

## **Case Study – Successful Operation of Biotechnology for Odour Control at Western Treatment Plant**

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### **ABSTRACT**

There are a number of biological and chemical technologies available for treatment of odours from sewage.

Melbourne Water installed the largest biotrickling filter (BTF) system in the southern hemisphere (at the time) at the Western Treatment Plant (WTP) in 2006, treating 126,000m<sup>3</sup>/h (74,160cfm) of odorous air from the Western Trunk Sewer (WTS) which conveys over half of Melbourne's sewage to the WTP.

Biological treatment of odorous air was preferable over chemical scrubbers for this application, as it has substantially lower operating costs, is much more sustainable, and does not produce hazardous wastes.

Extensive Process Proving Trials conducted on-site found that the biotrickling filter system exceeded its design performance requirements. In more recent times, the hydrogen sulphide (H<sub>2</sub>S) concentration has increased by about 50% from original design requirements due to increased sewage concentration and travel time resulting from water conservation activities. Despite this increase in H<sub>2</sub>S loading, the installation still meets or exceeds its original performance requirements.

The odour control facility (OCF) has proved to be robust and has coped well with altered process conditions, along with requiring minimal maintenance.

### **KEYWORDS**

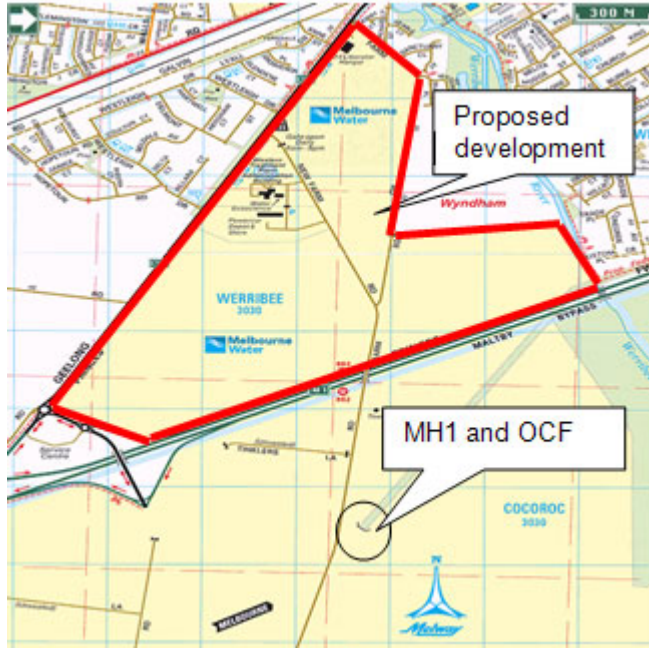
Biotrickling filter, odour control, performance, Western Treatment Plant, process proving

### **INTRODUCTION**

The WTP is located at Werribee, an outer suburb of Melbourne in Victoria and treats approximately 54% of Melbourne's sewage, averaging 450ML per day (119 mgd). Raw sewage

is delivered to the plant via the WTS. Manhole 1 (MH1) is located within the plant boundary and vents  $126,000\text{m}^3/\text{h}$  ( $74,160\text{cfm}$ ) of air extracted from the WTS for corrosion control in the upstream sewer. Prior to the installation of the OCF in 2006, air from the WTS was vented to atmosphere via a 30m stack. Its approximate location is shown in Figure 1 below.

**Figure 1 - Approximate Location of OCF at MH1**



Due to Melbourne Water's no odour policy and a proposed residential development within the northeast corner of the site, an OCF was installed to reduce odorous emissions from the extracted air. BTF technology was determined to be the most appropriate for this site due to the high  $\text{H}_2\text{S}$  load of up to 27 parts per million (ppm), as well as a number of other economic, social and environmental considerations.

This paper presents a case study on the implementation of BTFs to control  $\text{H}_2\text{S}$  and odour based on the results of the Process Proving Trial and subsequent testing after ongoing operation.

## EQUIPMENT SELECTION

BTF technology was determined to be the most appropriate for this site due to the high  $\text{H}_2\text{S}$  load as well as a number of other economic, social and environmental considerations. The BTF system with a multi-stage design, including its structured inert media, is guaranteed for 20 years, leading to much lower operating costs in comparison to conventional biofilters. It also has a significantly smaller footprint.

