MEMBRANE AERATED BIOFILM REACTOR - FIRST FULL-SCALE PLANT IN NEW ZEALAND.

Nadine Oschmann, Bronson Light (Veolia Water Technologies & Solutions), Kevan Brian and Hui Ian Tan (Watercare Services Ltd)

ABSTRACT

Membrane Aerated Biofilm Reactors or MABR's are a new technology for the treatment of wastewater. The process is energy efficient and ideal for process intensification where additional total nitrogen removal or nitrification is required. MABR applications are very well suited to process upgrades in New Zealand where oxidation pond systems are required to meet tighter nitrogen consents year-round. Therefore, MABR technology was installed at the Helensville wastewater treatment plant and has been selected as the technology of choice for several future pond upgrades by Watercare.

The existing biological treatment process at Helensville WWTP included a 3 mm rotary drum with spiral sieve screen followed by two stage oxidation pond system and an Ultrafiltration (UF) Tertiary Membrane Plant, which discharges into a third pond, before the treated effluent is discharged to the Kaipara River.

The WWTP has been historically non-compliant with resource consent requirements for several parameters. The WWTP has been upgraded with Membrane Aerated Biofilm Reactor (MABR), because of its ability to provide total nitrogen reduction in a compact footprint and the ease of integration with the rest of the treatment plant. The upgrade project included the installation of a new MABR system for nitrification, as well as installation of a third UF Membrane train. The objective of the MABR is to treat an average of 1,500m3/d of pond effluent to reduce ammonia nitrogen to meet the plant resource consent and to meet more stringent effluent quality targets. The MABR cassettes are installed in dedicated stainless-steel tanks upstream of the existing UF plant. Ammonia is removed by the nitrifier population on the inside of the biofilm. The plant was commissioned in March 2023.

This paper presents the results of the start-up and first few months of operation of the Helensville MABR plant.

KEYWORDS

Full scale MABR, nitrification, pond upgrade

PRESENTER PROFILE

Nadine has nineteen years' water and waste water treatment experience and has worked on a wide range of projects including wastewater treatment plants, sewer mining projects and advanced recycled water treatment plants. She has extensive experience in Membrane based technologies, including MABR and energy efficient waste water treatment plant design.

1 INTRODUCTION

The existing biological treatment process at Helensville WWTP included a 3 mm rotary drum with spiral sieve screen followed by two stage oxidation pond system and an Ultrafiltration (UF) Tertiary Membrane Plant which was installed in 2018. The UF plant discharges into a third pond, before the treated effluent is discharged to the Kaipara River. Figure 1 shows an aerial of the WWTP.

Figure 1: Helensville WWTP

2. BACKGROUND

The Helensville WWTP has been non-compliant with respect to the effluent ammonia median limit since October 2019. Influent and effluent ammonia concentrations from 2016 to 2021 are shown in Figure 2. Ammonia increased from around mid-2019 and exceeded the current consent limit of 25mg/L.

