Improving oxygen delivery in aerobic treatment and promoting the growth of nitrifiers using nanobubbles

Niroshitha Selvakumar, Graduate Engineer
Samuel Leong, Treatment Plant Planner

Greater Western Water – Wastewater Process & Optimisation

Date: 27th February 2025

Abstract

The nanobubbles pilot trial is a collaborative project between Greater Western Water and Custom Fluids. The trial aimed to improve the oxygen delivery in wastewater aerobic treatment and promote the growth of nitrifiers using nanobubbles in one of the primary treatment maturation lagoons in Greater Western Water's Bacchus Marsh Recycled Water Plant. This paper will delve into the results achieved from the trial using the new and innovative nanobubbles technology and the limitations faced.

Acknowledgement of Country

Greater Western Water respectfully acknowledges the Traditional Owners of the lands and waters upon which we work and operate, the peoples of the Kulin Nations. We pay our deepest respects to their Elders past and present who continue to forge the way ahead for their emerging leaders.

Table of contents

1.0 Introduction

1.1 The Nanobubbles Technology

How Do Nanobubbles Work in Water?
Nanobubbles are extremely small gas bubbles, typically smaller than 200 nanometres in diameter. Unlike regular bubbles, they behave differently in liquids and offer unique properties that make them useful in various industries. Nanobubbles enhance gas transfer efficiency, remain suspended in liquid for extended periods, and facilitate contaminant breakdown through oxidation (Yaparatne et al. 2022). Their unique properties make them highly effective for water treatment, agriculture, aquaculture, healthcare, and industrial applications.

- **Gas Infusion:** Nanobubbles are formed by entraining gas (e.g., oxygen, ozone, carbon dioxide, nitrogen, etc.) into water.
- **Long Suspension:** Due to their small size, high surface tension, lack of buoyancy, they remain in suspension for days/weeks/months (depending on agitation).
- **High Gas Transfer Efficiency:** Unlike regular bubbles, Nanobubbles dissolve more gas into water, improving oxygenation. Typically: 1.6-2.0 kgO2/kWh, 70%-90% SOTE and α-factor ≥1.
- **Collapse & Oxidation:** When collapsing, Nanobubbles generate hydroxyl radicals, which break down contaminants and biofilms.
- **Collapse inward (not outward),** releasing energy and reactive oxygen species (ROS), which help in cleaning and disinfection.
- **Possess a negative surface charge,** preventing them from merging while assisting dissipation throughout the water body.

1.2 Bacchus Marsh Recycled Water Plant

Bacchus Marsh Recycled Water Plant is located 8.5 km from the Bacchus Marsh township and 12.5 km from the Melton township. It is a lagoon-based wastewater treatment system that has an aeration lagoon and is designed to treat an average dry weather flow of 3.2MLD of sewage into Class C recycled water.

