Biofilter design and maintenance

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As Victoria's environmental regulator, we pay respect to how Country has been protected and cared for by Aboriginal people over many tens of thousands of years.

We acknowledge the unique spiritual and cultural significance of land, water and all that is in the environment to Traditional Owners, and recognise their continuing connection to, and aspirations for Country.

Contents

Purpose

This guide provides information for industry, consultants and assessors on how biofilters can be constructed and operated. This guide may help duty holders meet their general environmental duty (GED), in accordance with the *Environment Protection Act* (2017).

More information on how to comply with the GED is available in industry guidance: *Supporting you to comply with the general environmental duty* (publication 1741).

Legal status of this document

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Scope

Biofilters are typically used for treating odorous emissions from composting facilities, abattoirs, rendering plants and other industry. This guide provides information about biofilter operation for typical situations common in Victoria. It is designed to help readers understand biofilter design and operation. The guide can also assist with identifying problems and assessing biofilters' performances.

This guide focuses on open bed biofilters that use a filter media of wood chips and barks. These are the most common type of biofilters in Australia.

The guide includes:

- design and management parameters important in biofilter operation
- typical operational ranges for key parameters, including temperature, humidity and back pressure.

The guideline does not include:

- every requirement needed to design, operate, manage and maintain all types of biofilter
- a comparison of biofilters with other treatment technologies
- advice on how to tailor a biofilter design for a specific site or application.

For more information on odour, including the management and control of odours and other technologies used to treat odour, see the EPA website; https://www.epa.vic.gov.au/for-business/find-a-topic/odour

Biofilter fundamentals

Figure 1: Open bed biofilter with vertical plenum inlet to two cells

Biofilters are a bed of wet support media with a water layer containing microorganisms on the surface of the filter medium (Figure 1). This layer is known as the 'biofilm' (Figure 2).

Odorous air is introduced to the bed via an open plenum floor (Figure 3). The air contains organic compounds which are the food source for the microorganisms. The odorous air is treated as it passes through the biofilter bed into the biofilm where it breaks down to carbon monoxide (CO_2) and other oxidised compounds (Figure 2).

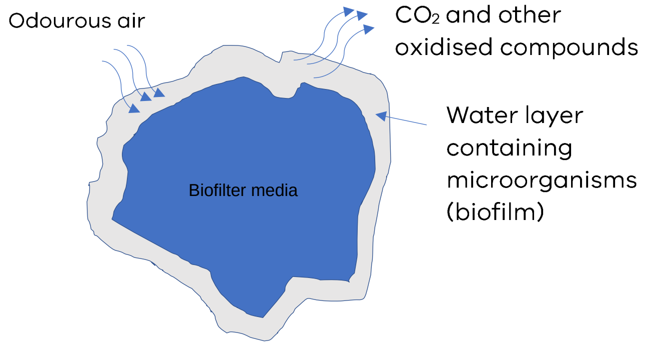

Figure 2: Schematic of biofiltration process

The biofilter bed is divided up into individual compartments, known as cells. The cells make it easier to refurbish or change the media as individual cells can be isolated one at a time for maintenance.

For a biofilter to operate effectively, the concentrations of organic compounds in the odorous air should be low enough so microorganisms in the biofilter bed are in a constant starvation mode. However, if the concentrations are too low it will cause microorganisms to die.

Keeping the microorganisms in starvation mode allows the microorganisms to readily destroy and digest any organic compounds from the odorous air that dissolve into the biofilm.

The common principles of good biofilter design and operation include:

- targeting odours that are soluble and biodegradable
- not treating odorous air that contains compounds that are toxic to microorganisms (such as disinfectants, pesticides etc.), as these may kill the microorganisms
- providing a constant load of odorous air to maintain maximum microbiological efficiency
- locating the biofilter as close as possible to the emission source. This minimises duct length, increases fan efficiency and limits condensation in the ducts (in cooler climatic conditions)
- the inlet stream being free of particulates or fatty material, as far as possible
- ensuring processed air exiting the biofilter is free of the characteristics of the target odour. However, there may be an odour of earthy or neutral character from the biofilter media.

Common features of effective biofilters include:

- a system to pre-humidify air before it passes into the biofilter (such as an atomiser or wet scrubber)
- an open plenum underneath the bed to transport air to the filtration media
- a sprinkler system to water the top of the bed to wet the media.

Figure 3 presents the generic layout of a biofilter.