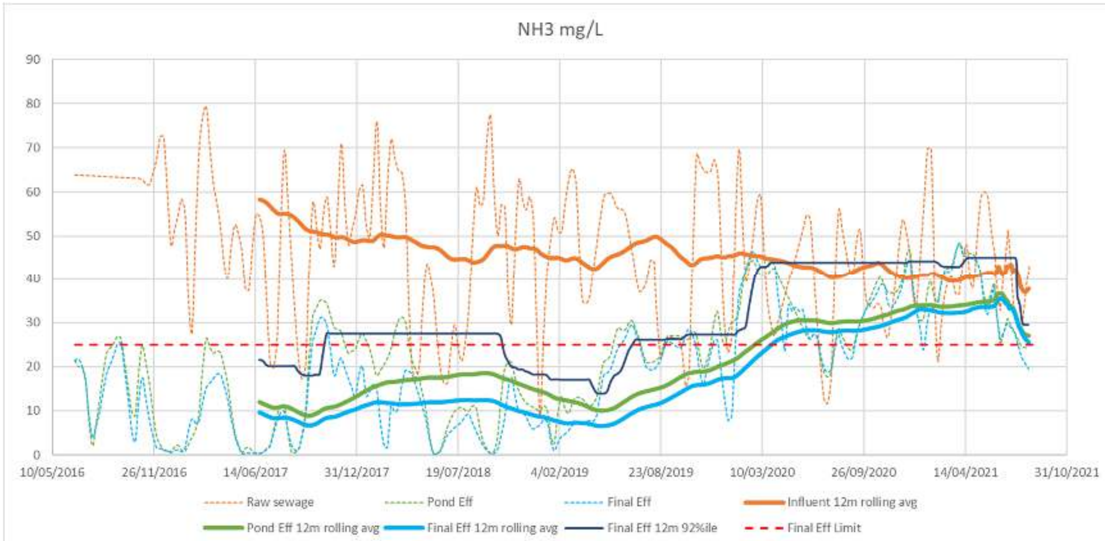

Figure 2: Pond Ammonia concentration (mg/L) from 2016 to 2021

In contrast the BOD removal capacity of the pond over the same period, was not impacted showing sufficient capacity of the pond in regard to biological BOD removal performance.

Ammonia is generally removed from ponds through assimilation by algae. Given that the Helensville UF plant does not allow these algal solids to leave the process, assimilated nitrogen is essentially trapped within the pond. The only removal mechanism is therefore via nitrification/denitrification to nitrogen gas. This process may occur in ponds; however, it is difficult to control and is generally very much slower than in a process such as activated sludge.

It was therefore likely, that elevated effluent ammonia at Helensville would continue and may never return to levels observed before the UF system was installed. Watercare received an abatement notice from Auckland Council in late 2021 due to the Helensville Wastewater Treatment Plant continued failure to comply with discharge consent standards. By December 2021, Watercare committed to delivering urgent and extensive improvements at the plant, within a year. Achieving this challenging commitment relied on taking an integrated team approach, excellent planning, and honest open communications.

Watercare engaged Veolia at the end of 2021 to develop a collaborative solution to upgrade the plant with the MABR technology. The technical solutions used for the Helensville Project were developed through 18 months of collaboration between Veolia and Watercare's technical teams.

3. MABR DESIGN

Membrane Aerated Biofilm Reactors or MABR's are a new technology for the treatment of wastewater. The process is energy efficient and ideal for process intensification where additional total nitrogen removal or nitrification is required. MABR applications are very well suited to process upgrades in New Zealand where oxidation pond systems are required to meet tighter nitrogen consents year-round. Therefore, MABR technology was installed at the Helensville wastewater treatment plant and has been selected as the technology of choice for several future pond upgrades by Watercare.

Membrane Aerated Biofilm Reactor (MABR) has been selected, because of its ability to provide total nitrogen reduction in a compact footprint and the ease of integration with the rest of the treatment plant. The upgrade project included the installation of a new MABR system for nitrification, as well as installation of a third UF Membrane train.

The MABR process employs a gas transfer membrane to deliver oxygen directly to a biofilm that is attached to the surface of the membrane. The MABR process leverages the synergy between a gas transfer membrane and an attached growth biofilm. Oxygen is delivered by diffusion to the biofilm with very high efficiency while substrate, such as ammonia, diffuses from the bulk solution into the biofilm. Preferential growth of nitrifiers versus heterotrophs in a counter-diffusional biofilm is a key differentiator of MABR as compared to conventional co-diffusional biofilm technologies, which makes it a great solution for ammonia polishing application. The MABR operating principle is illustrated in Figure 3.

