ENVIRONMENTALLY SUSTAINABLE ODOUR CONTROL FOR THE MERRIMAC WWTP UPGRADE

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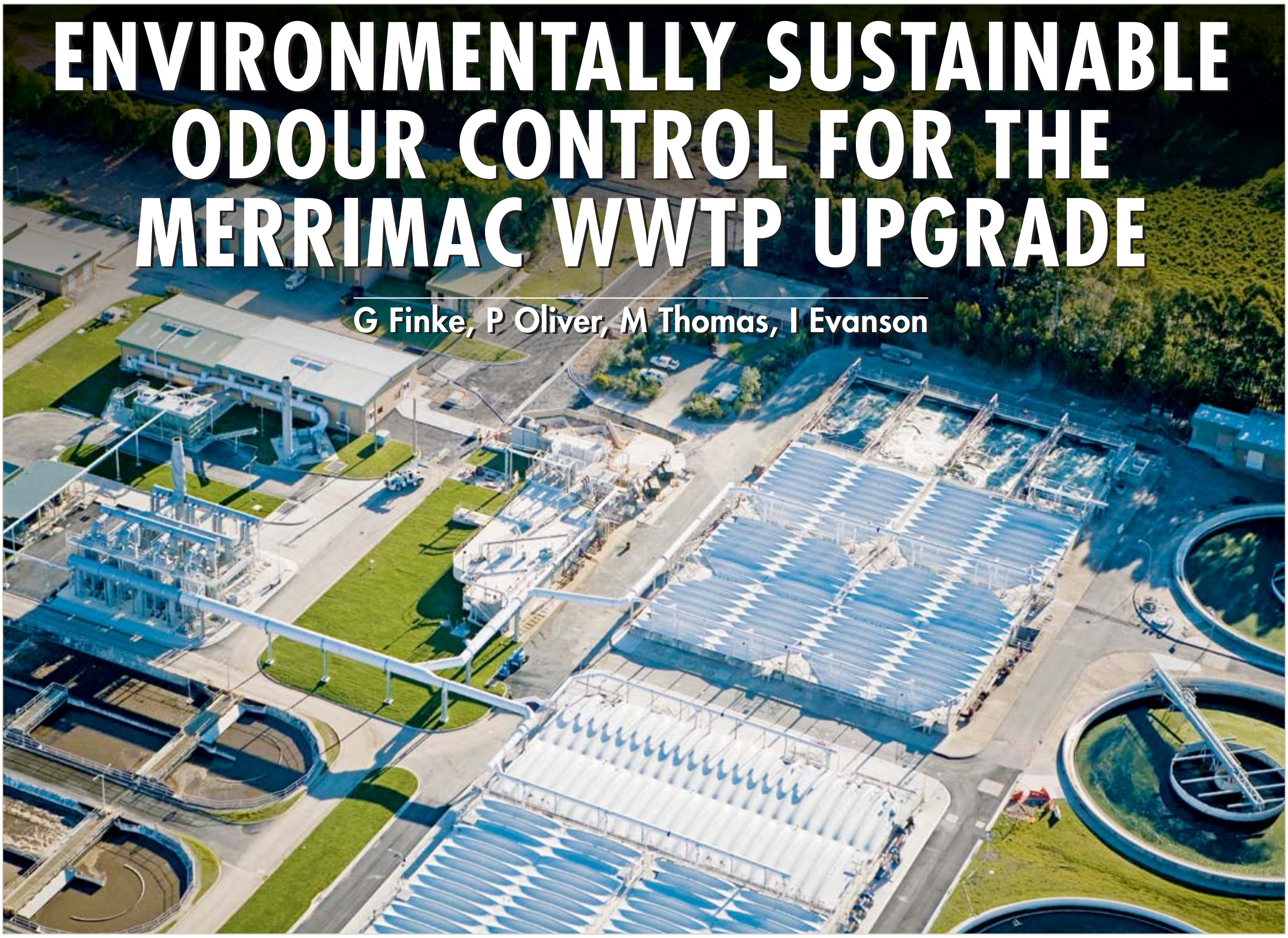

Abstract

A $55 million upgrade of the Merrimac Wastewater Treatment Plant has been completed by the Merrimac WWTP Waterfuture Alliance to cater for the substantial growth predicted for the Gold Coast population. This upgrade involved increasing the treatment capacity by around 60 percent to 57.5 ML/d.

