Decentralised Sewage Treatment - Case of Study

Client: Tomago Village Tourist Park
Location: Tomago, NSW, Australia
Treatment Type: Decentralised municipal wastewater
Capacity: 25 m^3/day
System Size: 4 x BioGill bioreactors.

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Glossary

BOD_5	Biological Oxygen Demand measured on fifth day
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
E.coli	Escherichia coli
Faecal Coliforms	Dysentery causing bacteria in sewer water (also referred to as TCC)
HRT	Hydraulic Residence Time
LPD	Litre per Day
kL	kilo Litre
NH_4^+-N	Ammonia Ion as Nitrogen
pH	Unit less measurement of acid/alkaline nature of solution
PLC	Program Logic Controller
PSC	Port Stephen Council
STP	Sewage Treatment Plant
TCC	Thermotolerant coliforms counts
TKN	Kjeldahl Nitrogen (organic nitrogen +ammoniacal nitrogen)
TN	Total Nitrogen
TON	Total Oxidised Nitrogen (NO_3^--N + NO_2^--N)
TP	Total Phosphorus
TSS	Total Suspended Solids
TVVP	Tomago Village Tourist Park
UV	Ultra Violet light

Project Summary

Client	Tomago Village Tourist Park
Location	NSW, Australia
Application	Decentralized sewage treatment
Treated effluent use	Discharge to wetlands
Type of process	Conventional extended aeration + BioGill
Volume	25 m^3/day Ave. 30m^3/day Max
Number of BioGill units	4 x BG230

Background

This report highlights the use of BioGill technology for the upgrade of the 50-year-old wastewater treatment plant serving Tomago Village Tourist Park (TVTP) located north of Newcastle, New South Wales, Australia.

In order to increase the plant throughput and improve the quality of the treated effluent discharged from the Park, in 2013 a BioGill system was retrofitted to an existing treatment train before secondary clarification and prior to discharge to an effluent holding pond. Because of recurrent nuisance algal blooms, two BioGill units were also installed to further improve water quality in the maturation pond prior to discharge to wetlands.

Situation

TVTP is located within the local government area of Port Stephens Council and is not served by a centralised municipal wastewater treatment plant.

The site had a total of 146 unit sites (not including tent sites), including 130 long-term sites and 16 short term sites. Following a Development Application submitted to the local Council in 2012 for the addition of 28 long-term units, Whitehead and Associates Environmental Consultants were engaged by the business owner to prepare an Onsite Sewage Management Assessment to assess the possible impacts of the proposed expansion on the performances of the existing treatment plant and investigate viable solutions to prevent water quality degradation.

This report revealed a number of underlying issues likely due to the age of the plant and predicted a possible increase of the total daily flow from the site up to 25% following the proposed expansion(1).

The existing sewage treatment plant onsite was a Smith and Loveless "Oxigest" Model 24B3 extended aeration activated sludge system built in the '60s and consisting of an aeration basin and a final settling tank. Treated water from the sedimentation tank was sent to a maturation pond with an approximate holding capacity of 350m^3 before being discharged to wetlands. Although a properly functioning facility of this type should produce a treated effluent with a maximum concentration of 20mgBOD/L and 20mgTSS/L, in general effluent water quality was poor and inconsistent. Further to this, the equipment at the facility was showing signs of deterioration due to corrosion indicating that the 50 year old plant was nearing the end of its useful life.

The effluent pond had also been shown to have a variable and generally poorer quality effluent compared to the treatment plant. In particular, Thermotolerant Coliforms were consistently very high compared to the adopted compliance limits. Severe algal blooms in the pond were also common indicating high level of nitrogen in the treated effluent.

Objectives

Given the investment in the tourist park, the owner wanted to find a cost effective technology that could be retrofitted to improve treatment performances of the existing wastewater treatment plant and ensure compliance with discharge levels.

Table 1 below provides the chemical characteristics of the influent and effluent compliance values (where applicable) as set by Council.

Parameter	Units	Expected characteristics (influent)	Compliance Limits (effluent)
Daily flow rate	m^3/day	25 (Average) 30 (Max)	
pH	units	6.0-9.0	6.5-7.0 (90%)
Dissolved Oxygen (DO)	mg/L		>5
Oil and grease (O&G)	mg/L		<3
BOD_5	mg/L	200-300	<20 (90%)
Total Suspended Solids (TSS)	mg/L	200-300	<30 (90%)
Total Kjeldahl Nitrogen (TKN)	mg/L	20-100	NA
Total Oxidised Nitrogen (TON)	mg/L	<5	<6 (90%)
Ammonia as N	mg/L		Nil (90%)
Total Nitrogen (TN)	mg/L	NA	NA
Total Phosphorus (TP)	mg/L	10.0-25	<8
Faecal Coliforms	cfu/100mL		100 (Median) 200 (80%) 300 (Max)
Chlorine residual	mg/L		0.5-2

Table 1: Quarterly monitoring parameters

Onsite wastewater treatment options were explored, with the criteria below used to select the most suitable option:

1. Cost effective solution capable of being easily retrofitted into the existing plant;
2. Demonstrated capacity to produce treated effluent to the required standards;
3. Plant to be simple to operate and maintain;
4. Plant to have flexibility to meet varying mass loads;
5. Low running cost.

