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MALENY iMBR STP, IRRIGATED FOREST AND TREATMENT WETLAND

TWO YEARS IN OPERATION AND MORE

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ABSTRACT

In 2014, Unitywater - a water distributor/retailer water authority in South-East Queensland embraced an immersed membrane bioreactor (iMBR) technology at Maleny sewage treatment plant (STP). Increasing process capacity in conjunction to higher effluent quality and fostering a community-based-partnership including an ecosystem-based-approach for disposal of effluent to vegetated native forest and treatment wetland, were identified as the foremost drivers for successful implementation.

Comprised of a hybrid of new technology and natural purification processes, the STP is now in its fourth year of operation. This paper presents the operational results for the first 24 months of iMBR operation under a range of operating conditions such as diurnal flows, wet weather periods, fluctuating membrane fluxes including varying mixed liquor feed quality and performance of the treatment wetland.

Over the period of monitoring, the selected membrane technology demonstrated a 'stable operation'. A full recovery process clean-in-place (CIP) was performed on one occasion. Impact on permeability was almost 'indistinguishable'. Higher energy consumption and excessive chemical cleaning were operational drawbacks requiring refinements moving forward. Performance of the wetland was competitive in removing nutrients and potential benefits delivered back to the community and environment.

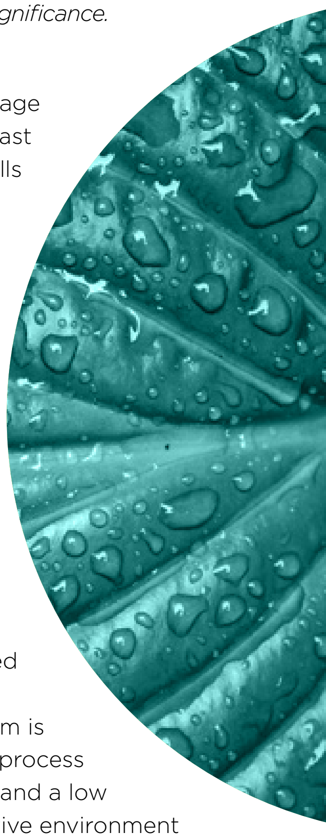
A SWOT analysis was undertaken to improve the operational excellence, and extend the useful service life of membranes including areas that critique the selection of the membrane technology conducted.

Keywords: Trans-membrane pressure (TMP), Average flux (J), Permeability (K), Solids mass flux (SMF), Membrane bioreactor (MBR)

An overview of the first two years of operating a modern 'iMBR' wastewater treatment technology integrated with an 'old technology' vegetated forest and an expandable nature-based treatment wetland of high cultural significance.

BACKGROUND

Unitywater inherited a second-hand sewage treatment plant (STP) from Sunshine Coast Council in 2010. Located in the nested hills of Maleny hinterland, the STP serviced 2,000 Equivalent Persons (EP) and was operating beyond its hydraulic and biological capacity. The STP infrastructure was old (last upgraded in 1989) and was relatively at the end of its serviceable life. Treated effluent irrigated onto a pasture block on the banks of Obi Obi Creek. Discharge into the downstream creek was a community sensitive issue due to the presence of a popular swimming hole – a recreational spot at Gardners Falls and Baroon Pocket Dam – an important drinking water catchment to an estimated population of 317,477 in Sunshine Coast (Quick Stats as at 30 June 2015). The dam is located 9.8 km from the STP. Increasing process capacity and production of a low turbid and a low nutrient effluent for discharge in a sensitive environment drove for a niche engineering intervention.



In 2014, Unitywater constructed an immersed membrane bioreactor (iMBR) process based STP under a 'Design and Construct (D&C) Contract' preceded by an Early Tender Involvement (ETI), which worked well in the project delivery. Valued at $17 million, the preferred option enabled a whole-life-cost savings of $18 million when compared to other conventional technologies. The constructed STP with 'state-of-art' technology officially opened to the local community on World Environment Day – 5 June 2014. A 13.8 hectares area of reforestation surrounded by unirrigated buffer and gully plantings, including three hectares of treatment wetland to enhance amenity value within the Maleny Community Precinct, were also developed.

Treated effluent is supplied to a golf course irrigator, Maleny Golf Club, in limited supply for night application and to a new irrigated forest area including a treatment wetland located at a low point of the gully, which eventually acts as the earth's 'kidneys' that disperses and seeps through permeable soils and removes residual nutrients and sediment from the high quality effluent, and then flows into Obi Obi Creek (Figure 1).

The project has won the *Australian Water Association's Queensland Water Award for Infrastructure Project Innovation in 2014 and a UN Environmental Award for Best Specific Environmental Initiative in 2015.*

To date, 30+ MBRs have been installed in Australia (Kicsi *et al.*, 2015). Literature on actual operational experiences of full-scaled plants is limited, and insufficient, albeit a few as reported by Solley *et al.* (2015); Short *et al.* (2015); including a trial demonstration by MacCormick and Brois (2007) and Hughes *et al.* (2015); and experiences from New Zealand by Mason *et al.* (2010). This paper presents the operational results under a range of membrane operating systems for the first 24 months including performance of the reuse water irrigation disposal system.

STP DESIGN

Inflows, Influent and Effluent Characteristics

Located on a green-field site approximately 30 km from Sunshine Coast within close proximity to Obi Obi Creek, the STP is an advanced BNR (biological nutrient removal) using 'ultrafiltration membranes' designed to treat 925 kL/d (design ADWF) of raw sewage to service an ultimate population of 5,000.

The local sewage catchment is mostly 'domestic' including retirement villages, eateries and restaurants, a hospital and the well-known 'Maleny Dairies'. Sewage inflow drops to near zero in the early hours of the morning and rises during peak daily water usage period.