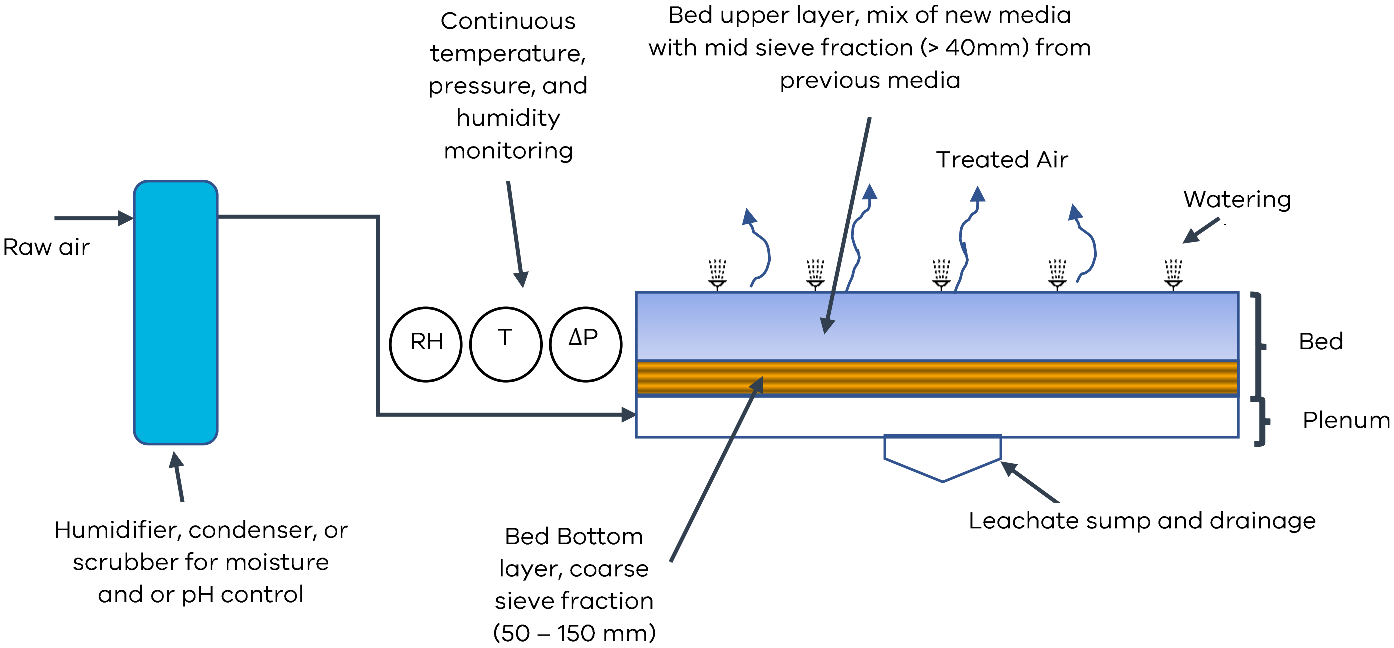

Figure 3: layout of a biofilter

Biofilter structure

Pre-treatment

Depending on the composition of the odorous air to be treated, it may be necessary to pre-treat the odorous air before is passes through the biofilter bed. This is done using scrubbers, humidifiers, atomisers or condensers. These remove particles or fats, increase the humidity to dry air flows, reduce temperature, or balance pH by removing ammonia and hydrogen sulphide.

Plenum

The plenum is at the base of a biofilter. The plenum is usually constructed from material that is structurally robust, such as concrete or plastic, which will not break down. The plenum is designed to allow good distribution of air flow, preventing preferential pathways (i.e., greater flow in some parts of the biofilter compared to others) resulting in excessive drying in parts of the bed.

The top of the plenum is typically a rigid mesh screen that can support media weight and allow drainage. Choice of screen is important as shade-cloth and geofabrics have been shown to block quickly and impact biofilter performance.

The plenum should have adequate void spaces to maintain designed air speed and allow sediment to drop through. This is to stop sediment accumulating in the bottom of the bed and fouling the biofilter (blocking flow, creating anaerobic pockets, etc.). There are many commercial prefabricated designs available, including modular cellular units or fully installed panels supported by columns.

Note: It is not recommended to use biofilters with PVC piping systems (a series of parallel holes underneath the media) in place of a plenum, as this can lead to blockages and a lack of flow to the biofilter.

