A Comparison of Biological Odour Control Technologies for Municipal Wastewater

Froud, Colin[2], Letto, Daryl[1], Webb, Derek[1],
[1] BIOREM Technologies Inc., Guelph, Ontario, Canada
[2] CSO Tecknik Ltd, UK

Permanent media biofilters have demonstrated odour removal efficiencies greater than 95% on a variety of highly odourous wastewater treatment processes, including biosolids storage and dewatering. Recently, biotrickling filters have emerged as a viable emission control solution for select municipal wastewater applications. The removal efficiencies and the range of compounds effectively treated with biotrickling filters tend to be more dynamic than other fixed film bioreactor processes. Other odourous compound removal is somewhat unclear and biotrickling filtration as a total odour control solution must be clearly defined data.

As with biofiltration, biotrickling filtration is a fixed film biological process used to treat odourous components of a waste air stream. The biotrickling filter has a recirculating liquid solution that provides the developed biofilm with a means of controlling pH, accumulation of metabolites, and provides the system with the required nutrients. The efficiency of the technology is specific to the microbiology that is cultured in the media.

The performance of biotrickling filters show equivalent or better performance on process air streams with a wide range of H_2S concentrations. Biotrickling filters treating an air stream consisting only of H_2S provides excellent total odour removal. The performance of biotrickling filters of a highly odourous air streams consisting of a variety of odourous compounds, such as volatile organic compounds (VOCs) and reduced sulphur compounds (RSC), show that biotrickling filters do not provide a total odour control solution.

This paper will compare and contrast the differences between biotrickling and permanent media biofiltration using published performance data and collected field data. A discussion of the advantages and disadvantages of each technology for the given treatment process will identify the framework to select the appropriate technology for the municipal wastewater application.

Key Words: Biofilter, Biotrickling Filter, Municipal Wastewater Treatment, Odour Control

Introduction

With increasing population densities across most major urban centres, encroachment on municipal wastewater treatment facilities is inevitable and poses unique challenges to operators, regulators and the surrounding communities to assimilate these operations without having a negative impact upon the quality of life of the residents. The minimization, collection, and control of odours associated with the handling and processing of the municipal wastewater creates a range of challenges to overcome so that plant operations do not impact their surrounding communities. The nature of the wastewater treatment process is such that a number of activities from the plant operations, such as the collection and conveyance of raw sewage, primary and secondary treatment, as well as the treatment of biosolids, generate odiferous compounds that vary their composition and proportions based upon a number of operating parameters such as sulfate concentrations, temperature, concentration of organic materials, dissolved oxygen and detention times.

Aerobic wastewater contains a variety of odour causing compounds such as organic acids (oleic, stearic), esters, alcohols, aldehydes as well as indole and skatole. Odour generation and composition becomes much more pronounced and complex in the presence of anaerobic conditions. When oxygen is consumed in the wastewater due to extended detention times and high organic loading, anaerobic areas develop and release odours at a much greater rate. Hydrogen sulphide and other organic sulphides such as methyl mercaptan (MM), dimethyl sulphide (DMS), and dimethyl disulphide (DMDS) have very low detection thresholds and can lead to health and safety issues.

Biological odour control technology is an applicable technology for wastewater treatment odour abatement and has been used for several decades in various jurisdictions across North America and Europe. Biofilters rely on naturally occurring bacteria immobilized on a substrate to biologically oxidize the odourous compounds. The bacteria require sufficient moisture, oxygen, and micro-nutrients to thrive. Another form of a fixed-film bioreactor, also commonly used for the treatment of odours is a biotrickling filter. Biotrickling filters rely on immobilizing bacteria on an inert surface consisting of either random or structured synthetic materials with a constant flow of water recirculated over the medium to provide the necessary nutrients and oxygen to the microbial populations.

With regulatory bodies and municipalities requiring greater and greater performance from abatement equipment to meet the demands of urban encroachment and quality of life issues, the appropriate selection of treatment technologies is critical to prevent off-site, negative impacts on the surrounding communities. The following paper will compare and contrast the differences between biofilters and biotrickling filters in the context of odour abatement for various unit treatment processes for a municipal wastewater treatment facilty. Field data, literature reviews will be used to discuss performance, advantages and disadvantages of each technology.

Characteristics of Odour

The sense of smell is a complex group of processes that is beyond the scope and intention of this paper. However, a general understanding of odour and the properties of odiferous constituents and their perception is useful for understanding the implications for odour abatement technologies.

Within the nasal cavity are receptors called cilia that reside in a region referred to as the olfactory epithelium. Chemical odourants pass by the olfactory epithelium and are dissolved into an aqueous state in the mucus layer overlaying the cilia. The rate of transfer is related to the water solubility of the odour causing compound and temperature. Compounds with greater water solubility will solubilize at much greater rates than hydrophobic compounds. The interaction between the chemical and the olfactory cells proceed through various processes which may ultimately elicit a response from the individual. The perception of the odour may be interpreted as pleasant or offensive based on a wide range of biological and psychological influences.

Odour can be characterized by a group of measurable, objective parameters: concentration, intensity, persistence and odour character descriptors. Subjective parameters such as hedonic tone, annoyance, objectionable and strength help describe the perception of the odour. (WEF, 2004).

