PPI

Biofilter performance evaluation

Summary Report

PRENV.015

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May 2003

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MEAT & LIVESTOCK AUSTRALIA

1 Brief outline of results

Pacific Air & Environment (PAE) was engaged by Meat & Livestock Australia (MLA) to monitor and evaluate the performance of a newly installed biofilter for control of odorous emissions from rendering at the Australian Country Choice (ACC) Cannon Hill meat-processing site. Stage 1 of the study was completed over a ten-week period from 24th May 2001 to 26th July 2001 during which the biofilter came online and the rendering plant scaled operations up to full production rates. Stage 2 of the project operated from October 2001 until early February 2003.

This report presents a brief outline of the results. The full report can be obtained from MLA upon request.

The odour removal efficiency is particularly useful for analysing how the biofilter reacts to changes in the input load. An overall odour removal efficiency of approximately 83% can be assigned to the biofilter. This figure is an average based on many odour samples and multiple sampling campaigns, occurring over a long period of time.

2 The ACC Biofiltration System

The newly installed biofilter at ACC Cannon Hill is a closed biofiltration system. It uses micro-organisms to break down organic (and some inorganic) odours from the inlet gas stream, which contains foul odours from the rendering plant. The micro-organisms digest the odorous compounds, converting them primarily to water and carbon dioxide. The treated gas stream is emitted through the outlet stacks to the atmosphere. Odour in the outlet air is caused by very low mass concentrations of organic compounds entrained into the flow from the biofilter medium, plus possibly some residual compounds from the rendering.

Figure 1 is a photograph of the ACC biofilter with the major components of the system identified. The foul gases enter the system through an inlet duct (1650 mm ID), which is fed from the rendering section of the meat processing plant. A 150 kW fan operates at 42 Hz to induce approximately 115 000 Nm^3/h of airflow through the system. The inlet stream flows through an air washer, which helps to remove volatile fatty acids from the gases. The air washer consists of an expansion in the ducting where water (which is inoculated with odour treating bacteria) is sprayed across the flow of inlet gases. The water is recirculated into the air washer through a sump, where approximately 10% is purged and fresh make-up water is added. After the air washer the inlet gases are fed through an inlet manifold into the four biofilter modules, which are equal in size. The dimensions of each module are 16 m (L) x 4 m (W) x 3 m (H). The biofilter currently treats approximately 450 m^3/h of gas per m^2 of bed. Each module has a multivane damper on the inlet riser, designed to provide equal flow across all modules. The odorous gases flow through the filter media of each module and are emitted to the atmosphere via four individual stacks (700 mm x 2000 mm) that serve each module.

Figure 1 Major Components of the ACC Biofilter

3 Results

3.1 Odour concentrations

The key indicator in measuring the performance of the biofilter is the odour removal efficiency. It is based on the ratio of odour load that is removed by the biofilter to the load that is fed to the biofilter. This section describes the performance of the biofilter during the Stage 1 and Stage 2 sampling periods.

The efficiency of odour removal varied between samples, ranging from 60% - 89%.

Figure 2 presents the measured inlet and outlet odour concentrations for each round of sampling, indicating how the emissions feeding into and being emitted from the biofilter changed over the start-up and steady state periods.

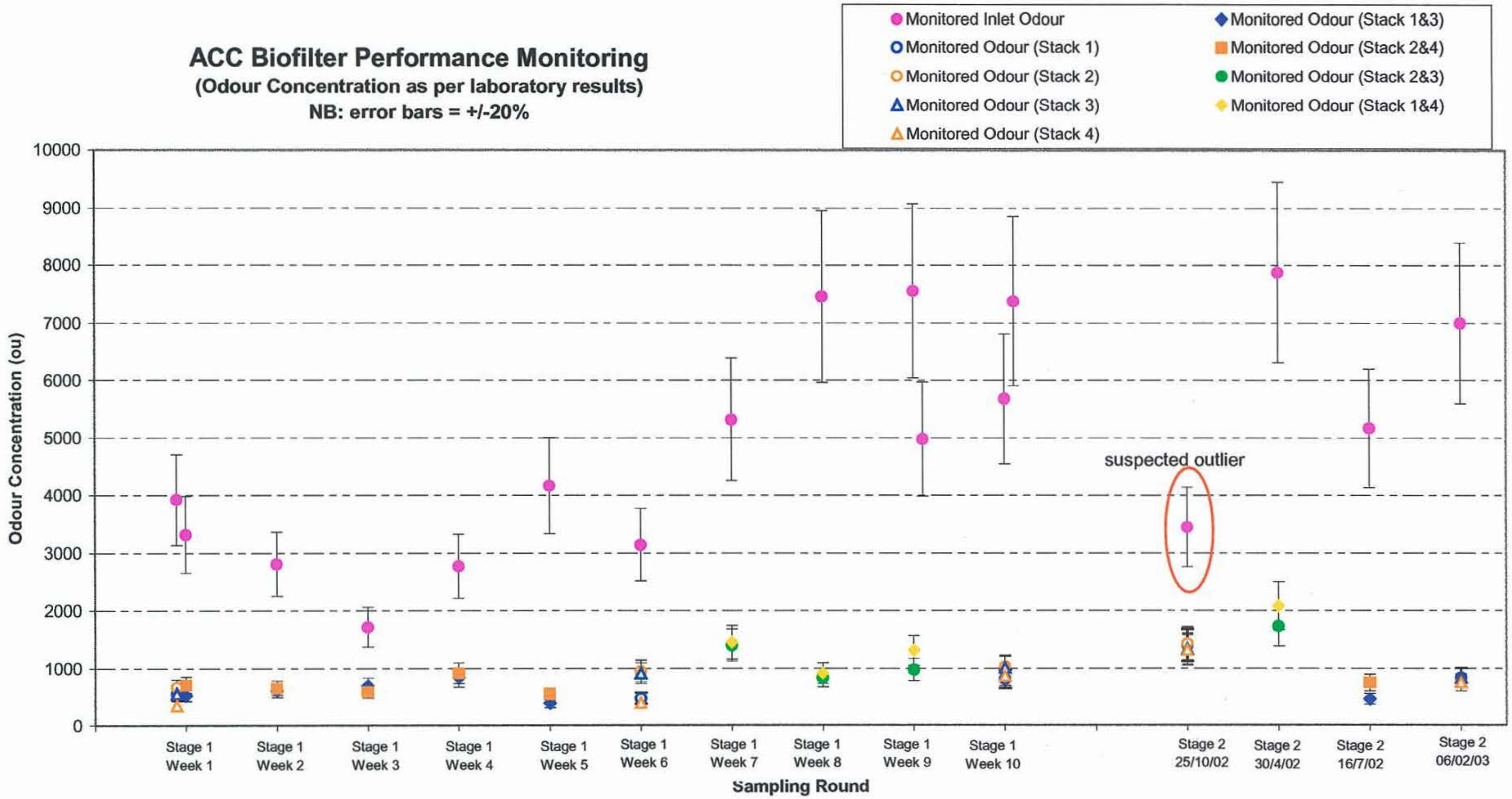

Figure 2 **Monitored Odour Concentrations (ou) at the Inlet Duct and Outlet Stacks (including composite samples)**

3.2 Odour removal efficiency

Figure 3 shows the relationship between odour emitted from the odour load applied to the biofilter. It shows two distinct ranges of biofilter operation. Below an odour application rate of approximately 120,000 ou.m^3/s (inlet flow measured together with odour concentration samples), exit odour concentrations fall to lower than 1000 ou. At an application rate of greater than 120,000 ou.m^3/s, higher outlet odour concentrations occur.

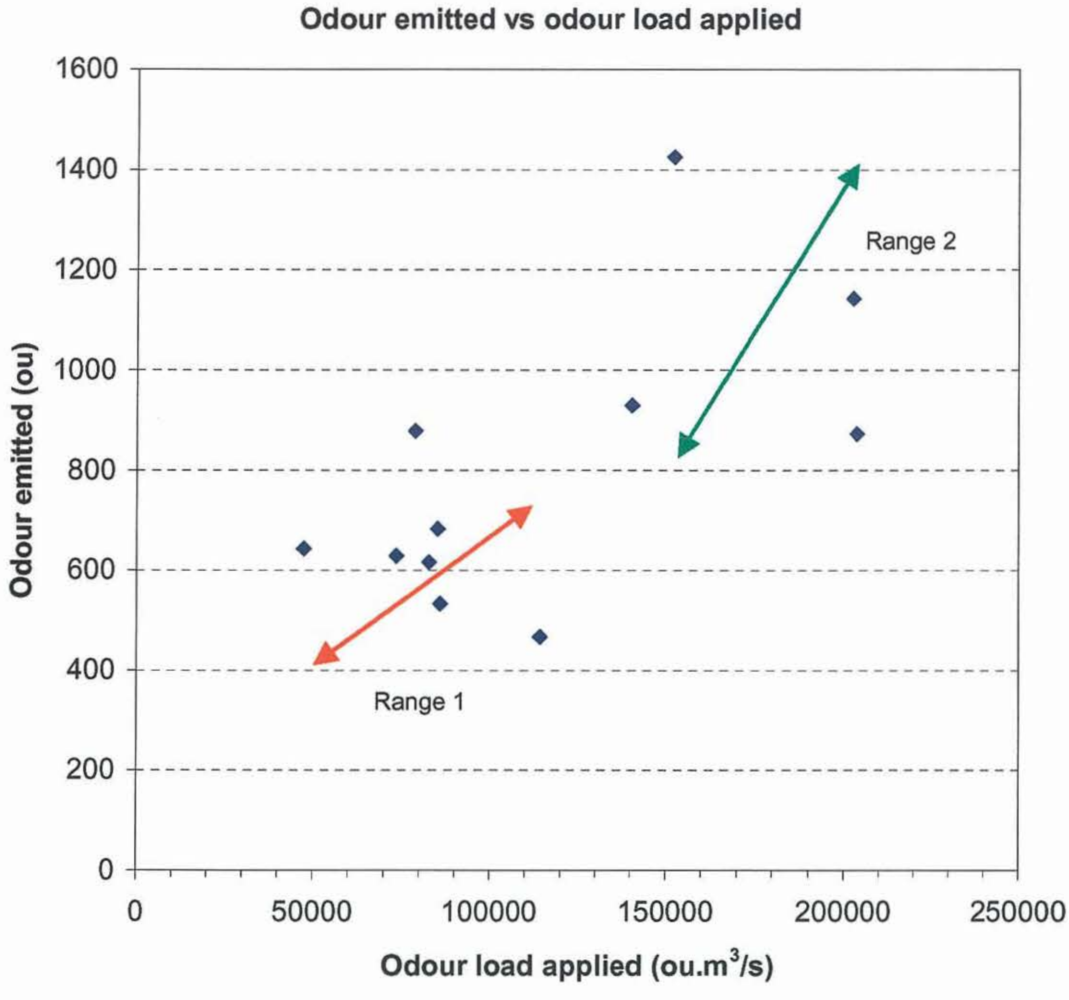

Figure 3 Odour emitted (ou) applied vs. odour load applied (ou.m^3/s) to the Biofilter during Stage 1

4 Conclusions

The average odour removal efficiency of the biofilter based on samples collected during steady state operation is approximately 83%. The biofilter removes a similar percentage of odour under higher loads as it does when treating lower odour emission loads for inlet odour emission rates ranging between 35 000 and 190 000 ou.m^3/s. At an application rate of greater than 120,000 ou.m^3/s, outlet odour concentrations greater than 1000 ou typically occur. Although the outlet odour concentration may be considered to be high, the odour offensiveness is not considered to be high, based on observations during sampling throughout the project.