Solution

BioGill technology

The park owner's research led him to an Australian biotechnology company called BioGill. BioGill manufactures patented Nano ceramic membranes™, developed in the research laboratories of the Australian Federal Government Agency, ANSTO.

BioGills are above ground, attached growth bioreactors that incorporate flexible membranes referred to as "gills". These gills are provided in multiple suspended loops supported in the vertical position with water delivery at the top of each loop. Water flows down and over the surface of the gill membrane. Microorganisms attach onto special Nano ceramic gel applied on the membranes.

The gills are hydrophilic with high affinity to water, allowing water to sorb into the gills creating a diffusive water flow pathway. Biomass grows on both the air side and the liquid side. Biomass growing on the air side is the aerobic biomass. Biomass growing on the liquid side is not aerobic and relies on electron acceptors other than oxygen like Nitrate (Anoxic) or organic substances (Anaerobic). The patented hydrophilic gel matrix of the "gills" creates wastewater capillaries allowing the air side biomass to feed on nutrients from the water side. This allows carbon removal, nitrification and denitrification to occur simultaneously. Further to this, enzymatic secretions of the biomass can diffuse into the liquid effectively breaking down refractory organic components such as fats, oil and grease.

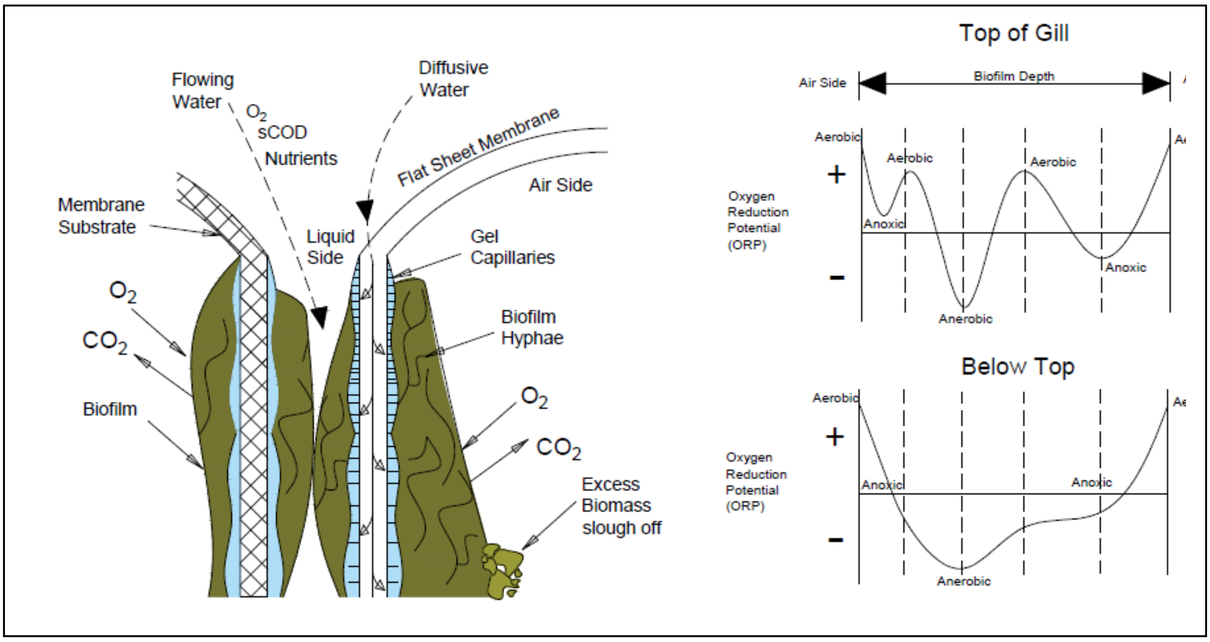

Figure 1: BioGill Depth Profile

The metabolic processes and microorganisms that grow on the gills under partially treated black water has not been fully characterized but inferred based on research work conducted by Taylor et. al.[(2-4).]

Early studies conducted by ANSTO suggest that fungal biomass growing on the air side of the gills has significantly elevated surface area relative to the membranes, that promotes oxygen mass transfer for increased metabolic activity so the metabolism of the biofilm inhabitants are only limited by nutrient concentration not oxygen availability, as is the case in submerged culture. The increased availability of oxygen on the gills produces Carbon Dioxide feeding the nitrification process to produce nitrates. A number of secondary reactions are expected to occur on the gills including oxidation of sulphides to sulphates, metabolism of lipids via lipase enzymes produced by obligate aerobic fungi producing acetate and proponiate and predation of free swimming bacteria by S-layer forming microbes such as Zoogloea sp. growing on the inner face of the membranes. Nitrate and Sulphate subsequently act as electron acceptors for the anoxic metabolism of denitrifying bacteria growing on the water side of the gills.

The metabolic activity of the bacteria generates heat causing the hot air to rise through the gills. Convective air moves upward between each set of loops to provide the oxygen transfer to the attached biofilm. When the reduced nutrient concentration becomes low enough, the gills become an efficient oxygen transfer device which makes the water in the recirculation tank approach saturation.

No blowers or aerators are used to provide air for the biomass. Energy is only required for the recirculation of wastewater from the recirculation tank to the membranes.

