THE ODOUR CONTROL FACILITY AT MURRUMBA DOWNS WWTP

Successful commissioning and optimisation of an automated wet chemical scrubbing system

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Abstract

The Murrumba Downs Wastewater Treatment Plant (WWTP) has recently been upgraded to increase capacity of the facility to 30.8 megalitres per day in order to meet the demands of a growing population within Brisbane's Northern Growth Corridor. The project utilised the latest technology in biological nutrient removal and odour control in order to meet rigorous environmental standards.

A significant part of the works was the construction of a new Odour Control Facility (OCF) to eliminate nuisance odours to the surrounding community. The OCF has a capacity of 67,000m^3/hr and comprises a two-stage wet chemical scrubbing system (Venturi scrubber, followed by a packed bed scrubber incorporating the Odorgard® catalyst system) using sodium hydroxide and sodium hypochlorite. In addition, an emergency bypass activated carbon filter system was provided. This paper details the steps in commissioning and optimisation of the odour plant to achieve the required discharge requirements of the project.

Introduction

The Murrumba Downs Waterways for Life Alliance was created in September 2007 to deliver, in two stages, the design and construction of an advanced water treatment plant (AWTP) and an upgraded wastewater treatment plant (WWTP). The WWTP upgrade allows the plant to treat wastewater for the projected population of 2016. The Waterways for Life Alliance comprised John Holland, MWH (Montgomery Watson Harz) and Pine Rivers Regional Council, which later became Moreton Bay Regional Council (MBRC) and is now UnityWater.

The first stage of the Alliance, the construction of the AWTP, commenced in September 2007 and was completed in September 2008. The second stage, the WWTP upgrade, commenced in June 2008 and was completed in January 2011, resulting in a reduction of nitrogen and phosphorous content in the treated effluent. The high-quality discharge complies with the EPA regulation that limits nitrogen to 3mg/l and phosphorous to 1mg/l, making it significantly cleaner when it is released into the Pine River. This paper relates to the OCF plant constructed under the WWTP upgrade, which included the following process/equipment:

- Provision of a new inlet works;
- Provision of two new Flow & Load Attenuation Tanks (FLATs);
- Provision of a new multistage activated sludge Bioreactor No. 2;
- Modification of the existing activated sludge Bioreactor No. 1;
- Modification of existing RAS system on existing Clarifiers No. 1 & 2;
- Provision of 2 new Clarifiers No. 3 & 4;
- Provision of new cloth media tertiary filtration system;
- Provision of a new in-channel UV disinfection system;
- Upgrade of the existing biosolids handling facilities;
- Provision of a new odour management system including odour covers, ducting, chemical scrubbers and exhaust air stack;
- Provision of new chemical systems;
- New outfall pipeline to Pine River.

This paper details the steps in commissioning and optimisation of the OCF to achieve the required discharge requirements of the project.

Background

The existing WWTP was the subject of community complaints and did not comply with the requirements of the current QLD EPA guidelines with respect to odour emissions. The upgrade of the WWTP involved the addition of process units, which (without suitable odour management) would increase the odour footprint of the site and risk increased community impact.

An existing biotower, which was located towards the south of the plant, extracted odour from the following areas:

- Inlet Works – Exit from Grit Chambers;
- Inlet Works – Screenings Building;
- Inlet Pumping Station 102;
- Inlet Pumping Station 103.

The existing odour treatment plant was undersized to be able to cope with the increase in odour sources or achieve the required performance, thus a new, larger plant was proposed.

The odour plant portion of the overall project comprised the design, supply and delivery to site, installation, testing, commissioning, optimisation and performance testing of a two-stage odour control system to treat 67,000m^3/hr of foul

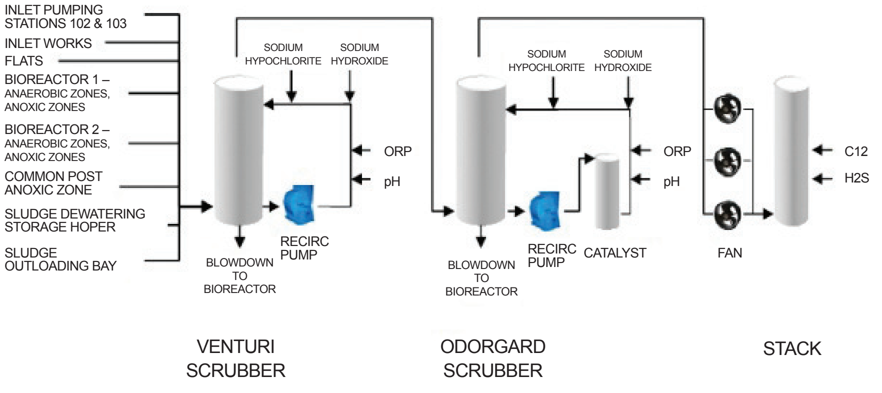

Figure 1. Process Flow Diagram.

air to a 500 OU/m^3 discharge specification. This part of the contract was carried out by Aromatrix Australia.