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Table of Contents

1 Executive Summary

Pacific Air & Environment (PAE) was engaged by Meat & Livestock Australia (MLA) to monitor and evaluate the performance of a newly installed biofilter for control of odorous emissions from rendering at the Australian Country Choice (ACC) Cannon Hill meat-processing site. Stage 1 of the study was completed over a ten-week period from 24th May 2001 to 26th July 2001 during which the biofilter came online and the rendering plant scaled operations up to full production rates. Stage 2 of the project operated from October 2001 until early February 2003.

This report outlines the results of the Stage 1 and Stage 2 odour sampling conducted from 25 October 2001 to 6 February 2003 and assesses the performance of the biofilter during both start-up and steady state operation. Assessment is primarily based on odour monitoring of emissions at the biofilter inlet and outlet streams. Observations on the biofilter operation were noted and these are presented to support monitoring results.

The key indicator in measuring the performance of the biofilter is the odour removal efficiency, calculated from the ratio of odour load that is removed by the biofilter to the load that is fed to the biofilter. The overall odour removal efficiency of the biofilter is approximately 83%. Odour monitoring results are presented in Table 2 and Table 3 and plotted in Figure 2 and Figure 3. The table and plots detail the variation in monitoring results between the sampling dates.

The removal efficiency has been observed to increase throughout the stage 2 period. The increase in efficiency may be attributed to either a decrease in flow rate, and corresponding increase in residence time, or an increase in bacterial activity in the biofilter. Figure 7 shows how the removal efficiency has reached equilibrium, and can be expected to now remain uniform.

The odour removal efficiency is particularly useful for analysing how the biofilter reacts to changes in the input load. The effect of changing load on the removal efficiency of the biofilter during Stage 1 is presented in Figure 4. The plot shows odour load applied to the biofilter against the total load removed. For input odour emission rates ranging between 35 000 and 190 000 ou.m^3/s the odour removal rate is reasonably uniform around a value of approximately 83%. The biofilter removes a similar percentage of odours under higher loads (up to 190 000 ou.m^3/s) as it does when treating the lower input of odour (down to 35 000 ou/s). The effect of changing load on the removal efficiency of the biofilter during Stage 2 is presented in Figure 6.

Individual bed performance was analysed by comparing the results for individual stacks and composite samples. The composite mixtures, which were a 50:50 mixture of two stacks, were alternated throughout the study period. The results indicate that individual performance of each biofilter bed fluctuated slightly but as a whole, the biofilter efficiency was relatively uniform.

During Stage 1 the average weekly outlet odour concentrations ranged from 470 - 1420 ou. During Stage 2 the measured outlet odour concentrations ranged from 456 to 2080 ou. Although the outlet odour concentrations appear to be reasonably high it is suspected, based on limited observations by the authors of this report, that the odour offensiveness at the inlet is much higher than at the outlet stacks. Odour offensiveness is a measure of how pleasant or unpleasant an odour is, and can be tested by introducing standardised concentrations of various odours to panellists who assign offensiveness ratings on a simple scale.

It was observed during the sampling program that the odour emitted from the outlet stacks had a vastly different characteristic smell to the untreated rendering emissions that are fed to the biofilter. The outlet odour could be described as an earthy type smell, similar to moist soil, at the sample ports. The outlet odour was not considered to be offensive whilst odour sampling was being conducted or when deliberate attempts were made to smell it.

Volume flow through each bed of the biofilter was variable during the start-up phase (Stage 1). The volume flows were measured at the inlet duct, air washer and outlet stacks upon commencement of the monitoring program and again at week 5 and week 10. Initially each bed received approximately equal amounts of the input load in accordance with the biofilter design. However, a volume flow imbalance between the beds was observed during the study. The biofilter beds that received the higher load due to higher volume flows appear to have performed similarly to the beds that received the lower load.

Due to concerns relating to the reliability of volumetric flow results during Stage 1, ACC provided volumetric flow measurement data for odour sampling during Stage 2. These tests were performed using an L-type pitot tube and a digital manometer to the US National Environmental Balancing Bureau (NEBB) standard for measurement of velocity. These measurements indicated that the flow through the biofilter was approximately 32 Nm^3/h for the first two sampling dates, and 23.6 Nm^3/h for the third sampling date during Stage 2. The flow is assumed to be distributed equally between outlet stacks.

The headline conclusions from this study, therefore, are the following:

- The biofilter odour reduction is approximately 83% and appears to have reached equilibrium.
- Little additional information is derived from sensor measurements of biofilter operating parameters. Effort needs to be invested in ensuring accurate and representative performance of the biofilter sensors.

2 Conclusions

This section outlines the conclusions for the ACC biofilter performance monitoring for the Stage 1 start up period and Stage 2 steady state period.

2.1 Stage 1

Stage 1 of the ACC biofilter performance monitoring was conducted over a ten-week start-up period, beginning on 24 May 2001 and concluding on the 26th July 2001. Odour sampling was conducted at the biofilter inlet duct and outlet stacks and observations on operations were recorded over the study period.

The main conclusions to the study can be summarised by the following points:

- The average odour removal efficiency of the biofilter based on weekly samples ranged from 63% to 89%.
- The overall average efficiency of odour removal across the biofilter for all samples taken during the start-up period was approximately 83%.
- The biofilter removes a similar percentage of odour under higher loads as it does when treating lower odour emission loads for inlet odour emission rates ranging between 35 000 and 190 000 ou.m^3/s.
- Individual performance of each biofilter bed fluctuated during the start-up phase but as a whole the biofilter performed at a reasonably uniform efficiency.
- Although the outlet odour concentration may be considered to be high, the odour offensiveness is not considered to be high, based on personal observations during sampling throughout the project.

2.2 Stage 2

Stage 2 of the ACC biofilter steady-state performance monitoring has been conducted beginning on 25 October 2001 and ending 6 February 2003. Odour sampling was conducted at the biofilter inlet duct and outlet stacks and observations on operations were recorded over the study period.

The main conclusions to the study can be summarised by the following points:

- The average odour removal efficiency of the biofilter based on the four samples ranged from 60% to 89%.
- The overall average efficiency of odour removal across the biofilter for all samples taken during the steady state period was approximately 79%.
- The efficiency of odour removal appears to have reached a steady state at approximately 89%.
- Individual performance of each biofilter bed fluctuated slightly during stage 2 but, as a whole, the biofilter performed at a reasonably uniform efficiency.
- Although the outlet odour concentration may be considered to be high, the odour offensiveness is not considered to be high, based on observations.

3 Study Objectives

Pacific Air & Environment (PAE) was engaged by Meat & Livestock Australia (MLA) to monitor and evaluate the performance of a newly installed biofilter for control of odorous emissions from rendering at the Australian Country Choice (ACC) Cannon Hill meat-processing site.

Stage 1 of the study was completed over a ten week period during which the biofilter came online and the rendering plant scaled operations up to full production rates. The main objective of stage 1 of the study was to investigate the performance of the biofilter during the start-up phase.

Stage 2 of the project was operational from October 2001 until February 2003. It evaluated the steady-state performance of the biofilter using quarterly odour sampling and analysis.

This report outlines the results of the Stage 1 and Stage 2 sampling.

4 The ACC Biofiltration System

The newly installed biofilter at ACC Cannon Hill is a closed biofiltration system. It uses micro-organisms to break down organic (and some inorganic) odours from the inlet gas stream, which contains foul odours from the rendering plant. The micro-organisms digest the odorous compounds, converting them primarily to water and carbon dioxide. The treated gas stream is emitted through the outlet stacks to the atmosphere. Odour in the outlet air is caused by very low mass concentrations of organic compounds entrained into the flow from the biofilter medium, plus possibly some residual compounds from the rendering.

Figure 1 is a photograph of the ACC biofilter with the major components of the system identified. The foul gases enter the system through an inlet duct (1650 mm ID), which is fed from the rendering section of the meat processing plant. A 150 kW fan operates at 42 Hz to induce approximately 115 000 Nm^3/h of airflow through the system. The inlet stream flows through an air washer, which helps to remove volatile fatty acids from the gases. The air washer consists of an expansion in the ducting where water (which is inoculated with odour treating bacteria) is sprayed across the flow of inlet gases. The water is recirculated into the air washer through a sump, where approximately 10% is purged and fresh make-up water is added. After the air washer the inlet gases are fed through an inlet manifold into the four biofilter modules, which are equal in size. The dimensions of each module are 16 m (L) x 4 m (W) x 3 m (H). The biofilter currently treats approximately 450 m^3/h of gas per m^2 of bed. Each module has a multivane damper on the inlet riser which are designed to provide equal flow across all modules. The odorous gases flow through the filter media of each module and are emitted to the atmosphere via four individual stacks (700 mm x 2000 mm) that serve each module.