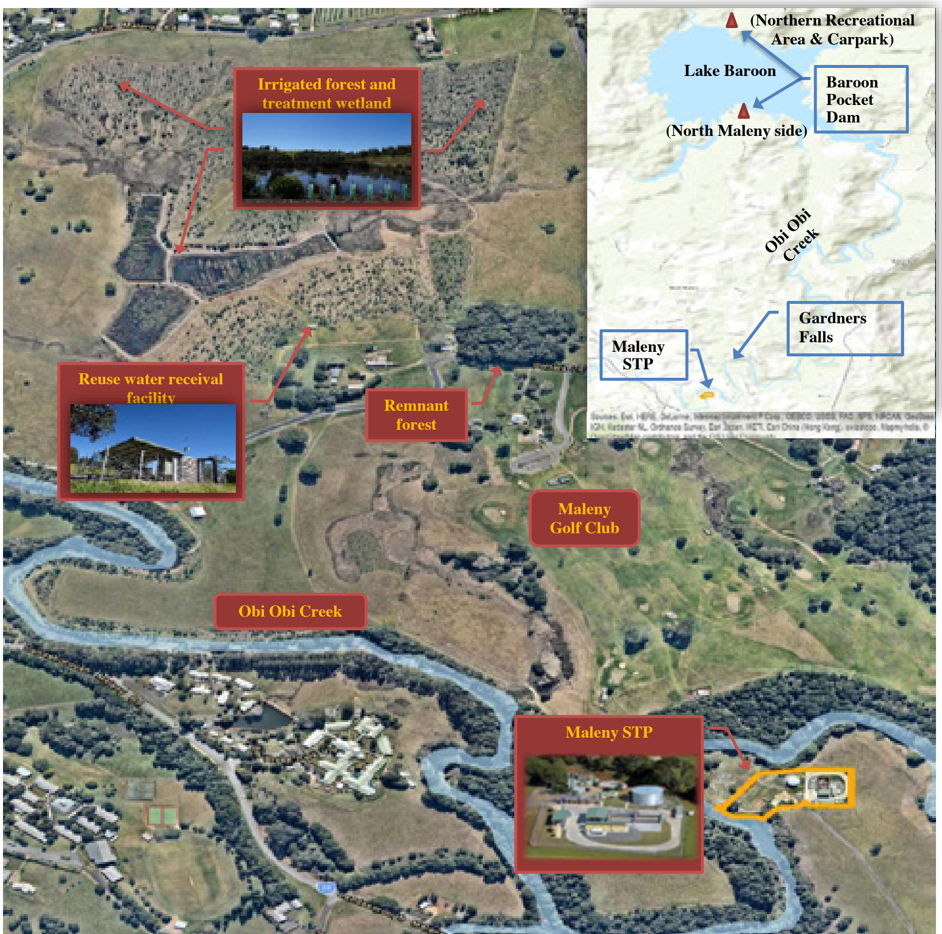


Figure 1. Location map showing the STP, treatment wetland and forest area in Maleny Community Precinct and Obi Obi Creek, Gardners Falls and Baroon Pocket Dam (insert).

Influent quality is typical of a non-toxic and non-inhibitory base. Maximum instantaneous capacity at 80 L/s (for less than two hours) and at 55 L/s sustained for a period of 30 days. The STP produces a 'Class 'A' effluent quality and recycled water supply compliance to The Water Supply (Safety and Reliability) Act, 2008 and Queensland Public Health Regulation, 2005 endorsed by the Environmental Authority (Table 1).

iMBR Process Anatomy

iMBR STP Process Train:

Incoming rising main sewage was screened using duty/duty assist 'Rotary perforated plate screens' (2mm basket screen) and de-gritted in a grit classifier, both accommodated in 316 SS built package works. Screened flows of up to 3xADWF allowed passage through a compartmentalised reactor configured as Modified Ludzack-Ettinger (MLE) process for secondary treatment. Mixed liquor separation occurs in two membrane tanks. Permeate is pumped to a 45 kL FRP (Fibre Reinforced Plastic) tank using bi-directional 'Rotary positive displacement pumps'. Treated effluent is further stored in a one ML GRP (Glass Fibre Reinforced Plastic) tank, and chlorinated when supplied to the golf course and when used as 'service water'. It is released directly with a small dose of chlorine (Cl_2) when discharged to native forest and treatment wetland, and when released as 'indirect potable reuse water' to Obi Obi Creek. Separate chemical facilities enable maintenance and recovery cleans for membranes. Alum is dosed for phosphorous removal. At the discretion of the operator, the wasted sludge is stored in a 45 kL polyethylene tank resulting in an average solids retention time (SRT) of 4-5 days at 'Camlock Connection Point' for tanker removal of partially thickened sludge (~3% DS).

Membrane Configuration:

A Polyvinylidene diflouride (PVDF) hollow fibre membrane manufactured with a nominal pore size of 0.04 µm coupled with the latest aeration technology, commercially known as *'LEAP*[i]*mbr'* was installed. The selected membrane technology was GE's ZeeWeed® 500d reinforced product having an immersible membrane area of 3,730 m² per train. Typical design mixed liquor suspended solids (MLSS) concentrations were between 8.4 to 12 g MLSS/L, respectively.
One critical control point was the permeate turbidity. If it exceeded 0.2 NTU (50th percentile) or 0.5 NTU (95th percentile), the screened effluent would bypass and be introduced into the creek, until the turbidity recovered and remained below 0.2 NTU.

Membrane Cleaning and Recovery Protocol:

Membrane cleaning using physical or chemical means are both performed. Physical cleaning is normally achieved by 'backflushing', *i.e.* reversing permeate back through the membrane, or 'relaxation', which is simply a 'ceasing operation' while continuing to scour the membrane's interfacial surface with air bubbles to purge activated solids. These two techniques are used in combination.