Odiferous constituents of the air stream contain a diverse array of compounds that each has their own unique characteristics and implications for the selection of abatement technologies. The key parameters or characteristics of interest for odour control systems are:

1. Water Solubility
2. Molecular Weight
3. Molecular Structure
4. Vapour Pressure
5. Odour Detection Threshold

These parameters all have a direct impact on the availability and biodegradability of the compounds as well as their potential to cause an off-site negative impact upon surrounding communities. The major groups of odourants that require consideration are:

1. Hydrogen Sulphide
2. Organic Sulphides
3. Ammonia and Nitrogen Compounds
4. VOCs

Hydrogen Sulphide

Hydrogen sulphide is generated through anaerobic decomposition of the organic material contained within the wastewater. It is one of the most prevalent and commonly discussed odour causing compounds found with the wastewater industry. It is a colorless, toxic gas that has a characteristic odour of rotting eggs. Hydrogen sulphide is heavier than air, contributes ot corrosion of infrastructure and can be immediately dangerous to life and health above concentrations of 100ppmv. It is moderately soluble in water and is readily biodegradable in biological systems. The odour detection is reported to be as low as 0.47 PPB (USEPA, 1985).

Organic Sulphides

These complex molecules are also produced as a byproduct of anaerobic decomposition of organic materials present in the wastewater. A diverse group of higher molecular weight compounds such as methyl mercaptan, ethyl mercaptan, dimethyl disulphide, and dimethyl sulphide, the organic sulphides are garnering more and more attention for ensuring all odours are effectively contained and treated at wastewater treatment plants. These compounds have a wide variety of solubilities and characteristic odours ranging from rancid, skunk-like to decayed cabbage. These compounds, other than methyl mercaptan, tend to be more recalcitrant to biodegration and have very low detection thresholds. Detection thresholds can be as low as 0.029 PPB (USEPA, 1985).

Ammonia and Nitrogen Compounds

Organic material contained within the wastewater will invariably contain proteins and amino acids. As this is degraded, ammonia, amines and other nitrogen-bearing compounds will be released. Typically, the contribution to odour from these compounds is low with liquid wastewater processes. The compounds tend to be highly water soluble and readily biodegradable. Odour detection thresholds vary significantly, with skatole at the low end (0.002 ppbv) to ammonia at the high end (15 ppmv) (WEF, 2004).

VOCs

There are many other potential odour contributors that can be released from treatment processes. These vary greatly in composition and their impact on the corresponding selection of abatement equipment. Organic acids such as acetic acid, butyric acid are readily biodegradable. Aldehydes, ketones and aliphatics may also be present in the air stream. The composition and concentration of these components are a function of the raw sewage sources. While these compounds are typically overpowered by the sulphur-bearing, and to a lesser extent, nitrogen-bearing compounds present in the air stream, they are becoming increasingly more important as consideration for optimized odour control applications in sensitized urban environments.

Odour Emissions for Individual Wastewater Unit Treatment Processes

The characteristics of the odours that are emitted from the various types of wastewater unit treatment processes vary considerably in terms of constituents and concentrations. While an accurate prediction of the actual types and concentrations is not possible due to the infinite number of variables that impact the generation and release of these compounds, a general framework for anticipating the conditions is. This framework will be presented in the following section.

Wastewater treatment processes can be classified into three main segments: Collection, Liquid-phase Treatment and Residuals or Biosolids Treatment.

The collection systems comprise of several types and for large, urban centres, can be a complex combination of the various types. Collection systems include gravity sewers, force mains, drop structures, interceptors and pumping stations.

Liquid-phase treatment units include a variety of particle and sediment removal stages, biological and nutrient removal stages.

Residuals or biosolids treatment are unit processes associated with the handling and processing of the solids fraction remaining after liquid-phase treatment.

Table 1 is presented as a framework for anticipating the odour potential for particular applications to aid with appropriate emission abatement equipment selection. While biological technologies are robust and flexible, not every application can be addressed appropriately with a single technology. Knowing when and how to use a technology is a critical element in the successful implementation of an odour control strategy.

Table 1: Odour Emission Characterization Framework

Source of Odours	Reason for Odour	Primary Constituents	Secondary Constituents
Collection Systems			
Gravity Sewers	Pressurization of the sewer atmosphere force odourous air from the various structures along the way (manholes, drop structures, reductions in pipe diameters, etc.).	Hydrogen Sulfide	VOCs, Organic Sulphides, Nitrogen-bearing Compounds
Force Mains	Sewer is under pressure and completely filled with wastewater, the result is a highly anaerobic conveyance system. Highly odourous air emerges where the force main wastewater is received.	Hydrogen Sulfide	VOCs, Organic Sulphides, Nitrogen-bearing Compounds
Pump Stations	Receiving various qualities of wastewater and is a source of potential release to ambient atmosphere	Hydrogen Sulfide	VOCs, Organic Sulphides, Nitrogen-bearing Compounds
Industrial Discharges	High temperature and high BOD wastewater that causes the depletion of dissolved oxygen and sulfide generation	VOCs, Organic Sulphides, Nitrogen-bearing Compounds	Hydrogen Sulfide
Liquid-Phase Treatment			
Preliminary Treatment i. Grit Chambers ii. Pre-aeration basins iii. Influent Channels and Distribution Boxes iv. Flow Equalization Basins	Odourous emissions are highly dependant on the characteristics of the influent wastewater: source of wastewater, detention time, turbulence, characteristics and volume of wastewater return from down stream processes.	Hydrogen Sulfide	VOCs, Organic Sulphides, Nitrogen-bearing Compounds
Primary Clarifiers	High turbulence contirbutes to the evolution of objectionable odours. Emissions are a function of the characteristics of the wastewater. The influent feed wells and effluent launders contribute a significant load to the overall odour emissions. A major source of odour emissions, but due to the large odour-emitting surface area, the odours are not strong and persistent, rather objectionable. This is a major source of odours on a volume per volume basis.	Hydrogen Sulfide, VOCs	VOCs
Biological Treatment	Activated-sludge process, fixed-film processes, final clarifiers, settling tanks. Low odour emission rates that are not well defined but described as musty odour or fresh character	VOCs, Organic Sulphides	VOCs, Hydrogen Sulphide
Residuals and Biosolids Treatment			
Thickening	Odours emanating from settled solids and the grease and scum that accumulates on the surface. Gravity thickeners, DAF, gravity belt, and rotary drum thickeners.	Organic Sulphides	VOCs, Hydrogen Sulphide
Blending and Holding Tanks	Excess holding times can increase the odours.	Organic Sulphides	VOCs, Hydrogen Sulphide
Stabilization	Various processes: aerobic digestion, anaerobic digestion, thermophilic aerobic digestion, alkaline stabilization, wet-air oxidation	Organic Sulphides, Ammonia, Nitrogen-bearing Compounds, Hydrogen Sulphide	VOCs
Dewatering	Pending the characteristics of the feed sludge. Mechanical means of dewatering: belt filter presses (turbulent discharge of filtrate), centrifuges (cake discharge chute), plate-and-frame presses (low turbulence), and drying beds (large exposed area).	Organic Sulphides, Ammonia, Nitrogen-bearing Compounds, Hydrogen Sulphide	VOCs
Composting	Aerated static pile, windrow composting, in-vessel composting	Organic Sulphides, Ammonia, Nitrogen-bearing Compounds, Hydrogen Sulphide	VOCs
Thermal Drying	Volatilization of odourous compounds due to the heat of drying.	Organic Sulphides, VOCs	Hydrogen Sulphide