A typical BioGill schematic is shown below.

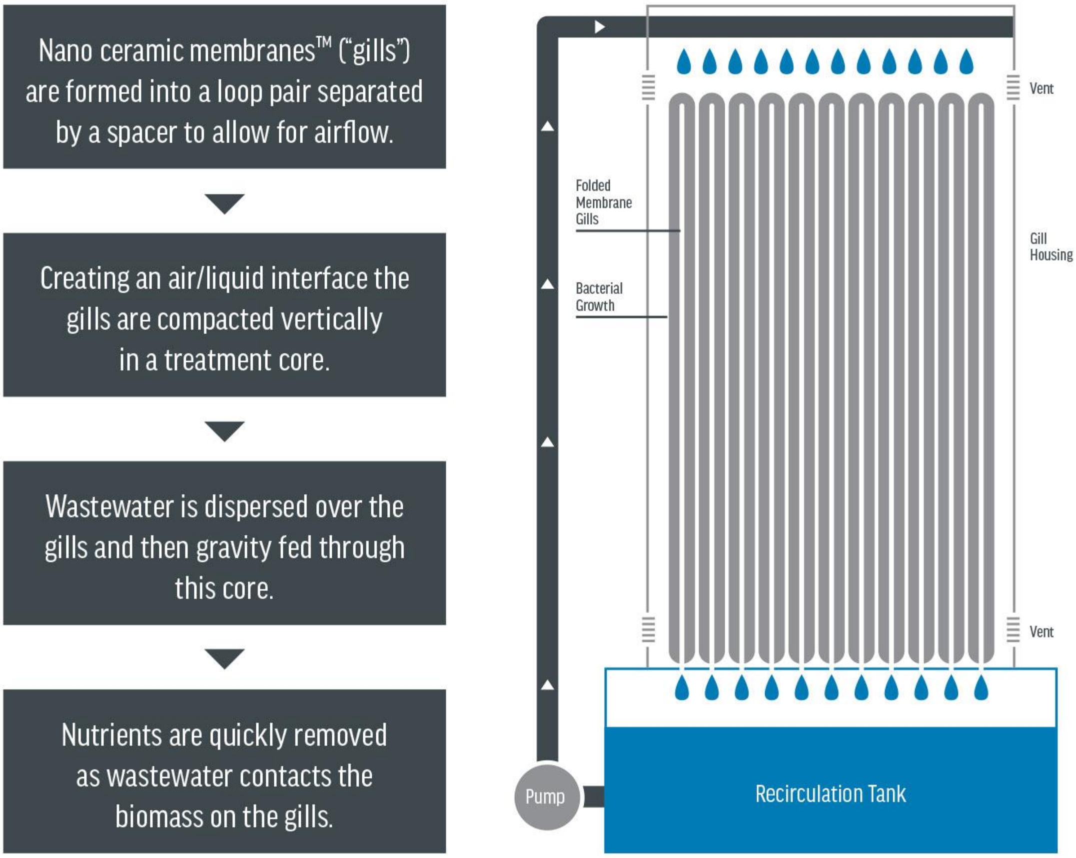

Figure 2: BioGill Schematic Diagram

How BioGill addressed the selection criteria

Cost effectiveness

The BioGill technology has a wide range of applications in particular for decentralised sewage treatment making it the perfect choice for the upgrade of existing plants. The BioGill core modules provide treatment by recirculating water across the suspended gills and can be retrofitted anywhere in the existing process train provided that solid particles larger than 1mm have been removed from the wastewater stream using fine screening or sedimentation.

The greatest asset of the flat sheet Nano ceramic membrane™ is its simplicity allowing for ease of production, assembly and installation.

BioGill technology does not require any specialised or custom made process units. This eliminates the need for expensive concrete structure or fabricated equipment. Most of the equipment necessary for a BioGill plant to work are off the shelf components such us pumps, pre-cast concrete or plastic tanks and uPVC pipework.

As such, the initial capital costs (including tanks, pumps and others) required to retrofit a BioGill system into an existing plant are minimal compared to traditional technologies. Further to this, the nature of BioGill allows this technology to be easily installed ensuring minimal disruption to the plant operations.

Proven performances

In order to determine the ability of the proposed system to provide an adequate level of treatment and achieve Council's requirements for treated water quality, Whitehead and Associates reviewed effluent quality data for other BioGill installations already in operation. A similar plant was located in Fiji at Mantaray Island Resort and a BioGill unit was treating greywater from a tourist park in Lane Cove, NSW.

Although the treatment plants reviewed had much smaller daily loads than those predicted for TVTP, the treatment process was similar and the report concluded that BioGill technology, followed by disinfection, would be an effective solution to reduce the risk of groundwater contamination as compared to applying secondary treated effluent to the wetlands as was practised(1).

Simple operation and maintenance

BioGill membranes have no moving parts and do not require aerators, mixers, backwash, air scouring or CIP cycles. BioGill spray nozzles are kept in stock and are available for next day deliver and all pipes and fittings are off-the-shelf, locally sourced white PVC pressure and drain pipes.

The gills only need to be inspected and hosed down every fortnight to displace excess biomass and solids that may have been accumulated on the water distribution system. This makes BioGill plants very easy to operate and maintain even by unskilled operators.