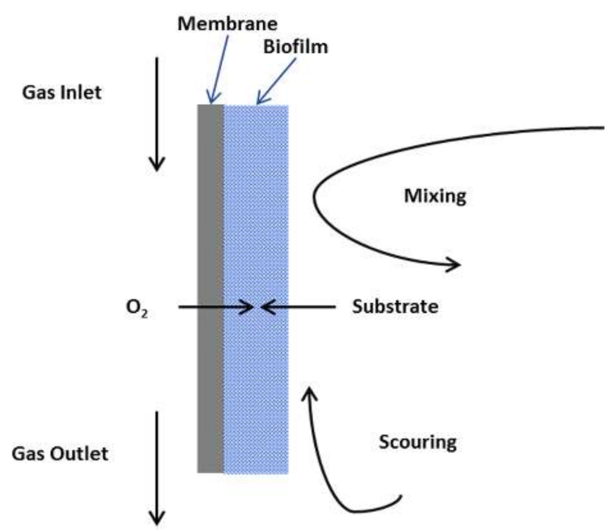

Figure 3: MABR Operation Principle

3.1 DESIGN BASIS

The objective of the MABR is to treat an average of 1,500m3/d of pond effluent to reduce ammonia nitrogen to meet the plant resource consent and to meet more stringent effluent quality targets

Table 1 and 2 presents the influent conditions and design loading at the Helensville WWTP used as the design basis.

Table 1: MABR influent design conditions

Parameter	Values
Average Daily Design Flow	1,500m3/d
Peak Design Flow	63 L/s
Annual Average Ammonia Concentration	33 mgN/L
BOD Concentration	45 mg/L
COD Concentration	180 mg/L
TSS Concentration	120 mg/L
Alkalinity	75-150 mg$CaCO_3$/L
pH	7-9
Temperature	15-25 degC

Table 2: MABR influent design loads

Parameter	Design Loads
	kg/d
$cBOD_5$ (kg/d)	67.5
Total COD (kg/d)	270
Ammonia Nitrogen (kg/d)	49.5
TSS (kg/d)	180

The MABR system has been designed to remove an average daily load of 34.5kg/d at an average inflow Ammonia concentration of 33mg/L to meet an average effluent Ammonia of 10mg/L.

The Plant is designed to meet the treatment objectives in table 3, measured at the effluent of the MABR system for Ammonia and in the UF Permeate for TSS.

Table 3: Plant effluent targets

Parameter	Value
MABR Effluent Target: TAN (mg/L)	≤ 10
UF Effluent Target: TSS (mg/L)	≤ 5

3.2 PROCESS DESIGN

The MABR design concept is to reduce the ammonia of the Helensville WWTP by supporting the growth of a biofilm on the ZeeLung media. The ZeeLung cassettes are installed in dedicated tanks downstream of the existing ponds. Ammonia is removed by the nitrifier population on the inside of the biofilm and the produced nitrate is removed by the denitrifier population in the outer layers of the biofilm.

The ZeeLung cassettes are supplied with low-pressure air, similar to a fine bubble aeration system. Air is delivered to the ZeeLung cassettes and flows downward through the modules. As air travels through the modules, oxygen diffuses through the ZeeLung media directly into the biofilm without the use of bubbles, resulting in a very high oxygen transfer efficiency and low energy requirement. Exhaust air is collected, and the exhaust oxygen concentration is continuously monitored, which is the main indicator for process performance.

Air is also supplied for mixing and scouring of the ZeeLung tank and cassettes. The result is an efficient system that requires a small air supply. The air supply for the ZeeLung system is delivered by ZeeLung blowers (duty / standby), mixing and scouring blowers (duty/standby), and all necessary valves and instrumentation required for automatic operation.

ZeeLung cassettes are installed in two new purpose-built tanks, each outfit with five cassettes and spare space to accommodate one additional cassette. The new ZeeLung tanks are located directly adjacent to the existing ponds. The two tanks are arranged in series to maximise the ammonia concentration and plug flow conditions throughout the tanks.

4. MABR CONSTRUCTION

The MABR cassettes are installed in dedicated steel tanks upstream of the existing UF Plant adjacent to the pond. The number of MABR tanks has been selected to allow stainless steel tank construction and ease of transport to site. Photos of the MABR tanks are shown below. The site had significant access and geotechnical constrains and MABR technology was also selected due to the ability to manufacture the tanks offsite, ease of installation, reduced civil requirements and a small footprint. Figure 4 shows a picture of one of the MABR tanks being installed.

Figure 4: MABR Tank Installation

The MABR cassettes are supported using 316L stainless steel mounting brackets attached to the walls of the tanks which support the necessary mounting hardware. Cassette installation is a simple process where a 316L stainless steel hangar frame designed for lifting and installing cassettes, allows cassettes to be installed into the tank from the tank surface. Figure 5 shows a picture of one of the MABR cassettes being installed into a tank.