Biological Odour Control Technologies

Historically, odour control at wastewater treatment facilities has been carried out using physical or chemical processes, employing chemical scrubbers or carbon adsorption. While effective for most applications, these treatment processes can also require significant operational budgets. Today, biological odour control processes are becoming widely accepted in the wastewater industry. Microbial processes have been demonstrated to remove odours to very high treatment efficiencies with fewer operational controls and costs as compared with conventional technologies. Biological treatment technologies also offer additional advantages over physical and chemical treatment. Most chemicals used in the control of odours tend to be either strong oxidizing or corrosive agents and have significant hazards associated with the handling, storage and use. Biological approaches do not use these chemicals and typically operate using only water and common nutrients providing a safe and environmentally sound solution to odour abatement.

Fixed film and suspended growth bioreactors are common to many biological processes, especially those of wastewater treatment plants. A fixed film bioreactor is a process that describes biofilter and biotrickling filters. A biological film, often termed a biofilm, is immobilized on a substrate which is fixed on a surface. The surface is typically selected with specific properties targeted at the efficiency of the biological process. The biofilm is a microscopic aqueous layer where the microbes reside. Odour causing compounds are able to solubilze in the biofilm such that the microbes can gain access to them for destruction. For example, a biofilter media is selected to have specific surface area properties and can be formulated with nutrients and buffers to encourage the growth of organisms responsible for destruction of odourous compounds in the air. Other parameters which are formulated and selected are moisture content, density, shape, size, and void space. Biotrickling filters are another example of a fixed film bioreactor. Again, a biofilm is immobilized on a substrate. The properties of the media are quite different. For the case of a biotrickling filter treating H_2S, more water is passed over the surface of the media, thus void space properties must allow the water to pass through the media without incurring excessive pressure drop. Also, the need for the media to be able to buffer the media to a neutral pH is not required as the drop in pH is encouraged. Other properties of the media are also carefully considered and selected to optimize the biological destruction efficiency of target odourous compounds.

Different micro-organisms are responsible for the success of a biological odour control technology. Autotrophic organisms synthesize their own food for metabolic energy. Metabolism of H_2S creates an acidic environment for the autotrophs to thrive. The media acidification promotes the growth of autotrophic bacteria, often termed acidophiles, which suppresses the growth of heterotrophic bacteria which function efficiently in a neutral pH environment. The pH is suppressed by the formation of sulfate. Hetertrophic bacteria are micro-organisms that require organic substrates as their source of energy - organic carbon. Heterotrophic bacteria are responsible for removal of other odourous compounds generated from low level VOCs and reduced sulfur compounds. Poor total odour removal is often observed when the media pH drops below the neutral pH range. The biofilter or biotrickling filter media is affected in two different ways. First, the accumulation of elemental sulphur can plug available pore space reducing the available surface area and H_2S/odour degrading capacity of the media. Secondly, as mentioned above, removal can be inhibited by the presence of H_2S or other gases and is more sensitive to pH changes compared with H_2S abatement (Smet, 1998).

Biofiltration

Biofiltration is an example of a fixed-film bioreactor. Microbial colonies are immobilized on a support structure or matrix consisting of many different types of materials. Historically, biofilter media has consisted of wood bark, roots, wood chips, compost or soil. Recent advances with the technology have been made possible with the advent of synthetic or manufactured medias such as BIOSORBENS® from BIOREM Technologies Inc.

Biofiltration consists of a two stage process. The first stage consists of the solubilization of the gaseous phase odour compound into the moisture layer or biofilm surrounding each of the media particles. The second stage is an oxidation stage. As opposed to chemical oxidation, no anthropogenic oxidants are used, rather, the microbes has the capability to degrade the compound for energy using its own means.

