattice truss, long run roof sheeting and minimal fall. The roof should be designed with a minimum wall clearance of 1200mm and with a minimum number of internal support columns. Columns and all steel work should be hot dip galvanised. The roof should be fitted with guttering and connected to stormwater

4.1.2 Filter Material Selection

Materials having significant biological activity are suitable as media for use in biofilters. The contact or residence times needed for the odorous compounds to be reduced to an acceptable level appear to be practically identical regardless of the particular filter material used. The filter bed material must however be selected to allow uniform flow in the bed without stream formation (ie. fissuring). Stream formation will cause odours to bypass the filter media and cause the biofilter to fail.

There are two principal types of media used in biofilters, compost based and soil based.

Compost filters consist of beds of compost material, peat moss or fibrous peat. Garbage compost, mushroom compost, paunch compost and garden compost have been successfully used in biofilters. If peat is used, it should be "rooty" peat with long bulky fibres, found at a depth of one to two metres in its natural state. Compost should be well matured and well turned to ensure an open structure. Constructing a filter with lumpy, un-matured compost is generally unsuccessful as this results in streaming of gas through the bed.

An important ingredient of a biomass is the compost material and various composts have been used in biofilter applications. It has also become clear in recent years that the actual make-up of the biomass is not of critical importance as long as the operating conditions for the biofilter are maintained, in particular attention is paid to moisture, temperature and pH.

The biomass acts more as a carrier substrate for the biological population, and the selective bacteria growth process that occurs creates a population that is attuned to decomposition of the volatile organics in the waste stream. These bacteria are similar to those that are active in the composting process itself.

The best compost materials for biofilters have high surface area, high air permeability, high water permeability and water holding capacity and a high microbial population. Compost containing extensive growth of fungal mycelia is not desirable as this can lead to non-homogeneous gas flow through the bed. This can result in channelling of the air flow through only part of the bed.

Soil filters consist of a bed of sandy or loamy soil, or a fine sand layer topped with soil. Soils vary widely in permeability and microbial activity. The performance of a soil filter depends on the internal pore structure which in turn depends on the type of soil used. Soil with a large internal void space does not necessarily have a highly porous internal structure as the pore structure is also dependent on surface area and particle size. For example, coarse sand, when compared to clay or loam, has a high permeability due to its large void space but, since the particles are larger and denser, it has a relatively low internal pore structure. Normal humus or clay soil may not be suitable for use in biofilters because variations in humidity, lead to cracking resulting in a high maintenance input to ensure effective operation.

Soil filters tend to be cheaper to construct than compost filters unless there is a ready supply of compost available. However, this is offset by the lower porosity of soil which results in a lower flow rate per cubic metre of volume (ie the bed needs to be proportionately larger) and higher operating pressures (ie increased operating costs). Soil filters have been used successfully for treating process gases from rendering plants and ventilation air control at sewage treatment plants.

4.1.2.1 Composted Paunch Material

The composting process overcomes the majority of negative aspect of raw paunch material, including high moisture content; foul odour; pathogens; and weed seeds.

The final product of good composting process has little resemblance to the initial paunch material and can be referred to as a compost similar to any other high organic compost such as kitchen waste, garden waste, chicken shed waste, mushroom compost, etc.

The odours inherent in raw paunch material that result from anaerobic digestion in the animal gut are eliminated during the composting process.

Composting of paunch is now being used as a disposal method for a number of Australian meatworks. The resultant composted product is reported to be an excellent soil conditioner and compost material and can be used as potting mix ingredients or as a complete plant growth medium.

It is this type of material that is suitable for inclusion in a biofilter bed.

Paunch compost has a high surface area, good water holding capacity, and is high in cellulose all of which make it an important component of the bed material.

4.1.2.2 Rice Husks

Rice husks are hydrophobic and very high in lignin. As such they play an important role in the bed mixture by keeping an open structure in the bed material and providing a component that degrades very slowly.

In order to gain these benefits it is important to ensure that components such as rice husks are evenly, and well mixed into the bed material.