Although the capital cost of the BTFs was about double that of a comparable chemical scrubber installation, they do not require expensive chemicals for treatment. Based on the estimated  $\text{H}_2\text{S}$  load, the payback period for the extra capital cost was less than three years. BTFs are also a more

sustainable alternative as they only require water and a small amount of nutrient for effective treatment. Additionally, they do not rely on chemical removal of contaminants, and do not create hazardous waste streams.

## KEY DESIGN PARAMETERS

Extensive sampling and dispersion modelling was used to develop the key design parameters listed in Table 1. These criteria also form the basis of the OCF performance testing requirements.

**Table 1 - Key Design Parameters**

Parameter	Influent Condition	Effluent Condition
Air Flow at 200C, Nm <sup>3</sup> /hr <sup>1</sup> (cfm)	126,000 (74,160)	
Air Temperature, °C (F)	15 – 35 (59-95)	
Air Relative Humidity, %	60 – 100	
H <sub>2</sub> S Concentration, ppm <sub>v</sub>	6 – 27	≤ 0.5 <sup>2</sup>
Absolute Peak H <sub>2</sub> S, ppm <sub>v</sub>	45.9	
Odour Concentration, OU	6,000 – 76,000	≤ 2000 <sup>3</sup>

<sup>1</sup> Normal cubic metres per hour, based on ideal gas flow at a temperature of 20°C and pressure of 1 atmosphere.

<sup>2</sup> To apply to at least 99.5% of all H<sub>2</sub>S readings, measured as the average of any ten consecutive readings taken at two minute intervals.

<sup>3</sup> Readings shall be measured in accordance with the procedures as specified in the Australian Standard AS4323.3.

The OCF comprises 10 PurSpring biotowers designed by Bioway Technologies Australia Pty Ltd and constructed by a joint venture between United Group Infrastructure and Bioway Technologies Australia.

The primary control system philosophy of the OCF is to provide the ability to operate the plant unmanned and automatically under normal operation, with supervisory control provided from the Main Operator Control Room via the existing Supervisory Control and Data Acquisition (SCADA) System.

## PROCESS PROVING METHODOLOGY

This section describes the methodology of the analysis and the equipment used for the measurements during the Process Proving Trial.

The Process Proving Trial was undertaken during the period from 27 November to 26 December 2006. The air sampling took place over a 4 week period, with odour samples taken at 6 day intervals to capture different daily trends. The aim was to collect 4 inlet and outlet odour samples on each day. During the period, a total of 21 inlet and 21 outlet odour samples were collected.

Continuous inlet and outlet H<sub>2</sub>S measurements were also taken throughout this period as well as measurement of a number of other operational parameters as outlined below.

Plant airflow was determined by measuring the air velocity using a pitot-tube in the discharge stack. The airflow distribution through the 10 bio-towers was measured by 10 differential pressure transmitters (Endress & Hauser, type Deltabar S) installed before and after the air outlet of each biotower. The total pressure drop across the OCF was measured using differential pressure transmitters (Endress & Hauser, type Deltabar S) installed in the ductwork before and after the OCF.

An online H<sub>2</sub>S transmitter (Drager, type Polytron 7000 H<sub>2</sub>S detector) and an H<sub>2</sub>S datalogger (Odalog, type 0-200ppmv) at the inlet sampling ports measured inlet foul air H<sub>2</sub>S concentrations to the OCF.

Outlet treated air H<sub>2</sub>S concentrations from the OCF were measured by an online H<sub>2</sub>S transmitter (Honeywell, type MDA Model SPM “Chemcassette” analyser), and an H<sub>2</sub>S datalogger (Odalog, type 0-2ppmv) installed at the outlet sampling ports.

Odour concentrations were measured by collecting bag samples and analysing them in a National Association of Testing Authorities (NATA) registered laboratory (EML) in accordance with the requirements of the AS/NZS method 4323.3.2001. This standard is the Australian equivalent of the international standard method EN13725. Samples from the inlet and outlet airstream were taken simultaneously.