All biofilters have similar components. They consist of a reactor or vessel to house the immobilization matrix; an air distribution system, a humidifying pre-conditioning stage, irrigation system, ventilation system and control system. Biofilters are commercially available in a wide variety of configurations and materials of construction. They can be purchased as integrated modular systems fabricated out of glass reinforced plastics, stainless alloys, PVC or HDPE. For larger airflows, modular systems can be placed in parallel or custom field erected systems can be constructed using pre-fabricated concrete panels, FRP panels or poured-in-place concrete systems. Older, low-tech designs often consisted of a perforated pipe network overlain by a pile of woodchips. Several examples of various configurations are shown in Figures 1, 2, and 3.

Figure 1: HDPE Modular Biofilters in Parallel

(Photo courtesy of BIOREM Technologies Inc.)

Figure 2: An Integrated Modular Stainless Steel Biofilter Vessel
(Photo courtesy of BIOREM Technologies Inc.)

Figure 3: An Open-top, Custom, Field-erected, In-ground Concrete Biofilter
(Photo courtesy of BIOREM Technologies Inc.)

While the selection of individual components and the design of the air flow distribution and moisture control systems are important, the most critical element to ensure long term, consistent performance of a biofilter across all operating conditions is the proper selection of media. Media selection needs to consider surface area, porosity, moisture retention, compressive strength and longevity. While organic materials provide satisfactory support for the proliferation of microbial colonies, the organic carbon contained in the material acts as another substrate for the bacteria.

The implications are that the media will be consumed with time and compaction will occur leading to the development of preferential flow paths as differential pressure increases (Iranpour, 2005). Also, a metabolic energy source is readily available, thus making odour causing compound not the preferential source of food for the odour degrading microbes. Synthetic materials, like BIOSORBENS®, have significant advantages over other medias: consistency, homogeneity and uniform particle sizes and have more even pore distributions (Easter, 2006). These synthetic medias provides a more consistent performance due to the inherent parameters of the media and formulation. Since it is a manufactured product, variability's from batch to batch can be eliminated with a rigorous quality assurance program. This ensures that the performance of a given application can be predicted accurately through the use of kinetic modeling.

Moisture control is also another critical element in the design of a biofiltration system. Moisture is important for the solubilization of the vapour phase contaminant as well as for support the microbiology. Materials that are too dry will not support the diverse microbiology required for a robust system to operate efficiently. However, if the media is over-saturated, there is a corresponding decrease in porosity which increases the media differential pressure. Increased media differential pressure results in increased operational costs and the potential for the development of preferential flow paths that can allow untreated air to escape.

Sizing and contact time is a critical parameter for the design of biofilters. The empty bed retention time is used as a surrogate indicator of elimination capacity through the media volume. Typical retention times vary from 7s to 180s. Systems employing soil as the immobilization matrix tend to require the longest retention times, greater than 90s. Organic blends of medias, including compost and root wood varieties, require retention times greater than 60s. Synthetic, high elimination capacity medias utilize retention times between 30 to 45s (Easter, 2006). These permanent synthetic medias can provide superior performance within reduced retention times due to the specific properties of the formulation that help address the complex mixture of odourants typically found in wastewater treatment applications. A reduction in retention times can have a significant impact on capital costs for an installation as the containment vessel size is reduced.

Advantages and Disadvantages of Biofilters

Biofiltration technology as a general rule offers whole of life cost reductions when compared against other technologies. When compared against chemical scrubbing or activated carbon systems, paybacks vary from application to application but typically are below the 2-3 year payback. The low cost of operation is primarily due to the lack of consumables. Organic media replacement costs must be factored in to the equation and can inverse life cycle costs. Maintenance requirements for a biofilter are very low and consists of maintaining the ventilation fans or blowers, recirculation pumps, and media replacement. With the advent of permanent media biofilters, the maintenance is even further reduced.

A drawback to the use of biofiltration technology is the footprint required for effective treatment. Media depth is limited to superficial velocities for phase transfer and compressive strength which dictates the level of compaction. Soil media biofilters can be as shallow as 0.6m, with organic medias typically around 1.0m and permanent synthetic media are able to be placed to a depth of 2.0m without fear of compaction or elevated differential pressures. The implication is that systems using organic or soil based medias will require much greater surface area than a synthetic media based system.

Performance of Biofilters

This section summarizes performance of biofilters from a variety of sources, including published literature as well as from field verification of operating systems. Organic and synthetic media biofilters were considered in the evaluation. The applications vary across all unit processes including collection, primary liquid-phase as well as residuals and solids handling. As an example, some of the most odourous and difficult odours to degrade are the reduced sulphur compounds present in the residuals and solids handling processes. Data collected from an inorganic synthetic media biofilter is shown in Figure 4. The reduced sulphur compounds are easily degraded to the detection limit of the instrumentation, GC-MS. In general, a biofilters performance increases with increasing retention time. This is true for the treatment of most odours associated with the processing of wastewaters as more time is available to degrade the odour causing compounds. As per the example in Figure 4, the design retention time was 45 seconds.