1. OPERATION AND MAINTENANCE

The effective operation of the biofilter has to be maintained by suitable servicing.

For the maintenance of the individual items such as wet scrubbers, fans, sprays, etc, manufacturers guidelines and common sense maintenance procedures should be followed.

1.1.1 Operating Instructions

The operating instructions should be easily understandable and provide advice for the following operating conditions: start-up and shut-down, normal operation, winter operation, malfunction, standstill periods.

The operating instructions should include a schematic and operational description of the filter unit and maintenance plans, as well as monitoring instructions.

1.1.2 Supervision of Operation

It is considered desirable to keep a diary in which every action taken during supervision of the operation of the biofilter, as well as the time and the operating conditions, is recorded.

1.1.3 Moisture

Sufficient moisture content in the filter layer is necessary among other things for sound operation of the filter. The lower limit is about 25% for fibrous peat, about 40% for garbage compost. The upper limit will be a function of the absorptive water storing capacity of the respective filter material.

Moistening equipment must be installed and operated in such a way that the moisture content keeps evenly distributed and within the desired limits throughout the filter layer.

Construction measures to allow for the drainage of excess water must be maintained.

Two options exist for keeping the filter bed moist. The first is installation of overhead sparays to wet the bed directly, the second is to install a spray mister in the vapour conditioning system to keep the inlet air at greater than 95% humidity.

Compared with controlled overhead spraying of the biofilter, the saturated vapour-system provides the advantage of maintenance-free moistening of the filter material. The decision as to which moistening system is more appropriate on the whole needs to be made for each set of circumstances.

1. OPERATION AND MAINTENANCE

The effective operation of the biofilter has to be maintained by suitable servicing.

For the maintenance of the individual items such as wet scrubbers, fans, sprays, etc, manufacturers guidelines and common sense maintenance procedures should be followed.

1.1.1 Operating Instructions

The operating instructions should be easily understandable and provide advice for the following operating conditions: start-up and shut-down, normal operation, winter operation, malfunction, standstill periods.

The operating instructions should include a schematic and operational description of the filter unit and maintenance plans, as well as monitoring instructions.

1.1.2 Supervision of Operation

It is considered desirable to keep a diary in which every action taken during supervision of the operation of the biofilter, as well as the time and the operating conditions, is recorded.

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1.1.4 Bed Maintenance

The necessary maintenance work depends mainly on the application, on the plant type and the type of filter layer. Particular care has to be taken with respect to moistening, surface treatment and abatement of vegetation. Therefore, the special inspection and maintenance instructions of the supplier have to be considered. The maintenance work, too, has to be recorded in the diary.

2. MEASURING BIOFILTER EFFICIENCY

2.1 GENERAL

The efficiency of a biofilter is determined by the odour concentration units in the inlet and outlet air.

The determination of odour concentrations (odour units-OU) is difficult because odours mostly consist of a complex mixture of compounds that vary with varying operating conditions.

The following methods may be used to determine the odour reduction efficiency of the biofilter.

2.1.1 Gas-chromatographic Analyses

Organic odorants can be determined by means of gas-chromatography. This method has limitations. Low concentrations and complex mixtures, as is often the case in odour complexes, require enrichment and possibly preliminary separation of the samples.

2.1.2 Spectrometric Analyses

Some organic compounds can be determined quantitatively with ultraviolet-infrared measuring instruments or by means of the visual spectrophotometry. Spectrophotometry can also determine inorganic odorous compounds. This technique has similar limitations to gas chromatography.

2.1.3 Total-Carbon Determination

In some cases odour concentration can be estimated from a total-carbon determination. A continuous recording measurement of the organic carbon content in the air sample is made with a flame ionisation detector.

2.1.4 Olfactometric Determination

The method most frequently applied recently to determine odour concentrations is the olfactometric method, in which the human nose is used as a detector. The sample for odour assessment may be presented statically or dynamically.

The measurement is performed with an olfactometer, which consists of a dilution device and sniffing facilities (tube, mask, cabinet). The panellists assess various defined dilution ratios of neutral and odorous air.