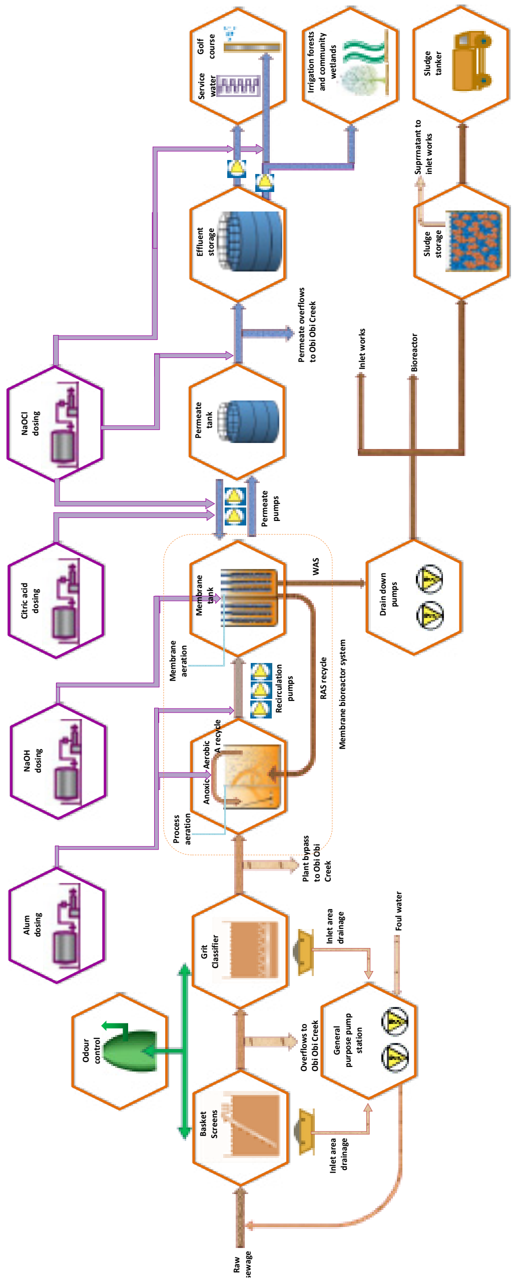


Figure 2. iMBR STP process train

Chemical cleaning involves using sodium hypochlorite (NaOCl), an oxidative chemical, in combination with citric acid ($C_6H_8O_7$). Maintenance clean is programmed for early morning (4 and 6 am). Every week the maintenance cycle includes backwashing with NaOCl (twice) and $C_6H_8O_7$ (once) solutions followed by a ten-minute soaking period, a day of backpulse and relaxing for the rest of the week and then repeating the process on a back-to-back recovery operation. Chemical cleaning combined with backflushing, also known as 'chemically-enhanced backflush' (CEB), is also performed.

Recovery clean or clean-in-place (CIP) is an intensive clean in which cassettes are removed from membrane tanks. Notionally, warning signs include a sudden drop in hydraulic performance characterised by increasing values of 'K' and or 'TMP or ΔP'. In the present case, the recovery clean has been conducted once as per the manufacturer's recommended interval – UF Train 1 on 26 Feb 2015 and UF Train 2 on 22 April 2015. No pinning/fibre-rub-through/fibre-pull-out was observed, however a thin 'slimy layer' flocked with solids was sighted on membrane surface in cassettes. The slime layer was cleaned using 0.1N NaOH and cassettes were reinstalled by soaking in 0.5% NaOCl solution (Figure 3).

TWO YEARS' OF iMBR OPERATIONAL PERFORMANCE AND EXPERIENCES

A suite of key treatment performance indicators (TPIs) analysed to evaluate the efficiency of the installed membranes include:

- iMBR performance indicators (MPIs):
  - Hydraulic side: Average flux (J), transmembrane pressure (TMP), permeability (K) and its recovery, physical and chemical cleaning cycle times and protocols
  - Biological side: Sludge wasting and high MLSS condition
  - Membrane life expectancy
  - iMBR plant health/status
- Power consumption (excluding sludge handling) and comparison to other plants
- Treated water quality

iMBR Performance Indicators (MPIs)

Hydraulic Performance:

Figure 4 shows the trends of selected MPIs stacked over each other with both trains operating at low fluxes in the performance proving period and gradually remained constant thereafter in the first two years of operation. The values of 'J' were 8.6 ± 1.91 ($\bar{x} \pm \sigma$) LMH for Train 1 and 8.6 ± 1.75 LMH for Train 2 in the first year. In the second year, there was a minimal increase reported at 9.1 ± 3.29 LMH in Train 1 and 9.0 ± 4.88 LMH in Train 2. These values were well below the recommended fluxes.

Figure 3. Membrane cassette a) removed for cleaning and b) soaked in NaOCl solution

1. "The word 'LEAP' (/lēp/) stands for *'Low Energy Advanced Performance'* associated with the new innovation aimed to produce bigger bubbles and more shear to reduce fouling in membranes." *(Source: GE Water and Process Technologies)*