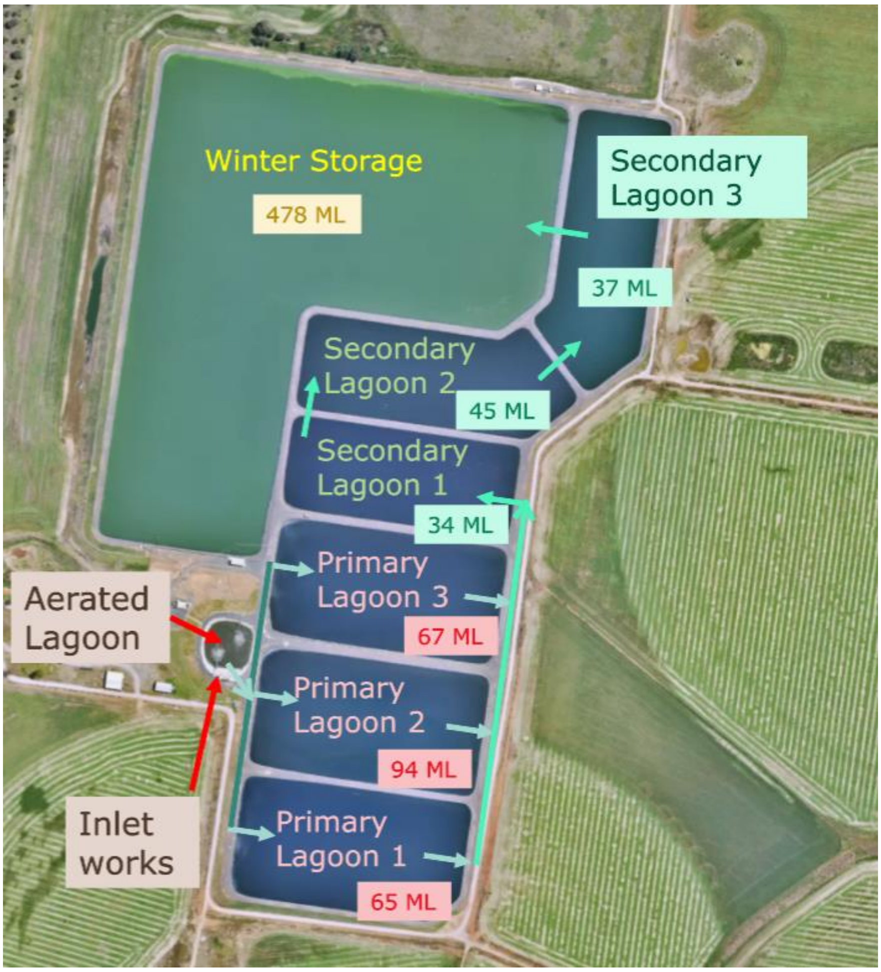

Figure 1: The overview process in Bacchus Marsh Recycled Water Plant

The process starts with the inlet works, where the influent is screened for any large solids and debris, then it is aerated through the aeration lagoon before splitting the flow into 3 Primary Lagoons running in parallel. After the 3 Primary Lagoons, the flow convenes and runs through a series of 3 Secondary Lagoons, and it is then stored as Class C recycled water in the 478 ML Winter Storage.

The standard aeration process was suboptimal, with an average dissolved oxygen (DO) level of 0.2 mg/L. The ammonia observed at the upstream of the treatment plant was in a range between 20 to 30 mg/L.

Due to the condition of the treatment plant, a trial of the innovative technology using nanobubbles was proposed to introduce its application in the maturation lagoon system to observe the effects of sustained increase in DO supply and the subsequent effects of nitrification, removing high concentrations of ammonia in the process. The trial was proposed to run for 6 months starting from the start of the summer period.

The objectives of this trial were the following:

- Sustained increase in DO supply in the lagoon system
- Encourage the start of the nitrification process
- Reduction in high concentration of ammonia

2.0 Methodology

The trial was set up with the use of four non-industrial pumps drawing water from the first Secondary Lagoon and pumping through two nanobubbles compressor to discharge into one of the 3 Primary Lagoons. The equipment was housed inside a shipping container for the purpose of security and portability throughout the 6-month trial.