The odour sample tested by panellists at the threshold concentration is defined as one odour unit. The threshold concentration of an odour sample expressed in number of OU.

2.1.5 Static Sampling

Static sampling requires special attention to a potential change of the sample between its collection and the time of analysis. The following sampling methods can be applied, most involve enrichment of the gas sample [35]:

- absorption in suitable liquids in a multi-stage set of gas-washing bottles,
- adsorption of some known odorants on the extensive surface of a collection medium (such as activated carbon),
- freezing of concentrated odour samples in a Kaiser tube,
- sampling into a gas mouse or a collection bag.

The only static sampling method applicable to olfactometry is the collection bag.

2.2 EFFICIENCY ASSESSMENT

Several measuring methods of those mentioned above may be applied in order to assess the efficiency of a biofilter.

If the efficiency assessment isl not to be related to reduction of defined components, but to the odour impression caused by the waste air up-stream and downstream of the biofilter, then the odour thresholds of crude and clean gas have to be determined by olfactometry.

The final assessment of an odour-reduction measure should consider not only the stated reduction in numbers of odour units but also the improved odour quality (characteristics) of the waste air, which is an effect of the biodegradation of odorants.

This measurement should be carried out only after an appropriate operation period of the biofilter (approximately two months).

3. IMPORTANT BIOFILTER MONITORING PARAMETERS

3.1 TEMPERATURE

The optimum temperature of the filter bed is 35°C. The incoming odour stream should not exceed 40°C.

If the biomass gets too hot the rate of decomposition of the odour components will decrease.

3.2 MOISTURE

Too little moisture causes cracking and odour release while too much fills the void space in the filter bed and prevents absorption.

The ideal is to keep the filter bed at close to the natural saturation level of the filter mixture

3.3 PH

The pH of the filter bed should be maintained between 7 and 8. In order to achieve this figure lime can be added if required.

In practice this is rarely found to be a problem in biofilters treating rendering odours.

Biofilters constructed without rooves allow rainfall to pass through the bed. This allows a natural flushing to occur.

3.4 BACK-PRESSURE

The pressure drop across the bed should be 20/30 mm water gauge or better.

Monitoring the back pressure will provide an indication of when the filter bed is beginning to break down and provide a timetable for turning or replacing the filter mass.

3.5 BED DRAINAGE

Drainage of the bed should be regularly checked.

Should the bed flood this will cause blockage, build up of back pressure and reduction of the filter throughput.

3.6 FILTER BED INTEGRITY

The integrity of the filter bed should be checked regularly.

The checks should include areas such as:

- leaks around any of the duct-work or seals
- any drying in isolated bed areas
- any cracking or streaming in the bed material

4. MEASUREMENT

Measurements required in the design of the overall system are:

4.1 TEMPERATURE

The temperature of the vapour stream into the biofilter bed should be recorded and if necessary controlled using controlled water sprays in a spray mist chamber following any vapour conditioning apparatus, and preferably after the fan.

The temperature of the biofilter bed should be recorded

4.2 HUMIDITY

Traditionally humidity control has been implemented by measuring the incoming vapour humidity and adjusting spray devices to keep humidity levels above 95%.

It has been found that these traditional air humidity measuring devices are not reliable in biofilter applications, and therefore a direct method of measuring the moisture content of the filter bed material has been preferred.

A direct measure of the volumetric soil moisture utilising a Delta-T Theta-Probe has been adopted and found to provide good readings and reliability.

If the spray mister can be designed to keep the vapour above 95% humidity then it has been found that the biofilter bed stays close to saturated moisture levels which provides ideal conditions for the biomass.

If desired the moisture probes can be connected to a controller that can start sprinkler hoses if the bed moisture levels fall below a set point.

4.3 FILTER BACK-PRESSURE

A U-tube manometer can be used to provide a manual readout of the filter back-pressure.

5. CONTROL SCHEMES

Two simple monitoring and control schemes are shown in the following schematics.

