Final Report
ENVENG 787: Project X

Model simulation and review of critical parameters impacting nitrification in Membrane Aerated Biofilm Reactor (MABR) system

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ABSTRACT

The Membrane Aerated Biofilm Reactor (MABR) has shown promising results in high removal efficiencies of nitrogen constituents. Pure oxygen or air is supplied through a gas permeable membrane which allows development of biofilm on the surface of the membrane. The MABR has proven simultaneous nitrification and denitrification process to occur. In this research project, GPS-X is used to simulate the critical parameters on the nitrification performance in the MABR system by evaluating the concentrations of biomass and nitrogen constituents in the theoretical biofilm developed. The GPS-X sample layout and default values were used, where critical parameters and values were changed one at a time to assess and review the MABR performance. Based on the model, operational parameters (inlet pressure, total mass transfer coefficient and oxygen fraction in inlet air) could achieve 80% ammonia removal efficiencies. Additionally, increase in ammonia concentrations were explored to assess the effects on the biofilm development.

Keywords: MABR, GPS-X, Nitrification

ABBREVIATIONS

AOB	Ammonia Oxidising Bacteria
DO	Dissolved Oxygen
HET	Heterotrophic Bacteria
MABR	Membrane Aerated Biofilm Reactor
NH4-N-N	Ammonia Nitrogen in Wastewater
NO2-	Nitrite
NO3-	Nitrate
NOB	Nitrite Oxidising Bacteria

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1.0 INTRODUCTION AND LITERATURE REVIEW

The increase discharges of nitrogen constituents, particularly ammonia nitrogen (NH4-N-N), nitrites (NO2-) and nitrates (NO3-), are widely known to contribute to an adverse environmental impact in particular in waterways when excess concentration levels cause eutrophication (Hornung, 1999). Furthermore, the increasing cost operating and removal inefficiencies conventional wastewater treatment plant (WWTP) has motivated numerous individuals in search for improvements to efficiently remove nitrogen compounds.

The membrane aerated biofilm reactor (MABR) has shown promising results in removal efficiencies, oxygen transfer rates and oxygen transfer efficiencies. Multiple pilot and full scale studies have been undertaken globally from a range of brewery wastewater, polluted surface waters, landfill leachate management, pharmaceuticals (Brindle et al., 1999; Wei et al., 2012; Li & Kaisong, 2018; Syron, Semmens, & Casey, 2015). Additionally, regulations and increased environmental awareness are major also drives to adapt and implement this technology.

This report will primarily focus on simulating and demonstrating critical parameters impacting nitrification of the performance of the MABR systems using a model base approach. The research project predominantly focusses on biomass and nitrogen concentrations in the biofilm layer.

1.1 MABR overview

The initial concept of a bubble free aeration has been suggested in the late 1980's (Côté et al., 1989). However, the concepts of oxygenation transfer through permeable plastics films or gas transfer membrane have been researched as early as 1960's (Schaffer et al, 1960; Yasuda and Lamaze, 1975). It was not until 1990's gained great interest on the transfer of oxygen though a gas permeable membrane and the term 'MABR' was first used (Semmens et al., 1994) The MABR systems have been commercially available since 2013 and the three main suppliers of the MABR technology systems are DuPont OxyMem, Suez Zeelung and Fluence. With Oxymem and Zeelung using hollow-fibre membranes and Fluence flat sheet membranes. This project is based on the hollow-fibre membrane.