The base of the plenum should be angled to a sump or drain so that leachate can be collected and treated, disposed of, or recycled. The leachate sump requires a correctly installed water seal to hold pressure in the plenum.

Air enters the biofilter by piping or ductwork. Two common arrangements are biofilters with horizontal ductwork (Figure 4), which provide air directly into the plenum, or biofilters that are ducted into vertical plenum spaces, which are connected to ductwork at one end and the plenum floor at the other (Figure 5).

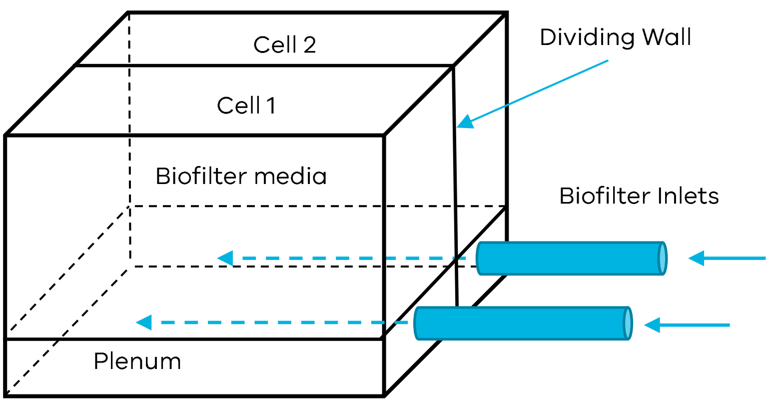

Figure 4: Horizontal entry to plenum

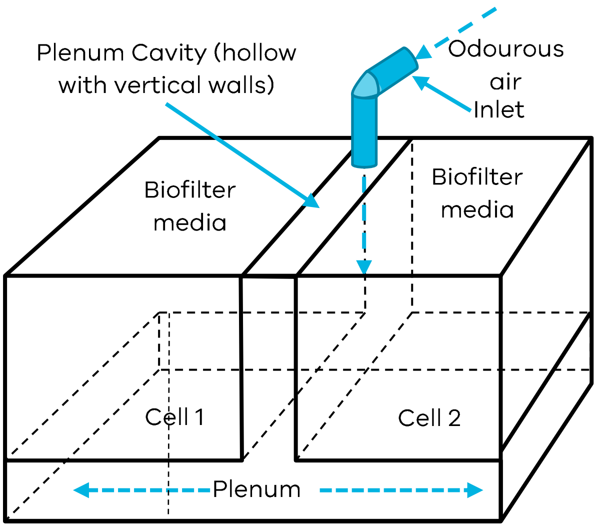

Figure 5: Vertical entry to plenum

Biofilter media

The following section is an example of how filter media might be layered in a bed.

Lower part of the bed:

This layer usually consists of very coarse fraction (50 to 200 mm) media. This layer optimises air distribution through the whole bed. The coarse layer has:

- high mechanical resistance to support the weight of the bed
- very high porosity medium enabling fine particles to be washed down from media breakdown.

Note: The porosity of the bed decreases with time as the media breaks down. This fills the voids between media.

Typical depth of this coarse layer is around a third of the total depth of the bed.

It is common to use wood that is hard and dense. Eucalyptus wood chips are sometimes used, although they are very dry and can absorb water. This can result in short circuiting.

> Note: It is recommended not to place inlet pipework through media, as this can result in short circuiting (when odours bypass the media and aren't treated properly) and preferential pathways around the outside of the ductwork. This is due to differential expansion and contraction of the ductwork in relation to the biofilter media.

Upper part of the bed:

The upper media layer is:

- a mixture of new filter media such as pine bark, wood, etc. (40 to 60 mm diameter)
- sieved coarse fraction of old media if media is being refurbished (>40 mm diameter).

When refurbished, this layer is typically two parts old media to three parts new media.

Softer woods and bark materials are often used in the upper media layer.

Top dressing:

There are some instances where top dressing the biofilter with finer media (typically fine bark or mulch) 25–40 mm is an option. This can aid moisture retention and increase retention time for treatment of odorous air in the bed by filling in surface voids and gaps. It can also act as an insulation layer by retaining heat in the biofilter during colder months.

Laying operations:

Laying a biofilter bed includes the following steps:

- Place the initial layer of very coarse fraction first.
- Add the rest of the medium evenly across the biofilter bed.
- Ensure layers of media are moist when placing them in the biofilter.
- Compact only along the edges and avoid compaction in the centre, as this can create preferential paths once the biofilter is in operation.