Figure 7: Monitor & Control via Spray Mister

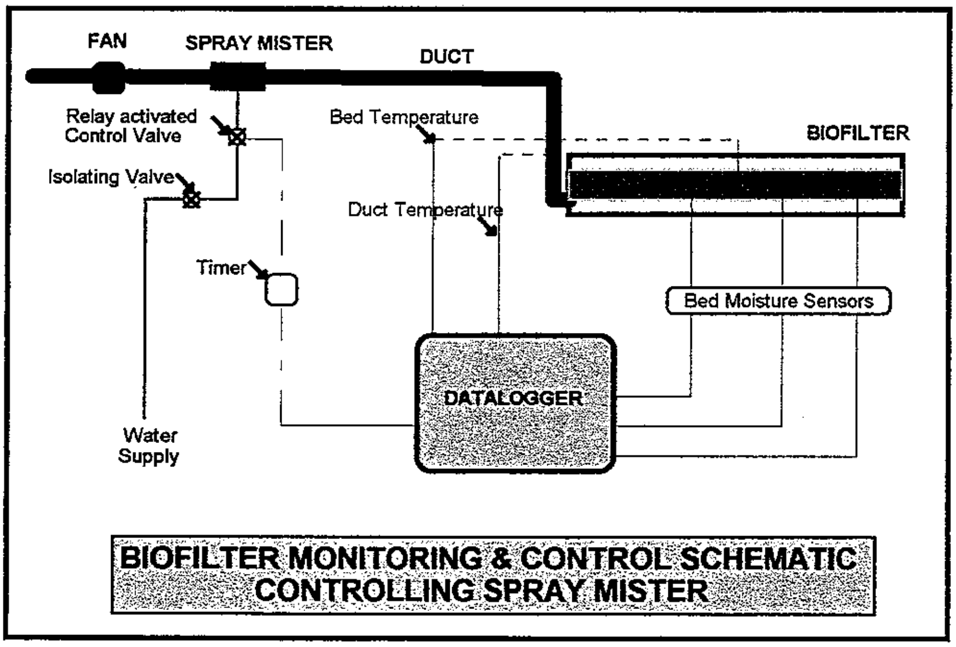
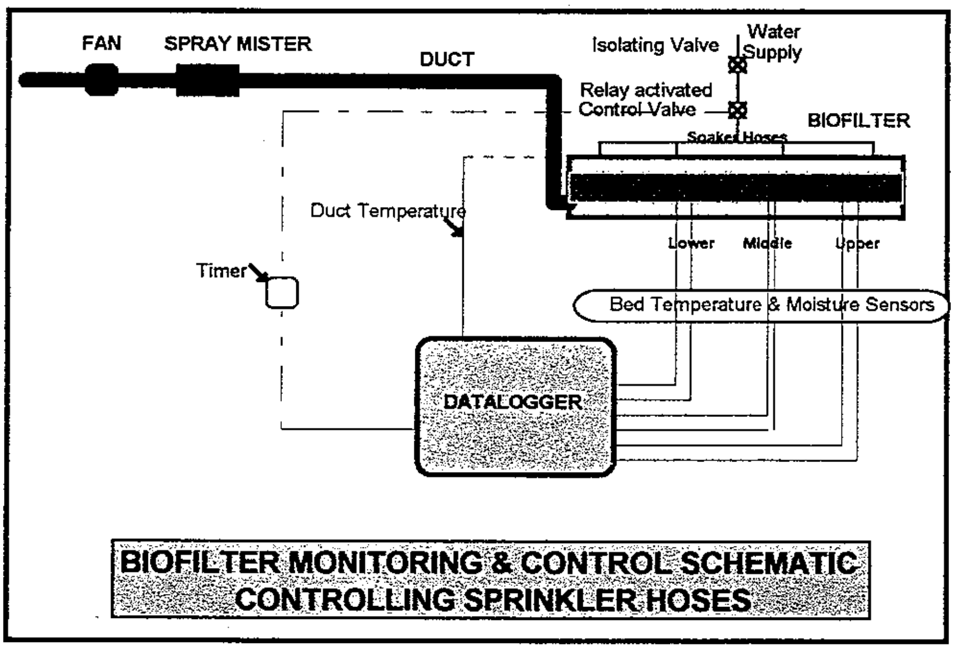