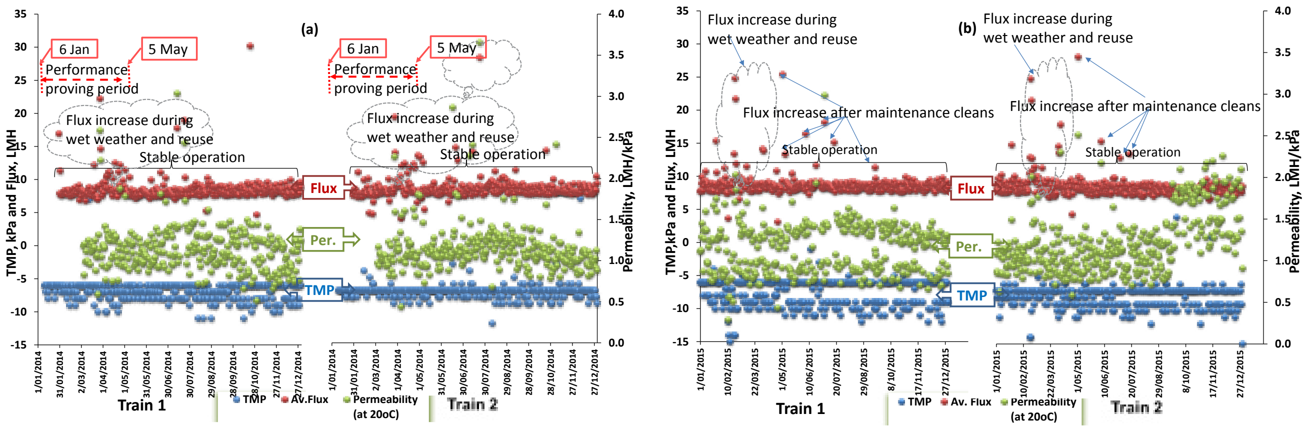


Figure 4. Plant hydraulic performance in a) 2014 and b) 2015

'TMP' tracked between -7.0 ± 1.38 kPa in Train1 and -7.2 ± 1.11 kPa in Train 2 in the first year. In the next year, a slight increase in 'TMP' was witnessed. The membranes were operated at -7.4 ± 2.61 kPa in Train 1 and -7.9 ± 1.64 kPa in Train 2. Still, the TMP difference (ΔP) before and after clean was almost negligible. Two distinct forms of 'TMPs' or 'ΔPs', one during 'production' and another during 'wasting' on a higher negative scale was sighted. On no occasions did the values exceed the target set points of -45 kPa (during production) and +45 kPa (during backpulse), respectively.

There were minor variations in the values of permeability (K). In the first year, 'K' was at 1.10 ± 0.49 LMH/kPa in Train 1 and 1.10 ± 0.32 LMH/kPa in Train 2, and at 1.20 ± 0.95 LMH/kPa in Train 1 and 1.20 ± 1.12 LMH/kPa in Train 2 in the second year. Permeability remained relatively constant and clustered within a small range demonstrating the membranes' capability in handling varying incoming feed water and withstanding to some extent variations in flux caused during wet-weather periods.

Judging by the trends, it appears there is no evidence to indicate significant increases in hydraulic resistance manifested by either decline in 'K' or increase in 'TMPs' or 'ΔPs', to conform any fouling of membranes. Apparently, it can even take place at low flux rates and sometimes lower values of 'TMPs' or 'ΔPs', and 'K' may mask fouling from happening in the initial stages of membrane operating system (Clech *et al.*, 2003). In summary, a stable performance was demonstrated in the first two-years of the membrane operating system.

Wet Weather:

Two thunderstorms and heavy rains of intensity – 215 mm on 28 March 2014 and 110 mm on 24 January 2015 resulted in flash flooding in the region. The membrane trains were tested against these events. Instantaneous peak hydraulic flows recorded were ~ 110 L/s > 80 L/s (design instantaneous flow).

Identical trends were found occurring in both trains. A sharp increase in alongside a decline in values of 'J' and 'K' suggests the trains handled wet-weather flows well without any damage to membranes (Figure 5).

The values of 'J' were well below the instantaneous design flux maxima of 47.5 LMH. Run-time of the permeate pumps was higher than usual by 6-8 hours leading to higher energy consumption. On both occasions, there were overflows sighted from bioreactor and permeate tanks.

Clean-in-Place (CIP):

The observed effect was 'no change' in 'K' (Figure 6). In fact, the CIP helped in normalising 'TMP' and brought down 'J' in Train 1, which was spiked due to rainy days prior to recovery clean. In the case of Train 2, the CIP was performed on a dry-weather day and showed trends of MPIs almost 'indistinguishable' between pre- and post-cleaning.

This lead to posing following questions on recovery cleaning protocol:

- What condition-based 'triggers' should be necessitated?
- What time-based conditions should be considered?

Conducting CIP involves hiring crane services, working at heights, routine operational safety issues, biological exposure, chemicals, etc.

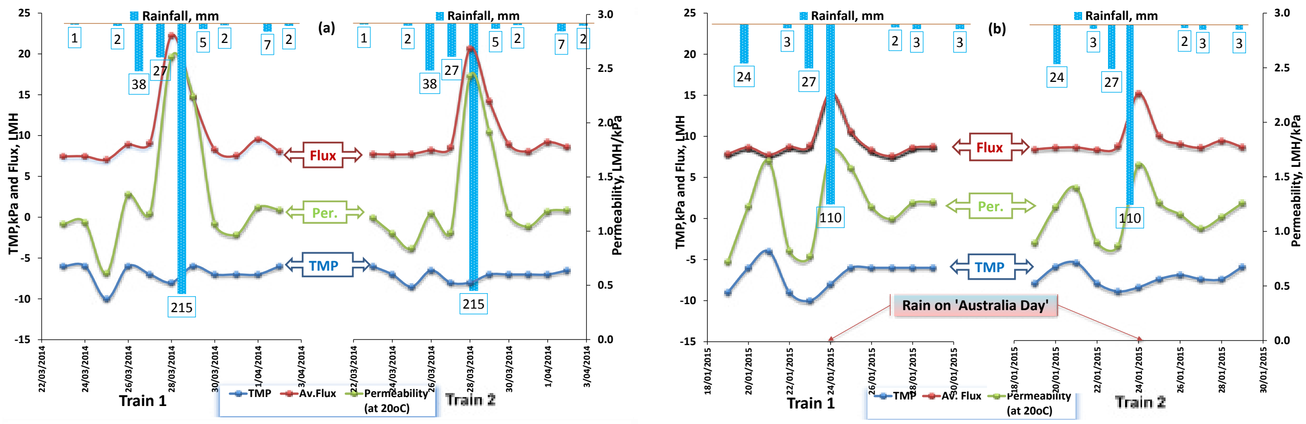


Figure 5. Impact of wet weather on hydraulic performance in a) 2014 and b) 2015

It may be worthwhile to reconsider the recommended intensive cleans that may be fine-tuned to suit a 'best practice' approach. A validation program challenging membrane cleaning and recovery protocol is therefore recommended following completion of the warranty period.

In conjunction with CIP, an operational lesson learnt was to clean diffusers in bioreactor and membrane tanks simultaneously and dredge tank floors of any accumulated sludge.