Implicit in this upgrade was the effective management of odour emissions from the new facility. It comprises the covering of the main bioreactors and other selected equipment, the installation of ductwork for extraction of foul air from these tanks, an expanded inlet works and biosolids processing facilities and finally a new 52,000 m^3/hr odour control facility. The selection of areas to be controlled for odour was based on extensive emissions sampling of existing facilities and associated dispersion modelling. Modelling was used to gauge the cost effectiveness of the various odour control scenarios in eliminating nuisance odours to the surrounding community.

The odour control facility selected for such a large plant was unique in that it represented an environmentally sustainable approach to odour control. This was achieved through the use of bacteria for the primary treatment stage rather than hazardous chemicals, as has been the case for most other large wastewater treatment plants around Australia. The facility consists of four bioscrubbers followed by four activated carbon filters and is currently the largest biological odour control facility for a wastewater treatment plant in Australia.

This paper discusses the integrated design approach to the odour management works and the construction, operation and performance testing of the facility, which has successfully achieved the project objectives on time and under budget for the benefit of Gold Coast Water and the community. It also details the design philosophy of the project that featured not only environmental, but practical sustainability of this essential community asset.

Four bioscrubbers followed by four activated carbon filters represent minimum whole-of-life cost.

Introduction

The Gold Coast Region within South East Queensland has been experiencing almost constant growth of around 4% since the end of World War 2; growth that is expected to continue to an expected maximum of 1.2 million people by 2056. Availability of water supply is one of the key constraints on the ultimate population level. To address this future growth, Gold Coast Water (GCW) has developed a master plan that caters for the expected population growth to the 2056 planning horizon.

The Merrimac Wastewater Treatment Plant plays a vital role in catering for the sewage treatment needs of approximately 25% of the Gold Coast population with a treatment capacity pre-2006 of 36 ML/d (120,000 EP). Therefore, upgrade of this plant was essential in addressing this projected growth and involved increasing the treatment capacity, through the construction of new wastewater treatment facilities, by around 60 per cent to 57.5 ML/d (equivalent to 190,000 EP) together with associated odour control works at a cost of $55 million. Due to site limitations, the maximum capacity possible is approximately 80 ML/d ADWF, with expansion beyond this requiring either substantial technological change or the sourcing of a new site.

A further $27 million upgrade is currently being undertaken for the plant involving the construction of a second recycled water storage lagoon (45ML), a new wet weather recycled water pump station, installation of additional pumps and other minor refurbishment works.

History of Odour Nuisance

The existing plant (pre-2006) had a history of odour nuisance, compounded in recent years by encroaching urban growth and odour sensitive areas such as the adjoining golf course (Lakelands) and two wedding reception areas in close proximity to the plant. Buffer zones had been reduced over many years, such that the EPA was becoming increasingly involved in dealing with odour complaints in areas surrounding the plant. Consequently, a feature of the design brief for the plant upgrade was the objective to effectively manage sewage originated odours from the site. A benchmark target was set at less than 2.5 odour units (as measured by dynamic olfactometry), at the adjacent Lakelands Golf Club. It was the first sensitive receptor beyond the plant boundary that other than passing people could be impacted.

During the planning of this project, it was recognised that the plant was approaching its design throughput capacity, and that minimum treatment standards could potentially be compromised during wet weather flows. Therefore, the project was fast tracked using a competitive tendering system.

Alliance Formation and Structure

GCW had always intended the works to be carried out by an Alliance of designers, contractors and specialist equipment supply companies and chose to deliver this outcome using a competitive 'Target Out-turn Cost' (TOC). Expressions of interest were called for Alliance partners to bid their capabilities for the chance of being selected for one of two final positions. Two consortia were selected and each was paid to provide a design and TOC. GCW retained copyright of all designs from this process, so that beneficial ideas from the unsuccessful team could still be incorporated into the final design if warranted.

Merrimac WWTP Odour Control Facility.

This process culminated in the selection of John Holland Water (JHW) and Montgomery Watson Harza (MWH) to join with GCW as the Merrimac WaterFuture Alliance (MWFA). Subsequently Richard Flanagan & Company (RFC), RPC Technologies and Aromatrix Australia were engaged as sub-alliance partners through a similar assessment process.