Figure 8: Monitoring & Control via Sprinkler Hose



6. AUTOMATED DATALOGGING

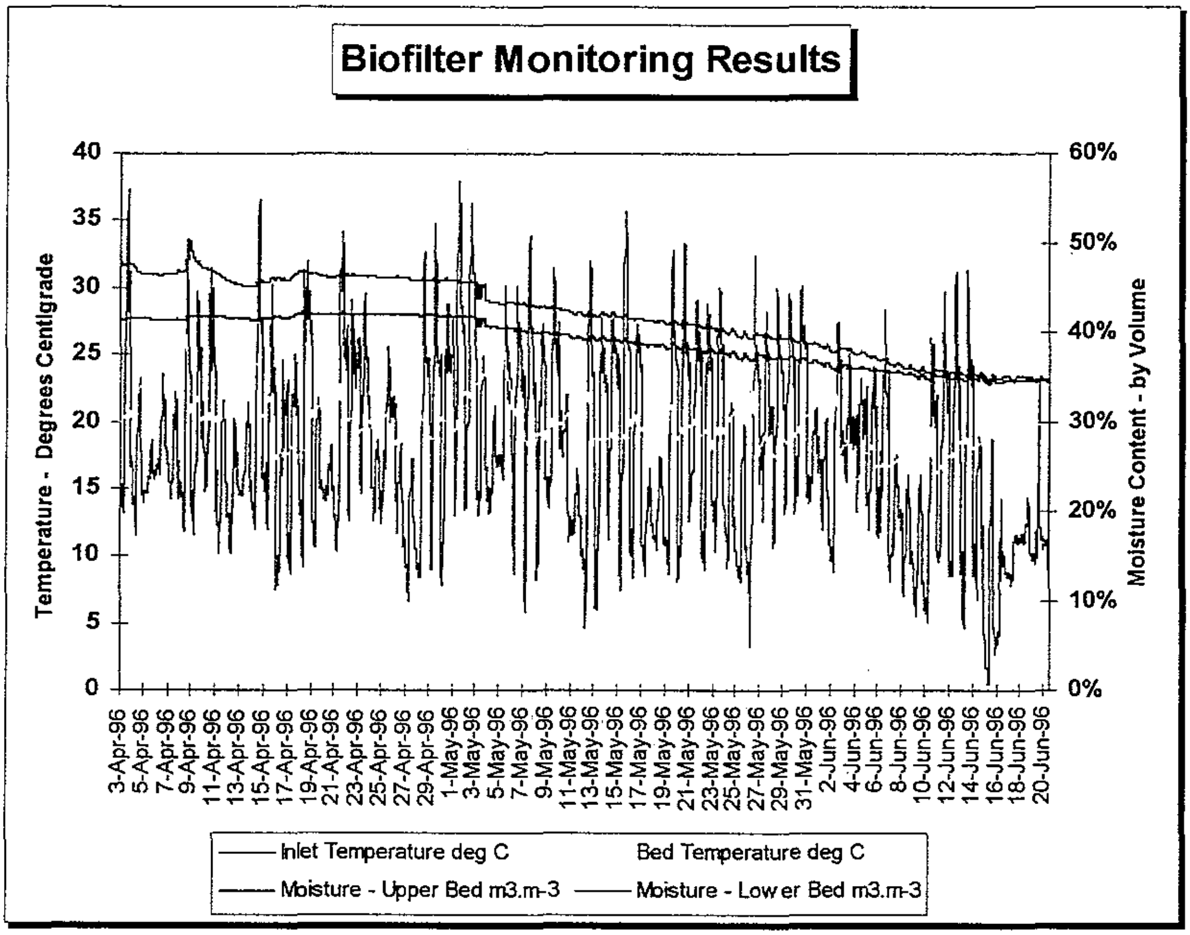
It is recommended that an automatic data recorder be installed as part of the overall biofilter system.