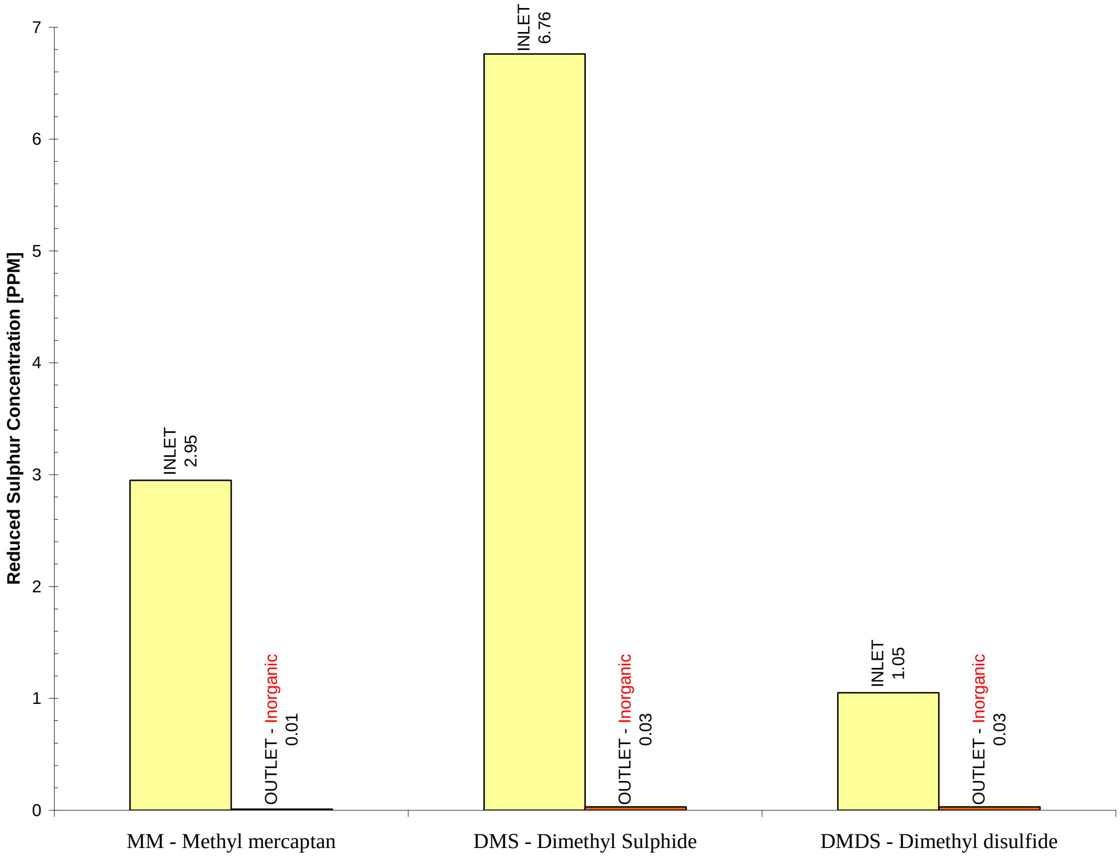

Figure 4: Reduced Sulfur Removal of Synthetic Biofilter Media (BIOSORBENS®) at a Biosolids Loadout Facility

The data in Table 2 shows both H_2S and odour data for various synthetic media biofilters. The source of the odours is identified. This is important to note as odour generated solely from H_2S is easily removed. More challenging odours are generated from sludge and biosolids applications. Thus synthetic media biofilters have the advantage of providing both H2S and reduced sulfur removal, where as organic media biofilter are more specific and cannot remove a variety of odourous compounds.

Table 2: Inorganc Synthetic Biofilter Media (BIOSORBENS®) System Performance

SYSTEM Reference	Treated Process Air	EBRT (sec)	System	Source of Odours	Inlet H_2S (PPM)	Outlet H_2S (PPM)	H_2S RE%	Inlet ODOUR (DT)	Outlet ODOUR (DT)	ODOUR RE% (DT)
A	18,000 CFM	26	BIOFILTAIR™	Biosolids	3.98	0.069	98	8,900	570	93.6
B	3,500 CFM	30	BASYS™	Equalization basins	14.0	0.059	100	15,000	390	97.4
C	6,000 CFM	35	BIOFILTAIR™	Belt presses, sludge holding tanks	59.1	0.170	100	11,050	849	92.3
D	1,800 CFM	18	BASYS™	Screen building	20.4	0.002	100	-	-	-
E	7,500 CFM	45	BIOFILTAIR™	Bar screen, grit basins	-	-		4100	80	98.0
F	5,000 CFM	27	BASYS™	Influent splitter box	53.2	0.000	100	-	-	-
G	300 CFM	40	BASYS™	Pump station	34.6	0.007	100	-	-	-
H	550 CFM	35	BASYS™	Bar screen	45.9	0.098	100	-	-	-

For organic based media biofilers, the performance tends to be limited on the more complex odourants such as DMS and DMDS. Performance also tends to decline with increasing age of the medium itself. Performance of the systems are a function of retention time, moisture content of the support matrix, temperature and pH. As hydrogen sulphide is reduced by microbial activity, one of the metabolites or byproducts of the metabolic processes is the generation of sulfate ions (SO_4^{2-}) that in the presence of water form a mild aqueous solution of sulfuric acid. The generation of this acid lowers the pH of the support medium eventually impacting the biology and shifting populations from heterotrophs to autotrophs. The acid can drop the pH of the media below the survival range of heterotrophic organisms. Autotrophic systems are excellent for hydrogen sulphide removal, but offer poor removal on other organic odours (Joyce, 1999). This is demonstrated on a biosolids composting operation at a Georgia, USA facility using a BIOREM organic media biofilter shown in Figure 5 and Table 3.