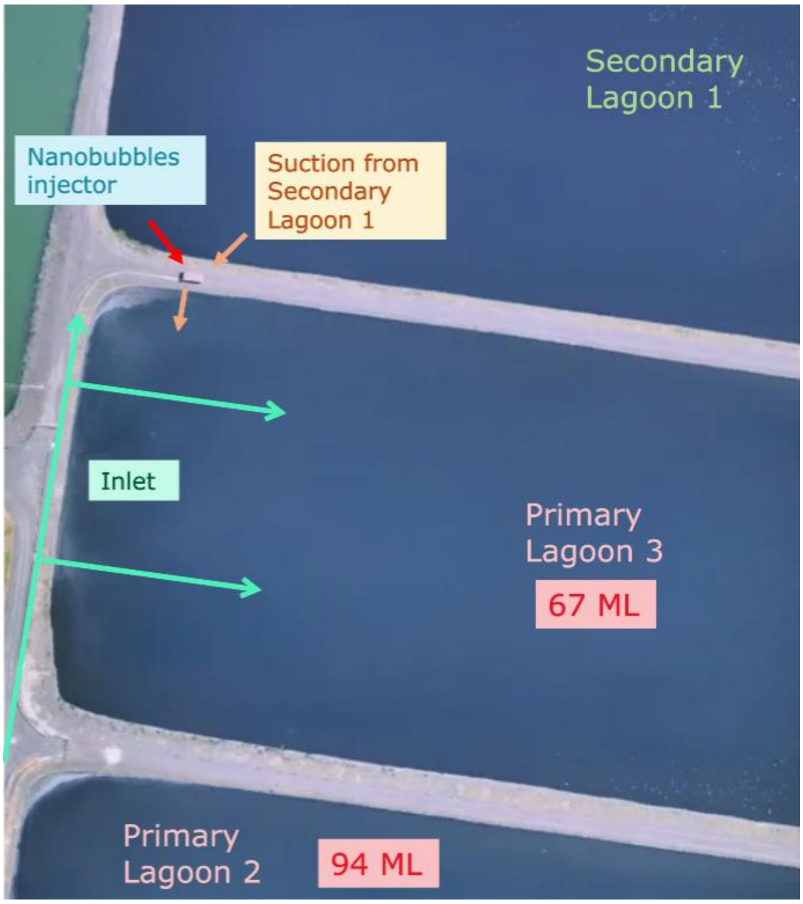

Figure 2: Schematic of nanobubbles trial set up

Figure 3: Images of the nanobubbles equipment during the trial

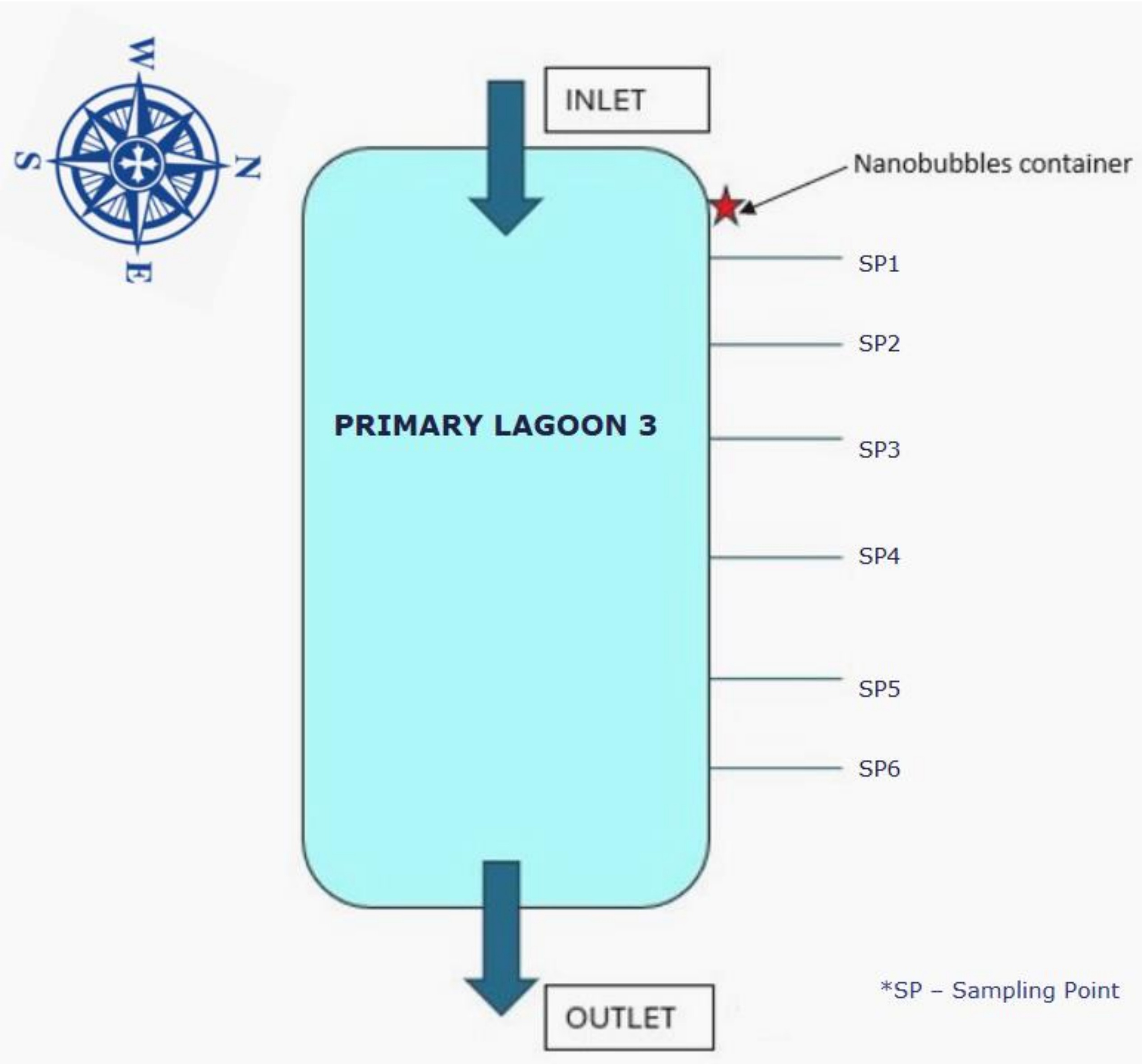

Figure 4: Sampling points in Primary Lagoon 3

Figure 4 depicts the six sampling points used to sample Primary lagoon 3 to cover the entire length of the lagoon. Additional sampling points were the two outlet channels of Primary Lagoon 3. For each sampling point along the length of the lagoon, two samples were taken; one for the surface level reading of DO and another at deeper level. The deeper level reading was approximately one metre under the surface. All samples were physically monitored with the use of a handheld DO probe.

3.0 Results

3.1 Data

Figure 5 highlights the data calculated from the six-month trial.

<table>
<tr><td rowspan="7">Primary Lagoon 3 Outcomes</td><td rowspan="5">Surface Level</td><td>0.26 mg/L</td><td>Average DO level across lagoon (pre-trial)</td></tr>
<tr><td>3.94 mg/L</td><td>Average DO level across lagoon (up to recent readings)</td></tr>
<tr><td>3.33 mg/L</td><td>Median DO level across lagoon (up to recent readings)</td></tr>
<tr><td>11.09 %</td><td>Decrease in Ammonia trends</td></tr>