Volatile organic compound (VOC) concentrations were analysed in laboratories using Gas Chromatography-Mass Spectrometry (GCMS) methods for hydrocarbon and sulphur compounds on the bag samples collected for odour concentration analysis. The only VOC detected above the detection limit was methane (between 1.1 and 9.6mg/m<sup>3</sup>) so no additional reporting of VOCs is provided in this paper. It is however noted that detection limits for VOCs may differ between laboratories around the world.

Air temperatures and humidity were measured twice daily. Temperature was measured using a calibrated temperature probe. Humidity was determined by measuring the wet bulb and dry bulb temperature and using the Mollier diagram to establish relative humidity.

## **ACCLIMATISATION OF ODOUR CONTROL FACILITY BIOTOWER #1**

One of the OCF biotowers (Biotower #1) was repaired 9 days prior to commencement of the Process Proving Trial, with start-up of Biotower #1 only occurring 6 days prior to the trial start.

A start-up period of approximately 8 weeks is usually required to ensure full acclimatisation of the OCF towers. This start-up period means that Biotower #1 was tested with only partial acclimatisation.

The airflow through Biotower #1 was initially restricted and gradually increased over 4 weeks in 25% increments to reach the 100% design value. During the first 4 weeks of the Process Proving Trial, as Biotower #1 was still starting up, the consequential extra air was distributed to the other nine towers. However, Biotower #1 was operated in normal operating mode together with the other 9 towers during sampling days.

Additional air samples were also collected on three of the four sampling days to analyse the expected odour concentration with only 9 biotowers in operation. This was done by closing the damper to Biotower #1 once sampling of conditions under normal operation (10 towers) had been completed. Approximately 5 minutes after closing the damper, sampling of the outlet airstream began.

### SYSTEM OPERATION DURING TRIAL

The operating conditions for the main process parameters of the OCF during the Process Proving Trial are summarised in Table 2 below.

**Table 1 - Operating Parameters of OCF**

Parameter	Range
Water Consumed (L/h) <sup>1</sup>	4,800-6,500
Nutrient Consumed (L)	2.5
Process Water pH	Upper:7.9 - 8.1 Lower:1.9-2.2
Airflow in Biotower #1 (% of design flow)	32% - 97%
Airflow in Other Biotowers (% of design flow)	98% - 112%
Temperature (°C) and Relative Humidity (%) of OCF	22.1 – 28.10C 73 – 93%
Temperature (°C) and Relative Humidity (%) of OCF during Process Trial	17 – 32degC 23 – 60%
Air Pressure at Inlet Sample Point	-500 to -600 Pa
Air Pressure at Outlet Sample Point	-300 to -400Pa
Pressure Drop in bio-towers (incl dampers) (Pa)	700 – 800Pa

<sup>1</sup> During the Process Proving Trial, potable water was only used during one period, totaling only 3.5% of total water usage.

Class C recycled water is used for irrigation and requires no additional nutrients. The recycled water nutrient content is in this case sufficient for the catalyst (mainly bacteria) of this process.

Several process upsets and process changes during the Process Proving Trial were also recorded, which included the following:

- A power failure of approximately 8 hours prior to the Process Proving Trial due to storm damage;
- Recycle water supply failure between December 10 to 12, requiring the use of potable water and additional nutrients;
- Measures to improve fan air delivery caused airflow to increase to approximately 18% higher than its design flow.

Of note is that despite these changes to the process, no significant effect to the H<sub>2</sub>S and odour removal efficiencies were observed.

## RESULTS

### Airflow

The design airflow through each OCF Biotower was 12,600m<sup>3</sup>/hr. During the Trial the airflow through Biotower #1 was increased from 32% in the first week to 97% in the last week. The airflow through the other Biotowers (Biotower #2 to Biotower #10) varied between 98% and 112% during the Process Proving Trial. The total airflow through all operational towers was measured at 140,000m<sup>3</sup>/hr, which is about 11% higher than design.

### Olfactometry Analysis

Results from the olfactometry analysis of the OCF are presented in Table 3.