Wall structure

The different composition of the walls and the biofilter media can cause differential rates of expansion. This can create a gap between the walls and the media, leading to short circuiting when odours bypass the media by travelling through preferential pathways up the side walls.

Compacting around the edges during application of the media can avoid this. There are also some examples of biofilters built with vertical walls designed so that compacting at the edges isn't necessary. These have a horizontal return (Figure 6) placed at right angles to the side walls. They are designed to divert airflow back towards the centre of the biofilter.

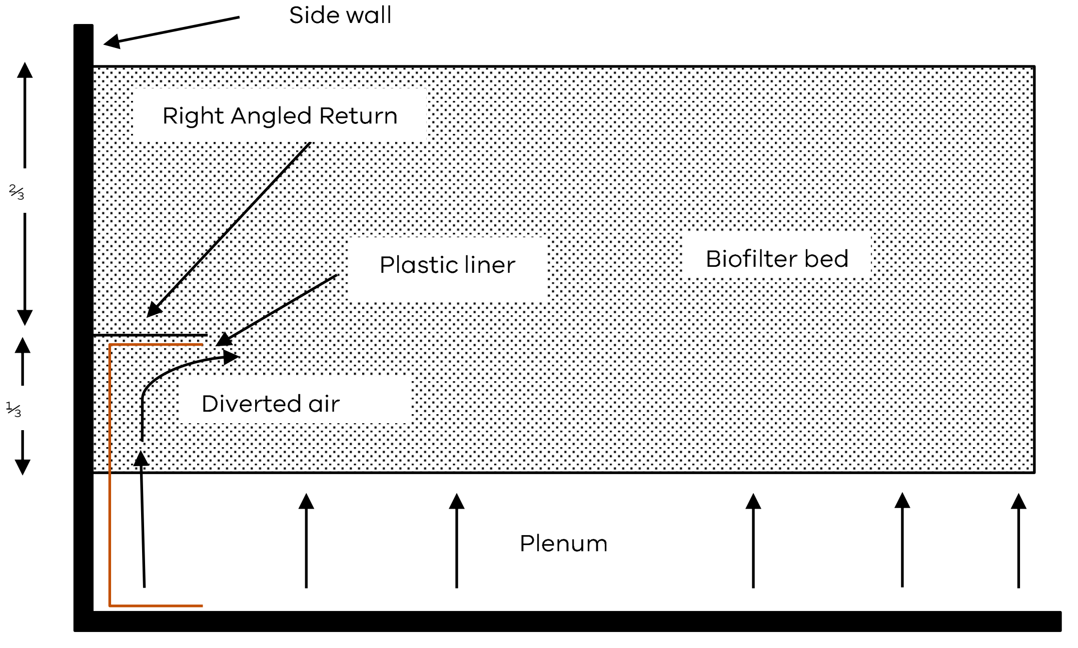

Figure 6 : Cross-section of right-angle return on biofilter wall

If the horizonal return approach is taken, it is recommended to proceed with caution if this may increase short circuiting at walls if the return extends too far into the filter media, as the material can settle below the 'return' and form an air gap at the wall.

This can be mitigated by:

- locating the horizontal return at a height of approximately one third of the filter media above the plenum along the walls
- keeping the width of the return narrow (no more than 100 mm wide) to avoid changing flow too much.

Operational principles

The effectiveness of odour destruction/abatement efficiency will depend on:

- the concentration of the odour to be treated and the surface load per cell
- residence time in the biofilter
- the microbiological activity for the compounds to be degraded

- physio-chemical parameters, such as temperature, pH and chemical composition, of the odours being treated
- filter media/bed and moisture.

Biofilter flow and loading

A biofilter is generally used to treat high air flow volumes with low concentrations of pollutants, typically odour (i.e., low concentrations of volatile organic compounds (VOC), reduced sulphur compounds, etc.).

It may be difficult to achieve acceptable breakdown at the biofilter outlet for higher odour concentrations (such as greater than 50,000 odour units – OU). Air with high odour concentrations may need to be pre-treated (via a scrubber or other means) or post-treated (polished) via carbon filtration or a similar system.

The operational parameters used in biofilter design are discussed below.