<tr><td>78.95 %</td><td>System Uptime.
Note: use of swimming pool pumps with no filtration resulting in <u>regular</u> blockages by algae/animals upstream of Nanobubble system.</td></tr>
<tr><td></td><td>16.82 %</td><td>Decrease in COD trends</td></tr>
<tr><td>Deeper Level (approx. 50cm-1m)</td><td>1.34 mg/L</td><td>Average DO level across lagoon. Note: Surface baseline 0.26 mg/L, near 0 mg/L at depth</td></tr>
<tr><td rowspan="2">Secondary Lagoon 1 Benefits</td><td rowspan="2">Surface Level</td><td>8.11 mg/L</td><td>Average DO level. Note: PL3 gravity feeds into SL1. System feed water taken from SL1.</td></tr>
<tr><td>74 %</td><td>Average DO level increase w.r.t measurement taken in week 4.</td></tr>
</table>

Figure 5: Data calculations from the six-month trial

3.2 Summary of findings

The trial started with an average DO of 0.26 mg/L from near surface readings. The aim of this trial is to increase this number to 2 mg/L. By the end of the 6-months trial, the surface level reading almost doubled with the results showing an average of 3.94 mg/L. An increase of DO in the deeper level readings starting with 0 mg/L before the trial and finalizing to an average of 1.34 mg/L after the completion of the trial was observed.