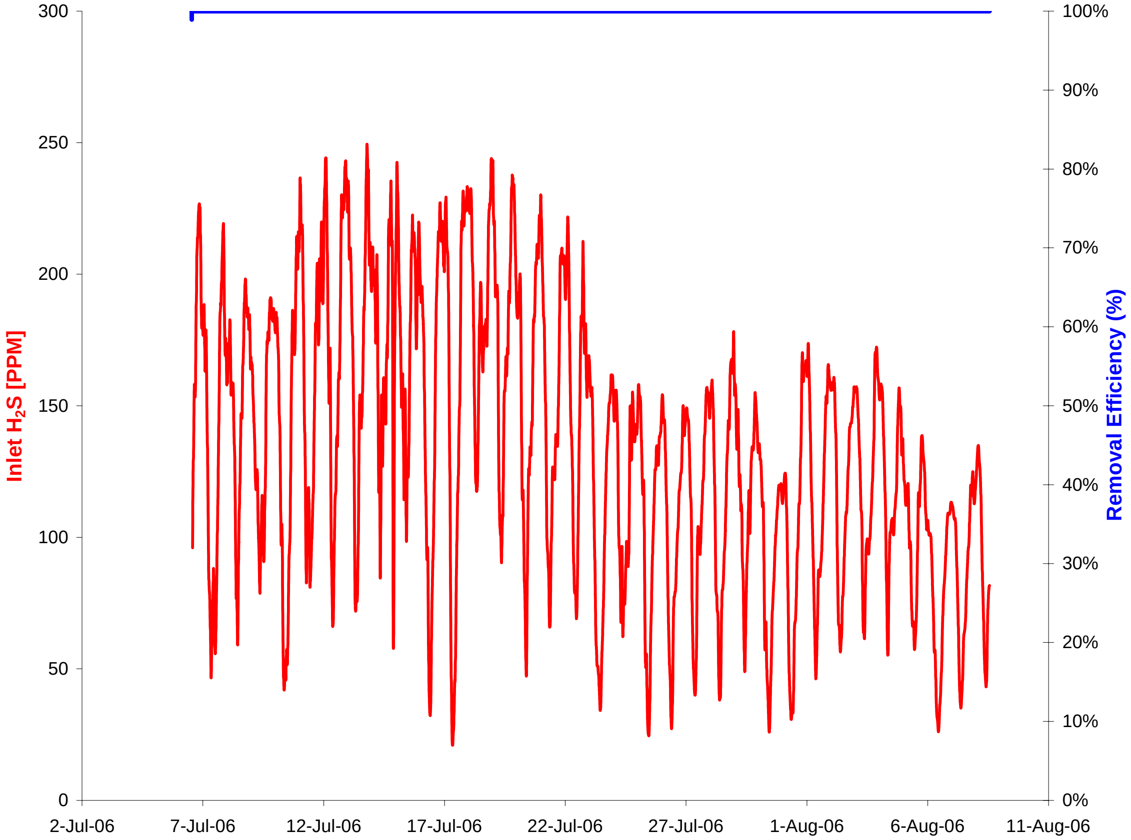

Figure 5: H_2S Removal of an Organic Media Biofilter

Table 3 shows the odour removal of the same system recorded shown in Figure 5 which was also recorded at the same time. A clear distinction is drawn here when comparing performance. Organic media biofilters removing H_2S efficiently may not provide the total odor removal required in the presence of other organics.

Table 3: Odour Removal of an Organic Media Biofilter

	SAMPLE #1	SAMPLE #2
INLET Concentration [OU]	10000	9400
OUTLET Concentration [OU]	2900	5300
REMOVAL EFFICIENCY (%)	71%	44%

Biotrickling Filters

Biotrickling filters are often labeled with a variety of names – biotower, bioscrubber, and sometimes even called a biofilter. For the purposes of this paper, we will refer to a biotrickling filter as a vapour-phase odour control technology that uses air-permeable inert media exclusively for the growth of attached microorganisms and the direct biodegradation of odour compounds. It employs a biological fixed film process. There are several key design features that distinguish this from a biofilter. An example of a biotrickling filter is shown in Figure 6.

Figure 6: A Modular FRP Biotrickling Filter

A biotrickling filter operates at a much higher superficial velocity than a biofilter. A biofilter superficial velocity is typically operated between 0.025m/s - 0.075m/s. A biotrickling filter typically operates at a velocity between 0.10m/s – 0.35m/s. This is a function of the type of media used for each technology and is limited in each case by a maximum desired operating differential pressure. The implication of being able to operate at higher velocities makes it possible to treat more process air in the same vessel, thus occupying a smaller area. Biotrickling filters also offer better control of nutrients and metabolic by-products. The recirculated water is a means to deliver nutrients to the biofilm for microbial growth and but also a means to flush unwanted metabolic by-products from the system.

Many different medias are available for biotrickling filters. These include lava rock, poly-urethane foam, and synthetic. The properties of biotrickling filter media required to provide suitable microbial environment is surface area, density, moisture retention, chemical resistance, microbial compatibility, compressive strength, and void space. A balance of these parameters is required to ensure efficient and complete treatment of odour causing compounds.

Advantages and Disadvantages of Biotrickling Filters

An obvious benefit is that the biotrickling filter can treat more air in a given volume. However, the range of compounds treatable is narrower. A total odour solution is hard to achieve as the pH of a biotrickling filter is homogenous. For wastewater applications, there are applications that a single system cannot deal with the range of compounds for a total odour solution. A biotrickling filter designed as a stand alone technology for total odour control in a mixed process air stream is not recommended for the reasons previously discussed. A biotrickling filter is ideal to treat high loading of H_2S. The small footprint area is also desirable. A similar result was noticed by Cox et al., when a reactor previously operated at a neutral-pH showed a drastic decrease of the removal rate of both H_2S and toluene when the pH was lowered to 3.8. For such cases, if near neutral pH is required for VOC removal, the co-treatment of H_2S and VOC in one reactor will need to be reconsidered. Sequential treatment, i.e., treatment of H_2S in an acidic reactor first followed by VOC treatment in a near neutral bioreactor as proposed by Devinny et al. may well be the method of choice (Cox, 2002).