Able to meet varying nutrient loads

Most wastewater treatment plants serving tourist parks are affected by varying seasonal and diurnal loadings, resulting in significant fluctuations in influent nutrient levels.

A number of researchers have shown that biofilm treatment plants achieve more consistently high COD removal than activated sludge plants under varying load conditions (5) (6). The attached biomass itself acts as temporary sink of organic substrates and a source of material thereafter during peak loading events (7).

To exploit the sink and source capabilities of the biomass in an attempt to dampen influent loading variations, thick biofilms appear to be superior to thin ones despite the fact that only a fraction of the thick biofilm can be expected to be penetrated by substrate and oxygen during normal operation of biofilm reactors(7).

Studies have also found that fungi, typically present on the air side of the gills, has evolved sophisticated mechanisms to sense and respond to environmental cues by activating developmental switches that result in coordinated changes in cell physiology, morphology and cell adherence. Critical depletion of nutrients often induces growth arrest to form spores capable of tolerating a wide range of environmental stresses (8).

Figure 3. Suspended biomass, vertically supported and surrounded by oxygen, growing on the membranes at this site.

It can be concluded that attached growth systems are more favourable than traditional suspended growth processes to counteract variable loading fluctuations and keep the effluent concentration from exceeding set discharge levels.

Power Consumption

The Wastewater Treatment Plant (WWTP) at TVTP is a hybrid between conventional extended aeration and BioGill technology, therefore it would be difficult to truly capture the unique advantages of BioGill just looking at the performances of this plant.

An objective comparison between a new extended aeration plant and a BioGill system designed to cater for the entire waste water production generated from Tomago Village Tourist Park has been prepared for this report.

Power is consumed in wastewater treatment plants to do the following:

1. Pumping liquid to and from process units;
2. Powering control equipment; and
3. Supplying biological treatment with air.

Pumping costs are relatively smaller than aeration cost and are also comparable between the various WWTP options. The same also applies to electrical control equipment. BioGill provides significant power savings when it comes to supplying air because it relies on passive air diffusion directly from the atmosphere to the biofilm biomass. This is different to suspended biomass relying on oxygen transfer from gas bubbles to liquid and then to biomass.

When all the above are taken into account, BioGill power consumption for treating typical municipal wastewater was estimated to be 0.52 kWh/m^3 while in a conventional system utilising high efficiency fine bubble diffusers and positive displacement rotary lobe blowers, power consumption would have been 0.86 kWh/m^3. This is approximately 40% or $1,000/year (calculated at 32cents/kWh) more than the power required by BioGill.

Details of the calculation can be found in Appendix A.

Design

Wastewater treatment plant configuration

In order to improve the quality of the treated effluent, four BioGill bioreactors were installed at TVTP. Two were added to the existing conventional activated sludge plant and two at the final effluent pond. The plant was designed to handle an average dry weather flow up to 25m^3/d as estimated by Whitehead and Associates.

Supernatant from the existing secondary sedimentation tank gravitates into an a collection pit where it is pumped into two above ground pre-cast balance tanks with approximately 12 hour hydraulic retention time at peak wet weather flow. Twice per day, wastewater is transferred from the balance tanks into a treatment tank with a capacity of 25m^3 for processing. Wastewater in the treatment tank is recirculated on the BioGill modules up to 10 times over a 12 hour period using a DAB pump model K14/400M. After each pass on the gills, wastewater gravitates back to the recirculation tank.

At the end of each treatment cycle, treated effluent is pumped through a WATERCO Micron S1050 dual media filter (sand and anthracite) and is disinfected using two Infralight 180W Model UV2500-A-V UV units connected in series and by dosing sodium hypochlorite. Treated water is held in a holding tank where it is used to backwash the media filter and excess water is discharged to an effluent pond nearby.

Figure 4 provides a nutrients balance of the system assuming a conservative concentration of 300mgBOD$_5$/L and 60mgTKN/L in the raw influent to the plant. Based on tank volumes and historic data, the existing extended aeration plant was expected to remove up to 85% of the BOD and TKN load. TSS in the supernatant from the existing secondary clarifier were expected to be in the order of 30mg/L or less. The two new BioGill core units are designed to metabolise left over BOD (50mg/L) thus producing and additional 20mgTSS/L as a result of the conversion of soluble BOD into new cell mass. The final polishing and disinfection stage is designed to reduce TSS to less than 30mg/L and TCC to less than 300CFU/100mL through a combination of multimedia filtration, UV disinfection and chlorine residual.

The two BioGill units installed at the final treatment pond are used to further improve water quality, control algae growth and reduce turbidity.