**Table 3 - Odour Analysis Results**

Day	Date	Sampling Session	Time start sampling	No. Towers	INLET (OU)	OUTLET (OU)	Removal Efficiency (%)
1	30 Nov	Morning	10:26am	10	23000	480	97.9
1	30 Nov	Morning	11:25am	10	21000	610	97.1
1	30 Nov	Afternoon	13:13pm	10	19000	860	95.5
1	30 Nov	Afternoon	14:19pm	10	18000	590	96.7
2	6 Dec	Morning	9:20am	10	22000	170	99.2
2	6 Dec	Morning	10:29am	10	22000	190	99.1
2	6 Dec	Afternoon	14:14pm	10	33000	320	99
2	6 Dec	Afternoon	15:32pm	10	60000	480	99.2
3	12 Dec	Morning	11:07am	10	23000	540	97.7
3	12 Dec	Afternoon	14:45pm	10	46000	1100	97.6
3	12 Dec	Afternoon	15:45pm	10	57000	1900	96.7
4	18 Dec	Morning	9:28am	10	40000	430	98.9
4	18 Dec	Morning	10:29am	10	ND <sup>1</sup>	170	ND <sup>1</sup>
4	18 Dec	Afternoon	13:10pm	10	29000	320	98.9
4	18 Dec	Afternoon	14:20pm	10	55000	380	99.3

<sup>1</sup> Not determined due to broken sample bag

The results from the olfactometry analysis when one biotower was taken offline (only 9 out of the 10 biotowers operational) are presented in Table 4.

**Table 4 - Odour Analysis Results**

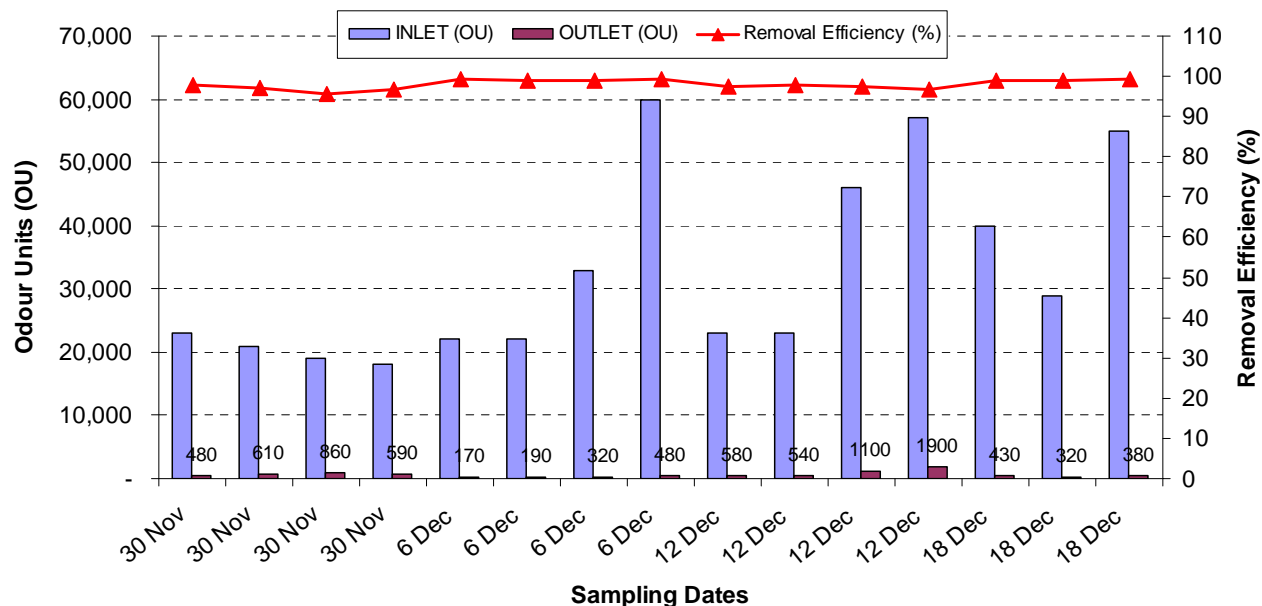
Day	Date	Sampling Session	Time start sampling	No. Towers	INLET (OU)	OUTLET (OU)	Removal Efficiency (%)
1	30-Nov	Afternoon	13:37pm	9	19000 <sup>1</sup>	1100 <sup>1</sup>	94.2
1	30-Nov	Afternoon	14:43pm	9	18000 <sup>1</sup>	720 <sup>1</sup>	96.0
2	6-Dec	Afternoon	14:52pm	9	33000 <sup>1</sup>	380 <sup>1</sup>	98.8
2	6-Dec	Afternoon	16:02pm	9	60000 <sup>1</sup>	420 <sup>1</sup>	99.3
4	18-Dec	Morning	10:49am	9	ND <sup>2</sup>	360 <sup>1</sup>	ND <sup>2</sup>
4	18-Dec	Afternoon	14:46pm	9	55100 <sup>1</sup>	630 <sup>1</sup>	98.9