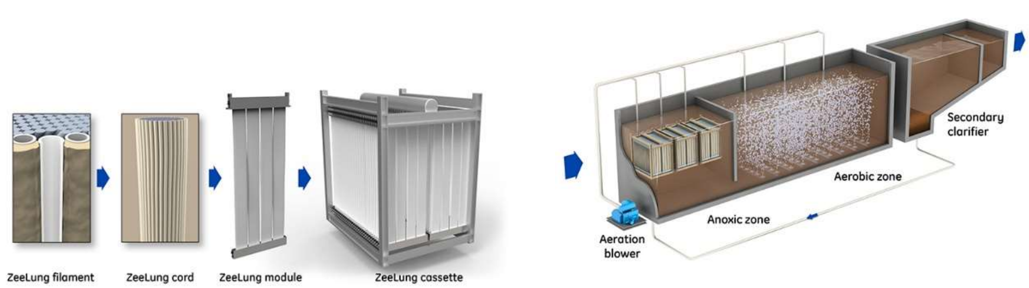


Figure 1 a) MABR system and b) MABR cassettes submerged into anoxic tanks obtained from SUEZ Zeelung website ("ZeeLung Membrane Aerated Bioreactor for Wastewater | SUEZ," 2021)

Contrary to the conventional wastewater treatment (WWT), the fundamental concept of MABR systems is that the membranes in arrayed in modules and cassettes are submerged into anoxic tank and process airflow, either containing pure oxygen or composition of air is supplied through the lumen and air is then transferred onto a gas permeable membrane (Casey et al., 1999; Lu et al., 2021). The membrane acts as a support surface which allows biomass to be attached and to develop a layer of biofilm. This creates a counter diffusional and interaction of dissolved oxygen (DO) and nitrogen constituents in the anoxic tank. Conventional co-diffusional biofilms suffer from mass transfer limitations that resulted higher DO concentration requirements and energy (Metcalf and Eddy, 2014). Nerenberg (2016) shown that by supplying air through the membrane lumen, it creates a counter diffusional interaction, oxygen transfer rate and efficiencies are potential higher compared to the conventional WWTP. Therefore, the low energy in aeration has the potential to decrease the cost of WWT operation (Martin and Nerenberg, 2012). Additionally, implementing MABR technology does not require additional footprint, as these are submerged into existing tanks in the secondary biological treatment.

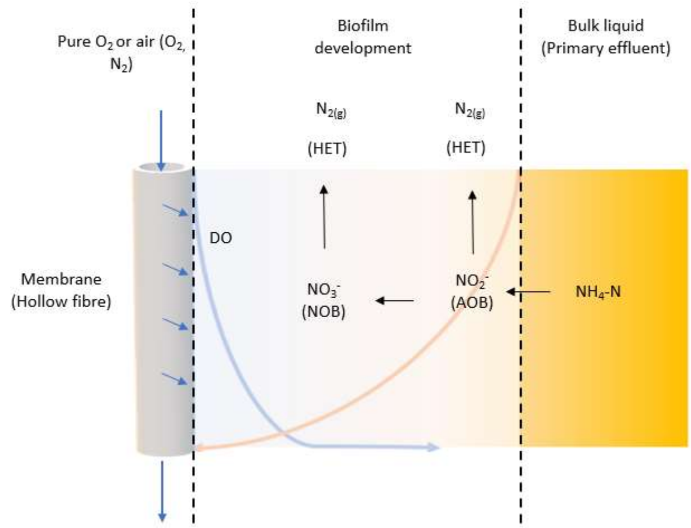


Figure 2 Profile conceptual model of a single membrane within a MABR system showing the processes occuring. DO profile is indicated by blue and orange the NH4-N-N

1.2 Nitrogen cycle: Nitrification and denitrification

The source of nitrogen in municipal wastewater originates from a variety of sources from human waste (proteins, amines, nucleic acid, peptides and amino acids), pharmaceuticals, minimal industrial waste food processing (food wastes).

It is critical to remove nitrogen compounds such as NH4-N, $NO2^-$ and NO3- to reduce the adverse impact in the receiving environment. Excess nutrients can lead to eutrophication in the waterways via uptake of nitrates by plants and animals (Hornung, 1999).

Nitrification is a process of reducing NH4-N to NO2- and NO3-. There is a two-step process, where the initial first step is oxidation of NH4-N to nitrites by ammonia-oxidising bacteria (AOB) bacteria such as Nitrosomonas. The second process of nitrification occurs when NO2- is oxidised to NO3- by Nitrifying-Oxidising bacteria such as Nitrobacter.