The trial resulted in a notable 16.82% reduction in COD, highlighting nanobubble effectiveness in enhancing organic matter breakdown. With COD being a key indicator of organic load, a reduction suggests improved microbial activity and oxidation processes. In facultative lagoons, where both aerobic and anaerobic bacteria play a crucial role, sustained increase in DO likely enhanced aerobic degradation, leading to more efficient organic matter breakdown. COD reduction contributes to better overall water quality but supports more stable lagoon operation by reducing excess organic buildup, which can otherwise lead to odours, sludge accumulation, and treatment inefficiencies. These findings suggest that higher and stable DO levels can be valuable for optimising lagoon performance.

4.0 Discussion

The trial demonstrated that nanobubbles effectively maintained a sustained increase in DO levels within the lagoon system.

4.1 Limitations

During the trial, the team encountered few limitations:

- Due to a limited budget, some of the equipment used for the trial was small scale and non-industrial such as the pumps.
- Additionally, the team were unable to install industrial filtration at the suction point and fixed instrumentations for DO monitoring.
- The lack of filtration led to frequent pump blockages. A temporary low-cost straining solution helped mitigate this issue for the remainder of the trial.
- No fixed instrument for DO monitoring meant the team had to physically sample to collate DO data which created limitations on collecting representable data due to simple grab samples rather than continuous, and on where the samples could be taken due to safety reasons.

Although the trial was conducted on a small scale with non-industrial equipment (excluding the nanobubble systems), the findings demonstrated that nanobubbles can enhance DO levels in wastewater treatment.

4.1.1 Ammonia reduction

In the context of insufficient DO levels from the upstream aeration lagoon, introducing the nanobubbles and its effects on a sustained increase in DO levels in Primary Lagoon 3, a decrease in ammonia trends of 11.09% was observed.

Being influenced by factors such as lagoon retention time, microbial community composition, or sludge age, ammonia reduction may have been greater and warrants further investigation to optimise nitrification efficiency.

4.2 Improvements

Other than higher and stable DO levels, additional factors to improve ammonia reduction in the lagoon system would be increasing the hydraulic retention time. One method to increase the hydraulic retention is to install polyethylene curtains as partial baffles to encourage the flow in a serpentine manner instead of straight. This will ensure the sludge age is longer and the nitrifying bacteria can take enough of the oxygen required from the nanobubbles and ensure the nitrification process takes place.

5.0 Conclusion

Our key observations and concluding takeaways from this trial are:

- Technology is straightforward to use but does rely on application specific knowledge during and implementation.
- While we acknowledge that DO is only one piece of the nitrification process puzzle, the technology works in achieving a sustained increase in DO.
- Minor mechanical challenges arose due to the small-scale nature of the trial.
- If trialled again in maturation treatment plants, we would consider baffling up the lagoon to increase retention time.

6.0 Acknowledgements

The team extends its deepest gratitude to Greater Western Water and Custom Fluids for their unwavering support, invaluable expertise, and steadfast commitment throughout the trial. Their generous guidance, technical insight, and dedication were instrumental in navigating challenges and ensuring the success of this project. Their contributions went far beyond expectations, offering not only critical expertise but also encouragement and collaboration that truly elevated the process. This trial would not have been possible without their tireless efforts, and we sincerely appreciate their willingness to share their knowledge, time, and resources. Their belief in our work has been a driving force, and we are profoundly grateful for the invaluable role they played in achieving this milestone.

7.0 References

Yaparatne S, Doherty ZE, Magdaleno AL, Matula EE, MacRae JD, Garcia-Segura S and Apul OG (2022) *Effect of air nanobubbles on oxygen transfer, oxygen uptake, and diversity of aerobic microbial consortium in activated sludge reactors*, ScienceDirect website, accessed 10 April 2024. https://www.sciencedirect.com/science/article/abs/pii/S0960852422004199?via%3Dihub