The efficiency of the various biofilter medias has enabled odour control companies to shrink the empty bed retention times required to treat H_2S. For example, a biofilter to treat 30 PPM of H_2S would typically require 30 seconds of biofilter media. A biotrickling filter could handle the same H_2S concentration of the same flow in less than 12 seconds. The disadvantage is that other compounds present in the air contribute to the odour and cannot be treated with any significant degree of efficiency.

Biotrickling filters are also more prone to upsets. They are at the mercy of the recirculated liquid within them. If the equipment fails or there is a upset to the supply water, then there is a potential for a system upset and incomplete treatment of the target compound.

Compared to biofilters, the system performance is not immediate. In the case of BIOSORBENS®, the media is formulated with adsorbents to remove odourous compounds and provide some immediate relief from the odourous air until the microbiology takes over. A biotrickling filter is not formulated with such adsorbants, and treatment of the odourants does not occur with any suitable efficiency until acclimation occurs. For this same reason, even an acclimated biotrickling filter system cannot handle large variations from their average odourant load. Figure 7 shows the drop in performance from 99% to about 96% when the concentration drastically changes. The performance recovers but requires some time to do so. The same phenomenon was observed by Duan as published in the Journal of Applied Microbiology and Biotechnology, as the biotrickling filter showed a more turbulent performance pattern, the RE% dropping to 81% at the highest loading (Duan, 2005).

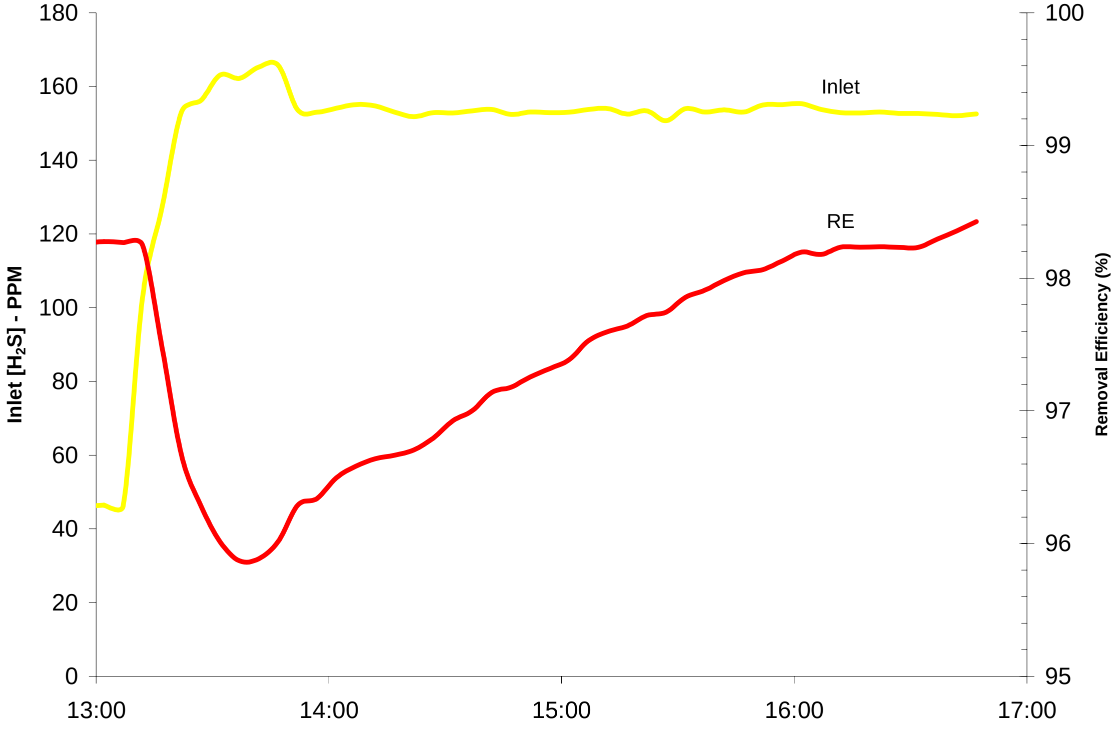

Figure 7: Response time of a Biotrickling Filter Treating H_2S at 40 PPM spiked to 160 PPM

System performance of a biotrickling filter is shown in Figure 8 below. The data log shows the typical fluctuation of H_2S typically observed through the day. This data was logged for 4 days. The removal is typically observed to be 99% or better. With large spikes in concentration from it's average load, the system performance is reduced until the biology compensates for the fluctuation in H_2S concentration. Odour and reduced sulfur data was also collected during the same time data from Figure 8 was collected. The methyl mercaptan is significantly reduced and the H_2S is removed to an efficiency of >99.5%. Odour data was also collected and it shows poor overall performance. The reason being that the residual reduced sulphur and other compounds present were not sufficiently destroyed thereby leaving a residual odour. This is the limitation of the biotrickling filter and the need for tandem style biological odour control system.