The final step of nitrogen removal is reducing nitrates or nitrites to nitrogen gas by denitrifying bacteria. HETerotrophic bacteria oxidises nitrites and nitrates to form nitrogen gas.

Nitrification:

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + 0.5O_2 \rightarrow NO_3^-$$

Denitrification:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

1.3 Modelling Software

There are different comprehensive modelling software's available for wastewater treatment. Example of software platforms include Hydromantis (Hatch) GPS-X, EnviroSIM BioWin, Dynamita SUMO, EAWAG Aquasim to name a few. All have a different approach in modelling the MABR system and is critical to note that although that modelling provides an indication of the performance of a system, an approach to modelling should stem from understanding the limitations and assumptions made for the software. Common modelling software that model's MABR for in literature were GPS-X, BioWin and AquaSim. Although, Aquasim is primarily for aquatic systems.

As with any modelling software, there are comprehensive and one takes a considerable amount of time to begin to comprehend the limitations of simulations within the modelling world. In relevancy to this project, GPS-X was used to simulate various scenarios to review the performance of the MABR system and in particular further evaluate and discuss the biomass concentration and communities within the biofilm layers.

1.3.1 Brief background: GPS-X platform

The GPS-X software platform developed by Hydromantis (now known as Hatch), provides a comprehensive library that consists of detailed parameters and variables, there are 52 state variables listed in their comprehensive model library (MANTIS2LIB). MANTIS2 incorporates the most commonly observed biological, physical, and chemical processes in WWTP.

1.3.1.1 GPS-X – Modelling MABR

In relation to the performance of MABR system, there are two sample layout's MABR system models to simulate: (1) MABR Hollow-Fibre Membrane and (2) MABR Flat sheet membrane. The MABR system is modelled in a completely mixed reactor similar to their previous attached growth system, hybrid model.

For both the MABR model's, GPS-X provides outputs in 3-D biofilm profile visualisations (examples are provided in Appendix D). The model assumes that a maximum biofilm thickness is set and developed. Within the biofilm, there are 5 layers that GPS-X models. The main processes that were considered in modelling the biofilm layers include (a) diffusion across membrane surface, (b) internal solids exchange, (c) diffusion within the biofilm layers, (d) diffusion to/from bulk liquid and (e) attachment and detachment of solids. Figure 3 shows a conceptual model of the 5-layers and process within the biofilm.

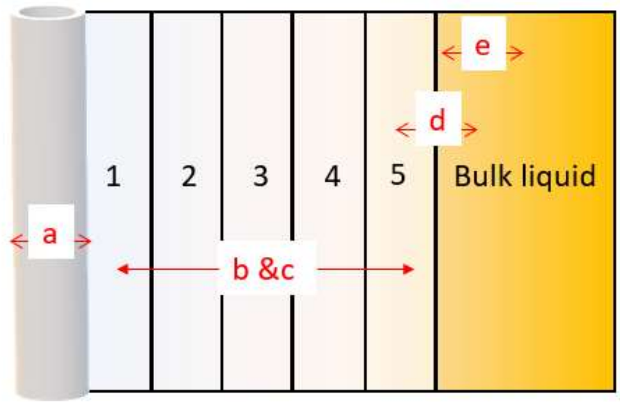


Figure 3 GPS-X models a 5-layer biofilm development with the MABR system. Layer 1 is closest to the membrane and layer 5 located adjacent the bulk liquid. Adapted from GPS-X Technical Reference

Additionally, for GPS-X to simulate an MABR system that shows a counter diffusional system, the air is assumed to be supplied in opposite direction to the primary effluent (bulk liquid influent into the MABR). For example, in the case for the hollow-fire membrane model, the MABR shows a default four (4) tanks in series where the primary effluent enters the MABR system through Tank 1 and the oxygen or process air is supplied through Tank 4.