Permeability Recovery:

Effectiveness of cleaning protocol was examined by permeability recovery K (%), which was calculated by the difference between permeability values immediately after cleaning (Kt) and at the end of previous tests recorded immediately before the clean (K[t-1]), as compared to permeability decline over the course of the cycle (Ko –Kt):

Permeability recovery,K (%)= (Kt-K[t-1])/(Ko-Kt) x 100............... Equation 1

In two years of operation, 225 chemical cleans (151 NaOCl and 74 $C_6H_8O_7$ in 2014) and 311 chemical cleans (208 NaOCl and 103 $C_6H_8O_7$ in 2015) including manual intervention ('declogging' while CIP) were performed. Varying results on permeability increase and its recovery after each maintenance clean were found. It was difficult to calculate recovery when both organic and inorganic cleans were performed on the same day. Typical recovery estimated was around 62% in Train 1 and 67% in Train 2.

High MLSS and Membrane Permeability:

In any membrane-based process system, as the mixed liquor (MLSS) concentrations in the membrane tank increases the hydraulic performance drops, which is the first litmus test for solids separation.

Both trains operated mostly within operating range of mixed liquor in the membrane tank (orange dots in Figure 7). Few outliers outside the recommended matrix were due to noises from instrumentation probes. The mixed liquor also shot up during cleaning and when not in production, and during operation of drain draw down pumps and also during thickening. Despite all this, a little change in was observed at a design mixed liquor range of 8.4 to 12 g MLSS/L and dropped marginally when operated up to 15 g MLSS/L (design maximum), which is the first of its kind in Australia. Similar results were also found in a trial undertaken at Rouse Hill STP, Sydney (MacCormick and Brois, 2007).

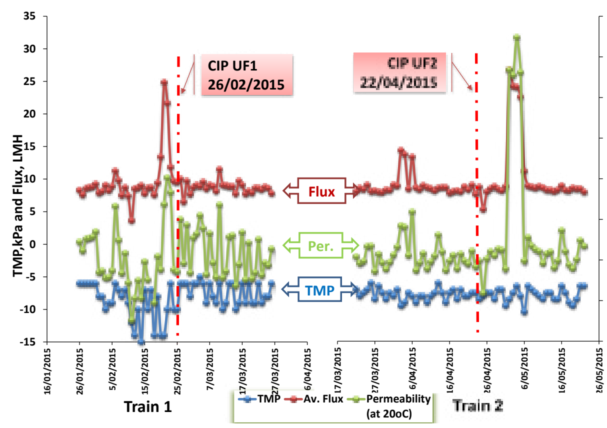


Figure 6. Impact of CIP on membrane performance

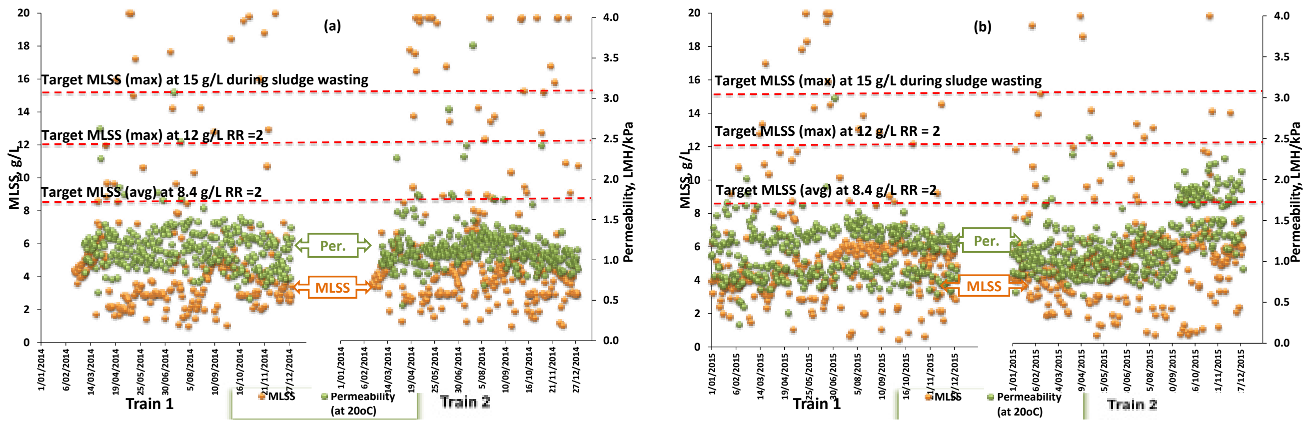


Figure 7. Impact of MLSS on membrane permeability in a) 2014 and b) 2015

MLSS in Aeration Zone and Solids Mass Flux:

An important parameter to watch is mixed liquor in the reactor, which is common for both trains. Results followed a season-based trend (purple dots) illustrating dynamic nature in the plant operation (Figure 8). Especially in winter, in three cold months of June, July and August, higher wasting was planned to bring down the mixed liquor concentrations. In the second year, the mixed liquor was brought under control to reduce energy requirements. The levels operated were well below the recommended design matrix of 5.5 to 6.7 g MLSS/L. Onsite NFR results of mixed liquor sample matched readings from Liquiline CM442 MLSS probe (AIT 3025) with minimal effect on sensitivity.

Estimation of solids mass flux (SMF) on a daily basis showed mostly operating below recommended value of 280 (310 max) GMH in both trains, indicating a marginal impact while operating at high MLSS concentrations and/or when sludge wasting occurred in membrane tanks.

Membrane Life Expectancy:

Predicting life expectancy of a membrane is an ongoing challenge both to the manufacturers as well as to the utility operators. Fouling propensity and morphological changes in the membrane fabric requires expert skills. Use of sophisticated techniques such as 'Confocal laser-scanning', 'Multi-photon microscopy' and 'Pressure-decay test' are expensive to perform. In such cases, longevity of the membrane product lies in maintaining 'healthy' TPIs (in-turn MPIs) within normal operating range and conducting periodic cleaning to ensure permeability recovery is not compromised during its service life (Maffescioni, 2015).