Figure 5: MABR Cassette Installation

To improve preliminary treatment upstream of the MABR, a 1.5mm Amiad pre-strainer was installed upstream of the MABR, shown in the picture below.

Figure 6: Pre- Strainers

The high-quality upgrade was delivered in an incredibly short timeframe, whilst keeping the costs to plan and without any serious incidents or accidents.

The project achieved practical completion ready for Operations to commence commissioning on 1 February 2023, under the budget estimate. This is only 6 weeks later than planned through one of the wettest construction seasons on record in Auckland.

5. MABR PERFORMANCE

The plant was seeded with nitrifying sludge from the Mangere WWTP on 16 March 2023. The plant was then operated in batch mode, till continuous operation approval was obtained from the Watercare operations team on 5 April 2023. Once the plant was fed continuously a biofilm established within one week, as shown in Figure 7. Exhaust O_2 is the main online performance monitoring parameter for MABR technology. As seen in the graph, exhaust O_2 drops over the week of the Biofilm growth phase and then tracks along with the feed loads of the plant showing the Biofilm is fully established. Following successful Biofilm establishment and operation of the plant for a month a 28-day performance test was entered on 15 May 2023.

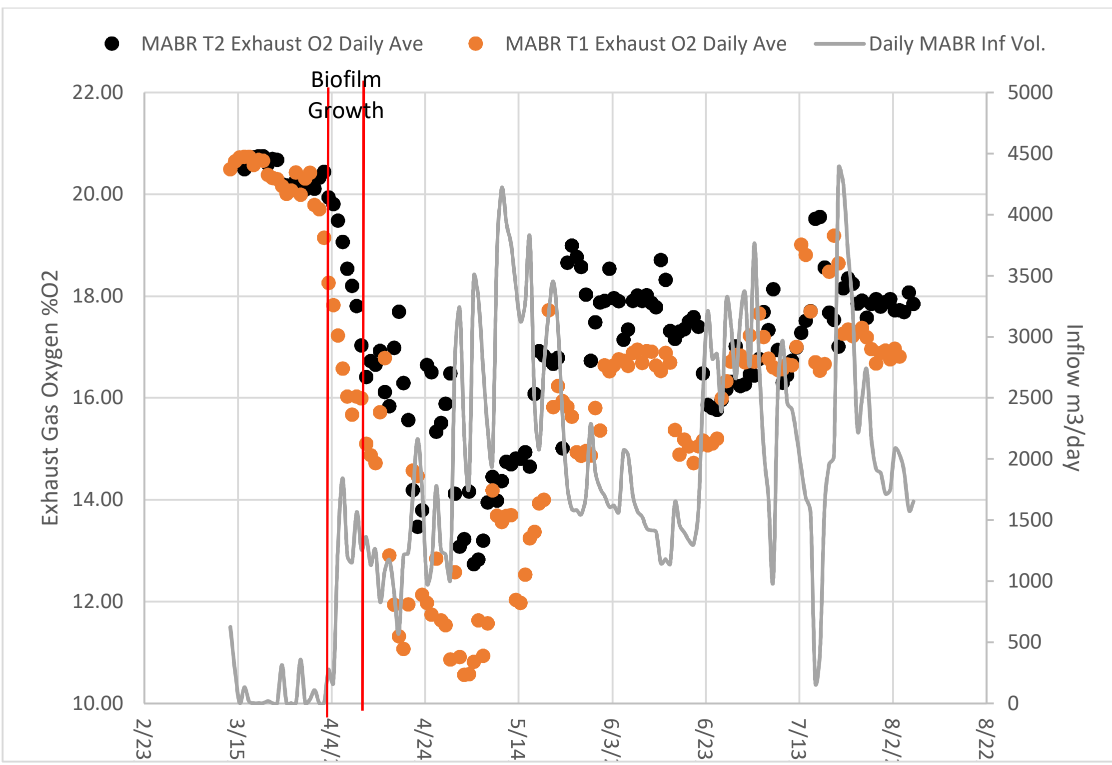

Figure 7: Exhaust O_2 and Influent flows since start up.