The new OCF treats odorous air from the following sources:

- New Inlet Works;
- New Flow & Load Attenuation Tanks (FLATs) 1 & 2;
- New Bioreactor 2;

Anaerobic Zone:

  - Anoxic Zone
  - Swing Zone
  - De-aeration Zone
  - Common Post Anoxic Tank;
- Augmented Bioreactor 1
  - Anaerobic Zone
  - Anoxic Zone
  - Swing Zone
  - De-aeration Zone;
- Inlet Pumping Station 102;
- Inlet Pumping Station 103;
- Dewatering System Sludge Storage Hopper;
- Dewatering System Truck Loading Bay.

Odour Plant Flowsheet

The Odour Control Facility (OCF) process flow is detailed in Figure 1, although this excludes the standby carbon filters.

Design Parameters

The OCF is designed on the loads summarised in Table 1 and based on an airflow of 67,000m^3/hr at 20^{o}C. Tables 2 and 3 show the required Venturi and final stack discharge qualities respectively.

Commissioning Procedures

Commissioning of the OCF was undertaken in a systematic process to ensure a high standard was achieved. The sequential commissioning phases were as follows:

- Installation test plans for mechanical, civil and electrical were completed by the relevant installer. This included cable checks for the electrical equipment and hydrostatic testing of vessels.
- Pre-commissioning checks were then completed by the commissioning team, the construction team and the vendors to ensure the equipment was ready for commissioning. This included loading of the control system software and I/O tests.
- Unit commissioning was then completed, which included Site Acceptance Testing of software and recirculation of water through process equipment.
- Process commissioning – introduction of odour load from WWTP and chemicals (Sodium Hypochlorite and Sodium Hydroxide).
- Process optimisation – tuning of ORP and pH PID control loops for each chemical scrubber.
- Performance and reliability test – two separate 14-day tests were completed with stringent guidelines on equipment reliability and discharge limits from the stack (including Hydrogen Sulphide, Mercaptans, Dimethyl Sulphide and odour).

The sequence in which the commissioning was undertaken can be summarised as follows:

- Once pre-commissioning checks were completed, commissioning was undertaken with full load;
- Ensure all sub-systems available;
- Commission under Mode 1 operation;
- Set blowdown rates from Odorgard and Venturi scrubbers;
- Observe control characteristics (pH/ORP) with Odorgard catalyst off-line and adjust control loops;
- Once pH and ORP suitably controlled within correct range and no elemental sulphur being generated, Odorgard catalyst brought online;
- Observe control characteristics and retune loops as required to optimise process;
- Undertake 1st performance test.

Issues During Commissioning

During the commissioning of the Murrumba Downs WWTP (and commissioning of wastewater treatment plants in general), issues always arise irrespective of the amount of testing which is undertaken. Issues which arose during the commissioning process of the OCF included the following:

- Low load conditions and the subsequent impact on the pH and ORP control loops;
- Over-sized equipment due to the low load (e.g. chemical dosing pumps and flowmeters);
- Appropriateness of sampling methods (Di-methyl Sulphide measurement interference);
- Storm events leading to power failures;
- Uncontrolled chemical release;
- Equipment reliability:
  - Chemical dosing pump Profibus communication errors/power and signal line interference;
  - Chemical dosing pump rates;
  - H_2S analyser foundation fieldbus communication errors;
  - pH and ORP probe response times;
  - Water supply system failures.

Further discussion is provided on some of these issues, as follows:

- Dosing pump communication faults – spurious faults were being generated by the Sodium Hypochlorite and Sodium Hydroxide dosing pumps. Initially it was thought to be an issue with the power supply and signal lines. Surge protectors/filters were installed but some faults remained. The code has currently been modified to mask the incorrect faults, while further

Table 1. Odour Control Unit design loads.