<sup>1</sup> Inlet samples were taken just prior to outlet sampling, with outlet sampling starting approximately 5 minutes after inlet sampling stopped

<sup>2</sup> Not determined due to broken sample bag

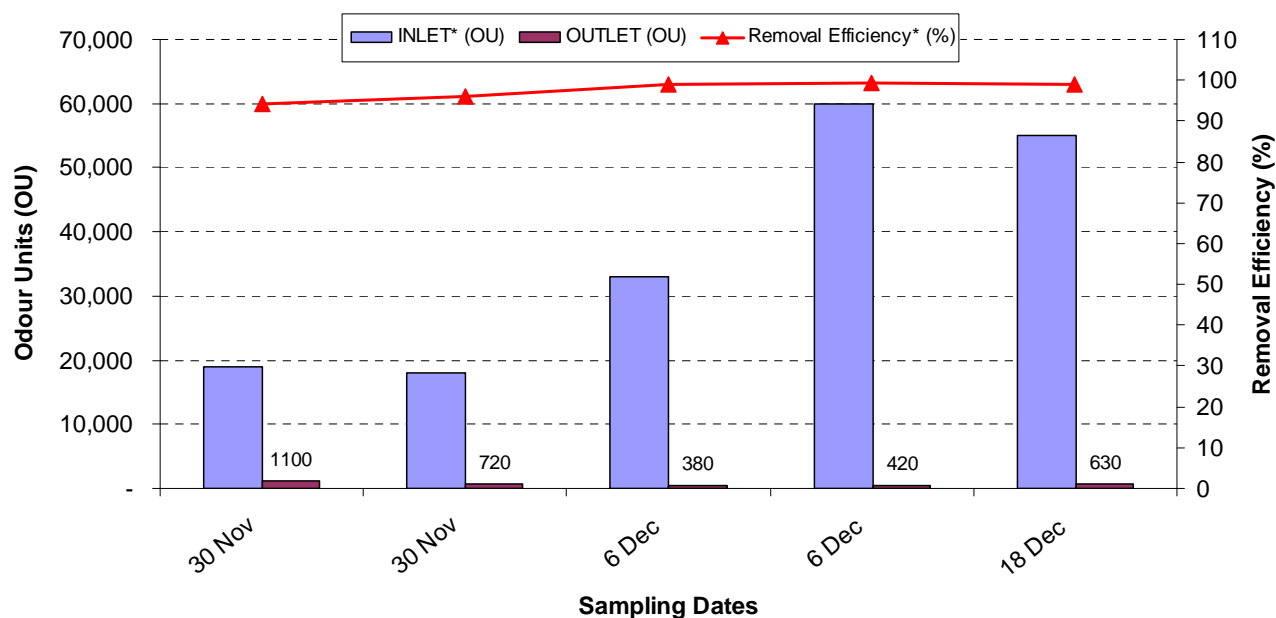
The inlet and outlet odour concentrations of all measurements for the OCF during normal operation (10 biotowers) are summarised in Figure 2. Results of samples unable to be determined due to errors were excluded from the analysis.

**Figure 2 - All Odour Sampling Concentration Data for Normal Operation**



The inlet and outlet odour concentrations for the OCF for one biotower out of service (only 9 towers in operation) are summarised in Figure 3. These samples were taken on three of the four sampling days, and undertaken as only 9 biotowers were fully acclimatised during the Process Proving Trial as described previously.