Figure 1 Major Components of the ACC Biofilter

5 Results

5.1 Volume Flow Monitoring

Volumetric flow through the inlet manifold and through the biofilter exhaust stacks was measured at the same time of odour sampling.

5.1.1 Stage 1

Volume flow through each bed of the biofilter was variable during the start-up phase. The volume flows were measured at the inlet duct, air washer and outlet stacks upon commencement of the monitoring program on 24 May. The results of the volume flow calculations indicated that each bed was initially receiving approximately equal amounts of the input load in accordance with the biofilter design (see Table 4□3). However, by the third week of monitoring it was observed that a higher flow was being emitted from stacks 3 and 4 in comparison with stacks 1 and 2. A volume flow measurement on week 5 (21 June) verified the suspected higher flows in 3 and 4, which were approximately twice the rate of 1 and 2. It is suspected that the unbalanced flow rates through the biofilter beds existed from week 3 (7 June) through to week 9 (19 July). The effect of the higher flows was not evident in the odour sampling results from the outlet stacks. The outlet concentrations of stacks 3 and 4 did not exhibit any marked differences from stacks 1 and 2. The biofilter beds that received the higher load due to higher volume flows appear to have performed similarly to the beds that received the lower load.

Table 1 Volume Flow Monitoring Results (Nm³/sec)

Date	Inlet	Air Washer	Stacks (1a) 1	2	3	4	Total
24-May (1)	21.9	26.5	4.99	5.73	5.5	5.7	21.9
21-June (1)	24.9		4.95	4.34	7.5	8.11	24.9
26-July (2)	26.1	23.9	5.33	6.98	6.23	6.82	25.4

Notes:Table 1

(1). Velocity profiles were obtained across biofilter flows using a calibrated hotwire anemometer. Volume flow rate was calculated in accordance with Vic EPA Standard Analytical Procedure B4 "Gas Velocity and Volume Flow Rate". (1a) A correction factor was applied to the measured flows across the stacks, to account for measurement error. The sample port did not allow for traversing the cross sectional plane of the stack in both directions with the hot wire anemometer. The correction to the measured values was verified by volume flow testing using a pitot tube (see (2))

(2). Velocity profiles were obtained across biofilter flows using a calibrated L-type pitot tube and a Testo digital manometer. Volume flow rate was calculated in accordance with Vic EPA Standard Analytical Procedure B4 "Gas Velocity and Volume Flow Rate".

(3) Nm³ = Gas volume in wet cubic metres at STP (0°C & 101.325 kPa).

5.1.2 Stage 2

Due to concerns relating to the reliability of previous volumetric flow results, ACC provided volumetric flow measurement data for the steady state sampling period. These tests were performed using an L-type pitot tube and a digital manometer to the US National Environmental Balancing Bureau (NEBB) standard for measurement of velocity. These measurements indicated that the flow through the biofilter was approximately 32 Nm^3/s for the first two sampling dates, and approximately 23.6 Nm^3/h for the third sampling date. These values were used accordingly for all calculations within this report. It was assumed the flow was distributed equally between outlet stacks.

The final odour sampling was conducted on 6 February 2003. Volumetric flow measurements from stacks 1 and 2 showed significantly lower volumetric flows than had been measured in previous sampling tests (approximately 2.2 Nm^3/s compared to an expected flow of approximately 5 Nm^3/s). The measured inlet flow rate was approximately 21.4 Nm^3/s, with the total outlet flow rate of 15.2 Nm^3/s. Anecdotal evidence, and physical observations suggest[1] that flow through units 1 and 2 is less than that through units 3 and 4, and this was clearly apparent on 6 February 2003. However, this does not explain the measured discrepancy between inlet and total outlet volumetric flows as tested on 6 February 2003. Testing error is one potential explanation, as is an air leak between the biofilter inlet and units 1 and 2.

5.2 Performance

The key indicator in measuring the performance of the biofilter is the odour removal efficiency. It is based on the ratio of odour load that is removed by the biofilter to the load that is fed to the biofilter. This section describes the performance of the biofilter during the Stage 1 and Stage 2 sampling periods.

Additional odour sampling was conducted subsequent to Stage 1 and prior to Stage 2. The additional sampling produced comparable results to the sampling performed during the Stage 1 and Stage 2 periods. The results of the additional sampling are included in a complete sample summary in Appendix A.

5.2.1 Stage 1

The results of the odour monitoring program conducted over the start-up phase are provided in Table 2. The concentrations and emission rates are given for each round of sampling. The odour removal efficiency is provided for each bed (or composite of beds where composite samples were taken) and for the total odour removed by the biofilter (bolded) for each round of samples.

[1] Conversation between Jim Hocking (ACC) and Fred Turatti (PAE), 6 February 2003.

The efficiency of odour removal varied between samples, ranging from 63% - 89%. The overall average efficiency of odour removal across the biofilter for all samples taken during the start-up period was approximately 80%.

Table 2 Summary of Stage 1 odour sampling results from Australian Country Choice biofilter

Date	Time(1)	Inlet Sample Concentration (ou) (3)	Inlet Sample Emission Rate (ou.m³/s) (4)	Outlet Stack Samples (2) Concentration (ou) (3)	Outlet Stack Samples (2) Emission Rate (ou.m³/s) (4)	Odour Reduction Removal Efficiency (%) (5)
24th May	14:10	*Inlet:* 3 920	*Inlet:* 85 848	*Stack 1:* 557 *Stack 2:* 671 *Stack 3:* 557 *Stack 4:* 346	*Stack 1:* 2 779 *Stack 2:* 3 845 *Stack 3:* 3 064 *Stack 4:* 1 972 *Total: 11 660*	86 83 86 91 ***86***
24th May	13:25	*Inlet:* 3 320	*Inlet:* 72 708	*Stack 1&3:* 522 *Stack 2&4:* 710	*Stack 1&3:* 5 476 *Stack 2&4:* 8 115 *Total: 13 591*	84 79 ***81***
31st May	12:45	*Inlet:* 2 810	*Inlet:* 61 539	*Stack 1&3:* 605 *Stack 2&4:* 653	*Stack 1&3:* 6 346 *Stack 2&4:* 7 464 *Total: 13 810*	78 77 ***78***
7th June	16:15	*Inlet:* 1 720	*Inlet:* 37 668	*Stack 1&3:* 694 *Stack 2&4:* 592	*Stack 1&3:* 7 280 *Stack 2&4:* 6 767 *Total: 14 047*	60 66 ***63***
14th June	12:39	*Inlet:* 2 770	*Inlet:* 60 663	*Stack 1&3:* 840 *Stack 2&4:* 917	*Stack 1&3:* 8 812 *Stack 2&4:* 10481 *Total: 19 293*	70 67 ***68***
21st June	13:06	*Inlet:* 4 170	*Inlet:* 103 833	*Stack 1&3:* 388 *Stack 2&4:* 546	*Stack 1&3:* 4 831 *Stack 2&4:* 6 798 *Total: 11 628*	91 87 ***89***
28th June	12:59	*Inlet:* 3 140	*Inlet:* 78 186	*Stack 1:* 473 *Stack 2:* 950 *Stack 3:* 915 *Stack 4:* 392	*Stack 1:* 2 341 *Stack 2:* 4 123 *Stack 3:* 6 863 *Stack 4:* 3 179 *Total: 16 506*	85 70 71 88 ***78***
5th July	14:08	*Inlet:* 5 320	*Inlet:* 132 468	*Stack 1&4:* 1 450 *Stack 2&3:* 1 400	*Stack 1&4:* 18937 *Stack 2&3:* 16576 *Total: 35 513*	73 74 ***73***
12th July	11:54	*Inlet:* 7 460	*Inlet:* 185 754	*Stack 1&4:* 914 *Stack 2&3:* 831	*Stack 1&4:* 11937 *Stack 2&3:* 9839 *Total: 21 776*	88 89 ***88***
19th July	13:15	*Inlet:* 7 560	*Inlet:* 188 244	*Stack 1&4:* 1 310 *Stack 2&3:* 975	*Stack 1&4:* 17109 *Stack 2&3:* 11544 *Total: 28 653*	83 87 ***85***
19th July	17:45	*Inlet:* 4 980 (6)	*Inlet:* 124 002			
26th July	13:40	*Inlet:* 5 680	*Inlet:* 148 248	*Stack 1:* 810 *Stack 2:* 1 026 *Stack 3:* 1 009 *Stack 4:* 872	*Stack 1:* 4 317 *Stack 2:* 7 161 *Stack 3:* 6 286 *Stack 4:* 5 947 *Total:* 23 712	86 82 82 85 ***84***
26th July	17:40	*Inlet:* 7 380 (6)	*Inlet:* 192 618			
Overall Average Removal Efficiency of Odour Emissions across Biofilter						***80 %***

Notes: Table 2

(1). Time that the first sample was taken. Subsequent samples were taken within 30-50 minutes.

(2). Some source tests involve composite samples, eg. 'Stack 1&3', in which the sample bag was filled with air from each of the nominated stacks for a nominal sampling time of 1.5 minutes, to achieve a 50:50 mix of air from the two sources.

(3). ou = Odour concentration (odour units) (as determined by olfactometry panel).

(4). ou.m³/s = Odour emission rate per second (i.e. odour concentration (ou) by volumetric flow rate (m³/s))
(5). Odour removal efficiency is based on the ratio of average odour concentration across outlet stacks to the inlet odour concentration (i.e. [1-{average concentration out}/{concentration in}] x 100%) or equally, the ratio of total odour emissions from all stacks to the rate of emissions entering the biofilter (i.e. [1-{total emission rate out}/{emission rate in}] x 100%).
(6). Additional inlet odour samples taken during early evening. No outlet samples were taken with these samples.
(7). Note that it is not a requirement of the Australian Standard 4323.3 (Dynamic Olfactometry) to standardise odour measurements with respect to the butanol threshold provided the butanol threshold is in the range 20 - 80 ppb.

5.2.2 Stage 2

The results of the odour monitoring program conducted over the steady-state phase of the project are provided in Table 3. The concentrations and emission rates are given for each round of sampling. The odour removal efficiency is provided for each bed (or composite of beds where composite samples were taken) and for the total odour removed by the biofilter (bolded) for each round of samples.