For Maleny STP, the membrane life/full replacement originally provisioned was for 10 years. Considering healthy KPIs indicated during the first two years, it is too early to state the end of 'useful-life-period'.

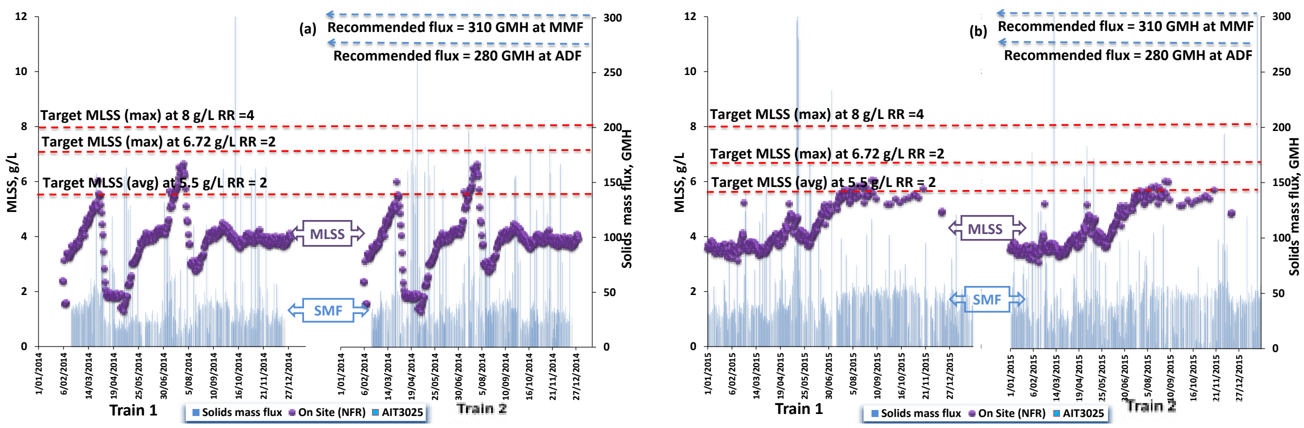


Figure 8. Impact of MLSS and solids mass flux on hydraulic performance in a) 2014 and b) 2015

Elsewhere, the ZeeWeed 500 products have been separately researched, and analysed since their commercial introduction in 1990s. Published sales data demonstrate a life of around 10 years depending upon the cleaning regime and operational discipline followed (Cote *et al.,* 2012). The data is specific to membranes installed in North America and not tested against Australian sewage conditions. Locally, a period of 7+ years has been demonstrated in a MBR retrofit at Cleveland Bay Wastewater Plant at Townsville, Queensland (Kicsi *et al.*, 2015).

iMBR Plant Health/Status:

A combination of selected KPIs (TPIs and MPIs) were evaluated against the operational set-points to ascertain the health and status of the plant. Statistical parameters of each KPI of interest were worked out against individual set-point in terms of Low (L), Low Low (LL), High (H) and High High (HH) on a daily basis.

A 12-month rolling average was then calculated to arrive at the health/status for each year and converted into a percentage.

Identical results were found for both trains for both years at >75% indicating membrane operating system monitoring parameters at 'higher-end' of the normal range (50 to 80%) for stable operation under dynamic conditions.

Power Consumption and Comparison with other Membrane-Based Plants in Australia

Figure 9 shows a scatter diagram of total daily inflow versus daily power consumption superimposed with calculated daily specific power consumption rate.

The daily power consumption was 'at par' with the old STP that had conventional activated process treatment. Currently, the STP consumes on average 780 kWh/d (2014 and 2015) and peaks up to 1,400 to 1,700 kWh on heavy rainfall days.

The trend in power consumption lies somewhere between the two sets of daily specific energy consumption rates (1.2 and 2.0 kWh/kL determined based on first principles). The range of power consumption rate varied between 0.7 to 5.2 kWh/kL (median at 1.9 kWh/kL) in 2014 and 0.2 to 2.7 kWh/kL (median at 1.7 kWh/kL) in 2015. At start-up, fluctuations were attributable to power failures as trains did not return to 'auto-mode' until there was a physical intervention by plant operators.

Typical published energy benchmarks for operating recycling water schemes are seldom compared based on the understanding that "each case is different and site specific." Short *et al.* (2015) and Kicsi *et al.* (2015) have reported power consumption rates ranging from 0.5 to 1.05 kWh/kL for plant capacities of 29 to 35 ML/d. Experiences with MBR plants in Cairns (16 and 19 ML/d capacity) indicate between 0.57 to 0.7 kWh/kL. In comparison, the Maleny iMBR STP appears to be on a higher end of the specific energy consumption. It is to be noted that the plant is operating at 50% of its design hydraulic/organic load. This reaffirms the view that energy consideration plays a pivotal role in choosing a membrane-based treatment especially with small-scale plants.