**Figure 3 - Odour sampling concentration data for only nine biotowers in operation**



A summary of the odour concentrations observed under both operating conditions are presented in Table 5 below.

**Table 5 - Summary of odour concentrations observed at the OCF**

Parameter	Normal Operation (10 biotowers)	One biotower out of service (9 biotowers)
Inlet odour (OU)	18,000 - 60,000	18,000 - 60,000
Outlet odour (OU)	170 – 1,900	360 – 1,100
Odour removal efficiency (%)	95.5% - 99.2%	94.2% - 99.3%
Average odour removal (%)	98.5%	98.3%

As apparent from Table 5, the OCF installed at MH1 WTP had consistently good removal efficiencies between 95.5% to 99.2% regardless of the odour levels of the incoming air for normal operation. The odour removal efficiency when one biotower was taken out of service (only 9 biotowers in operation) was also noted to be consistently good, with removal efficiencies between 94.2% and 99.3%.

## Hydrogen Sulphide Concentrations

H<sub>2</sub>S concentrations were analysed and logged online using the automatic online H<sub>2</sub>S analysers, with the results of the Process Proving Trial shown in Figure 4 for measurements using the online transducer, and Figure 5 for measurements using the Odialog.

**Figure 4 - H<sub>2</sub>S concentration measured with online transducers (Drager for inlet concentrations and Honeywell for outlet concentration)**

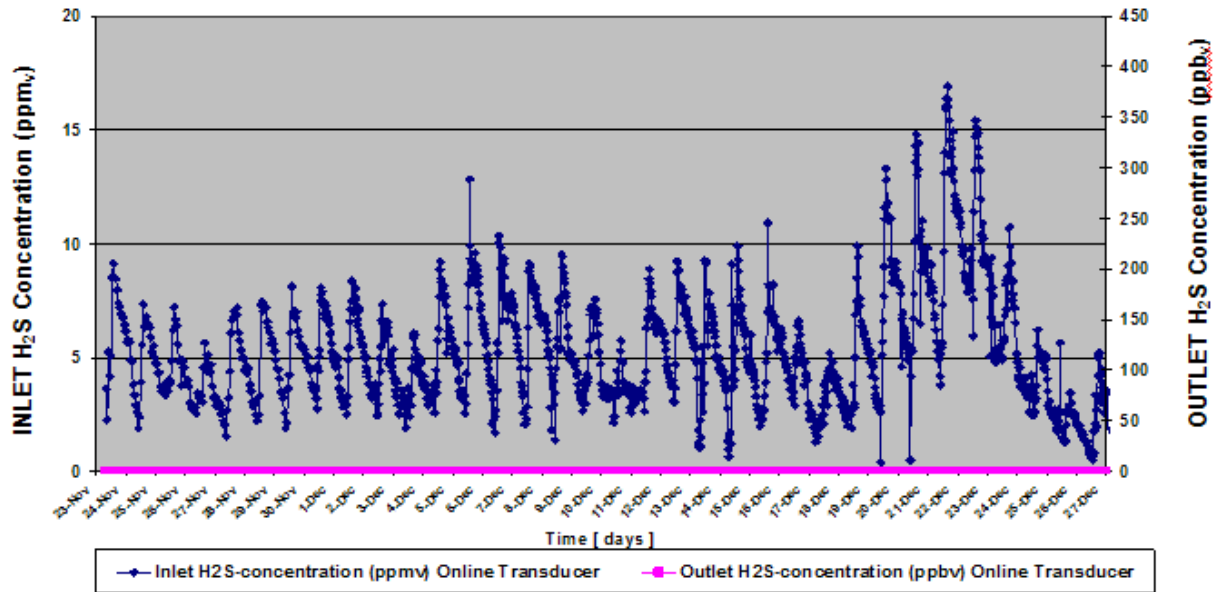
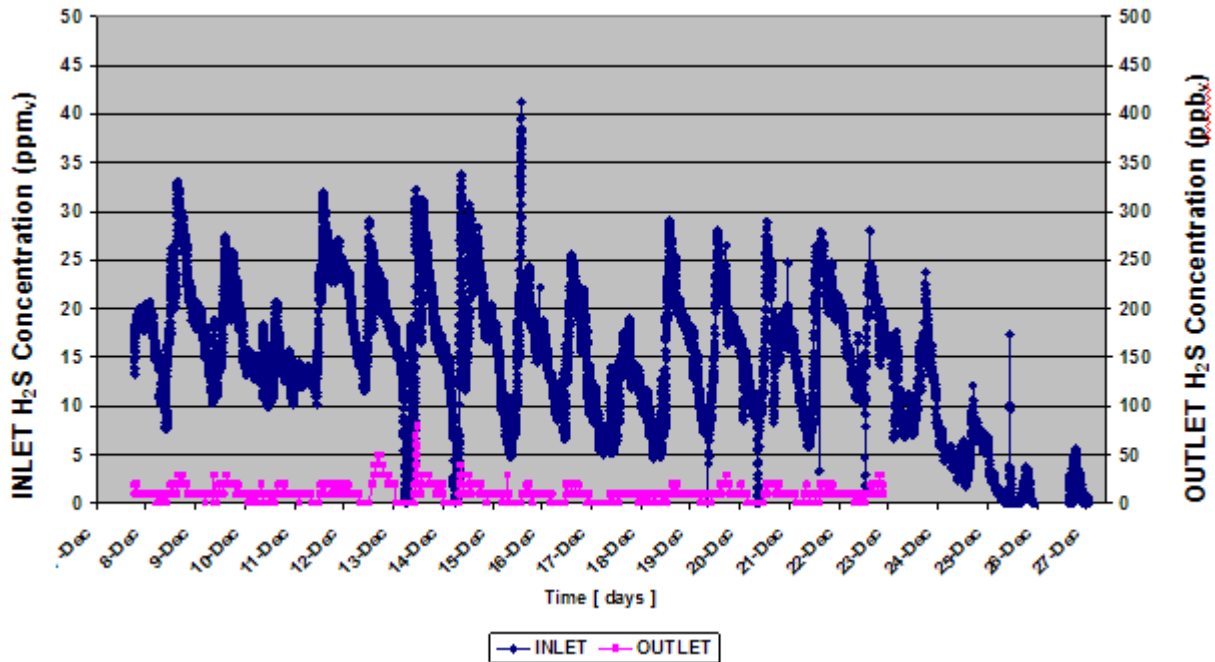