The efficiency of odour removal varied between samples, ranging from 60% to 89%. The overall average efficiency of odour removal across the biofilter for the steady-state period was approximately 78%.

Table 3 Stage 2 odour sampling results from Australian Country Choice biofilter

Date	Time (1)	Inlet Sample Concentration (ou) (3)	Inlet Sample Emission Rate (ou.m³/s) (4)	Outlet Stack Samples (2) Concentration (ou) (3)	Outlet Stack Samples (2) Emission Rate (ou·m³/s) (4)	Odour Reduction Removal Efficiency (%) (5)
25/10/2001	16:04	3 450	110 000	*Stack 1:* 1 400	*Stack 1:* 11 200	59
				Stack 2: 1 430	*Stack 2:* 11 400	59
				Stack 3: 1 340	*Stack 3:* 10 700	61
				Stack 4: 1 320	*Stack 4:* 10 500	62
					Total: 43 800	**60**
30/04/2002	13:17	7 880	252 000	*Stacks 1&4:* 2 080	*Stack 1&4:* 33 200	74
				Stacks 2&3: 1 730	*Stack 2&3:* 27 600	78
					Total: 60 800	***76***
16/07/2002	14:20	5 169	122 000	*Stacks 1&3: 456*	*Stacks 1&3:* 5 383	91
				Stacks 2&4: 748	*Stacks 2&4:* 8 831	86
					Total: 14 214	**88**
6/02/2003	09:19	7 000	150 000	*Stack 1:* 830	*Stack 1:* 1 901	88
				Stack 2: 750	*Stack 2:* 1 620	89
				Stack 3: 830	*Stack 3:* 4 424	88
				Stack 4: 750	*Stack 4:* 4 095	89
					Total: 12 040	**89**
Overall Average Removal Efficiency of Odour Emissions across Biofilter						***78 %***

Notes:Table 3
(1). Time that the first sample was taken. Subsequent samples were taken within 30-50 minutes.
(2). Some source tests involve composite samples, eg. 'Stack 1&3', in which the sample bag was filled with air from each of the nominated stacks for a nominal sampling time, to achieve a 50:50 mix of air from the two sources.
(3). ou = Odour concentration (odour units) (as determined by olfactometry panel).
(4). ou·m³/s = Odour emission rate per second (i.e. odour concentration (ou) by volumetric flow rate (m³/s))
(5). Odour removal efficiency is based on the ratio of average odour concentration across outlet stacks to the inlet odour concentration (i.e. [1-{average concentration out}/{concentration in}] x 100%) or equally, the ratio of total odour emissions from all stacks to the rate of emissions entering the biofilter (i.e. [1-{total emission rate out}/{emission rate in}] x 100%).
(6). Note that it is not a requirement of the Australian Standard 4323.3 (Dynamic Olfactometry) to standardise odour measurements with respect to the butanol threshold provided the butanol threshold is in the range 20 - 80 ppb.
(7). Dynamic olfactometry was performed by Unilabs Environmental.

The odour sampling results for Stage 1 and Stage 2 provided in Table 2 and Table 3 respectively are displayed together as plots in Figure 2 and Figure 3. Figure 2 presents the measured inlet and outlet odour concentrations for each round of sampling, indicating how the emissions feeding into and being emitted from the biofilter changed over the start-up and steady state periods. Figure 3 shows the results of outlet concentrations only.

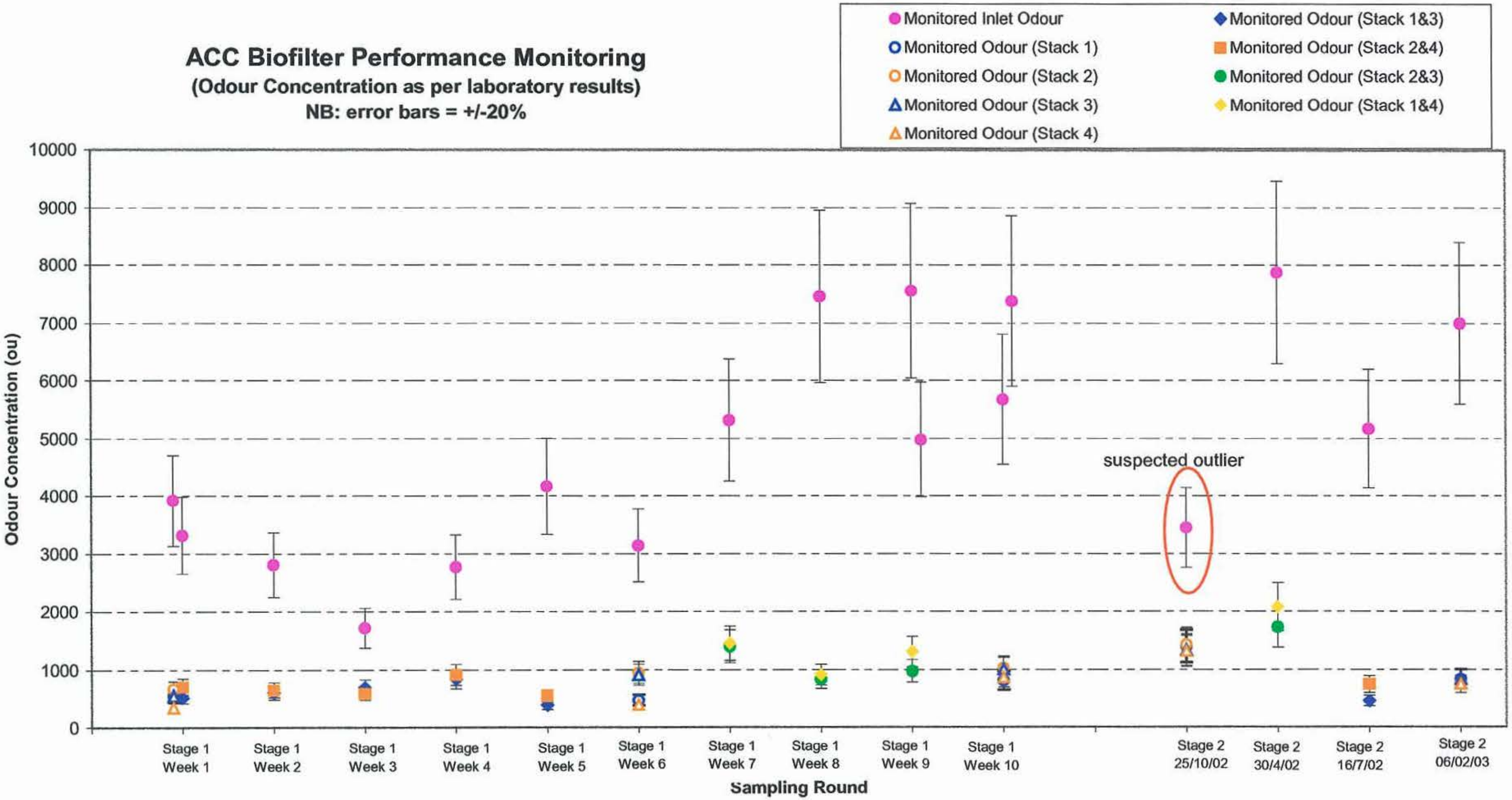

Figure 2 **Monitored Odour Concentrations (ou) at the Inlet Duct and Outlet Stacks (including composite samples)**

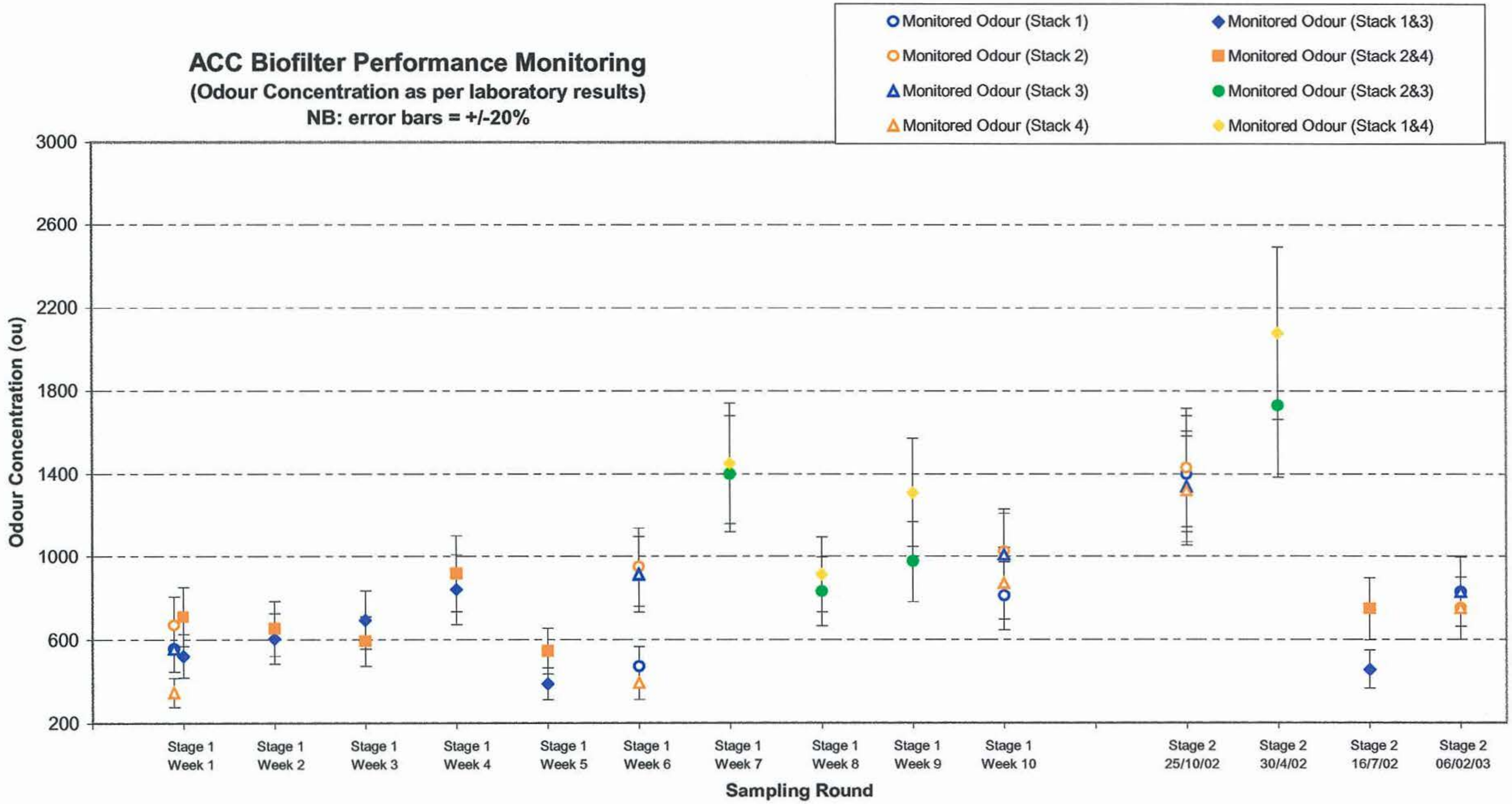

Figure 3 **Monitored Odour Concentrations (ou) at the Outlet Stacks (including composite samples)**