In order to achieve effective management of the project, the Alliance was structured in the following manner:

- Design review groups – which reviewed and developed designs to address integration issues and ensure project objectives were achieved;
- Alliance Project Management Team (APMT), which handled the day to day operation of the Alliance and the project;
- Alliance Leadership Group (ALG) which provided strategic direction and financial control and adjudicated on the rare escalation of issues from the APMT.

All designs were rigorously reviewed at weekly technical review meetings attended by all Alliance members and in particular GCW operators and maintenance staff. This process resulted in many design improvements with full compliance with GCW and regulator standards. It also enabled close cooperation between Alliance members and proved to be a very proactive means of resolving problems. It also led to many innovations and design 'breakthroughs' not normally experienced in jobs of this size and nature.

Integrated Design Approach

During the design planning stage, atmospheric dispersion modelling (using the Ausplume dispersion model), was undertaken to assess various odour mitigation scenarios. However, one of the first major hurdles to overcome was calibration of this model to previous odour complaints. The closest meteorological station was Coolangatta Airport, approximately 15kms to the south of the site. While it was thought that this data would give a fair and accurate approximation of local atmospheric conditions, the resultant model was not able to mimic the location of the majority of recorded odour complaints. It also indicated other populated areas where complaints should have been received but weren't. The solution to resolving this issue came from the plant operators who had been keeping an 'unofficial' daily plant log of weather conditions over many years. The use of this data within the model produced almost instant correlation with surveyed complaints, and became the basis for all subsequent planning and design decisions, including the many "what if" scenarios.

Once the model was calibrated and sensitive receptors identified, internal odour sources within the plant were located and quantified. An extensive emissions testing survey of odour sources was undertaken and used within the model to determine treatment priorities. This survey concentrated on the emissions of odour (AS4323.3) and specific odorous compounds such as hydrogen sulphide, mercaptans, dimethyl sulphide and volatile organic compounds. The principal odour sources in order of severity were the Preliminary Treatment Area (PTA) (incorporating inlet screens, grit removal, screenings and grit cleaning and compaction facility), the anoxic and anaerobic zones of the bioreactors, the waste sludge belt filter press building and the dewatered sludge storage hopper.

Once this survey was completed, treatment options for each part of the site were considered, together with other site-specific conditions. For example, the zincalume roof and bearers inside the belt filter press building were showing signs of premature corrosion due to the warm moist conditions developed during press operations as well as the accumulation of sewer gas within stagnant pockets within the building. The solution was to specify an extraction rate that would provide for effective air movement within all areas of the building thus preventing stagnant pockets from forming and reducing condensation. Modelling showed that discharge of this ventilation air through a 15m high stack at sufficient velocity would result in ground level concentrations below the benchmark target and therefore eliminated the need for further treatment.

All other odour sources were covered and extracted to an Odour Control Facility (OCF) at a rate of 52,000 m^3/hr (with the requirement for the OCF to allow upgrade to a maximum capacity of 72,000 m^3/hr) which was designed to achieve almost 100% capture efficiency, and which is equivalent to 15 air changes per hour based on the enclosed headspace volume.

The relatively large volume of air to be treated somewhat narrowed the odour treatment choices available with regard to whole of life costs (WOLC) and footprint. Biofilters (e.g. compost and soil bed filters) alone were ruled out due to the extensive area requirements, although both biofilters and activated carbon adsorption systems by themselves exhibited high WOLC (low capital but high media replacement costs). Chemical scrubbing, which is typically implemented for plants of this size, not only exhibited high WOLC, but also had the possibility of added risk and adverse environmental impact from the use of hazardous chemicals. The most cost effective and environmentally sustainable option proved to be the use of bioscrubbers (otherwise known as biotrickling filters - refer article titles "Biotrickling Filters Cut the Cost of Odour Control" in March 2006 *Water Journal*, for a detailed description of this technology). as the main treatment stage followed by activated carbon polishing. Although capital costs are higher than some of the other options, operation and maintenance costs are much lower (Figure 1).