Surface load (SL) per cell:

Assuming the air flow rate (Q in m^3/h) in each cell is evenly distributed across the cell's whole surface area (A in m^2), the surface load per cell is calculated as:

$$SL = Q/A \ (\mathrm{m^3/m^2.h})$$

Specific load will depend on the type of media used and the depth of the bed. Seek professional advice during the design phase on how to optimise the surface load.

Empty bed residence time (EBRT)

The EBRT is used as an estimate of how long the air being treated spends inside the biofilter. EBRT only gives a general estimate of air flow through the whole empty biofilter bed because the calculation doesn't include the biofilter media. EBRT is therefore considered a conservative estimate because it predicts a faster flow than what would occur in the media. Actual retention time would be theoretically higher, leading to longer contact time in the bed.

If H (m) is the depth of the bed, A (m^2) the surface area of the cell and Q (m^3/s) the volumetric air flow rate, the EBRT(s) is calculated as:

$$EBRT = (HA)/Q$$

Optimising contact time of odorous air in the biofilter depends on the size of the biofilter, the filter media used, and the odour stream being treated. However, these general recommendations apply in most cases:

- EBRT is typically 30-50 seconds
- flow monitoring is undertaken to demonstrate even distribution across the surface of the biofilter
- the outlet odour concentration is less than 1000 OU (typically between 300 and 600 OU)
- the treated air exiting the biofilter has little or no recognisable odour associated with the untreated air.

When the solubility of the target compounds is low, or when there is an increase in odour concentration (> 10,000 OU) due to operational or process changes, seek professional advice on how to manage these loads.

Inlet gases chemistry and pH

It is important to characterise the hydrogen sulfide, ammonia and VOC load going into a biofilter.

To maximise the microorganism population size and diversity, and biofilter media life, the ideal biofilter pH is between 6 and 8.

A biofilter exposed to high levels of hydrogen sulfide will cause the moisture in the biofilter media to become acidic (low pH), as the sulfide is converted to sulfuric acid. Acidic water in the biofilter will start to attack concrete and degrade wood-based biofilter media, significantly reducing its capacity to treat odour as the media collapses, thereby impeding airflow.

A biofilter cannot usually handle hydrogen sulfide inputs above 50 ppm. Even with lower hydrogen sulfide levels, it may be helpful to add limestone or other basic materials to biofilter media to manage the acid that forms.

Similarly, high ammonia concentrations (greater than 80 ppm) can impact biofilter performance, as it can be absorbed by the filter media and evaporate out later.

Therefore, to determine the which biofilter media or pre-treatment is appropriate, EPA recommends determining hydrogen sulfide and ammonia concentrations of the odorous air.

EPA also recommends seeking professional assistance for the treatment of inlet gases with high hydrogen sulfide or ammonia concentrations. This is because it may be necessary to consider using bio-scrubbers or bio-trickling filters with inorganic media when dealing with sewer gas or other sources with high hydrogen sulfide content. For more information on other odour control technology see the EPA website: https://www.epa.vic.gov.au/for-business/find-a-topic/odour/advice-for-businesses/control-details

Note: It may also be necessary to install water scrubbers with hydrogen peroxide in cases with high hydrogen sulfide concentrations, or mild strength acids for high ammonia concentrations, to reduce the concentration of these compounds prior to biofiltration.

Biofilter media/bed moisture

Bed moisture should be maintained at a consistent range throughout the bed, ensuring that the inlet's air relative humidity is stable and evenly distributed. Surface watering (Figure 7) should be applied evenly across the bed, including along the walls.

Moisture levels in the bed can be measured following AS 1289.2.1.1-2005 or equivalent standard. Moisture is usually measured in the inlet using a humidity sensor.

Figure 7: Biofilter with sprinkler system

Do not overwater the media as this can flood lower regions of the biofilter, causing back pressure to increase. Excessive watering can also result in significant cooling of the surface of the media by evaporation, leading to microorganisms dying off.

Monitoring

Continuous monitoring

Continuous monitoring of the odour level at the outlet of the biofilter is impractical. Therefore, the following surrogate parameters may be monitored at the inlet Figure 8) to assess operating performance and determine trends:

1. air temperature
2. relative humidity
3. back pressure.

The microorganism population depends on stable temperature and the right level of moisture to degrade odorous compounds. If parameters stray outside the limits listed below, the microorganisms' living conditions may be impacted and the biofilter will not perform optimally.

Monitoring back pressure can ensure that consistent air flow rates are being achieved.