5.3 Overall odour removal efficiency

5.3.1 Stage 1

The odour removal efficiency is particularly useful for analysing how the biofilter reacts to changes in the input load. Figure 4 presents the effect of changing load on the removal efficiency of the biofilter for Stage 1. The plot shows load applied to the biofilter against the total load removed. For input odour loads ranging between 35 000 to 190 000 ou.m^3/s the odour removal rate is reasonably uniform as indicated by the small scatter of data points around the linear trendline. The biofilter removes a similar percentage of odours under higher loads (up to 190 000 ou.m^3/s) as it does when treating the lower odour (down to 35 000 ou.m^3/s). The trendline equates to a removal efficiency of approximately 83%.

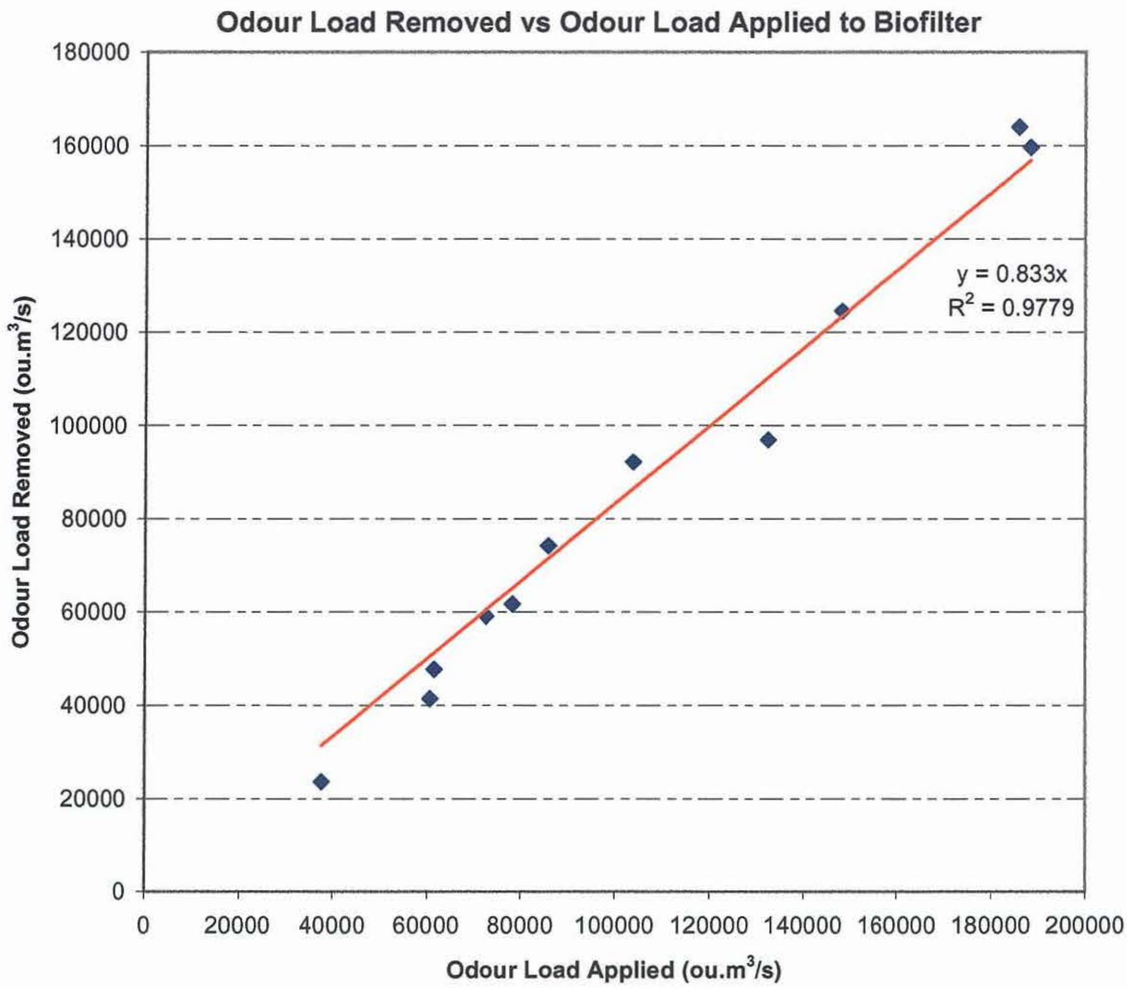

Figure 4 Odour Load Removed vs. Odour Load Applied to Biofilter During Stage 1

Figure 5 shows the relationship between odour emitted from the odour load applied to the biofilter. It shows two distinct ranges of biofilter operation efficiency. Below an odour application rate of approximately 120,000 ou.m^3/s (inlet flow measured together with odour concentration samples), exit odour concentrations fall to lower than 1000 ou. At an application rate of greater than 120,000 ou.m^3/s, the outlet odour concentrations greater than 1000 ou typically occur.

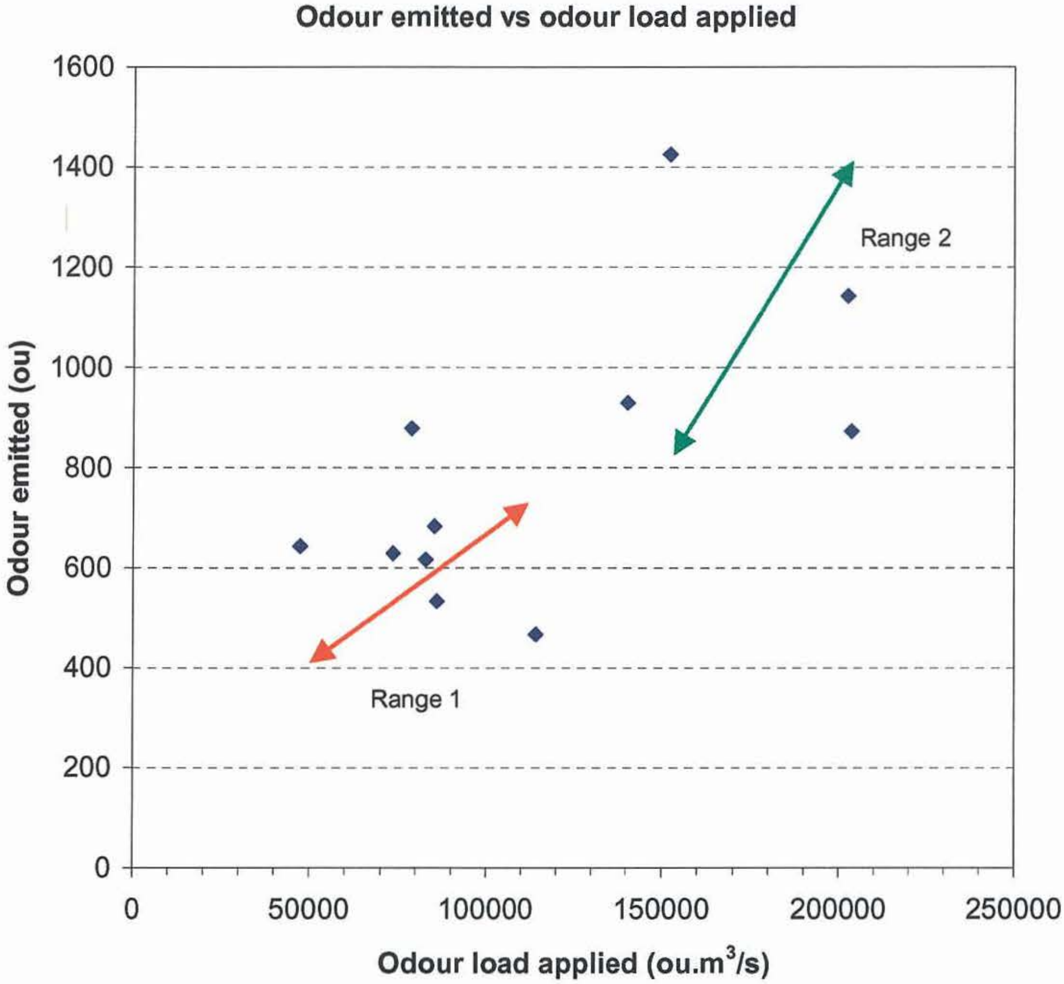

Figure 5 Odour emitted (ou) applied vs. odour load applied (ou.m^3/s) to the Biofilter during Stage 1

5.3.2 Stage 2

Figure 6 presents the effect of changing load on the removal efficiency of the biofilter based on Stage 2 results. The plot shows load applied to the biofilter against the total load removed. If a linear relationship is assumed to exist between odour load removed and odour load applied (as is shown in Figure 6), then a removal efficiency for the biofilter of approximately 79% is obtained.