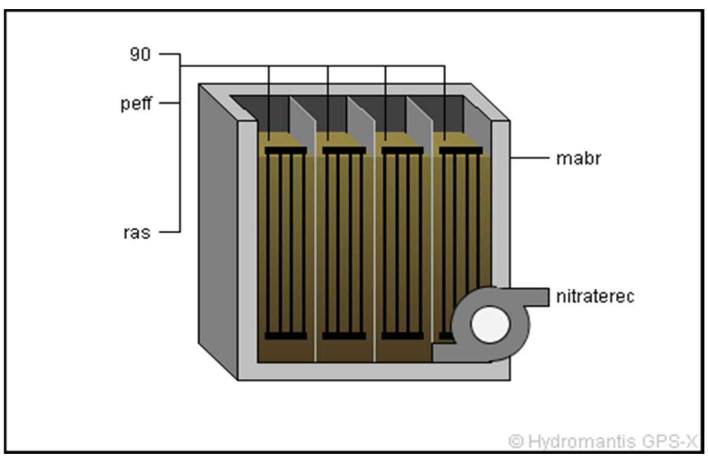


Figure 4 MABR system in GPS-X comprising of 4 tanks in series.

1.1 Project objectives

The primary objective of this research project is to have a fundamental concepts and approaches and understanding of MABR processes through a model-based approach by utilising GPS-X software.

- Demonstrate MABR performance on selected critical parameters and scenarios
- Describe biomass development through the biofilm
- Provide an insight to modelling MABR systems in GPS-X

1.1.1 Research question and hypothesis

Research question: Based on the selected parameters, how does the different scenarios affect the biomass concentration and communities through the biofilm

1. Ammonia concentration: Increase in ammonia inhibits biomass growth for complete nitrification
2. Operational parameters: An increase in Total mass transfer coefficient, inlet pressure and oxygen fraction increase in oxygen profile through the biofilm layers and further promotes nitrification.

3.0 METHODS AND MATERIALS

3.1 Modelling approach

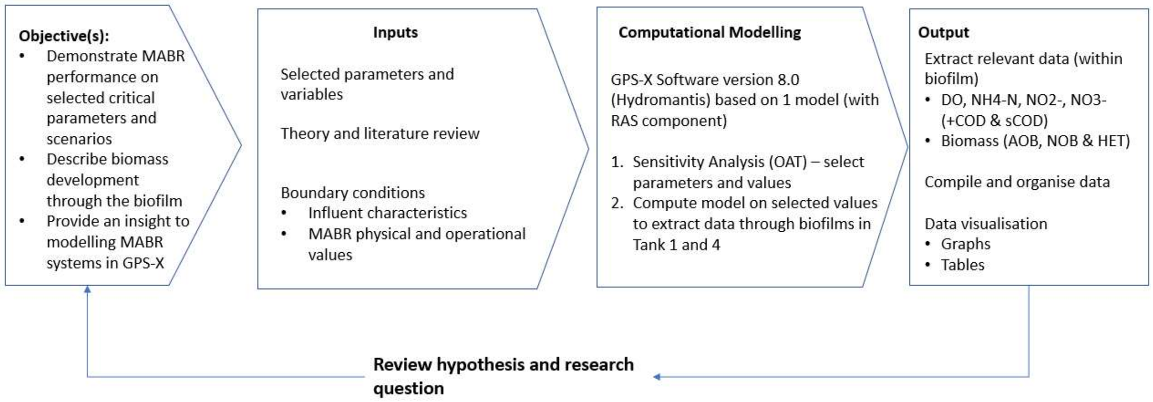


Figure 5 Modelling approach

There are certain condition, assumptions and limitations to need to be noted to understand in providing an insight to the performance of the MABR system based on selected critical parameters. Figure 4 summarises the approaches and thought process to provide an understanding of the main objectives of the project. GPS-X version 8.0 was used to model the performance of the MABR system.

The following subsections will detail the method and materials of the project.

3.1.1 Model Inputs

Data

The primary data are based on the values provided in GPS-X software. The main library used for the influent characteristics is *CODStates,* where key input variables were for Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP). A screenshot of the CODStates library is provided in Appendix F

Influent characteristics

The default raw influent characteristics, MABR physical and operational values are summarised in Tables 1 and 2, respectively. Additionally, the highlighted cells denote the parameters and scenarios that have been selected to further evaluate and discuss.