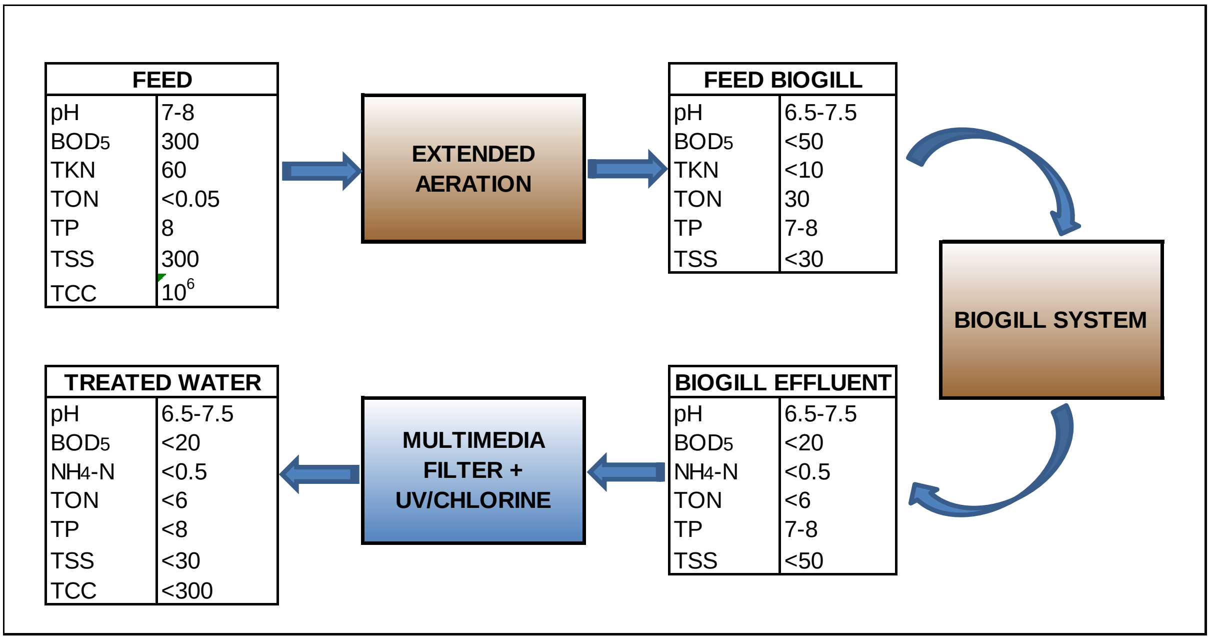

Figure 4: *Nutrients balance*

Sludge management

BOD is taken up by the biomass and used first for life sustaining activities. Excess BOD is used to produce more cells and grow the biofilm in size. In a BioGill system, excess biomass slough off the flat sheet membranes once they exceed the membrane carrying capacity threshold. A theoretical biofilm design thickness of 2 mm is used to calculate the total system biomass. This is also in line with what was visually observed and measured onsite.

BioGill systems run at low Food to Biomass ratio (F/M) which is a desirable design criteria. Low F/M means the system is supporting a higher population of microorganism for the given food source. Low F/M also means that an older population is present and using more of the food for maintenance energy and less for sludge generation. The term that quantifies the above is called the endogenous decay coefficient which accounts for loss of biomass due to the oxidation of internal storage products, cell death and predation by higher microorganism.

A sludge yield of 0.35 g VSS/gBOD or less is typical for BioGill plants. Conventional systems running low sludge ages have sludge yield between 0.4-0.8 gVSS/gBOD (M&E, 5th Ed).

This means that BioGill generates little volumes of sludge compared to traditional technologies. At TVTP, waste activated sludge (WAS) produced by the original extended aeration plant is stored into a sludge thickening tank and is periodically pumped out and disposed offsite using a vacuum truck. Because of the little sludge generated by the two additional BioGill units, excess sludge from the gills is completely removed by the sand filter and returned to the extended aeration plant with the backwash water.