Collecting monitoring data for these parameters (via a control chart linked to appropriate alert systems) enables the operator to quickly implement corrective actions as required.

EPA recommends establishing operational triggers for these three parameters and using them to determine when to take remedial action. More detail on specific triggers is provided below.

1. Inlet air temperature

Ideally, air temperature should be maintained between 20°C and 45°C. This is the optimal temperature range for most microorganisms.

2. Inlet air relative humidity

Inlet air relative humidity should be at 100% relative humidity (saturation point), ideally above 85% most of the time. Short periods of lower relative humidity can be tolerated. However, long or repetitive periods of drier air are likely to reduce moisture and compromise the performance of the biofilter.

EPA recommends establishing the effective humidity and temperature range for each system. Upper and lower limits should be set to trigger corrective action if the recommended limits are exceeded for longer than three to four hours or more than 30 hours over any consecutive seven-day period.

3. Biofilter back pressure

The typical working range in a biofilter is 400–1200 Pa, however this will vary depending on the design of the biofilter. A change in back pressure (or pressure drop) is an indicator of airflow problems, which will affect biofilter performance.

If biofilter pressure rises it could be because of flooding, degradation and collapsing of media, fouling of media, or blocking up of plenum spaces. A decrease in biofilter pressure could be due to drying or cracking as air bypasses the media or passes through the media too quickly.

A rapid change in back pressure should trigger immediate action to investigate the causes of the change. In some cases, it may be advantageous to have a control system that can isolate or shut down plant or processes. This can prevent major offsite discharges of untreated air.

In biofilters, there will be a gradual increase of back pressure over time. Therefore, EPA recommends having plans in place that are triggered at predetermined backpressure levels. For example, investigation could be triggered if the backpressure increases 50%, with 75% triggering remedial action or refurbishment.

It is important to:

- assess the increase in back pressure when new media is added to the biofilter. This is to ensure the required flow rate is maintained
- establish baseline performance for a biofilter upon commissioning. This means the operator can establish a working operating back pressure for the biofilter.

Once a baseline has been established, trigger levels or alerts for action can be set to initiate:

- an investigation into biofilter performance
- remedial action such as ‘fluffing up’ media to increase porosity
- media replacement.

It is important to continuously monitor and log back pressure and follow the monitoring results to identify any trends in biofilter performance.

Daily monitoring

This is based on visual inspection and is best done early in the morning. It should include checks for:

1. even flow across the surface area of the bed (during cool temperature periods), to look specifically at steam plumes. These can indicate uneven flow distribution and areas of high flow
2. dry spot areas – to identify if watering is needed
3. presence of weeds – these need to be removed as their root systems can create gaps and preferential pathways

4. leaks, damage, or changes in vibration/noise in ductwork, pipes, fans and humidifiers
5. character of odour emissions – to check for untreated or partially treated emissions across the biofilter media. This is especially important at duct entry points, edges of cells, etc.

Weekly monitoring

1. Check of velocity, temperature and relative humidity at specific locations at the fan outlet(s) and before the biofilter inlets. This needs to be done using portable and calibrated devices under specific fan operating modes to represent normal, standby, start up and potential abnormal conditions.
2. Review the trends for velocity, temperature and relative humidity by comparing with previous measured data.
3. Compare temperature and relative humidity measured with portable devices to readings from continuous monitoring. This is to identify potential differences that may result from probe response drift (a slow change in the response of a gauge or instrument over time), calibration issues, etc.

Monthly monitoring

1. Use a sampling hood or equivalent (Figure 8) to measure velocities and by inserting measurement probes inserted in the chimney of the sampling hood.

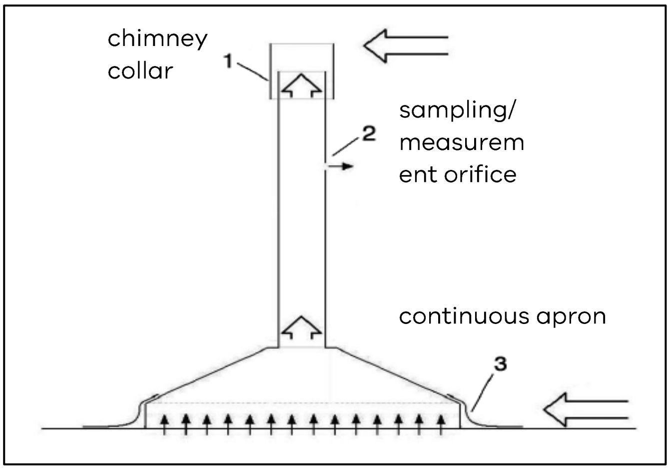

Figure 8: Sample Hood Device (VDI 3880)