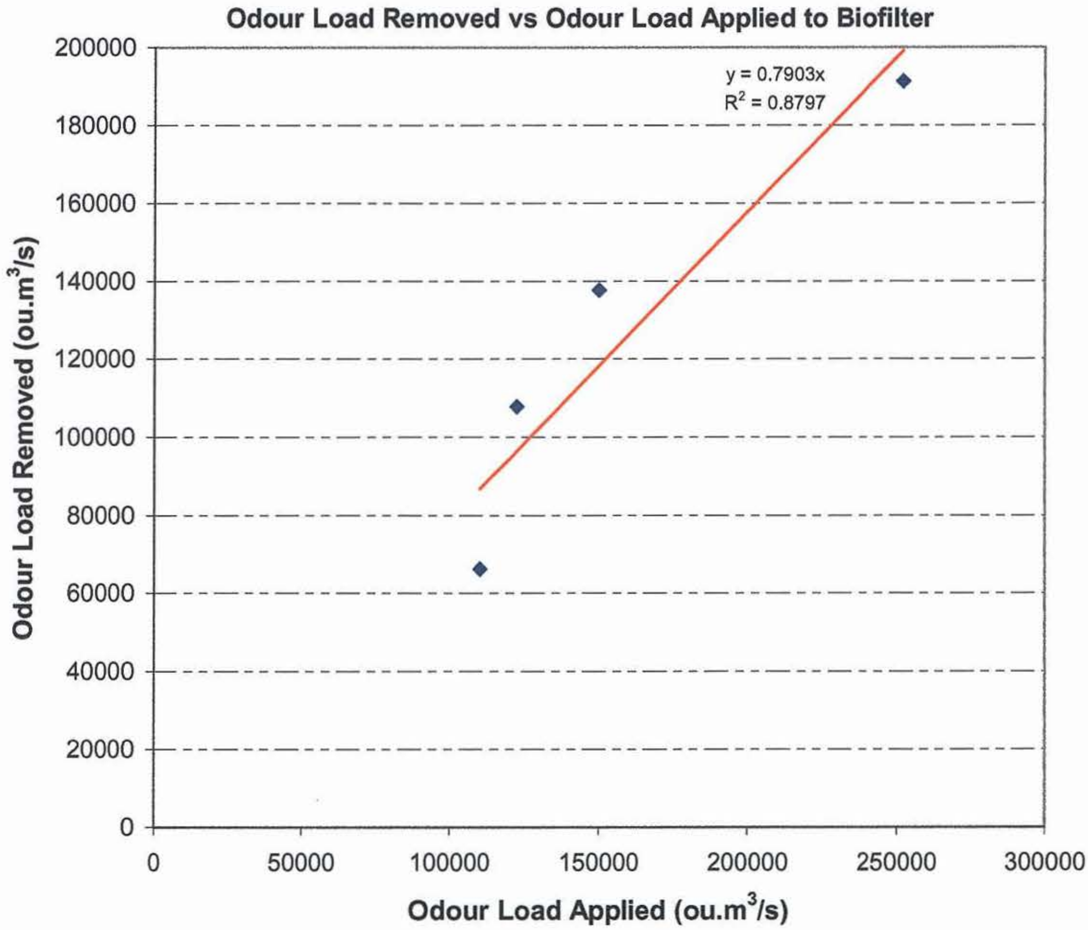

Figure 6 **Odour Load Removed vs. Odour Load Applied to Biofilter during Stage 2**

Assuming a linear relationship, flow measured at the same time as odour sample collection.

For the first sample (25 October 2001) the average outlet concentrations ranged between 1 320 and 1 400 ou. The inlet odour concentrations for the second sample (30 April 2002) were significantly higher, but higher removal efficiencies (about 75% compared to about 60%) led to only slightly higher outlet concentrations (1 730 and 2 080 ou). Similar inlet odour concentrations and a greater odour reduction efficiency (88%) for the third sample (16 July 2002) led to outlet concentrations that were significantly lower (456 and 748 ou) than was recorded for the previous two samples. The increase in efficiency may have been a result of a reduction in flow rate (23.6 Nm3/s compared to 32 Nm3/s), which led to an increase in residence time, or an increase in the bacterial activity in the biofilter.

The last stage 2 odour sampling was conducted on 6 February 2003. This sampling set showed an odour inlet concentration of approximately 7000 ou, with odour outlet concentrations of 830, 750, 830 and 750 ou, for stacks 1 to 4, respectively. All stacks showed approximately the same odour reduction efficiency of between 88 and 89%.

Figure 7 shows how the efficiency of the biofilter has increased between October 2001 and February 2003. The increase follows a logarithmic pattern, and suggests that the odour reduction efficiency peaks at approximately 89-90%. The available data indicates that bacterial activity has reached equilibrium, and that the performance of the biofilter can be expected to now remain uniform, provided that there is no disturbance to the system.

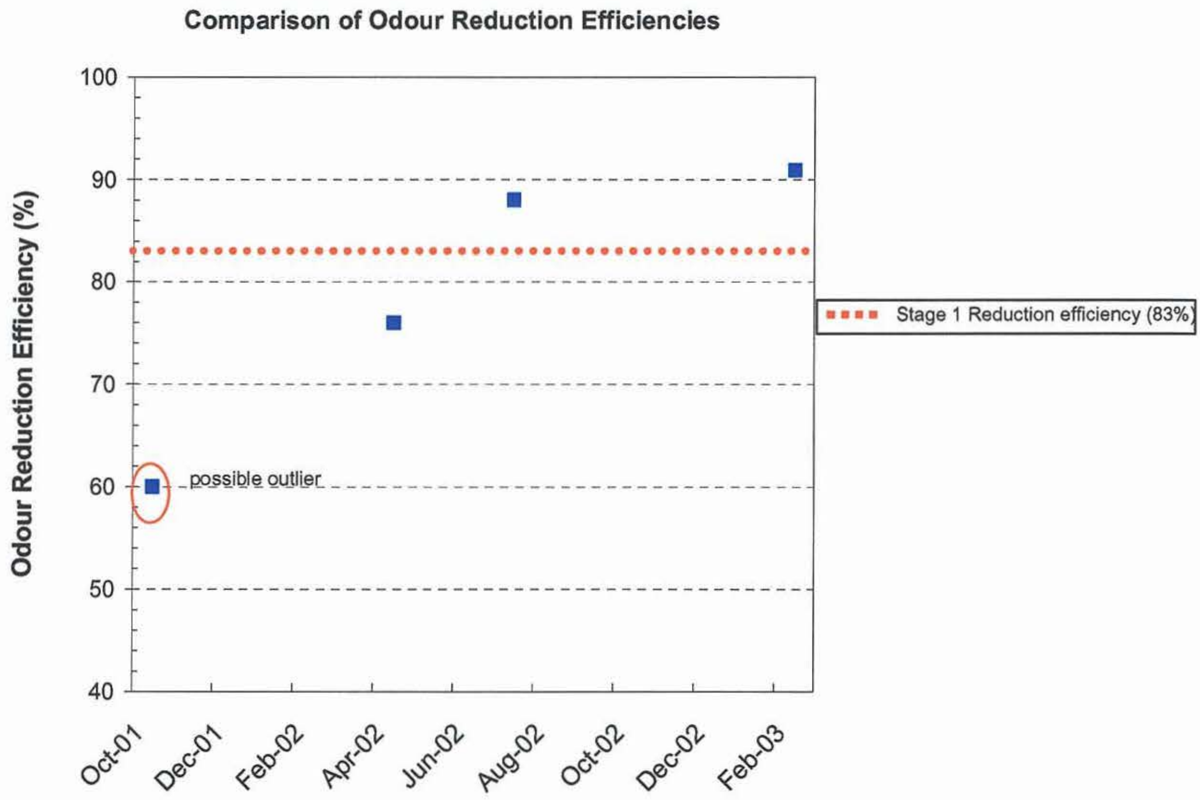

Figure 7 **Comparison of odour reduction efficiency across the biofilter during the stage 2 sampling period.**

5.4 Individual biofilter bed performance

Individual bed performance can be analysed by comparing the results for individual stacks with the composite samples. The composite samples were a 50:50 mixture of exhaust gas from two stacks. This section describes the individual bed performance during the stage 1 and stage 2 study periods.

5.4.1 Stage 1

The composite mixtures were alternated at week 6 of the study (i.e. weeks 1-5 composite samples were of stacks 1 & 3 and 2 & 4; weeks 7-9 composite samples were of stacks 1 & 4 and 2 & 3). From the results of odour samples taken from individual stacks (weeks 1, 6 & 10) it appears that bed 4 consistently outperformed the other beds in reducing odour, followed in order of performance by bed 1, bed 3 and bed 2. However, the composite samples show that stacks 1 and 4 did not consistently outperform stacks 2 and 3, since during week 7-9 when stacks 1 and 4 were sampled as composites, the results indicate a higher outlet concentration than the stack 2 and 3 composites. It appears that individual performance of each biofilter bed fluctuated during the start-up phase, but as a whole the biofilter efficiency was relatively uniform.

For the first half of the Stage 1 study period the average outlet concentrations for each week ranged between 470 - 880 ou. After week 6 inlet odour concentrations increased, effectively causing higher outlet odour concentrations since the odour removal efficiency remained uniform at approximately 80%. The outlet ranged between 870 - 1420 ou from week 7-10.

5.4.2 Stage 2

Composite mixtures were taken as part of the second and third samples (30 April 2002 and 16 July 2002 respectively). The second sample was composites of stacks 1 and 4, and stacks 2 and 3, and the third sample was composites of stacks 1 and 3, and stacks 2 and 4. Odour samples were taken from individual biofilter units in the October 2001 and February 2003 testing. Results of these two analyses imply that there is little statistically significant difference in the performance of individual biofilter beds. It appears that although the individual performance of each biofilter bed may vary slightly, the performance of the biofilter as a whole is relatively uniform.

5.5 Odour Offensiveness

Odour offensiveness is a measure of how pleasant or unpleasant an odour is, and can be tested by introducing standardised concentrations of various odours to panellists who assign offensiveness ratings on a simple scale. It was observed during the sampling program that the odour emitted from the outlet stacks had a different characteristic smell to the untreated rendering emissions that are fed to the biofilter. The outlet odour could be described as an earthy type smell, similar to moist soil. The outlet odour was not considered to be offensive whilst odour sampling was being conducted or when deliberate attempts were made to smell it.

5.6 Other Observations

5.6.1 Stage 1

It is noted that the air washer was reinoculated with an odour treating bacteria during week 8, due to the loss of the original culture. The effect of the absence of bacteria in the air washer during their regeneration period is not evident in the results. Note that the inlet odour sample is taken prior to the air washer. Although outlet concentrations increased around the time of the reinoculation the increase in outlet odour appears to be directly related to the increase in inlet odour rather than to a change in the effectiveness of odour reduction in the air washer.