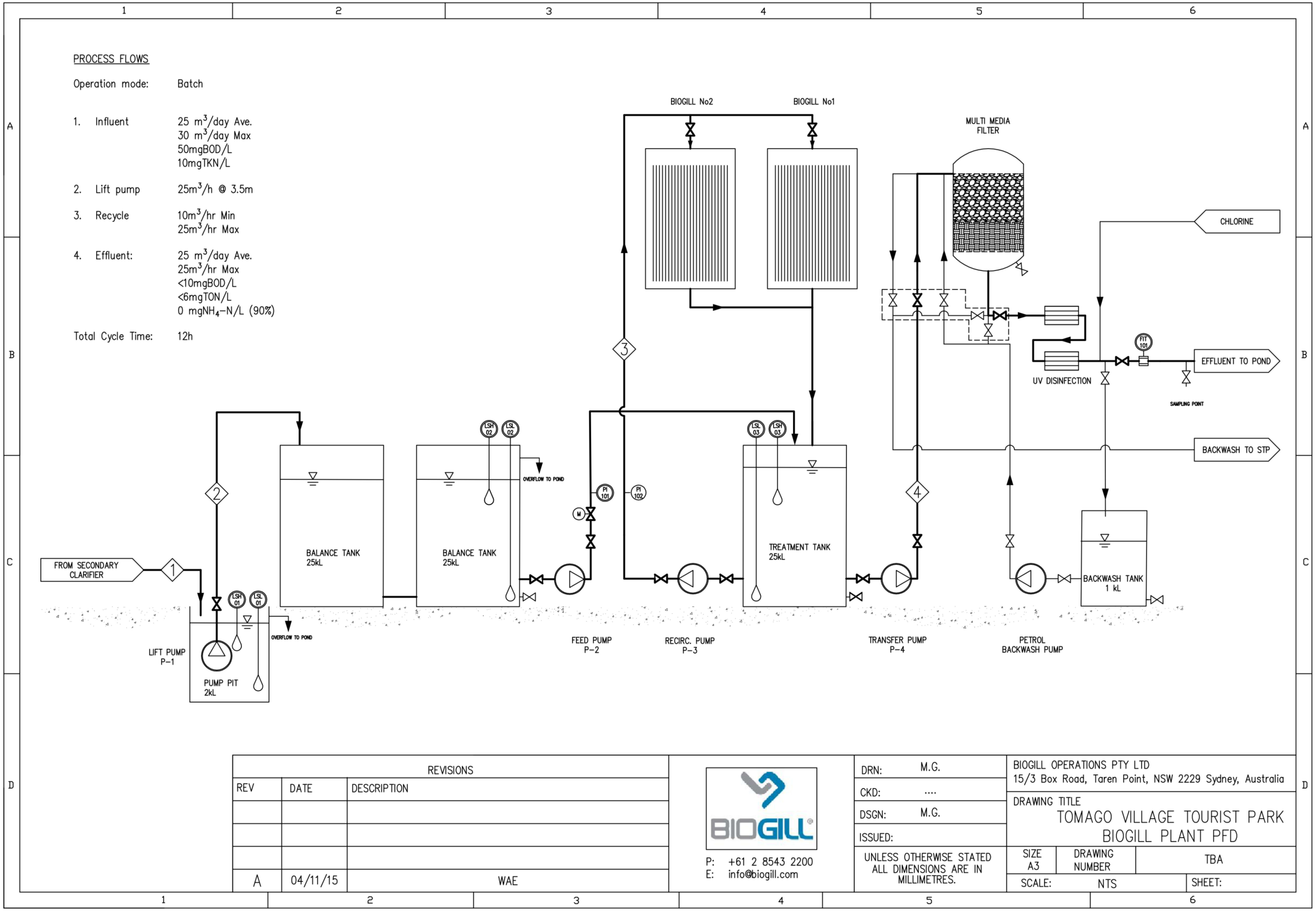

Figure 5: *PFD of TVTP*

Results

The plant was commissioned in October 2013, and underwent a number of modifications during the first months of operation. The lack of substantial data on sewage generation and occasional sludge carry overs from the existing sedimentation tank were the main causes of the initial operational problems and inconsistent effluent quality results. Based on the occupancy of the park it was speculated that 18,000 to 24,000L of sewage would have been produced per day, but more accurate investigations based on working cycles and tank levels revealed that up to 51,000L per day of wastewater was fed to the plant during wet weather events. To fix this issue, the stormwater system onsite had to be modified and the BioGill working cycles optimised.

The quarterly inspection of the plant carried out by Whitehead & Associates in December 2014, concluded that the performances of the augmented Sewage Treatment Plant (STP) were good, with the majority of the physical parameters meeting the compliance requirements or falling within their expected value range.

The analyses and results are summarised in Table 2.

Sample Site	Analysis	Results 20/11/14	Units	Guidelines or Compliance Value
STP Influent	pH	8.6		6 - 9
	BOD_5	296	mg/L	200-300
	Total Kjeldhal Nitrogen	91.8	mg/L	20-100
	Total Oxidized Nitrogen	<0.05	mg/L	5
	Total Phosphorus	8	mg/L	10-25
	Average flow	30.6	m^3/day	
STP Effluent After Biogill				
	pH	6.9		6.5-7.5
	Dissolved Oxygen	3.3	mg/L	>5.0
	BOD_5	<2	mg/L	<20
	Total Suspended Solids	31	mg/L	<30
	Total Oxidized Nitrogen	2.8	mg/L	<6.0
	Ammonia (N)	0.5	mg/L	0
	Total Phosphorus	7.3	mg/L	<8
	Total Oil & Grease	<2	mg/L	<3
	Faecal Coliforms	<90	CFU/100mL	<300

Table 2. Wastewater quality summary.

A water sample was also taken upstream the BioGill system and results are presented in Table 3.

Sample site	Parameters	Results 03/12/14
BioGill Feed	**pH**	7.8
	TSS	74
	Ammonia (N)	0.5
	TKN	7.2
	BOD_5	42
	TCC	1,200,000

Table 3: BioGill feed water. Results from December, 2014

BOD_5 and TKN were within the expected values shown in Figure 4 while TSS were high, indicating ongoing bulking sludge issues in the existing extended aeration plant. TCC values in the treated effluent indicate that a pathogen reduction in excess of 3log was possible regardless of the relatively high TSS load to the sand filter.

The two additional BioGill units installed on the existing pond also proved to be very effective at removing residual nitrogen thus reducing the frequency and severity of nuisance algal blooms. In the first six months of operation, only one bloom was observed but the floating plants were identified as innocuous Duckweed (family Lemnaceae). Duckweed is an important food for wild waterfowl and fish, both directly and as a source of food for small creature that are in turn eaten by the birds and fish. As it grows, Duckweed absorbs nutrients from the water. Thus it has a positive role in controlling the growth of algae, both by removing nutrients and by shutting out sunlight as the Duckweed covers the water surface[9].