Figure 5 - H<sub>2</sub>S concentrations measured with calibrated Odalogs at inlet and outlets



Outlet concentrations lower than the detection limit of 50 ppb<sub>v</sub> were not detected and instead logged as 1 ppb<sub>v</sub> on the online analysers (due to programming).

Of note is that the Honeywell and Drager transducers were calibrated on 13 December and 19 December respectively after the Drager Transducer showed consistently lower results than the Odalog. Calibration of the Drager transducer with a 25 ppm<sub>v</sub> H<sub>2</sub>S span gas showed a measured reading of only 14.9 ppm<sub>v</sub>. This highlighted that the inlet H<sub>2</sub>S reading prior to 19 December were most likely reading low by a factor of about 1.68. Even after calibration, the Drager transducer still measured lower readings than the Odalog, which was calibrated prior the testing period.

A summary of the H<sub>2</sub>S result observations are shown in Table 6 below.

Table 6 - Summary of H<sub>2</sub>S observations at the OCF

Parameter	Online Transducers	Odalogger
Inlet H <sub>2</sub> S (ppmv)	0.1 – 16.9 (Drager)	0 – 41
Outlet H <sub>2</sub> S (ppmv)	≤ 0.050 (Honeywell)	0 – 0.080
H <sub>2</sub> S removal efficiency (%)	≥ 99.1%	99.1% - 99.9%

From Table 6 above, the OCF is also found to exceed its original design performance requirements with respect to H<sub>2</sub>S removal efficiency.

## Other Operating and Performance Information

During the Process Proving Trial, the OCF was operated in a stable manner without major upsets.