Biofilter bed 2 was suspected to be operating at higher moisture than the other beds. From week 2-7 it was noticed that the sampling hose was moist upon withdrawal from stack 2. On week 5, stacks 1 and 4 were also operating at higher moisture than normal. The higher moisture did not seem to have any notable effect on the odour results when compared with the results from low moisture stacks.

5.6.2 Reliability of biofilter operating parameters

The biofilter operating parameters were manually recorded from the data management system on the days that odour sampling was performed. They were analysed with the odour monitoring results to determine if any correlations exist. However, the quality of much of the recorded data is questionable due to instrumentation failure, insufficient sensors, and incorrect location of sensors[2]. For example:

- relative humidity sensors provide a reading of greater than 100%, or negative numbers;

[2] Conversation between Bob de Lange (ACC), Jim Hocking (ACC) and Fred Turatti (PAE) on 24 February 2003.

- temperatures often read negative numbers.

Recently installed sensors replacing the original sensors still show significant instability and unreliability, according to ACC staff. It is not possible to correlate sensor data with measured odour concentrations. ACC staff and PAE are satisfied that at least two parameters are reasonably well known:

- The relative humidity of the inlet (post washer) and outlet gas streams is approximately 100%; and
- The temperature of the inlet (post washer) and outlet gas streams is between 28 and 30°C.

These two parameters are not expected to vary in any significant way given the nature of the biofilter process.

Although the failure of instrumentation and lack of some sensors is not expected to have adversely affected the operation of the biofilter directly, it should be recognised that a complete analysis of the operation cannot be performed in the absence of these process parameters, and correlations between odour emissions and operating parameters cannot be determined. In general, based on the parameters that were recorded and appear to be realistic, the biofilter operated in reasonably steady state conditions over the duration of the start-up phase. The biofilter appears to have reached steady-state operating conditions as of February 2003.

6 References

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Unilabs Environmental, Monitoring Conducted on the Biofilter at ACC in Cannon Hill for Pacific Air & Environment 24th & 31st May 2001, (June 2001).

Unilabs Environmental, Monitoring Conducted on the Biofilter at ACC in Cannon Hill for Pacific Air & Environment 7th & 14th June 2001, (June 2001).

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Unilabs Environmental, Monitoring Conducted on the Biofilter at ACC in Cannon Hill for Pacific Air & Environment 25th October 2001, (October, 2001).

Unilabs Environmental, Monitoring Conducted on the Biofilter at ACC in Cannon Hill for Pacific Air & Environment 30th April 2001, (May 2001).

APPENDIX A - SUMMARY OF RESULTS

FROM ALL ODOUR SAMPLING PERFORMED AT THE AUSTRALIAN COUNTRY CHOICE BIOFILTER, CANNON HILL

Summary of odour sampling results from Australian Country Choice biofilter

Sample ID	Sample Date	Source [1]	Sample Time	Odour Concentration (ou) [2]	Odour Reduction (% removal efficiency)	Fraction of performance criteria (420 ou)
KS1	24th May	Pre Biofilter	14:10 - 14:12	3920		
KS2	24th May	Stack 1	14:29 - 14:31	557	85.8	1.3
KS3	24th May	Stack 2	14:29 - 14:31	671	82.9	1.6
KS4	24th May	Stack 3	14:42 - 14:45	557	85.8	1.3
KS5	24th May	Stack 4	14:42 - 14:45	346	91.2	0.8
Average Odour Reduction [4] & Performance Fraction [5]					**86.4**	**1.3**
PAE1	24th May	Pre Biofilter	13:25 - 13:30	3320		
PAE2	24th May	Stack 1&3	13:40 - 13:47	522	85.5	1.2
PAE3	24th May	Stack 2&4	13:51 - 13:57	710	78.6	1.7
Average Odour Reduction [4] & Performance Fraction [5]					**82.1**	**1.5**
PAE4	31st May	Pre Biofilter	12:45 - 12:49	2810		
PAE5	31st May	Stack 1&3	13:02 - 13:06	605	78.5	1.4
PAE6	31st May	Stack 2&4	13:11 - 13:15	653	76.7	1.6
Average Odour Reduction [4] & Performance Fraction [5]					**77.6**	**1.5**
PAE7	7th June	Pre Biofilter	16:15 - 16:17	1720		
PAE8	7th June	Stack 1&3	16:31 - 16:34	694	59.8	1.7
PAE9	7th June	Stack 2&4	16:42 - 16:45	592	65.7	1.4
Average Odour Reduction [4] & Performance Fraction [5]					**62.7**	**1.5**
PAE10	14th June	Pre Biofilter	12:39 - 12:41	2770		
PAE11	14th June	Stack 1&3	12:50 - 12:53	840	69.6	2.0
PAE12	14th June	Stack 2&4	13:00 - 13:03	917	66.9	2.2
Average Odour Reduction [4] & Performance Fraction [5]					**68.2**	**2.1**
PAE13	21st June	Pre Biofilter	13:27 - 13:30	4170		
PAE14	21st June	Stack 1&3	13:06 - 13:09	388	90.7	0.9
PAE15	21st June	Stack 2&4	13:15 - 13:18	546	86.9	1.3
Average Odour Reduction [4] & Performance Fraction [5]					**88.8**	**1.1**
PAE16	28th June	Pre Biofilter	13:22 - 13:25	3140		
PAE17	28th June	Stack 1	12:47 - 12:50	473	84.9	1.1
PAE18	28th June	Stack 2	12:59 - 13:02	950	69.7	2.3
PAE19	28th June	Stack 3	13:07 - 13:10	915	70.9	2.2
PAE20	28th June	Stack 4	13:14 - 13:17	392	87.5	0.9
Average Odour Reduction [4] & Performance Fraction [5]					**78.3**	**1.6**
PAE21	5th July	Pre Biofilter	14:31 - 14:34	5320		
PAE22	5th July	Stack 1&4	14:08 - 14:11	1450	72.7	3.5
PAE23	5th July	Stack 2&3	14:19 - 14:21	1400	72.7	3.3
Average Odour Reduction [4] & Performance Fraction [5]					**73.2**	**3.4**
PAE24	12th July	Pre Biofilter	12:15 - 12:20	7460		
PAE25	12th July	Stack 1&4	11:54 - 12:00	914	87.7	2.2
PAE26	12th July	Stack 2&3	12:05 - 12:11	831	88.9	2.0
Average Odour Reduction [4] & Performance Fraction [5]					**88.3**	**2.1**
PAE27	19th July	Pre Biofilter	12:15 - 12:20	7560		
PAE28	19th July	Stack 1&4	11:54 - 12:00	1310	82.7	3.1
PAE29	19th July	Stack 2&3	12:05 - 12:11	975	87.1	2.3
Average Odour Reduction [4] & Performance Fraction [5]					**84.9**	**2.7**
PAE30	19th July	Pre Biofilter	17:45 - 17:49	4980		
PAE31	26th July	Pre Biofilter	14:18 - 14:21	5680		

PAE32	26th July	Stack 1	13:40 - 13:43	810	85.7	1.9
PAE33	26th July	Stack 2	13:45 - 13:48	1026	81.9	2.4
PAE34	26th July	Stack 3	13:58 - 14:01	1009	82.2	2.4
PAE35	26th July	Stack 4	14:10 - 14:13	872	84.6	2.1
Average Odour Reduction [4]& Performance Fraction [5]					**83.6**	**2.2**
PAE36	26th July	Pre Biofilter	17:40 - 17:43	7380		
CTEQ1	31st Aug	Pre Biofilter	~13:00	6420		
CTEQ2	31st Aug	Stack 1	~13:00	1030	84.0	2.5
CTEQ3	31st Aug	Stack 2	~13:00	1320	79.4	3.1
CTEQ4	31st Aug	Stack 3	~13:00	1290	79.9	3.1
CTEQ5	31st Aug	Stack 4	~13:00	1140	82.2	2.7
Average Odour Reduction [4]& Performance Fraction [5]					**81.4**	**2.8**
PAE37	6th Sept	Pre Biofilter	~13:00	5170		
PAE38	6th Sept	Stack 1	~13:00	1188	77.0	2.8
PAE39	6th Sept	Stack 2	~13:00	1692	67.3	4.0
PAE40	6th Sept	Stack 3	~13:00	1457	71.8	3.5
PAE41	6th Sept	Stack 4	~13:00	1390	73.1	3.3
Average Odour Reduction [4]& Performance Fraction [5]					**72.3**	**3.4**
PAE42	7th Sept	Pre Biofilter	~13:00	3770		
PAE43	7th Sept	Stack 1	~13:00	780	79.3	1.9
PAE44	7th Sept	Stack 2	~13:00	1716	54.5	4.1
PAE45	7th Sept	Stack 3	~13:00	812	78.5	1.9
PAE46	7th Sept	Stack 4	~13:00	1950	48.3	4.6
Average Odour Reduction [4]& Performance Fraction [5]					**65.1**	**3.1**
PAE47	10th Sept	Pre Biofilter	~13:00	2007		
PAE48	10th Sept	Stack 1	~13:00	1064	47.0	2.5
PAE49	10th Sept	Stack 2	~13:00	1037	48.3	2.5
PAE50	10th Sept	Stack 3	~13:00	1066	46.9	2.5
PAE51	10th Sept	Stack 4	~13:00	1086	45.9	2.6
Average Odour Reduction [4]& Performance Fraction [5]					**47.0**	**2.5**
PAE52	12th Sept	Pre Biofilter	~13:00	2352		
PAE53	12th Sept	Stack 1	~13:00	1388	41.0	3.3
PAE54	12th Sept	Stack 2	~13:00	1634	30.5	3.9
PAE55	12th Sept	Stack 3	~13:00	1400	40.5	3.3
PAE56	12th Sept	Stack 4	~13:00	1429	39.2	3.4
Average Odour Reduction [4]& Performance Fraction [5]					**37.8**	**3.5**
PAE57	14th Sept	Pre Biofilter	9:00	2742		
PAE58	14th Sept	Pre Biofilter	~13:00	3441		
PAE59	14th Sept	Stack 1	~13:00	1738	49.5	4.1
PAE60	14th Sept	Stack 2	~13:00	2220	35.5	5.3
PAE61	14th Sept	Stack 3	~13:00	1987	42.3	4.7
PAE62	14th Sept	Stack 4	~13:00	2190	36.4	5.2
Average Odour Reduction [4]& Performance Fraction [5]					**40.9**	**4.8**
PAE63	14th Sept	Pre Biofilter	17:00	3298		
PAE64	27th Sept	Pre Biofilter	~13:00	8278		
PAE65	27th Sept	Stack 1	~13:00	2256	72.7	5.4
PAE66	27th Sept	Stack 2	~13:00	1085	86.9	2.6
PAE67	27th Sept	Stack 3	~13:00	1118	86.5	2.7
PAE68	27th Sept	Stack 4	~13:00	2594	68.7	6.2
Average Odour Reduction [4]& Performance Fraction [5]					**78.7**	**4.2**