2. Record the values for pre-located assessment points on each cell including:
   - the middle of the cell
   - along the walls of the cell where preferential paths are likely to occur.
3. Check the monthly velocity and temperature data for trends. A general reduction in velocity at several pre-located points may indicate that the media has started to compact. An increase in velocity and/or variations in temperature may be a sign of preferential paths.
4. Use the monthly data set to identify if there is an unbalanced flow through the cell. This is done by comparing standard deviation to the mean. The following deviations from the mean warrant investigation to identify potential issues (such as dry spots, preferential paths, wall effects, etc.):

a) Velocity: +/- 20% (deviation from mean).

b) Temperature: +/- 5°C (deviation from mean).

Methodology for selecting appropriate sampling locations can also be found in VDI 3880 Olfactometry – Static Sampling, Section 5.2.2.

It is best to conduct flow assessments when there are low wind speeds, as high winds cause too much fluctuation in velocity measurements as they blow across the collar of the chimney.

Yearly monitoring, commissioning and post refurbishment

After the first three months of the biofilter operation, or following the refurbishment of a cell, a composite odour sample should be collected, and its odour concentration measured.

It is also recommended to conduct this testing annually as part of an annual reporting cycle. This should be undertaken in conjunction with velocity and temperature measurements using the odour sampling hood at the pre-determined locations.

The main steps in annual testing are:

1. Measure odour concentration, air temperature, velocity and relative humidity with calibrated devices at each biofilter inlet.
2. Measure the odour concentration air temperature, velocity and relative humidity emitted from each cell. (It is advised that when refurbishing media that this testing is done before and after media replacement.).
3. Odour emissions from a well-functioning biofilter will be between 300 and 600 odour units, will be substantially free of the odour being treated and will generally have an earthy or woody odour from the media itself.
4. Use a control chart to review parameter data and track biofilter performance. Use this to ensure future tests are within the standard deviation.
5. Compare data to the continuous monitoring values for the temperature and the relative humidity at the day and time of the measurement and to previous monitoring periods to analyse for trends.

An example of how to select sampling positions can be found in the VDI Standard for static odour sampling - VDI 3880 Section 5.2.2. For sampling and analysis, follow the Australian Standard AS4323.3.

The area source should be subdivided into sections of the same size. The sections are formed on the following principles:

- Rectangular sources are subdivided into equal square sections (typically 10 m^2).
- Recommend nine squares per biofilter cell and at least four for smaller biofilters.
- The sample hood should be placed in the centre of each sample area.
- For some smaller biofilters it may be possible to sample the whole surface area by means of a cover or tarpaulin.

Testing and monitoring recommendations

1. Assessment and measurement should be performed under reproducible conditions to allow comparison with previous data.
2. Testing should also be conducted when the biofilter would be experiencing its highest odour concentration loading.
3. Recorded data should be available for review and include the type of measuring devices used, the name of the operator, the location of sampling points and the operational conditions of the biofilter and its load.
4. EPA recommends that testing is representative of the highest volumetric airflow rate and lowest residence time, or highest inlet odour concentrations (based on peak seasons or production).

Media refurbishment

'Fluffing up' media

Fluffing up is where media in the bed is turned and redistributed to create increased porosity in the bed and even out flow distribution. It can include replacement of part of the media with fresh material where it is particularly degraded.

'Fluffing up' has its merits in woodchip and bark biofilters, as mud and silt build up in the bed due to the breakdown of the media and gradual washing down of particulate matter. Fluffing up the bed means that media is redistributed evenly across the volume of the bed, which improves air flow.

'Fluffing up' media can also create the illusion of a drop in pressure by expanding the media and allowing more space for the air to flow.

Media can compact when the air pulses from centrifugal fans cause movement in the bed, meaning media can recompact even after 'fluffing up'.

Some types of media (such as aged compost and rice hulls) don't respond well to fluffing up, as they break down and essentially turn into mud. This media should be replaced on a regular basis.