Table 1 Raw influent characteristics

Influent Characteristics	Value	Unit
Flow	100000	m3/d
TSS	209.2667	mg/L
VSS	156.95	mg/L
sBOD(5)	90.33483	mgO2/L
BOD(5)	221.7686	mgO2/L
sCOD	147.49	mgCOD/L
COD	430	mgCOD/L
NH4-N-N	25	mgN/L
NO2-	0	mgN/L

Influent Characteristics	Value	Unit
NO3-	0	mgN/L
sTKN	27.77778	mgN/L
TKN	30.57278	mgN/L
TN	30.57278	mgN/L
Alkalinity	250	mgCaCO3/L
pH	7	-
Temperature	12	Degrees Celsius

Table 2 MABR Physical, Operational and Membrane Settings

MABR - Physical Settings	Value	Unit
Tanks in series	4	-
Tank Depth	4	m3
Maximum volume	6000	m3
Membrane settings		
Media outside diameter	0.0011	m
Media length	1.95	m
Cords per module	5950	-
Modules per cassette	64	-
Area per Cassette	1920	m2
Displaced volume per cassette	0.15	m3
Total number of cassettes	240	
Number of cassettes	40	each tank
Total media surface area (all 4 tanks)	410576.2	m2
MABR - Operational Settings (Inner Biofilm Aeration)	**Value**	**Unit**
Inner Aeration Setup Method	Set Pressure Difference	
Inlet Pressure	1.8	Bar
Outlet Pressure	1.25	Bar
Oxygen Fraction in inlet air	0.21	-
Oxygen Fraction in outlet air	0.1	-
Total mass transfer coefficient (K)	3.33	gO2/h/m2/bar
Biofilm related parameters	**Value**	**Unit**
Maximum biofilm thickness	0.25	mm
Density of biofilm	1020000	mg/L
Dry material content of biofilm	0.08	-

Mass transport, model stoichiometry and kinetic

The mass transport, model stoichiometry and kinetic parameters remained unchanged. A copy of the values is listed in Appendix A.

Model layout

The performance of the MABR system is based on a full-scale WWTP provided by GPS-X sample layout. Additionally, the MABR system includes a recycled ratio from the secondary clarifier, therefore NO2- and NO3- concentrations were recycled. Figure 5 shows the sample layout provided in GPS-X with the red box indicating the primary focus, therefore only relevant values are extracted from MABR system.

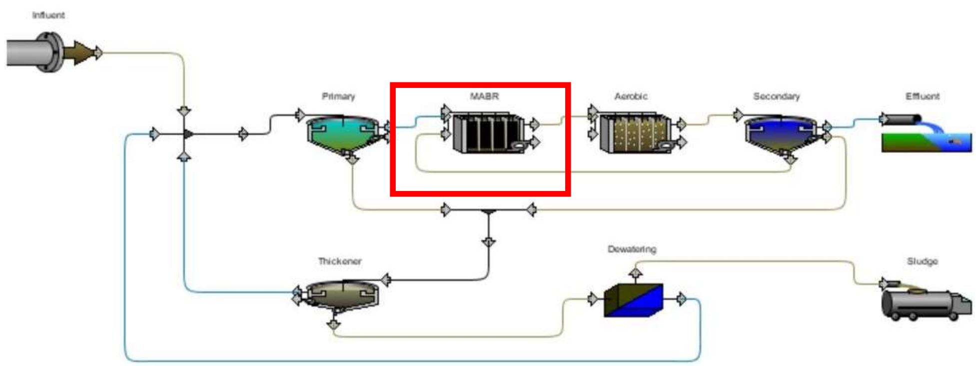


Figure 6 GPS-X model sample layout

3.2 Sensitivity analysis and one-at-a-time (OAT) approach

In the GPS-X software, users are able to conduct a sensitivity analysis either by a step function based on one parameter or Monte Carlos analysis. Sensitivity analysis step function was used where initially eight parameters were simulated. Additionally, the step function allowed to define the frequency of change.