Figure 6: BioGill working at the pond

Conclusions

Two BioGill were successfully retrofitted at Tomago Village Tourist Park to improve the performances of an aging extended aeration plant. Two additional units were also installed in the final pond to further reduce nutrients and prevent algal growth.

The upgraded plant was able to achieve a BOD_5 concentration in the final effluent as low as 2mg/L and Ammonia nitrogen less than 0.5mg/L. Total oxidised nitrogen was also low and less than 3mg/L.

Because of recurring sludge settling issues in the existing extended aeration plant, TSS fed to the BioGill system were typically high, but the combination of dual media filtration, UV disinfection and chlorine dosing proved to be adequate to achieve good TSS removal efficiencies and pathogen reduction levels in excess of 3log. The two units installed in the final maturation pond also proved to be effective at reducing frequency and severity of algal blooms.

BioGill technology is the optimum solution for the retrofit of existing facilities or for new decentralised wastewater treatment plants with minimum power requirement. BioGill can also be used as a pre-treatment stage for MBR, MBBR or conventional treatment to reduce size, cost and power consumption.

Further information about BioGill can be found on our website: www.biogill.com.

References

1. Onsite Sewage Management Assessment for Tomago Village Tourist Park, Tomago Road, Tomago, NSW. Whitehead & Associates Environmental Consultants Pty Ltd. August 2012
2. A. P. Taylor. “Sewage Treatment” International Application Published Under the Patent Cooperation Treaty (PCT), World Intellectual Property Organization WO 2007/056818 A1 (24.05.2007)
3. A. P. Taylor. “Trial of a Nano-Particulate Membrane Bioreactor for the Treatment of Sewage” Proceedings of AWA Membrane Speciality II, Melbourne Australia, February 21-23 (2007)
4. A. P. Taylor, K. S. Finnie, J. R. Bartlett and P. J. Holden. “Membrane Bioreactor” International Application Published Under the Patent Cooperation Treaty (PCT), World Intellectual Property Organization WO 2005/111193 A1 (24.11.2005).
5. Dr. Belinda Mcswain-Sturm, Erin Bellassai, 2008. The University of Kansas. Laboratory project: Impact of variable loading on a fixed film reactor versus a suspended growth reactor.
6. Andreottolla, G., Foladori, M., Ragazzi, M., Tatàno, F. 2000. Experimental comparison between MBBR and activated sludge system for the treatment of municipal wastewater. Wat. Sci. Tech. 41(4), 375-382.
7. P.A. Wilderer, P. Arnz and E. Arnold. Application of Biofilm and Biofilms Support Materials as a Temporary Sink and Source. Institute of Water Quality Control and Waste Management, Technical University of Munich, Germany.
8. Sandra Regina Ceccato-Antonini; Peter Edwin Sudbery. Braz. J. Filamentous growth in Saccharomyces cerevisiae. Microbiol. vol.35 no.3 São Paulo July/Sept. 2004
9. http://www.naturia.per.sg/buloh/plants/duckweed.htm

Appendix A

In this report a comparison between the power consumption of a traditional extended aeration process and BioGill technology has been carried out.

The considerations that underpin our design are outlined as follows:

Extended Aeration - Design		
Design flow	25	m^3/day
BOD_{in}	250	mg/L
TKN_{in}	50	mg/L
BOD_{out}	20	mg/L
TN_{out}	20	mg/L
BOD load	6.25	kg/day
TKN load	1.25	kg/day
Wastewater temperature		°C
	0.05	
Design F/M	125	kgBOD/kgTSS.day
Total biomass required	4.5	kgTSS
Design MLSS	27.8	g/L
Reactor volume	25	m^3

Actual Oxygen Requirements (AOTR) for BOD removal and complete Nitrification/Denitrification			
	Factor	**Unit**	**kg O_2/d**
Synthesis	0.6	kgO_2/kgBOD	4
Nitrification	4.57	kgO_2/kgN	6
Denitrification credit	2.86	kgO_2/kgN	-4
Endogenous respiration	0.05	kgO_2/kgTSS	6
		Total	12
Aeration time	12	hrs/day	
Anoxic/mixing time	12	hrs/day	
AOTR	**1.0**	**kgO_2/hr**	

In conventional activated sludge systems, a field correction factor needs to be applied to work out the Specific Oxygen Transfer Rate (SOTR). SOTR represents the aeration requirements of the system at standard conditions (tap water, 20°C, 1 atm pressure, zero salinity, etc.) and it is what manufacturers use to provide equipment without bias for site specific conditions.

Field Correction Factor and SOTR can be calculated as follows:

$$FCF = \alpha \cdot \theta^{(T-20)} \cdot \frac{\beta \cdot C_{SW} - C_I}{C_{SS}}$$

$$SOTR = \frac{AOTR}{FCF}$$

1. α factor: Used to upside the airflow to cater for loss of gas transfer efficiency from gas to liquid due to the water being dirty;

2. β factor: Used to upsize the air flow to cater for the reduction in transfer efficiency caused by the increased salinity of wastewater;

3. θ factor: Used to relate how temperature changes affect the rate at which oxygen can be transferred into the water. This is important because most aeration equipment is sized and rated at standard temperature conditions of 20 degrees Celsius. Typically, a theta factor of 1.024 is used.