Replacement of biofilter media

Inattention to biofilter media can cause:

- untreated odours impacting on the community
- increased costs in power consumption, as fans running the extraction system come under increased load
- increased back pressure blowing seals in ducts and pipework
- reduced effectiveness in maintaining negative pressure in buildings, resulting in an increase in fugitive emissions.

Indications that biofilter media needs to full replacement are:

- increase in energy requirements and inefficiency of fans supplying air to the biofilter
- the pressure drop is so great that design flow rates cannot be maintained

- the source odours being treated become obvious at the surface of the biofilter
- breakdown of the wood chips in the bed, with presence of large fraction of fines (muddy or composted appearance from visual inspection)
- variation of the height or undulation on the surface of the biofilter (compressed zones)
- significant drop in height of the biofilter.

Biofilter seeding and biomass maintenance

Microorganisms in the new medium will acclimatise to the incoming raw air stream within three to four weeks. The length of time will depend on conditions such as temperature, nutrient levels and moisture.

Media lag time can be reduced by mixing in (inoculating) the new media with a microbial culture. This can be done either by mixing media recovered from the bed material being replaced or using a grown culture of microorganisms applied via the irrigation system.

The presence of the inoculated fraction in the new media will speed up the spread of the new microbial population into the whole medium.

With partial inoculation, the initial odour removal will likely be lower than expected under normal conditions. If the fan has a variable speed feature, start feeding the media with a lower raw air flow rate than normal. Assess odour character and intensity daily to determine if the odour treatment is acceptable. The operator can then increase the raw air flow rate over several days until the desired flow rate is achieved.

It may also be necessary to increase the watering regime for three to four days to ensure the media contains enough moisture. Test daily to achieve target optimum moisture levels.

Flow and leak checking

Regularly test any access doors or ductwork fans leading to the biofilter enclosure for leaks while air is pushed through the media.

Smoke tests can also be used to verify:

- flow patterns within buildings. Focus on areas where room ventilation is ducted to biofilters. This is to check for dead zones, eddies, etc.
- an indicative picture of flow distribution in the media for various areas of the biofilter
- the homogeneity of the media and identification of dead-zones or possible preferential paths.

A second cost-effective option is to conduct inspections on cold mornings and observe steam distribution across the biofilter.

Glossary

Biofilm: Aqueous layer on the surface of biofilter medium where microorganisms live, and odour destruction takes place

Inlet Odour: Odorous untreated air where it enters the biofilter.

(Filter) media or medium: Substrate on which microorganisms grow on a film of water covering the surface of the media (biofilm). Can be made from bark, woodchip, oversize compost, zeolite and other materials with sufficient surface area to support the biofilm.

Fluffing: Activity of mixing up biofilter media to increase porosity.

Cell: Self-contained unit in a biofilter, i.e. a single bed with no dividing walls would be a single cell biofilter.

Air flow rate (Q): Average flow rate of air in each cell of a biofilter (m^3/h).

Odour unit (OU): The concentration of an odorant in 1 m^3 of air that is just detectable by 50% of the human population, standardised as equivalent to 40 ppb n-butanol.

Outlet Odour: Treated air emitted at the surface of the biofilter.

Preferential pathways: Areas in the biofilter bed where air flow is greater than in other parts of the bed. This can lead to short circuiting.

Short circuiting: The situation where odorous air bypasses filter media and leaves the biofilter untreated (also known as breakthrough).

Surface area (A): Area of each cell (m^2).

Surface load (SL): Per cell, the average flow rate across whole cell surface area (m^3/m^2.h).

Theoretical air velocity: Flow (in m/s) expected at the surface of the biofilter (Q/A).

References

Below is a list of standards that may be of use for further reference:

1. Verein Deutscher Ingeniere (VDI) Standard No. 3477 Biological waste gas treatment – Biofilters.
2. Verein Deutscher Ingeniere (VDI) Standard No. 3880 Olfactometry – Static Sampling.
3. AS4323.3 Determination of Odour Concentration by Dynamic Olfactometry.
4. AS 1289.2.1.1-2005 (R2016) – Methods of testing soils for engineering purposes – Soil moisture content tests – Determination of the moisture content of a soil – Oven drying method (standard method).
5. AS 1289.1.3.1:2015 – Methods of testing soils for engineering purposes – Sampling and preparation of soils – Undisturbed samples – Standard method.
6. AS 1289.1.4.1-1998 (R2013): Methods of testing soils for engineering purposes – Sampling and preparation of soils – Selection of sampling or test sites – Random number method.

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