The Ammonia influent and effluent concentrations and loads during the performance trial are presented in Figure 8 and 9 below. The MABR effluent ammonia concentrations were significantly below the consent limit of 10mg/L, with the MABR achieving a median Ammonia concentration of 1.43mg/L, which was significantly lower than expected. However, the pond influent concentration was also significantly lower than the design of 33mg/L with a median of 20mg/L recorded during the performance proving period. The % removal, shown in Figure 10 on the other hand was over 90% median, which is significantly higher than the design removal rate.

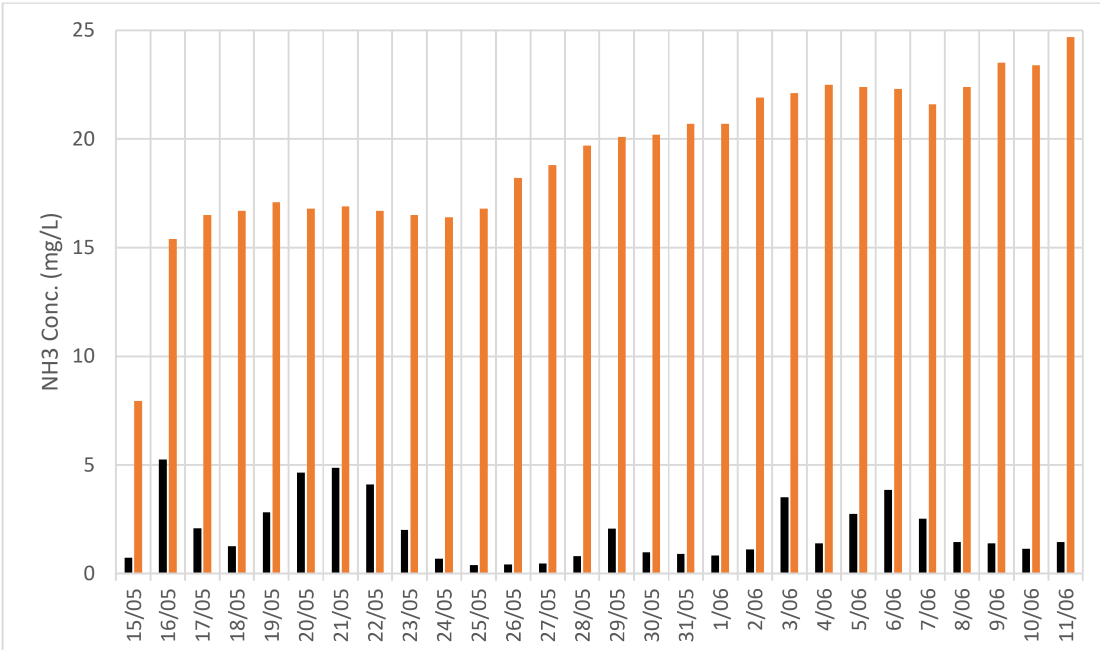

Figure 8 : Influent and Effluent Ammonia Concentrations

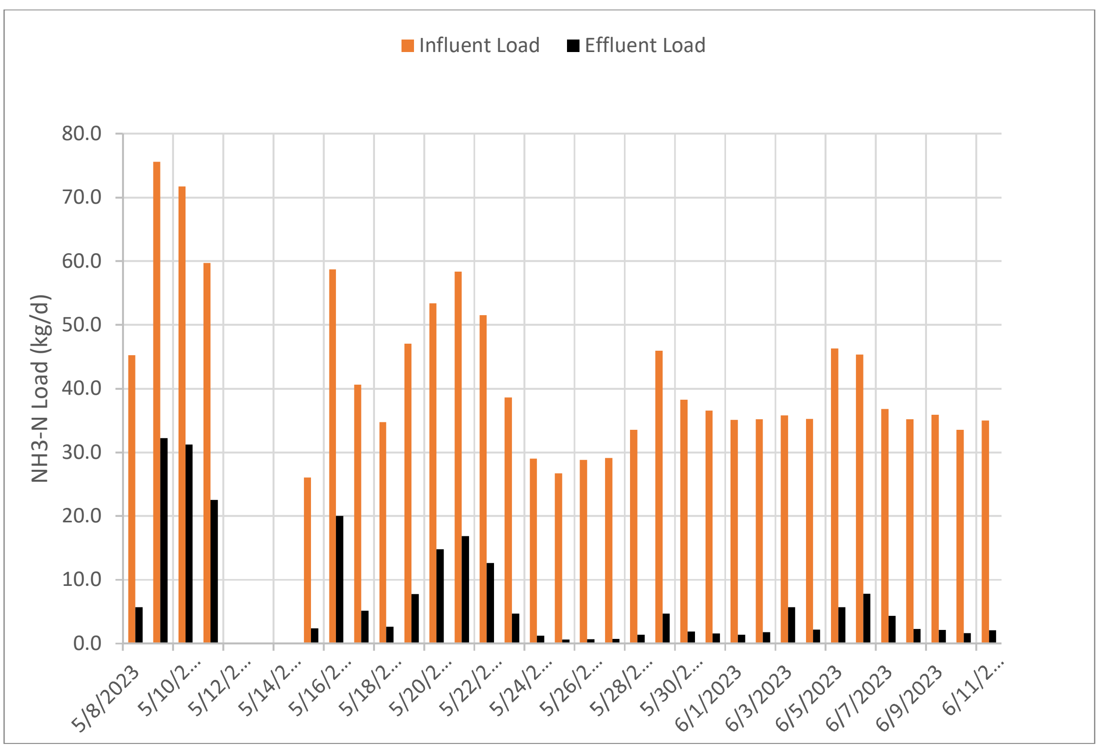

Figure 9: Influent and Effluent Ammonia Loads

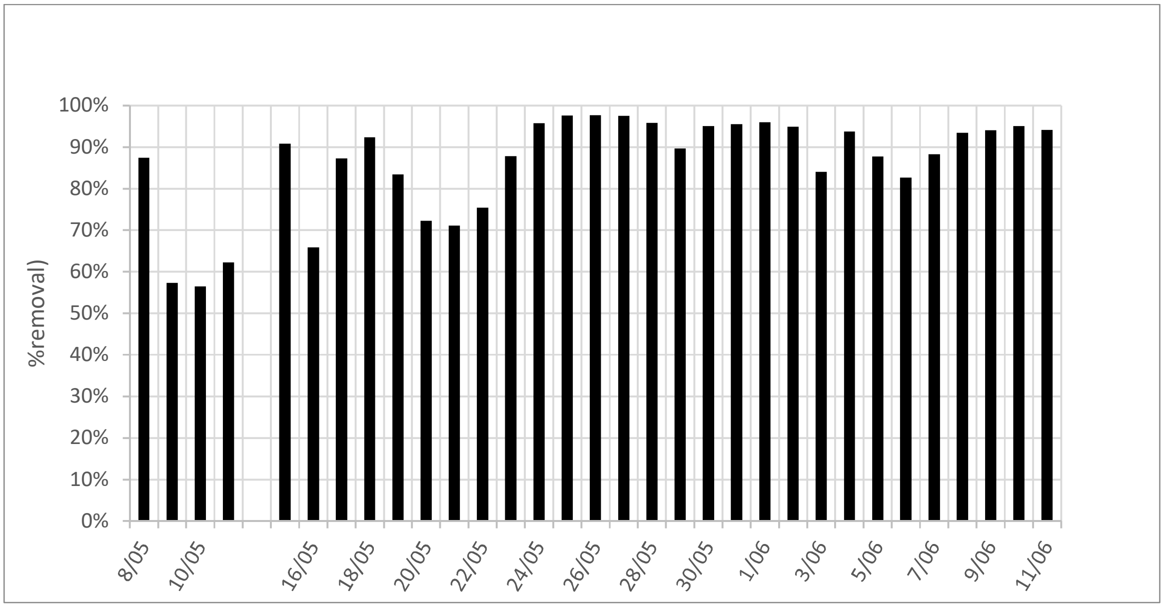

Figure 10: % Ammonia removal rates

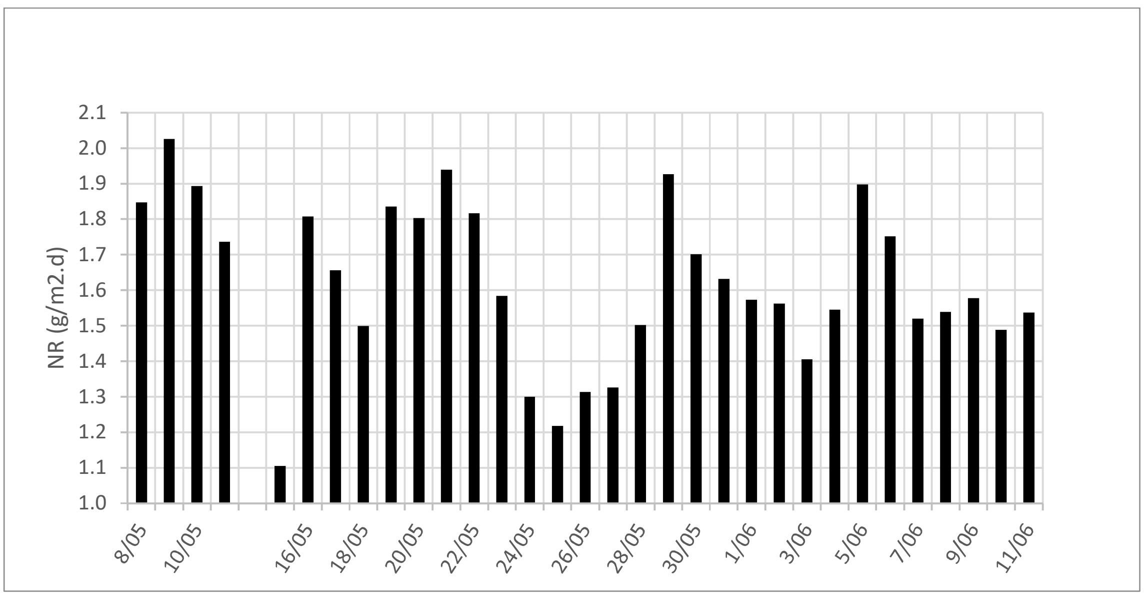

Figure 11: MABR system Nitrification rates