PAE69	25th Oct	Pre Biofilter	16:04	3450		

PAE70	25th Oct	Stack 1	16:14	1400	83.1	3.3
PAE71	25th Oct	Stack 2	16:18	1430	82.7	3.4
PAE72	25th Oct	Stack 3	16:22	1340	83.8	3.2
PAE73	25th Oct	Stack 4	16:30	1320	84.1	3.1
Average Odour Reduction [4]& Performance Fraction [5]					**83.4**	**3.3**
PAE74	30 Apr	Pre Biofilter	13:17	7880		
PAE75	30 Apr	Stack 1&4	13:31	2080	74	4.9
PAE76	30 Apr	Stack 2&3	13:44	1730	78	4.1
Average Odour Reduction [4]& Performance Fraction [5]					**76**	**4.5**
PAE77	16 Jul	Pre Biofilter	14:35	5169		
PAE78	16 Jul	Stack 1&3	14:10	456	91	1.1
PAE79	16 Jul	Stack 2&4	14:20	748	86	1.8
PAE79	16 Jul	Pre Biofilter	15:45	2548		
Average Odour Reduction [4]& Performance Fraction [5]					**88**	**1.4**
PAE80	6 Feb 03	Pre Biofilter	09:19	7000		
PAE81	6 Feb 03	Stack 1	09:52	830	88	2.0
PAE82	6 Feb 03	Stack 2	09:46	750	89	1.8
PAE83	6 Feb 03	Stack 3	09:40	830	88	2.0
PAE84	6 Feb 03	Stack 4	09:31	750	89	1.8
Average Odour Reduction [4]& Performance Fraction [5]					**88**	**1.9**

Notes: 1. Some source tests involve composite samples, eg. 'Stack 1&3', in which the sample bag was filled with air from each of the nominated stacks for a nominal sampling time of 1.5 minutes, to achieve a 50:50 mix of air from the two sources.

2. ou = Odour concentration (as determined by olfactometry panel).

3. Note that it is not a requirement of Australian Standard 4323.3 (Determination of Odour Concentration by Dynamic Olfactometry) to standardise odour measurements with respect to the butanol threshold provided the result is determined between the butanol range 20 - 80 ppb.

4. Average Odour Reduction is based on ratio of average odour concentration across outlet stacks to the inlet odour concentration (i.e. [1-{average concentration out}/{concentration in}] x 100%).

5. Fraction of performance criteria = {Odour Concentration (ou)}/{Performance criteria (420 ou)}. Note that the performance criteria only apply within specified plant operating parameters, which are not shown here. See Annexure 1.1 of sub consultant contract between ACC and Clean TeQ for further details.

APPENDIX B - METHODOLOGY FOR MONITORING AND ANALYSIS

General monitoring methodology

During Stage 1 odour sampling was conducted on a weekly basis at the ACC biofilter at Cannon Hill over a ten-week period. During Stage 2 odour sampling was conducted on the following dates - 2 25/10/2001, 30/04/2002 and 16/07/02. The samples were taken at or near to 1pm on most occasions to allow for the rendering plant to reach maximum rates for a few hours before testing. The general approach involved odour sampling of the biofilter inlet duct and the outlet stacks. Volume flows and temperatures were taken throughout the monitoring period. In order to keep monitoring costs down, sampling of outlet stacks involved taking composite samples of two stacks in one sample bag for some sample dates. The monitoring results shown in Table 4□2 provide further detail on the monitoring. The monitoring regime for Stage 1 and Stage 2 is outlined briefly in Table A1 and Table A2 respectively.

Table A1: Monitoring regime for ACC biofilter performance evaluation during Stage 1

Week	Sources sampled for odour	Volume Flow measured	Temperature measured
1[a]	Inlet Individual Stacks 1,2,3,4	Volume flows were taken by hot wire anemometer	Temperatures were taken by hot wire anemometer
1	Inlet Composite Stacks 1&3 and 2&4	See week 1[a]	See week 1[a]
2	Inlet Composite Stacks 1&3 and 2&4	Based on week 1[a]	Based on week 1[a]
3	Inlet Composite Stacks 1&3 and 2&4	Based on week 1[a]	Based on week 1[a]
4	Inlet Composite Stacks 1&3 and 2&4	Based on week 1[a]	Based on week 1[a]
5	Inlet Composite Stacks 1&3 and 2&4	Volume flows were taken by hot wire anemometer	Based on week 1[a]
6	Inlet Individual Stacks 1,2,3,4	Based on week 5	Based on week 1[a]
7	Inlet Composite Stacks 1&4 and 2&3	Based on week 5	Based on week 1[a]
8	Inlet Composite Stacks 1&4 and 2&3	Based on week 5	Based on week 1[a]
9	2 x Inlet Composite Stacks 1&4 and 2&3	Based on week 5	Based on week 1[a]
10	2 x Inlet Individual Stacks 1,2,3,4	Volume flows were taken by L-type pitot tube & digital manometer	Temperature were taken using a calibrated type K thermocouple and a Fluke thermocouple indicator

Notes: a. Katestone Scientific performed odour sampling on the same date on behalf CleanTeq. These data were made available to Pacific Air & Environment and included in the study dataset.

Table A1: Monitoring regime for ACC biofilter performance evaluation for Stage 2

Sample	Sources sampled for odour	Volume Flow Measurement Equipment
25/10/2001	Inlet Individual Stacks 1,2,3,4	L-type pitot tube and digital manometer
30/04/2002	Inlet Composite Stacks 1&4 and 2&3	L-type pitot tube and digital manometer
16/07/02	Inlet Composite Stacks 1&3 and 2&4	L-type pitot tube and digital manometer

Test methods

Gas Velocity and Volume Flow Rate - 24th May 2001 & 21st June 2001

Velocity profiles were obtained across the biofilter stacks using a calibrated hot wire anemometer on 24th May 2001 and 21st June 2001. Positions for velocity pressure measurement were determined by the equal area method. Volume flow rate was calculated in accordance with Victorian EPA Standard Analytical Procedure B4 "Gas Velocity and Volume Flow Rate".

The estimated accuracy is * 10%.

NB: The accuracy of this method was deemed unacceptable when the results were analysed. Due to the set-up of the sample ports on the stacks it was not possible to traverse the cross sectional plane in both directions. The assumption that equal flow exists across the area was invalid. The total flows out of the biofilter stacks were approximately twice the inlet flows. The flows from each stack were corrected to equate to the inlet flows after validation by the pitot tube method on 26 July 2001.

Gas Velocity and Volume Flow Rate - 26th July 2001

Velocity profiles were obtained across the stack using a calibrated L-type pitot tube, and a Testo digital manometer.

Positions for velocity pressure measurement were determined by the equal area method. Gas velocity and volume flow rate were calculated in accordance with Victorian EPA Standard Analytical Procedure B4 - "Gas Velocity and Volume Flow Rate".

The estimated accuracy is ± 10%.

Temperature - 24th May 2001 & 21st June 2001

Temperatures were obtained across the biofilter stacks using a calibrated hot wire anemometer on the 24th May 2001. Temperature was not measured on 21st June 2001.

The estimated accuracy is * 1oC.

Temperature - 26th July 2001

Stack gas temperature was monitored using a calibrated type K thermocouple and a Fluke thermocouple indicator in accordance with British Standard 1041: Part 4 - "Guide to the Selection and Use of Thermocouples". Gas meter temperature was measured with a calibrated mercury in glass thermometer in accordance with BS 1041: Section 2.1 - "Guide to the Selection and Use of Liquid-in-Glass Thermometers".

The estimated accuracy is ± 1oC.

Odour (Australian Standard 4323.3)

Odour sampling and analysis was conducted by Unilabs Environmental in accordance with Australian/New Zealand Standard 4323.3 (Air Quality - Determination of Odour Concentration by Dynamic Olfactometry).

Sample Collection

The samples were collected by Pacific Air & Environment or Unilabs using the "lung-in-the-box" technique. Sample gas was drawn through a Teflon tube that fed into a nalophan sample bag.

Sample Analysis

The odour concentration of each sample was determined using dynamic olfactometry forced choice mode. Two ports were available to each panel member; one presenting the odorous gas and one presenting a neutral reference gas. Individual threshold estimates for each panel member were determined and the corresponding odour concentrations were calculated. The odour panellists were all familiar with the procedure and specially selected in accordance with the Australian Standard criteria. The total number of dilutions of the sample at which 50 percent of all responses of the panellists confirmed odour detection is reported as the odour concentration, and is expressed in odour units (ou).

Offensiveness

Offensiveness is calculated by diluting each sample to an odour concentration of 10 ou. The odour panellists are asked to determine the offensiveness of the sample using the six step scale described in Table A3.

Table A3: Odour Offensiveness Six Step Scale

Description of Odour	Panellist Offensiveness Response	Weighted Offensiveness Rating
No odour detected	0	0
Odour detected, but not annoying	1	0
Odour detected, and a little annoying	2	1
Odour detected, and annoying	3	2
Odour detected, and very annoying	4	4
Odour detected, and extremely annoying	5	8

The offensiveness of the sample is the average of the weighted offensiveness ratings.

DEFINITIONS

ou	Measured odour concentration
ou·m^3/s	Odour unit emission rate
STP	Standard temperature and pressure (0°C and 101.325 kPa).
Nm^3	Gas volume in wet cubic metres at STP.