4. Water Temperature: This affects how much Oxygen water can hold. The higher the temperature, the lower the O_2 saturation concentration;

5. Site elevation. This affects the density of atmospheric air. This represents up to 10% increase in air flow due to site being 950m above sea level. The air at this elevation is less dense and hence 10% more will be required and

6. Tank depth: This directly affects aeration efficiency when diffused aeration is used. Oxygen transfer from gas to liquid is not instantaneous and is time dependant. The less time a gas bubble spends in the water, the less time is available for Oxygen to diffuse from gas to water. This means that the shallower the tank, the worse the efficiency. This is a significant factor in submerged aeration with reported efficiency between 5-6.25% per meter depending on how many aerators are installed or aerator density. This limitations makes submerged aeration unsuitable for shallow tanks which happens to be most of the off-the-shelf tanks available for volumes under $50m^3$.

SOTR Calculation			
AOTR	Actual Oxygen Requirement	1.0	kgO_2/hour
C_s	Saturation value for oxygen in clean water at 20 °C	9.09	mg/L
C_{st}	Saturation value for oxygen in clean water at process temp	8.74	mg/L
α	Alpha factor - film co-efficient	0.7	
β	Beta factor - saturation reduction due to dissolved solids	0.95	
X	Dissolved oxygen concentration required to be maintained	2	mg/L
THETA	Temperature co-efficient taken as	1.024	
T	Waste water temperature	22	°C
	Calculated SOTR	**1.99**	**kgO_2/hour**

Diffused Aeration Design		
Diffusers Efficiency	18	$gO_2/Nm^3.m$
SOTR	1.99	$kg/O_2.hr$
Design Tank Depth	2.5	m
Diffusers Depth	2.2	m
Air Flowrate	50.18	Nm^3/h
No of duty blowers	1	
Capacity of each blower	50.18	Nm^3/h
Gas Density at Normal Conditions	1.29	kg/m^3
Gas Mass Flow	0.018	kg/s
Ambient Temperature	25	°C
Altitude Above Sea Level	0	m
Inlet Pressure abs	1.0	atm
Line and diffusers Losses	1.5	m-H_2O
Outlet Pressure (Water Depth + Line losses)$_{abs}$	1.395	atm
Absorbed power at shaft	1.2	kW
Rated Power (Max) per blower	1.5	kW

CONCEPT DESIGN - Extended Aeration plant to cater for 25mc/day

Estimate assumes that water from the inlet works gravitates into an above ground bioreactor
Estimate assumes that mixed liquor is aerated 12hrs/day and mixed 12hrs/day

Process Area	Equipment	No. of duty items	No. of standby	Rated P (each item) kW	Shaft P draw kW	Motor effy %	P draw kW	Operating time hrs/d	Energy use kWh/d
Inlet works	Coarse screen 3mm. Tsurumi KS200S	1	0	0.1	0.08	68	0.12	12	1.4
Treatment tank	Blowers. 50 Nmc/h @ 40pa. Gardener Denver Sutorbilt Legend - 2M	1	1	1.5	1.20	82.0	1.46	12	18
Control	Control (5Amp 24VDC)	1	0	0.12	0.11	100	0.11	24	2.6
Total Daily Energy Use, kWh @ 25kL/d									**21.6**
Total Annual Running Cost - $ based on 32c/kWh									**2,518.8**
Consumption									**0.86**

BioGill - Design		
Design flow	25	m^3/day
BOD_{in}	250	mg/L
TKN_{in}	50	mg/L
BOD_{out}	20	mg/L
TN_{out}	20	mg/L
BOD load	5.75	kg/day
TKN load	1.15	kg/day
Wastewater temperature	22	°C
Removal efficiency	9	gBOD/m^2.day
Surface area required (Min)	500	m^2
Number of BioGill units	3	
Actual surface area	690	m^2
Passes per day	10	
Recirculation time	21	hours per day
Recirculation rate	12	m^3/day

CONCEPT DESIGN - BioGill plant to cater for 25mc/day

Estimate assumes that water from the inlet works gravitates into an above ground balance tank
Estimate assumes that water from the gills is reciculated to an above ground treatment tank
Estimate assumes 10 passes per day over a treatment period of 21 hours

Process area	Equipment	No. of duty items	No. of standby items	Rated P (each item)	Shaft P draw	Motor effy	P draw	Operating time	Energy use
				kW	kW	%	kW	hrs/d	kWh/d
Inlet works	Fine screen 1mm. Tsurumi KS200Z	1	0	0.1	0.08	68	0.12	16	1.9
Balance tank	Forwarding pump. 25mc/h @ 3m TDH. Non clogging KSB Sewabloc K 065-250G H 100L 06	1	0	1.5	0.47	82.0	0.57	1	0.57
Treatment tank	Recirculation pump. 12mc/h @ 3m TDH. Non clogging KSB Sewabloc K 050-250G H 100L 06	1	1	1.1	0.31	82.0	0.38	21	8
Control	Control (5Amp 24VDC)	1	0	0.12	0.11	100	0.11	24	2.6
Total Daily Energy Use, kWh @ 25kL/d									**13.0**
Total Annual Running Cost - $ based on 32c/kWh									**1,516.8**
Estimated Consumption kWh/k|L									**0.52**