Description	Units	Average Load	Peak Load
Hydrogen Sulphide (H_2S)	ppm	47.5	152.0
Ammonia (NH_3)	ppm	0.2	0.5
Mercaptans (R-SH)	ppm	0.8	2.0
VOCs (1)	ppm	7.4	31.7
Di-methyl Sulphide (DMS)	ppm	0.8	1.4
CO_2	ppm	3000	

Table 2. Required Venturi discharge quality.

Parameter	Design % removal	Maximum discharge concentration (ppm)
Hydrogen Sulphide (H_2S)	>60%	60.8
Di-methyl Sulphide (DMS)	>30%	1.0
Mercaptans (R-SH)	>30%	1.4
VOC	-	37.2
Ammonia	>50%	0.25
CO_2	-	3000

discussions are undertaken with equipment suppliers to fully resolve the problem.

- Sodium Hydroxide pump faults – pumps were not providing correct flows initially. All valves were cleaned and PRVs/PSVs were reset.
- ORP control loop (Sodium Hypochlorite dosing) – this loop was difficult to tune due to the sensitive relationship between ORP and chlorine concentration. This was eventually fine-tuned and now operates effectively.
- Chemical flowmeters – due to lower than expected inlet concentrations, flowmeters were oversized for the low dose rates being sent to the Venturi and Odorgard scrubbers. These were replaced with flow meters of a lower range.
- During commissioning, there was an uncontrolled release of approximately 3000L of 12.5% Sodium Hypochlorite into the Venturi scrubber. Due to the volume of Sodium Hypochlorite, it could not be discharged to the inlet works using the blowdown pump station and, therefore, was taken offsite. Procedures were subsequently put in place to prevent a repeat of this occurrence.
- Due to project time constraints, the OCF was initally run using only the standby carbon system during the WWTP flow tuning phase.
- pH and ORP probes were initally not responding well due to probe insertion depths which contributed to PID loop tuning problems. Probe housings were subsequently replaced to improve flow path and response times.

The use of the foundation fieldbus communication protocol for the H_2S analysers, together with the Delta V site wide control system, proved problematic. High H_2S alarm points and discrepancy alarms between dual validation units were incorporated to protect the catalyst from high H_2S concentrations. Communication errors related to several units, resulting in spurious readings (ie, extremely high and low concentrations) which caused high alarm set-points to be exceeded, which shut down the Odorgard scrubbing system. After considerable time and effort trying to correct these errors, the communication protocols for these analysers were changed to 4-20mA analog outputs, which solved this problem entirely.

The issue concerning low loads and the appropriateness of sampling methods is discussed later in this paper.

The advantage of commissioning most of the plant while having the construction team still available on the site was invaluable, ensuring defects were immediately attended to and rectified. As such, all of the above issues were attended to immediately.

Process Commissioning and Optimisation

The following provides a brief description of the level of automation integrated into the OCF and outlines the system performance and optimisation phases which were undertaken as part of the commissioning activities.

A high level of control, automation and redundancy has been integrated into the OCF, some of which is listed below:

- Dual pH and ORP probes for each scrubbing system;
- PID control loops for sodium hydroxide and sodium hypochlorite dosing (ie, pH and ORP control) for both scrubbing systems;
- PID control loops for maintenance of recirculation pump flowrates for both scrubbing systems;
- Dual inlet Odorgard scrubber H_2S analysers (to protect catalyst) with discrepancy alarms);
- Automatic catalyst bypassing based on pH and ORP set-points and other alarm conditions;
- Automatic probe cleaning cycles (based on time period and probe discrepancy alarms);
- Automatic Sodium Hypochlorite dosing pump gas purging;
- Four modes of plant operation with automatic changeover on various alarm conditions.

For the pH and ORP control loops, three regions were configured with Gain, Reset and Rate coefficients able to be independently applied to each region. This provided considerable flexibility for control of each parameter.

The effectiveness of the Odorgard catalyst is sensitive to pH and ORP conditions and needs to be protected if these conditions are unfavourable. The system at Murrumba Downs employed automated inlet, outlet and bypass valving, which isolated the catalyst if the pH dropped below 8.3 or the ORP below 500mV. Only once levels were raised above these set-points was the catalyst allowed to be brought back online.

The main areas which caused problems or provided the most significant level of optimisation were:

- Tuning of pH and ORP Control;
- Sampling Methods.

These are discussed in more detail in the following sections.