This data recorder provides information useful for good operation of the system, and provides a permanent record for discussion with environmental authorities during license renewal negotiations or whenever odour problems may occur.

Automatic data logging allows the important parameters of moisture and temperature to be recorded and plotted for inclusion in environmental reporting.

An example of a typical data log is provided below.

Figure 9: Typical Biofilter Data Output



7. MANUAL MONITORING

In order to keep a regular monitor of the biofilter performance it is recommended that a series of checks be performed on a regular basis and also when problems occur.

Keeping of these records will assist any future discussions with the environmental authorities.

A sample monitoring sheet has been provided in Appendix 3.

APPENDIX 1

REFERENCES

APPENDIX 2

LIST OF AUSTRALIAN BIOFILTERS

APPENDIX 3

MONITORING SHEET

WEEKLY BIOFILTER MONITORING RECORD

PLEASE CONDUCT THE MONITOR ONCE A WEEK

OR WHEN AN ODOUR COMPLAINT IS RECEIVED DATE:....................

WEATHER CONDITIONS

Please tick boxes

CONDITIONS	
Fine	
Overcast	
Raining	

WIND SPEED	
Still	
2 to 5 kms/hr	
5 to 10 kms/hr	
10 to 20 kms/hr	
Greater than 20	

TEMPERATURE	
0 to 10 °C	
10 to 20 °C	
20 to 30 °C	
Greater than 30 °C	

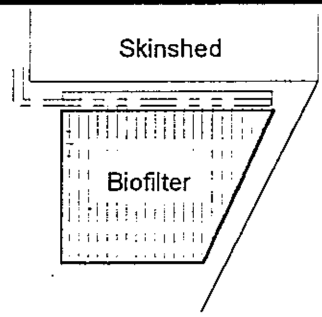
PLEASE INDICATE WIND DIRECTION WITH AN ARROW ON THE DRAWING

WALK UP TEST

Start approx 200 metres downwind and walk up to the biofilter noting any odour.

BIOFILTER ODOUR		
Distance	**Odour**	**Odour Characteristic**
150 to 200 metres	Y/N	
100 to 150 metres	Y/N	
50 to 100 metres	Y/N	
0 to 50 metres	Y/N	

BIOFILTER CONDITION (MAKE COMMENTS) Note leak location etc on drawing	
Surface leaks	Y/N
Surface growth	Y/N
Dry depth at surface	.... cms



Observations: Note operation of associated equipment.

Sprinklers	Fan
Scrubber	Rendering Building

Comments: Please note and comment on any other relevent information eg other odour sources, rendering area breakdowns, etc

Actions: Please note any actions taken

Name:.............................. Signature:...................................