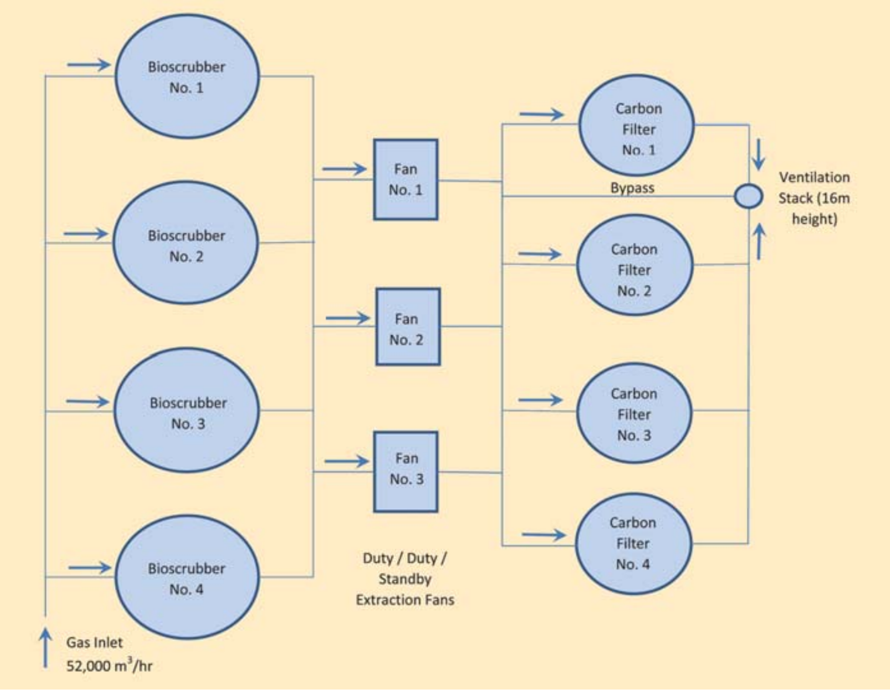

Figure 1. Process Flow Diagram.

Additional Design Parameters and Limitations

The Merrimac WWTP is a fully operational facility and since it was nearing its maximum loading capacity at the commencement of this project, the design and construction of the plant upgrade was not permitted to impact on the capacity and treatment effectiveness in any way. Planning for cut-ins for example had to be planned for low flow periods such that any flow backlog could be cleared before the next diurnal peak. This often meant crews working through the night to achieve process interruptions with 4.30am being the time of lowest flows. Because of this, plant operators had to be kept informed of all developments and design decisions. This was simplified by appointing the plant supervisor to the APMT as well as the client's representative (Asset Creation Specialist) to advise as required on standards and limitations as well as environmental, maintenance and specialist asset management issues.

From an environmental perspective, the plant borders an area of public open space that is a significant wetland precinct and forms part of the major Merrimac floodplain. As a consequence, strict attention was given to acid soils management, as well as site restriction on any land fill or encroachment on the flood plain that could affect potential flood levels. This restricted activity to the rising portion of the site had placed some significant limitations on where various process components could be located, while still allowing reasonable site access to service vehicles, tankers and B-doubles for sludge disposal. B-doubles, or double articulated semi trailers as they are also known, are permitted on the eastern seaboard as a means of reducing transport costs and improving capacity for each truck movement. However, the main drawback is that they require wider passages through the plant, and more extensive turning circles, all of which are additional factors influencing the amount of process space available within the plant.

Construction and Commissioning

Construction of the upgrade of the Merrimac Wastewater Treatment Plant occurred in two phases. Phase 1 works involved increasing the capacity of the Merrimac WWTP from 35ML/day to 57.5ML/day through the modification to the existing inlet works and construction of new wastewater treatment bioreactors, two new clarifiers, a new biosolids handling facility, a new disinfection system and plant recycled water systems. Phase 2 works involve construction of the odour control facility (OCF).

A further upgrade (Phase 3) is currently being undertaken involving the construction of a second recycled water storage lagoon (45ML), a new wet weather recycled water pump station, installation of additional pumps and other minor refurbishment works.

Phases 1 and 2 have been completed on time and without any Lost Time Injuries (LTIs) on the 370,000 plus hours worked.

Table 1. Performance Trials Results.

