

final report

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Prepared by: Pacific Air & Environment (PAE)

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Biofilter performance evaluation

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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 startup 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.m³/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.m³/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 Nm³/h for the first two sampling dates, and 23.6 Nm³/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.

Contents

| | Pa | age |
|---------------------|--|----------------------|
| 1 | Conclusions | 5 |
| 1.1 1.2 | Stage 1 Stage 2 | 5 5 |
| 2 | Study Objectives | 6 |
| 3 | The ACC Biofiltration System | 6 |
| 4 | Results | 8 |
| 4.1 | Volume Flow Monitoring | 8 |
| 4.1.1 | Stage 1 | 8 |
| 4.1.2 4.2 | Stage 2 Performance | 9 .10 |
| 4.2.1 | Stage 1 | .10 |
| 4.2.2 4.3 | Stage 2 Overall odour removal efficiency | .12 .16 |
| 4.3.1 | Stage 1 | .16 |
| 4.3.2 4.4 | Stage 2 Individual biofilter bed performance | .17 .19 |
| 4.4.1 | Stage 1 | .19 |
| 4.4.2 4.5 4.6 | Stage 2 Odour Offensiveness Other Observations | . 20 . 20 . 20 |
| 4.6.1 | Stage 1 | . 20 |
| 4.6.2 | Reliability of biofilter operating parameters | .21 |
| 5 | References | . 22 |
| 6 | Appendix A – Summary of results | .23 |
| 7 | Appendix B – Methodology for monitoring and analysis | . 26 |

1 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.

1.1 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.m³/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.

1.2 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.

2 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.

3 The ACC Biofiltration System

The newly installed biofilter at ACC Cannon Hill is a closed biofiltration system. It uses microorganisms 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 Nm³/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 m³/h of gas per m² 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

4 Results

4.1 Volume Flow Monitoring

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

4.1.1 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 4113). 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.

| | Tubi | C I | volume i low monitoring results (ium isee) | | | | |
|------------------------|-------|--------|--|------|------|------|-------|
| Date | Inlet | Air | Stacks ^(1a) | | | | |
| | | Washer | 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 |

Table 1 Volume Flow Monitoring Results (Nm³/sec)

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

4.1.2 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 Nm³/s for the first two sampling dates, and approximately 23.6 Nm³/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 Nm³/s compared to an expected flow of approximately 5 Nm³/s). The measured inlet flow rate was approximately 21.4 Nm³/s, with the total outlet flow rate of 15.2 Nm³/s. Anecdotal evidence, and physical observations suggest¹ 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.

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

4.2 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.

4.2.1 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. 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%.

| | | Inlet | Sample | Outlet Stack | Outlet Stack Samples ⁽²⁾ | | |
|-----------|---------------------|-----------------------------|---------------------------------------|--|---|-----------------------------------|--|
| Date | Time ⁽¹⁾ | Concentration | Emission Rate | Concentration | Emission Rate | Removal | |
| | | (ou) ⁽³⁾ | (ou.m ³ /s) ⁽⁴⁾ | (ou) ⁽³⁾ | (ou.m ³ /s) ⁽⁴⁾ | (%) ⁽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: 2779 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 (8) | 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 | | | | |
| 0 | Overa | II Average Rem | oval Efficiency o | f Odour Emission | s across Biofilter | 80 % | |

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

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). $ou.m^3/s = Odour \ emission \ rate \ per \ second \ (i.e. \ odour \ concentration \ (ou) \ by \ volumetric \ flow \ rate \ (m^3/s))$
- (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.

4.2.2 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%.

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

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

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). $ou \cdot m^3/s = Odour$ emission rate per second (i.e. odour concentration (ou) by volumetric flow rate (m^3/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)

Page 15 of 29

4.3 Overall odour removal efficiency

4.3.1 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.m³/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.m³/s) as it does when treating the lower odour (down to 35 000 ou.m³/s). The trendline equates to a removal efficiency of approximately 83%.





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.m3/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.m3/s, the outlet odour concentrations greater than 1000 ou typically occur.



Odour emitted vs odour load applied

Figure 5 Odour emitted (ou) applied vs. odour load applied (ou.m³/s) to the Biofilter during Stage 1

4.3.2 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.





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.





4.4 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.

4.4.1 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.

4.4.2 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.

4.5 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.

4.6 Other Observations

4.6.1 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.

4.6.2 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 sensors². For example:

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

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

5 References

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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).