Tuning of pH and ORP Control

The pH and ORP feedback control system is critical to the successful operation of the facility. Initial set-point and tuning parameters were configured based on the design inlet concentrations. For example, Venturi and Odorgard scrubber set-points of 9.2 and 450mV, and 9.5 and 750mV were set for pH and ORP respectively. The ORP set-point for the Venturi scrubber was 450mV in order to generate elemental sulphur and reduce the required hypochlorite demand. Alternatively, the Odorgard ORP set-point was maintained at 720mV in order to produce dissolved sulphates and limit elemental sulphur that could cause blockages to the scrubber packing and catalyst.

The first performance test was carried out between 11 and 24 November 2009, with results summarised in Table 4.

It should be noted that the Venturi ORP varies from 400 to 500mV, due to the fact

Table 3. Required Odorgard discharge quality.

Parameter	Design % removal at peak inlet design load	Maximum discharge concentration at peak load (ppm, unless stated otherwise)	
Hydrogen Sulphide (H_2S)	>99.9%	0.05	Total including all contaminants not to exceed 500 OU
Di-methyl Sulphide (DMS)	>99%	0.01	
Mercaptans (R-SH)	>99%	0.01	
Chlorine	-	0.5	
VOC (average Mol. Wt 120)	There shall be sufficient removal of Ammonia and VOCs to achieve stack discharge max. concentration specified (at peak load)		

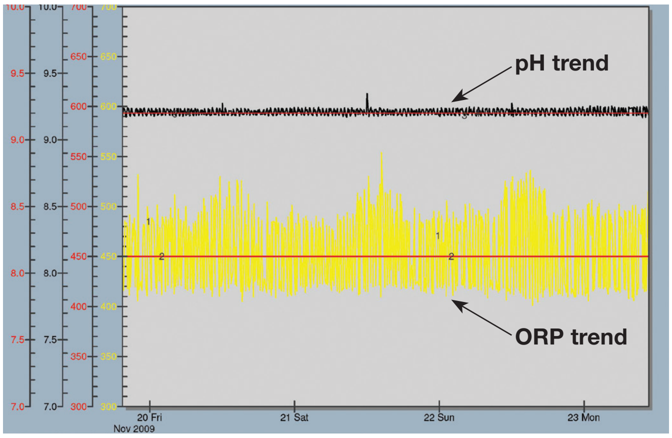

Figure 2. Venturi scrubber pH and ORP trend.

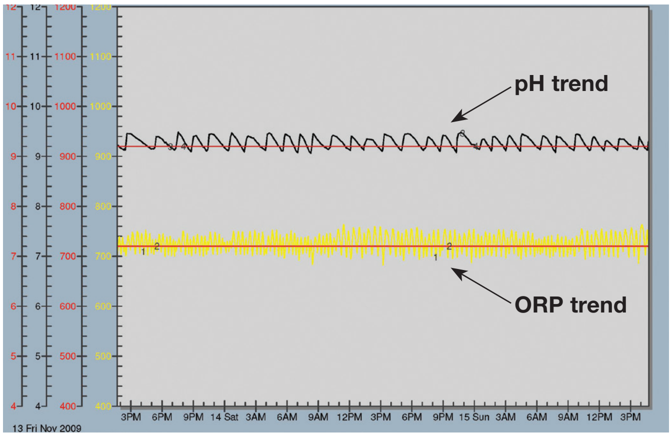

Figure 3. Odorgard scrubber pH and ORP trend.

that the ORP is unstable within this range (ie, small changes in the hypochlorite concentration create relatively large changes in the ORP). For the Odorgard system, the ORP setpoint is much higher and the variability less due to the stability within this range (see Figures 2 and 3).

The results of this first test show that all parameters met the contract specification limits except for the outlet odour concentration with 8 values out of the 50 over the required 1000OU limit. Note that as per the EPA license requirements, the required maximum outlet odour concentration was initially 1000 OU/m³ for the first test due to the staged upgrade program. This was reduced to 500 OU/m³ for subsequent performance tests.

Table 4. Summary of results for 1st performance test (11–24 November 2009).

Date	Units	Value
Control loop set-points:		
Venturi		
pH set-points		9.2
ORP set-points	mV	450
Odorgard		
pH set-points		9.5
ORP set-points	mV	720
Inlet H_2S concentrations (continuous measurement)	ppm	0 to 23 (average = 6.5)
Outlet concentrations:		
H_2S	ppm	<0.04
Mercaptans	ppm	<0.008
Di-methyl Sulphide	ppm	<0.003
Odour	OU/m³	41 to 2,050 (average = 453)

During this test, a number of system faults/reliability issues arose that resulted in 'downgrade' of the normal operating mode as follows:

- H_2S analyser foundation fieldbus communication errors;
- Dosing pump Profibus communication errors/power and signal line interference;
- Probe failure during a clean cycle;
- Storm events leading to power failures;
- Service water pump failures.