Parameter	**Min (ppm)**[1]	**Ave (ppm)**[1]	**Max (ppm)**[1]	**No. of Samples**	**Std. Dev.**	**Removal Efficiency (%)**	**Specification Requirement**	
							Removal at Peak Load (%)	**Max discharge concentration (ppm)**[1]
Inlet to odour control facility								
H_2S – On-site analyser	4.1	5.8	8.5	42	1.27	N/A		
H_2S –Tubes	3.0	5.2	8.5	42	1.53	N/A		
Mercaptans– Tubes	0.10	0.21	0.78	42	0.14	N/A		
DMS–Tubes	0.20	0.60	1.60	42	0.67	N/A		
VOC–PID	0.00	0.27	1.40	42	0.33	N/A		
Odour (OU/m^3)	40650	64167	101000	42	16482	N/A		
Stack outlet								
H_2S – On-site analyser	0.000	0.0005	0.003	42	0.001	99.99[2]	99.75	0.1
H_2S –Tubes	<0.010[3]	<0.010[3]	<0.010[3]	42	0.000	>99.81[2,3]	99.75	0.1
Mercaptans– Tubes	<0.003[3]	<0.003[3]	<0.0033	42	0.000	>98.6[2,3]	99.9	0.003
DMS–Tubes	<0.01[3]	<0.01[3]	<0.013	42	0.000	>98.3[2,3]	99.5	0.03
VOC–PID	<0.05[3]	<0.062[3]	0.150	42	0.030	>77.0[2,3]	N/A	N/A
Odour (OU/m^3)	17	68	163	42	42	99.89[2]	N/A	1000

Notes: 1 Concentrations in ppm unless specified

2 Removal efficiency based on bioscrubber inlet and stack outlet concentrations

3 Precise values not achieved due to detection limits with measurement techniques used

The covering of an operating bioreactor and associated ducts presented a number of challenges to the team. A number of construction techniques were used including mounting temporary handrails on the covers during the installation period to prevent falls as well as full time spotters throughout the job. Limiting the number of lifts and placement of covers was achieved by joining a number of covered section panels together on the ground and lifting these into position in a single lifting step.

The commissioning of the OCF and associated covers and ducts were undertaken in a phased approach to ensure that there would be minimal fugitive odour release at any time. The site utilised a temporary odour treatment system to treat odours from the PTA. It was important to minimise any downtime of odour treatment so Aromatrix's standard bacterial inoculation procedure for the bioscrubbers was essential to ensure that when the changeover occurred, it would be able immediately to treat odorous air to an acceptable level.

The seeding of the bioscrubbers involved obtaining recirculation fluid from another bioscrubber facility installed by Aromatrix for Gold Coast Water. An acclimatisation period of six weeks was adopted to ensure the bacterial population was fully developed prior to performance testing. The carbon filters ensured that the required odour discharge concentrations were compliant at the time of changeover whilst the bioscrubber was acclimatising to the odour load.

The changeover from the temporary odour treatment system to the new OCF involved removal of temporary ductwork and the connection of the new permanent ductwork to the PTA. An extensive ductwork system was designed to extract odorous air from the wastewater treatment bioreactors 4 and 5, and the sludge hopper, in addition to the PTA. However due to timing of the installation of covers and ducts, and the progressive odour loading of the OCF, initial flows were purely from the PTA. Once installation of the covers and ductwork was complete and the bioscrubber performance stabilised, these were progressively brought on line.

Performance Testing

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 21 days for hydrogen sulphide, mercaptans, volatile organic compounds (VOC) and odour dilution units. Samples were taken from the inlet of the OCF, between the bioscrubbers and the carbon filters and at the discharge to the ventilation stack. Less frequent sampling of dimethyl sulphide (DMS) was also undertaken at each of these locations. Samples were taken at different times of the day throughout the 21 day period to ensure coverage of different diurnal conditions.

Draeger tubes were used for measurement of hydrogen sulphide (together with a continuous monitoring analyser), mercaptans and dimethyl sulphide. VOCs were measured by a MiniRAE 2000 portable VOC Photoionisation Detector. With regard to odour concentrations, gas samples were analysed on the day of sampling in accordance with AS4323.3. The duration between sampling and analysis did not exceed 9 hours and were generally sampled within 4 hours.