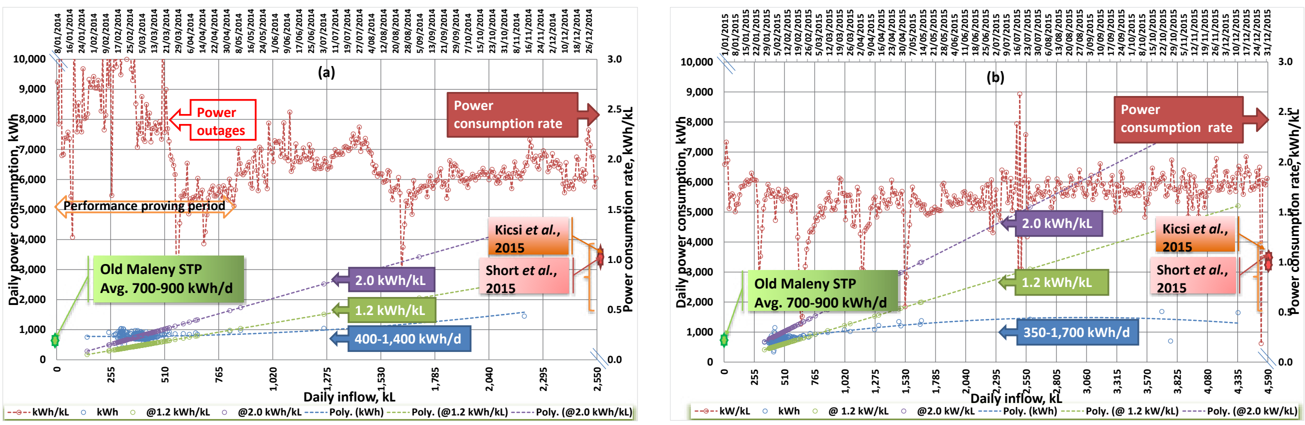


Figure 9. Power consumption in a) 2014 and b) 2015

Table 1. Effluent quality

Parameter	Number of samples (2014+2015)	2014	2015	Release limit/ Supplier's guarantees in italics	Limit type
Suspended solids, mg/L	74+48	4.0	5.0	10	80th percentile (long term)
Turbidity, NTU	*Daily*	*(UF1/UF2) 0.03/0.13 0.1/0.2*	*(UF1/UF2) 0.03/0.11 0.1/0.2*	*<0.2 <0.5*	*50th percentile 95th percentile*
Total N, mg/L	118+48	3.29	2.53	5	50th percentile (long term)
Total P, mg/L	119+48	0.11	0.37	1	50th percentile (long term)
Escherichia coli(a), CFU per 100 mL	116+49	<1	<1	<100	Median
Intestinal enterococci#,(a), CFU per 100 mL	78+47	<1 230	<1 <1	<40 <150	Median Maximum

UF1/UF2 refers to Ultrafiltration trains 1 and 2.

#Preferred faecal indicator bacteria for assessing recreational water quality determined in accordance to AS/NZS 4276.9:2007.

(a)*Indicative log reduction values (LRV) of enteric pathogens and indicator organisms stipulated in Australian Guidelines for Water Recycling-Natural Resources Management Ministerial Council Publication (NRMMC, 2006).*

Treated Water Quality

Table 1 presents the sample results of the permeate quality independent of the influent quality including surrogate parameters specific to membrane processes such as turbidity, and pathogens like *Escherichia coli* and *Enterococcus spp.*

The iMBR technology surmounts its capability of being an effective 'solids barrier' treating to a superior water quality, as exhibited by a 'whitewater' sample collected at forefront of post membrane filtration tank for bacterial examination (Figure 10).

SWOT Analysis

A Strength, Weakness, Opportunities and Threat (SWOT) analysis was undertaken, focussed around 'value added benefits' to understand the strengths, weaknesses, core advantages, and areas that critique the use of new membrane technology. Various workshops/conferences involving internal and external stakeholders were held taken into account.

A symbiotic progression and relationship between each component of the matrix corresponding to a wedge or a pie was plotted (Figure 11). As a cursory to the SWOT analysis, the benefits found in adopting membrane-based technology include the ability to operate at higher biomass, long sludge age and eliminating the need for a new secondary clarifier within the existing block of land. Typical mixed liquor concentrations of >8 g MLSS/L (designed to pre-thicken sludge up to 1.5%), coupled with settling characteristics becoming irrelevant especially with no sludge blanket depth measurements in operational philosophy has led to its popularity among plant operators. In addition, the membrane technology significantly removes *E.coli* and *Intestinal enterococcus spp.* and reduces the burden of tertiary filtration and to some extent downgrades chemical usage in disinfection process prior to effluent reuse. Past studies have also confirmed excellent log removals for *E. coli* and faecal coliforms (Branch *et. al.,* 2015) and also reduction in disinfectant using MBRs (Hai *et. al.,* 2014). In hindsight, oxygen demand being premium, and energy consumption from mixed liquor feed; membrane aeration; permeate suction and reverse flow; and cleaning chemical usage prohibits a 'fair conclusion' on economies of scale when compared to operating a conventional clarifier for removing activated solids. In the present case, the power and chemicals costs constituted to~16% of operational expenditure (2014/15).

Going forward, in order to bring down the operational costs, one such initiative using a weak acid such as formic acid for cleaning aeration diffusers was trialled. So far, the results indicate a less significant improvement in the membrane performance.

IRRIGATED FOREST AND TREATMENT WETLAND SYSTEM

Components and Performance

The Maleny Community Precinct site encompasses a total area of 126 hectares - a former dairy farm. Owned by Sunshine Coast Council, the site had a series of natural channels and shallow pools overgrown by Kikuyu grass (*Pennisetum clandestinum*) with scattered remnant trees prior to restoration. In 2012, Unitywater signed an agreement to lease approximately 30 hectares of land from the Council. Approximately 175 ML of reclaimed water from STP is discharged annually via a 1.4 km x DN250 rising main and a reuse water receival facility for irrigation to forest (currently irrigated to 10.5 hectares) and treatment wetland in the precinct (Figure 12). Pump discharge to forest occurs daily even when rainfall is up to 15 mm/d and direct discharge to wetland occurs when rainfall exceeds 15 mm/d and during wet weather

Figure 10. Water sample collected on 10 June 2015

days. Spray irrigation using Nelson R2000 Rotators (approximately 3,200 Nos) is carried out between 8 PM and 6 AM. Reuse water is naturalised as it trickles through soils in free draining areas and up to 60% of applied water gets lost through evapo-transpiration.