It is considered that these system faults resulted in unstable operation and caused odour breaches, as discussed. For this reason, the test was considered to have failed and needed to be repeated once the system faults had been addressed. The repeated test was carried out from 16–29 March, to ensure odour levels were at their maximum, and the full performance of the system could be tested.

It was also considered that the Odorgard ORP set-point could be reduced due to the much lower inlet concentrations

Table 5. Summary of results for repeated 1st performance test (16–29 March 2010).

Date	Units	Value
Control loop set-points:		
Venturi		
pH set-points		9.2
ORP set-points	mV	450
Odorgard		
pH set-points		9.5
ORP set-points	mV	650
Inlet H_2S concentrations (continuous measurement)	ppm	6 to 33 (average = 17)
Outlet concentrations:		
H_2S	ppm	<0.006
Mercaptans	ppm	<0.005
Di-methyl Sulphide	ppm	<0.009
Odour	OU/m³	81 to 353 (average = 185)

Table 6. Summary of results for 2nd performance test (1–14 July 2010).

Date	Units	Value
Control loop set-points:		
Venturi		
pH set-points		9.2
ORP set-points	mV	450
Odorgard		
pH set-points		9.5
ORP set-points	mV	670
Inlet H_2S concentrations (discrete samples only)	ppm	1.0 to 4.0 (average = 1.7)
Outlet concentrations:		
H_2S	ppm	<0.023
Mercaptans	ppm	N/A
Di-methyl Sulphide	ppm	N/A
Odour	OU/m³	60 to 303 (average = 138)

Table 7. Comparison of gas measurement methods.

Pollutant	Apparatus
Inlet concentration to Venturi and Odorgard scrubbers	
H_2S	Electrochemical sensor (Draeger Polytron 7000)/Gastec adsorption tube
Ammonia	Gastec adsorption tube
Mercaptans	Gastec adsorption tube
Di-methyl Sulphide	Gastec adsorption tube/GCMS
Carbon Dioxide	Gastec adsorption tube
VOCs	MiniRAE 2000 portable VOC monitor
Stack outlet	
H_2S	Gastec adsorption tube/GCMS
Mercaptans	Gastec adsorption tube/GCMS
Di-methyl Sulphide (DMS)	Gastec adsorption tube/GCMS
VOCs	MiniRAE 2000 portable VOC monitor
Chlorine Gas	Electrochemical sensor (Draeger Polytron 7000)
Odour	Dynamic olfactometry (AS4323.3:2001)

Note: Concentrations in ppm unless specified.

than design. This was also supported by the presence of a chemical/chlorine smell noted in the stack discharge during the first test and preliminary tests leading up to the re-test. The results from the second test are summarised in Table 5.

It should also be noted that leading up to the performance trial, wet weather conditions significantly reduced the inlet H_2S concentration. This proved particularly difficult during the retuning phase of the feedback loops, with multiple set-point changes required prior to the formal test.

Table 8. Comparison of analysis methods for the measurement of Di-methyl Sulphide.

Date	Units	Gastec Method No. 77	GCMS
20 Nov 2009	ppm	0.06	0.003
21 Nov 2009	ppm	0.08	<0.0002
22 Nov 2009	ppm	0.08	<0.0006
23 Nov 2009	ppm	0.07	<0.0002
24 Nov 2009	ppm	0.06	<0.0002
25 Nov 2009	ppm	0.08	<0.0002

The contract required an additional performance test for H_2S and odour only, on the completion of an upgraded wastewater treatment reactor. The results for this test are summarised in Table 6.

As detailed in Table 6, all the results obtained indicated that the plant successfully passed the required performance, with the highest value of 303 OU being recorded and an average of 138 OU, which were well below 500 OU requirement.

Sampling Methods

The sampling methods employed are summarised in Table 7.

With regards to the testing of DMS, issues occurred during the performance trial involving saturation of the TBM pre-filter on some Venturi inlet and outlet adsorption samples. As a result, Gastec's gas sampling system No. 53 was used for measurement of the remaining DMS samples (which incorporate a Pyrotec Pyrolyzer pre-treatment stage) as recommended by Gastec Corporation. This sampling system does not have the same interference potential as their sampling No. 77; however, the lower detection limit is only 0.2ppm.