From the results of the performance trial, the OCF achieved a hydrogen sulphide (H_2S) removal efficiency based on manual sampling methods and the continuous monitoring analyser of >99.81% and 99.99% respectively. Tha average stack outlet concentration was 0.0005 ppm as measured by the analyser.

The removal efficiency of mercaptans across the OCF was measured to be >98.6% with concentrations discharged from the stack always <0.003 ppm. For DMS, the removal efficiency across the OCF was >98.3% while all outlet concentrations from the stack measured at <0.01 ppm. For VOCs, the removal efficiency across the OCF was >77% with an average outlet concentration from the stack of <0.06 ppm.

Odour removal efficiency across the OCF was 99.89%. The inlet concentrations ranged between 40,650 OU/m^3 to 101,000 OU/m^3 while the stack outlet concentrations ranged between 17-163 OU/m^3 with an average outlet concentration of 68 OU/m^3.

Based on the above results, the OCF has achieved the design performance requirements with 100% compliance for H_2S and odour. For mercaptans and DMS, sampling methods were not sufficiently accurate to quantify removal efficiencies specified, although all measured outlet concentrations were less than design levels.

Key Features

One of the benefits of the OCF is its compact modular design having been constructed to allow easy upgrade to a future maximum capacity of 72,000 m^3/hr (additional area has been currently reserved for this upgrade) through the addition of bioscrubbers, carbon filters and fans. The other benefit relates to the ease of media replacement for any of the vessels. Activated carbon is very effective at adsorbing contaminants and has been designed for a minimum media life of 12 months. By having four units operating in parallel for the bioscrubbers and carbon filters, media replacement can be carried out relatively easily by taking one unit off line at a time whilst keeping the overall facility operating at the required performance. Another design feature was the dual bed arrangement of the carbon filters which is effectively two filters in one resulting in a substantially reduced footprint compared to traditional single deep bed filters.

The bioscrubbers were designed to operate on recycled water (Class B) in addition to potable water. Using recycled water brought the obvious benefits of conserving the community's valuable potable water supplies, however it also contained enough nutrients for the bacteria within the bioscrubber to function effectively without the need for external nutrient dosing which is required when potable water is used. Although a dedicated nutrient dosing facility has been incorporated, it is not currently used as part of normal operation.

A further consideration of the modular design, and one of the design features that helped guarantee a low WOLC for this plant, was the consideration of future maintenance and renewal activities within the OCF. Considerable discussion centred on optimising design such that almost all of the major process units and ductwork can be removed from site and replaced without having to unbolt anything more than just the adjacent process component. All walkways were constructed of marine grade aluminium and featured bolted sections that are easily demountable if a vessel beneath needs to be extracted for maintenance or renewal, although most have clear vertical access and can be removed through the use of cranes.

One of the major reasons for adopting marine grade aluminium for stairs and landings, apart from the obvious corrosion resistance, was the "man-handle-ability" of the removable sections. Attention to this detail also means that expected times for major component replacement is considerably reduced, potentially saving thousands of dollars in environmental costs and fines. The plant has also been set up such that any process unit can be isolated and/or bypassed while the plant is still on line ensuring compliance with the plant's operating license.

Significant attention had to be given to the disposal of waste fluid (blowdown) from the bioscrubbers. Since this waste stream has a low pH, it couldn't just be discharged to the nearest waste stream within the plant as it could potentially interrupt the wastewater treatment process. To address this issue, a new pump station was built with a dedicated delivery pipe to the centre of the secondary anoxic stage of the bioreactor. This location presented the most cost effective discharge point for suitable flow mixing and dilution so as not to adversely impact the treatment process.

Lastly, occupational health and safety (OH&S) was an important issue for all Alliance partners during the project. The OH&S procedures implemented resulted in no lost time injuries over the 370,000 manhours worked.

Conclusions

The OCF implemented as part of the upgraded Merrimac WWTP represents an environmentally sustainable approach to odour control. This has been achieved through the use of bacteria for the primary odour treatment stage rather than hazardous chemicals, as has been the case for most other large wastewater treatment plants around Australia.

Through the use of an integrated design approach by all members of the Alliance, and the implementation of a proven technology, the OCF has successfully achieved the project objectives under budget for the benefit of Gold Coast Water and the community.

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