The upsets that were experienced prior to or during the Process Proving Trial did not influence the operating efficiency of the OCF.

The weather conditions did not change much during the Process Proving Trial. During the sampling days, the ambient temperature ranged from 17-32 °C and the relative humidity ranged from 23-60%. The inlet odour concentration ranged from 18,000-60,000 OU and the inlet H<sub>2</sub>S concentration ranged between approximately 0-40 ppm<sub>v</sub>. A summary of the operating parameters during the trial is provided in Table 2.

It can be concluded that during the Process Proving Trial the OCF had been operating according to design specifications.

## CONCLUSION FROM ODOUR PERFORMANCE TRIAL

A summary of the OCF performance in comparison to the original design specifications are presented in Table 7 below.

**Table 7 - Design Specification and Results of process Proving Trial**

Parameter	Design Specifications	Process Proving Trial Results
Inlet Odour Concentration (OU)	6,000-76,000	18,000-60,000
Outlet Odour Concentration (OU) – average and range	< 2000 <sup>1</sup>	570 170 – 1,900
Odour Removal Efficiency (%)	96%	98.5%
Inlet H <sub>2</sub> S Concentration, (ppmv) average and range	6 – 45.9	0 – 41.3
Outlet H <sub>2</sub> S Concentration, (ppmv) average and range	< 0.5 <sup>2</sup>	0.010 0 – 0.080
H <sub>2</sub> S Removal Efficiency (%)	99.5%	99.6%

<sup>1</sup> Readings shall be measured in accordance with the procedures as specified in the Australian Standard

<sup>2</sup> To apply to at least 99.5% of all H<sub>2</sub>S readings, measured as the average of any ten consecutive readings taken at two minute intervals.

No major failures or process upsets were recorded during the Process Proving Trial, with stable operation recorded. Minor process upsets experienced prior to or during the Process Proving Trial itself did not influence the operating efficiency of the OCF.

No major change in the weather conditions were observed during the Process Proving Trial, with ambient temperatures ranging from 17 to 32<sup>0</sup>C and relative humidity between 23 to 60% during sampling days.

Tests were conducted to determine the odour and H<sub>2</sub>S removal efficiency of the OCF for situations where one biotower is offline. The results indicated that even when one biotower was out of service, the required odour and H<sub>2</sub>S removal efficiencies were achieved.

The Process Proving Trials found that the biotrickling filter well exceeded its performance requirements.

## SUBSEQUENT OPERATING PERFORMANCE

As part of ongoing performance monitoring, Melbourne Water has conducted periodic odour sampling on the inlet and outlet of the OCF. The monitoring was undertaken without any process optimisation which would further improve the results.

Environmental Testing Consultants (ETC) undertook all the sampling and testing and the results are shown in Table 8.

**Table 8 - Summary of odour concentrations observed at the OCF**

Date	Number of Online Biotowers	Inlet Odour Concentration (OU)	Outlet Odour Concentration (OU)	Odour Removal Efficiency (%)
20 Oct 06	10	23000	1600	93
20 Oct 06	10	24000	3300	87
12 Feb 07	10	40000	2000	95
12 Feb 07	10	35000	1800	95

All the results apart from one on October 20 demonstrated similar performance to that experienced during the Process Proving Trial. This result could be an anomaly associated with the testing which is not unusual.

In more recent times, drought and reduced water usage as a result of water restrictions and improved trade waste management have seen both liquid and gas phase sulphide levels increase by about 50%. Hydrogen sulphide levels of up to 64.5 ppm<sub>v</sub> were recorded in February 2008 on

the inlet to the OCF which was consistent with a measured increase in dissolved sulphide levels from approximately 3.5 mg/L to approximately 7 mg/L. Outlet H<sub>2</sub>S levels continue to be less than 50 ppb<sub>v</sub>.

## **CONCLUSIONS**

After several years of operation the OCF still meets or exceeds its performance requirements. This is despite the increase in sewer hydrogen sulphide levels since its design. The facility operates effectively on Class C recycled water and requires no additional nutrients. The OCF has proved to be robust and has coped well with altered process conditions, and requires minimal operator attention and maintenance.

## **ACKNOWLEDGEMENTS**

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