For the measurement of DMS on the stack discharge, concentrations above the required concentration limits were observed using the adsorption tube method. Since it was

Table 9. Performance trial results.

Parameter (discrete sampling except where advised)	Min (ppm)	Ave (ppm)	Max (ppm)	No. of Samples	Std. Dev.	Specification Requirement	
						Removal at Peak Load (%)	Max discharge conc. (ppm)
Inlet to Venturi scrubber							
H_2S – On-site analyser	6	17	33	† (see notes)	N/A		
H_2S – GCMS	4.9	5.4	6.6	14	0.46		
Ammonia – Tubes	0.1	0.31	0.43	28	0.12		
Mercaptans – GCMS	0.02	0.08	0.37	14	0.09		
DMS – GCMS	<0.001	<0.015	0.04	14	<0.01		
Carbon Dioxide – Tubes	700	784	900	28	52		
VOC – PID	0.55	0.80	1.15	28	0.15		
Stack outlet							
H_2S – On-site analyser	0.000	0.000	0.000	† (see notes)	N/A	99.9	0.05
H_2S – GCMS	<0.001	<0.003	0.01	14	<0.002	99.9	0.05
Mercaptans – GCMS	<0.001	<0.002	0.005	14	<0.001	99.0	0.01
DMS – GCMS	<0.001	<0.002	0.009	14	<0.040	99.0	0.01
VOC – PID	<0.1	<0.1	<0.1	28	0.0	N/A	N/A
Odour (OU/m^3)	81	185	353	28	75	N/A	500

Notes: N/A = not applicable
† Continuous measurement taken over entire sampling period

Murrumba Downs Sewerage Treatment Plant.

assumed that cross-interference was the reason for the higher than expected results rather than this being all due to DMS, two additional odour samples per day were taken as a substitute. In order to investigate the accuracy of Gastec's sampling system No. 77, samples were analysed by both this method and GCMS (Gas Chromatography – Mass Spectroscopy), which has no such interference. The results of this analysis are presented in Table 8, which show GCMS results significantly lower than those measured using adsorption tubes.

Plant Final Performance

Performance testing of the facility was a critical aspect of the project. An extensive sampling program was specified, requiring duplicate gaseous sampling and analysis over each of the 14 days for Hydrogen Sulphide, Mercaptans, DMS, VOCs, Ammonia, Carbon Dioxide and Odour Dilution Units.

Samples were taken from the inlet of the OCF, between the Venturi and Odorgard scrubbers and at the discharge to the ventilation stack. Samples were taken at different times of the day throughout the 14-day period to ensure coverage of different diurnal conditions. As discussed, there were a number of issues associated with the first performance trial. These were addressed with the repeated first test performance data as shown in Table 9.

The chlorine concentration measured from the stack discharge was zero (ie, 0.000ppm) throughout the trial, which satisfied the contract requirements that concentrations not exceed 0.5ppm.

Based on results of GCMS analysis, the maximum discharge concentration from the stack for Hydrogen Sulphide, Mercaptans and Di-methyl Sulphide was 0.006ppm, 0.005ppm and 0.009ppm respectively. These are all below the specification requirement of 0.05ppm, 0.01ppm and 0.01ppm respectively.

For Ammonia, the inlet concentrations were generally higher than the average and peak design load concentrations of 0.2ppm and 0.5ppm respectively. Nonetheless, the average removal efficiency across the Venturi scrubbing system was 70%, which was higher than the guaranteed minimum level of 50%.

The average, 95th percentile and maximum odour concentrations at the stack discharge were 185 OU/m^3, 330 OU/m^3 and 353 OU/m^3 respectively, with a standard deviation of 75 OU/m^3. These are below the specification requirement of 500 OU/m^3 from the ventilation stack. Power consumption and other consumables are listed in Table 10. The optimisation undertaken throughout the commissioning phase has resulted in substantially lower chemical and water consumption with reduced power consumption also being realised. Based on these results, the OCF has achieved the design performance requirements with 100% compliance.

Table 10. Summary of power consumption and other consumables.

Date	Units	Measured
Sodium Hypochlorite	Litres	7,806
Sodium Hydroxide	Litres	1,015
Brine	Litres	5,070
Potable water	Litres	672,000
Power consumption	kWhrs	67,417

Conclusion

Overall, the Murrumba Downs WWTP OCF commissioning process ran smoothly, with only a few issues arising. As a whole, the project commissioning was successful and the major design aims have been achieved on time and on budget. Issues were identified and defects rectified in a timely manner, by having the construction team available during the commissioning and optimisation process.

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