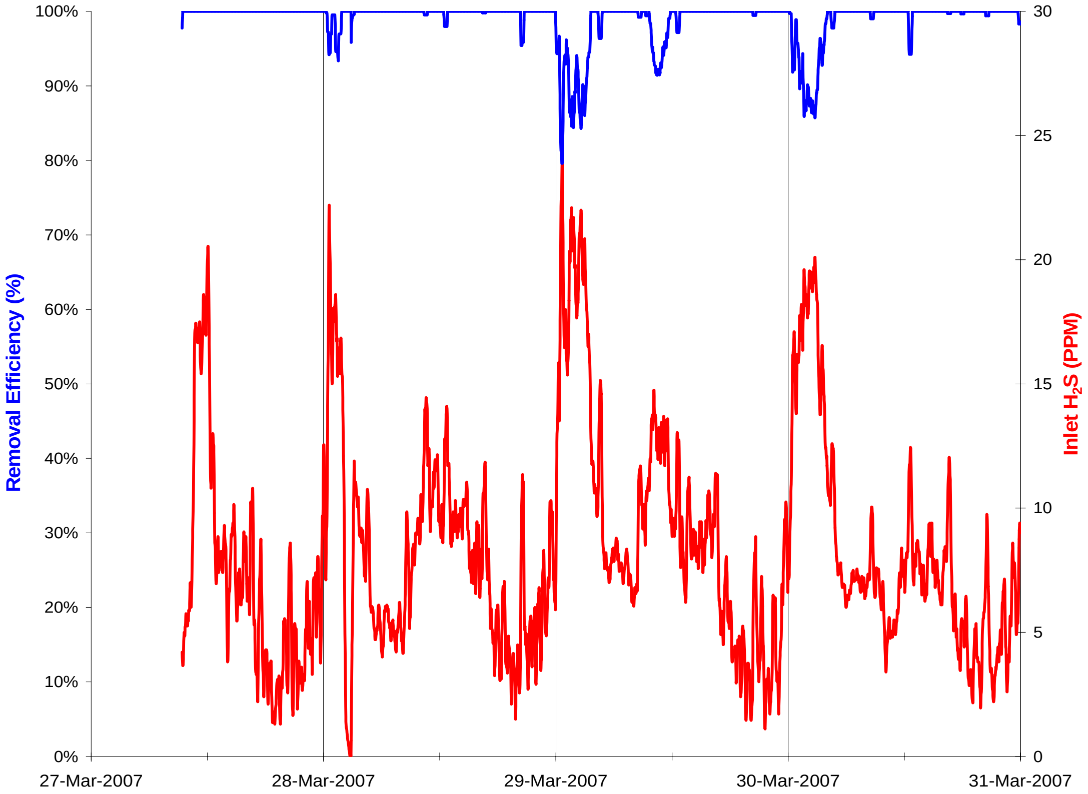

Figure 8: H_2S Data Log for a Synthetic Media Biotrickling Filter

Table 4: H_2S, MM, and Odour Data for a Synthetic Media Biotrickling Filter

	Hydrogen Sulfide (H_2S) - PPM		**Methyl Mercaptan (MM) - PPM**		**Odour (OU)**	
SAMPLE #	1	2	1	2	1	2
INLET	22.5	37.2	2.303	2.41	18000	14000
OUTLET	0.062	0.18	0.246	0.299	4900	3700
Removal Efficiency (%)	99.7%	99.5%	89.3%	87.5%	72.8%	73.6%
Odour Threshold (WEF, 2004)	0.00047		0.0011		N/A	

Conclusions

The use of biotechnology for odour and emissions control at municipal wastewater treatment facilities is efficient, robust and reliable when the appropriate technology is paired with the right process conditions. A properly designed system that takes into account the complex perspectives of optimized odour management techniques is essential to ensure success.

The key factors to consider when selecting the technology are presented below:

1. Source of Odours. This is important for understanding the potential chemical constituents of the air stream. For example, knowing that the odour sources emanate primarily from a belt filter press, a heterotrophic biofilter system, capable of handling the organic sulphides should be selected rather than an autotrophic biotrickling filter system.
2. Contaminant Types and Concentrations. In addition to specifying the source of odours, characterization of the air stream is also important to ensure that the appropriate design parameters are utilized. Hydrogen sulphide is a critical component to understand to ensure that acidification of the biofilter bed does not occur. For autotrophic biotrickling filter design, peak and average concentrations are also required to ensure the appropriate retention time and recirculation rates are employed to maintain equilibrium within the reactors.
3. Required Performance. The required performance of the abatement equipment plays a large role in determining the selection of the technology and of the particular design parameters that should be employed. The removal of hydrogen sulphide is relatively easy as compared with the more recalcitrant organic compounds and can have an impact on technology selection. If the source of odours is primarily from H_2S, as with most pump stations and collection systems, addressing just H_2S rather than the other minor constituents can aid in reducing the capital cost of the installed equipment as retention times will generally be quite low.
4. Space Availability. Consideration must be given to the available space for the abatement equipment. Combination systems (BTF followed by carbon polishing) may be required to accommodate tight spaces.
5. Proximity of Neighbours. The location of sensitive receptors and the prevalent wind conditions also play a factor in determining the level of performance required, which has a direct impact upon equipment selection and design parameters.

In general, biotrickling filter technology is an ideal technology to address applications with elevated hydrogen sulphide concentrations. It also performs quite well on low concentrations of H_2S at low retention times. Autotrophic trickling filters are not suitable for high efficiency removal of total odours based on organic sulphur compounds and other volatile organics. Heterotrophic systems provide better removal at extended retention times, however, the performance lags behind a properly designed biofilter for total odour control.

Biofiltration is a more robust technology better suited for total odour removal. Systems designed using synthetic, permanent medias like BIOSORBENS® are able to provide consistent performance over the life of the installation and respond very well to the diurnal variations associated with liquid phase wastewater treatment.

Total odour applications with elevated hydrogen sulphide must be designed with a tandem approach to ensure that autotrophic conditions are maintained within the first stage (biotrickling filter) and heterotrophic conditions are maintained in the second stage (biofilter).

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