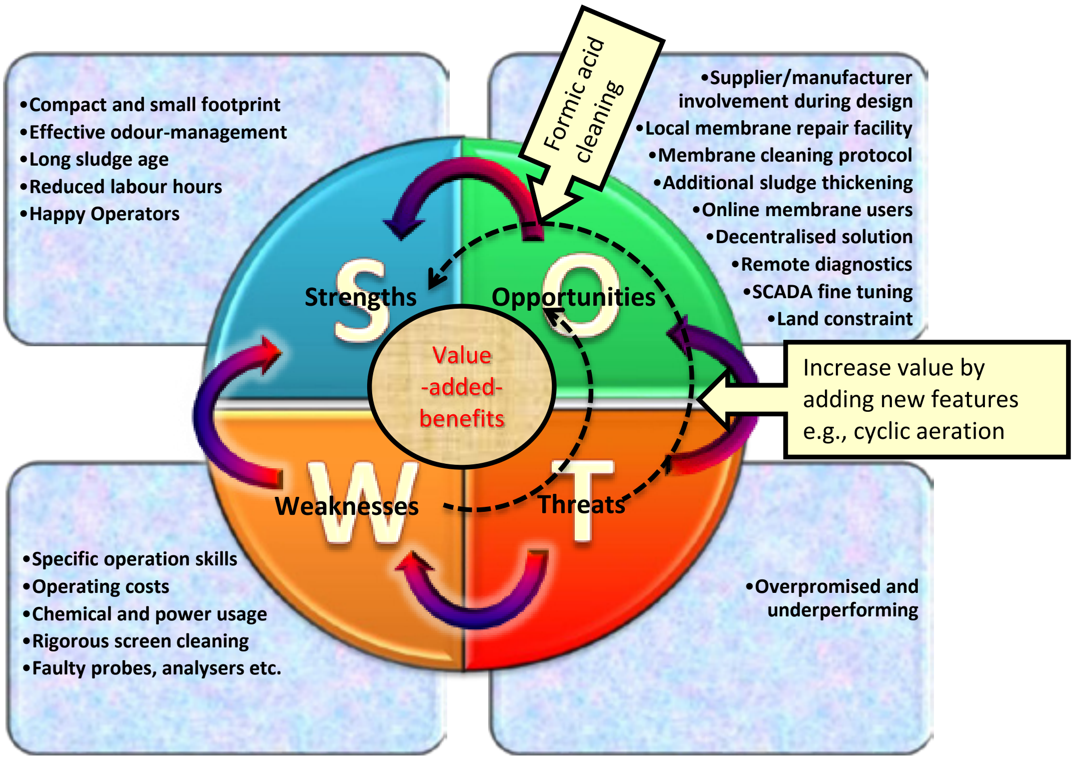


Figure 11. SWOT analysis chart

The wetland has a free water surface system and consists of three cells with individual rock weir inlets and vertical riser outlets.

Results of pre- and post-wetland samples indicate approximately 94-97% removal in median values of nitrogen, in particular to nitrate-nitrogen and nitrite-nitrogen (less important), and ammonia nitrogen and undetectable range for other agronomic parameters in the reusable water.

Approximately 525 kg and 412 kg of nitrogen and 63 kg and 84.5 kg of phosphorous in 2014 and 2015 is utilised through soil adsorption, which was otherwise destined for release to Obi Obi Creek and in turn to Baroon Pocket Dam.

Figure 12. Aerial view of irrigated forest located on the hill slopes and treatment wetland in the valley floor surrounded by large native trees. The figure also shows local community groups involved and results of reuse water pre- and post-treatment in treatment wetland.

Community Involvement/Participation and Giving Back to the Community

Maleny has a history of and community passion for environmental issues. Wetlands are of high cultural significance. Traditional owners of the land, the Jinibara people, have played an active role in the creation of rainforest and treatment wetland to ensure the heritage of the land is respected and artefacts of cultural significance protected (listed as 'Fairview').

Local bush care groups include the Lake Baroon Catchment Care Group volunteers, Barung Landcare, Maleny District Green Hills, and more than 350 school students from Ananda Marga Rivers School. Community tree planting events resulted in 1,500 native seedlings being planted, and in the next 3-4 years planting of the understory species stocking at 2,500 stems/ha will be completed by Verterra Ecological Engineering. Unitywater has been working with the Sunshine Coast Council, University of the Sunshine Coast, and the local community to ensure the green infrastructure is up-kept with the Community Precinct Master Plan.

In summary, adopting an ecosystem-based-approach through local community involvement has enabled Unitywater to develop an alternative green engineering solution to hard engineering problems and showcase it to the community and to stakeholders.

Biodiversity

Restoration of rainforest and wetland have led to transforming essentially a monoculture into a rich habitat land full of biodiversity. The precinct now provides a real habitat to a variety of flora and fauna including aquatic plants, water birds, mammals, and marsupials, etc. Plant species in the wetland include a dense plantation of *Lepironia articulata*, *Persicaria strigosa, Baumea articulata, Ranunculus inundates,* etc.

A list of fauna sighted include black rats, brown hares, red foxes, stripped marsh frogs, etc. reported in a biodiversity research project undertaken by the University of the Sunshine Coast.

CONCLUSIONS

A number of significant outcomes have been witnessed at Maleny iMBR STP. Summarily, these include:

- An iMBR is distinctly a decentralised process suitable for remote and or isolated communities such as Maleny.
- Hygienically superior water quality of permeate - the iMBR performed well especially for parameters of turbidity, Escherichia coli and Enterococci spp.
- Membrane life is a function of operating within the TPIs (and MPIs) evidenced by stable performance, especially with minimal change in membrane permeability.
- From an operational perspective, the iMBR carries additional costs associated with the membrane operating system especially energy usage for air scouring, and permeate pumping in smaller plants.

- Excessive chemical dependence is a drawback. A validation in chemical usage and recurrence interval for cleaning is 'mandatory' in order to achieve economics in operation. Cleaning chemicals also adds up to higher operational expenses.
- Combined with natural wetland and irrigated forest, the upgrade worked well in creating a flora and fauna biodiversity in the Maleny Community Precinct - a recipe for a 'win-win' proposition.
- Collaboration with the local community, local council and internal stakeholders yielded a range of benefits delivered back to the community and to the environment.
- Appreciable reduction in nutrients released to the environment. Approximately 525 and 412 kg of nitrogen in 2014 and 2015 and 63 and 84.5 kg of phosphorous in 2014 and 2015 was reduced from getting released into Obi Obi Creek.

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