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6 Appendix A – Summary of results

From all odour sampling performed at the Australian Country Choice Biofilter Cannon Hill

| 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 |
| | A | verage Odour Red | uction ⁴ & Perform | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perform | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perform | mance Fraction * | 77.6 | 1.5 |
| PAE7 | 7th June | Pre Biofilter | 16:15 - 16:17 | 1720 | 100000200 | |
| 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 |
| | A | verage Odour Red | uction ⁴ & Perform | mance Fraction [°] | 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 |
| | A | verage Odour Red | uction *& Perfor | mance Fraction [°] | 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 |
| DAELC | A | verage Odour Red | uction & Perform | nance Fraction | 88.8 | 1.1 |
| PAEIO | 28th June | Pre Biofilter | 13:22 - 13:25 | 3140 | 01.0 | |
| PAE1/ | 28th June | Stack 1 | 12:47 - 12:50 | 4/3 | 84.9 | 1.1 |
| PAEIS | 28th June | Stack 2 | 12:59 - 13:02 | 950 | 09.7 | 2.3 |
| PAE19 | 28th June | Stack 5 | 13:07 - 13:10 | 915 | 70.9 | 2.2 |
| PAE20 | 28th June | Stack 4 | 15.14 - 15.17 | 592 | 87.5 | 0.9 |
| DAE21 | A Sth Inter | Dra Diofiltar | 14-21 14-24 | sance Fraction | /8.3 | 1.0 |
| PAE22 | 5th July | Stack 1.84 | 14.09 14.11 | 1450 | 70.7 | 2.5 |
| PAE22 DAE23 | Sth July | Stack 184 | 14.08 - 14.11 | 1400 | 72.7 | 3.3 |
| TAL25 | Jui Jui y | Verage Odour Red | uction 4& Perfor | mance Fraction 5 | 73.2 | 3.1 |
| PAF24 | 12th July | Pre Biofilter | 12.15 - 12.20 | 7460 | 13.4 | 3.4 |
| PAE25 | 12th July | Stack 1.84 | 11:54 - 12:00 | 014 | 877 | 2.2 |
| PAF26 | 12th July | Stack 2&3 | 12:05 - 12:11 | 831 | 88 0 | 2.2 |
| 111220 | A | verage Odour Red | uction 4& Perform | mance Fraction 5 | 88 3 | 2.0 |
| PAE27 | 19th July | Pre Biofilter | 12:15 - 12:20 | 7560 | 00.5 | |
| PAE28 | 19th July | Stack 1&4 | 11:54 - 12:00 | 1310 | 82.7 | 31 |
| PAF20 | 19th July | Stack 2&3 | 12:05 - 12:11 | 975 | 87.1 | 23 |
| | A | verage Odour Red | uction 4& Perform | mance Fraction 5 | 84.0 | 2.7 |
| PAE30 | 19th July | Pre Biofilter | 17:45 - 17:40 | 4980 | 94.2 | |
| | ar in our j | | | | | <u>.</u> |

Summary of odour sampling results from Australian Country Choice biofilter

| PAE31 26th July Pre Biofilter 14:18 - 14:21 5680 | 62 |
|--|----|
|--|----|

| | | - | | | | - |
|-------|-----------|------------------|------------------------------|-----------------------------|------|-----|
| 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance Fraction * | 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance Fraction * | 37.8 | 3.5 |
| PAE57 | 14th Sept | Pre Biofilter | 9:00 | 2742 | | |
| | | | · | I | | - |
| 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance Fraction ⁵ | 40.9 | 4.8 |
| PAE63 | 14th Sept | Pre Biofilter | 17:00 | 3298 | | |
| | -1- | | • | ļļ | | • |
| 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 Sent | Stack 3 | ~13:00 | 1118 | 86.5 | 2.7 |
| PAE68 | 27th Sept | Stack 4 | ~13:00 | 2594 | 68.7 | 6.2 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance Fraction ⁵ | 78.7 | 4.2 |
| | | | | | | |
| | | | | | | |

| I | 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance Fraction * | 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 | | |
| | A | verage Odour Red | uction ⁴ & Perfor | mance 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 |
| | A | verage Odour Red | uction ⁴ & Perfor | mance Fraction * | 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.

7 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.

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

| Table A | A1: Monitoring regime for . | ACC I | biofilter | performance | evaluation | during St | age 1 |
|---------|-----------------------------|-------|-----------|-------------|------------|-----------|-------|
| | | | | | | | |

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 fo | r Stage 2 |
|-----------|------------|------------|---------------|-------------|---------------|-----------|
|-----------|------------|------------|---------------|-------------|---------------|-----------|

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

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 $\pm 10\%$.

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 ± 10 C.

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).

Offensivenes

S

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

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

| 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 |

DEFINITIONS

| ou | Measured odour concentration | |
|-----------------|--|--|
| ou•m³/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. | |