APPENDIX 4

RANGE OF DESIGN PARAMETERS

	Garbage Composting Plant	Rendering Plant	Rendering Plant	Poultry excrement drying plant	Animal fattening - pigs
Filter material	Garbage compost	Garbage compost	Fibrous peat/ spruce brushwood	Fibrous peat/ spruce brushwood	Fibrous peat/ spruce brushwood
Volumetric crude gas flow	26,000 m^3/h	60,000 m^3/h	100,000 m^3/h	20,000 m^3/h	11,000 m^3/h
Filter area	264 ^2m	600 ^2m	800 ^2m	200 m^2	39 m^2
Filter bed/height of layer	1 m	1 m	0.8 m	0.5 m	0.4 m
Weight per volume unit	0.5 to 0.6 t/m^3	0.5 to 0.6 t/m^3	0.4 t/m^3	0.4 t/m^3	0.4 t/m^3
Void fraction of filter material	80 to 87%	80 to 87%	75 to 90%	75 to 90%	75 to 90%
Mean retention time of gas in filter layer	27 s/42 s (divided filter area)	≥28 x	≥15 s	≥10 s	≥5 s
Filter area load/ spec. air throughrate	100 m^3 m^2 h	100 m^3/m^2 h	125 m^3/m^2 h	100 m^3/m^2 h	282 m^3/m^2 h
Differential pressure in filter layer	700 to 1,300 Pa	800 to 1,200 Pa	150 Pa	≤100 Pa	40 to 70 Pa
Moisture cont. of filter material (depending on temperature and moisture of waste gas)	50 to 60%	50 to 60%	50 to 70%	>75%	25 to 75%
pH value	7.2	7.2	3.5	3 to 4	3 to 4
Crude gas temperature	28°C	30°C	15 to 30°C	35 to 55°C	15 to 32°C
Cleaning efficiency	approx 96%	approx 92%	approx 93%	approx 95%	approx 90%
Spec. energy consumption: *a) water (per annum)*	0.4/ 0.7 m^3/m^2a	05/ 08 m^3/m^2a	Ø1.25 m^3/m^2a	fully saturated. vapour	0.3/ 0.6 m^3/m^2a
b) current	1.5 to 2 kWh/ 1,000 m^3 (including exhaust air system)	1.5 to 2 kWh/ 1,000 m^3 (including exhaust air system)	0.08/0.44 kWh/ 1,000 m^3 (with pre-separator and exhaust air system)	./. (filtering plant charged by drier fan)	522 kWh/ (a.1,000 m^3 /h) (incl. pre-separator and sty ventilation system)
Pre-separator eg for dust, fatty vapours etc	recommended	recommended	necessary	necessary	necessary
Loss after smouldering of fresh compost (as a measure of the portion of organic substances)	60%	60%	98%	98%	98%

Source: VDI3477 - Biological Waste Air Purification

Composted crust from anaerobic ponds

Being able to recycle a by-product from the abattoir production process to create a low-cost, high-performance form of compost material is again the major benefit of using this material.

Soil-based filters

Soil-based filters consist of a bed of sandy or loamy soil, or a fine sand layer topped with soil. Soils, however, vary widely in permeability and microbial activity. The performance of a soil filter depends on the internal pore structure which, in turn, depends on the type of soil used.

Unless there is a supply of compost available, soil filters tend to be less costly to construct than compost filters. This is offset, however, by the lower porosity of soil which results in a lower flow rate per cubic metre of volume (ie the bed needs to be proportionately larger) and higher operating pressures (ie increased operating costs). Soil-based filters have traditionally been used in wastewater odour reduction applications.

The actual make-up of the biomass is not of critical importance as long as the operating conditions for the biofilter are maintained – in particular moisture, temperature and pH.

Biofilter ... Optimum Operating Conditions

Although basic maintenance of a biofilter is minimal, it will not function optimally if neglected:

- Optimum temperature for the filter bed is 35°C. The incoming odour stream should not exceed 45°C.
- The correct balance of moisture content is critical – too dry a bed can cause leaking of the odour stream. Too moist a bed will not allow absorption of odours.

These can be measured by a series of sensory probes situated throughout the filter bed.

Weekly monitoring is essential. Monitoring should also occur when an odour complaint is received.

In addition to temperature and moisture, a satisfactory monitoring record should show:

- Weather conditions – whether fine, overcast or raining
- Wind speed and direction
- Temperature
- Whether any odour exists and whether it is noticeable up 200m downwind of biofilter
- Characteristic of any odour existing
- Location of odour leaks
- Observation of associated equipment – sprinklers, scrubbers, fans, rendering building.
- Action taken

The pH level should be maintained between 7 and 8. If necessary, lime can be added to help maintain this level. The pH of compost beds only needs to be probed occasionally.

Biofilters ... Suitable for Your Operation

Biofiltration is a highly viable process for a rendering operation and should be considered under any of the following circumstances:

- Planned upgrade of a rendering plant
- Planned replacement of current odour control equipment
- Building a new plant
- Unacceptable frequency of odour complaints
- Need for improved environmental performance
- Management looking for a long-term cost effective solution to afterburner fuel cost
- Treatment required for high volume odour streams

BIOFILTRATION

- Energy responsible
- Cost effective
- Low maintenance
- Effective odour control