The plant nitrification rates are presented in Figure 11. The achieved system nitrification rates ranged from 1.1 to 2 g/m2/d, with a median of 1.57 g/m2/d. as MABR is a concentration driven process and the effluent ammonia concentrations observed were low (1.43mg/L median), it is expected that much higher nitrification rates can be achieved under higher loads.

In addition, the performance trail was conducted over the colder part of the year, with nitrification rates to increase with warmer temperatures.

6. CONCLUSIONS

The Helensville MABR upgrade project has been a great success, with the MABR meeting and exceeding all performance criteria, with discharge Ammonia concentration of 1.43mg/L achieved as a median during the performance test.

The plant now fully complies with the discharge consent and the effluent is of a significantly higher quality having a positive impact on the receiving environment.

MABR is ideal for oxidation pond upgrades in New Zealand where additional total nitrogen removal or nitrification is required to meet tighter nitrogen consents year-round. MABR is also simple to operate and require minimal operator intervention which is ideal for regional plants that are not continuously manned. As an additional bonus MABR is 4-6 times more energy efficient and has lower greenhouse gas emissions compared to conventional activated sludge plants. Therefore, MABR technology has been selected as the technology of choice for several future pond upgrades by Watercare and should be considered for any pond systems which struggle with nitrification.

MABR technology is easy to integrate, due to the ability to manufacture the MABR tanks offsite, ease of installation, reduced civil requirements and a small footprint.

The project team is immensely proud of the accomplishments of the Helensville Project and the positive impact it has had on the water industry and the environment.

ACKNOWLEDGEMENTS

We would like to acknowledge Watercare for being an early adopter of MABR technology and seeing the opportunity for this technology in the New Zealand context. In addition, we would like to acknowledge the Watercare and Veolia WTS project and commissioning teams for making the project a great success.