After the eight parameters were simulated, four parameters were evaluated further to explore the biomass and nitrogen concentrations within the biofilm at different set values which were determined from the sensitivity analysis. The four parameters and scenarios that are discussed in this project are based on NH4-N-N concentration and three operational settings of the MABR (Inlet pressure, Total Mass Transfer Coefficient (K) and Oxygen Fraction).

3.2.1 Operational settings: setting pressure difference (Total Mass Transfer Coefficient)

In regards to the operational settings of the process airflow to the membranes, when modelling MABR system's there are three different options for specifying the oxygen transfer (1) setting mass transfer coefficient, K_La in units of 1/d, (2) setting the mass transfer of oxygen directly, in kg/d and (3) using the pressure difference equation adapted from Cotes (1989). The 3rd option was chosen as it considered the inlet pressure. Additionally, the pressure-difference oxygen transfer model is the default setting and the equation is

$$J = K \frac{\frac{p_{in}}{H} - \frac{p_{out}}{H}}{\ln\left(\frac{\frac{p_{in}}{H} - C_L}{\frac{p_{out}}{H} - C_L}\right)}$$

Where:

J = oxygen flux, mol/m^2-sec

K = mass transfer coefficient, m^2/sec

P_{in} = partial pressure of oxygen at inlet, Pa

P_{out} = partial pressure of oxygen at outlet, Pa

H = Henry's Law constant, Pa-m^3/mol

C_L = Oxygen concentration in liquid, mol/m^3

3.3 Assumption and Limitations

Few assumptions and limitations of the modelling are as follows:

- The model uses default values of GPS-X layout. Where applicable and necessary, values are changed to discuss further the changes in concentrations within the biofilm. Otherwise, model scenarios were frequently reset to the base model before simulating another scenario.
- As the model is based on full scale WWTP, only data extracted from the MABR system are discussed.
- As the MABR system has a default value of four (4) tanks in series, only Tank 1 and 4 are discussed to further assess concentrations and the performance of the reactor.
- Oxygen transfer rate (OTR) and Oxygen Transfer Efficiencies (OTE) are not included in the report.
- The model is not calibrated.

3.4 Data outputs

GPS-X further provides a comprehensive report. Additionally, various types of graphs and tables were generated. Only relevant data were extracted and are compiled into summarised tables and graphs are displayed either in the main report or as supplementary provided in the appendices.

4.0 RESULTS AND DISCUSSIONS

Detailed results of sensitivity analysis for the selected parameters are provided Appendix B. Detailed extracted values, compiled tables and further graphs for each scenario are provided in Appendix C and D. Additionally, 3-D biofilm profiles generated in GPS-X for selected concentrations are provided in Appendix E. The 3-D biofilm profiles have provided a visual understanding of key processes occurring in the systems.

4.1 Sensitivity Analysis

Based on the results and findings of the sensitivity analysis, four selected parameters were further analysed to evaluate the level of concentration through the biofilm and to determine the NH4-N-N removal efficiencies

Selected scenarios for the four parameters are listed in table 3.

Table 3 Selected parameters and scenarios.

Parameter	**Scenario's**
Increase in NH4-N-N concentration	14, 20, 25, 30, 36 (mg-N/L)
Inlet Pressure	1.3, 1.8, 2.5, 3.0, 5.0 (Bar)
Total Mass Transfer Coefficient	1.0, 3.33, 6.0, 10 (gO2/h/m2/bar)
Oxygen Fraction	0.1,0.2, 0.3, 0.4, 1.0 (-)

4.1 NH4-N-N concentration through the biofilm

The results from the sensitivity analysis indicated that there were significant changes in the biomass concentration between 20 to 30 mg-N/L of NH4-N-N concentration in the MABR effluent. Further evaluation and analysis were made at the selected values of NH4-N-N concentrations at 15, 20, 25, 30 and 36 mg-N/L. It is important to note that concentration that exceeded 36 mg-N/L were not evaluated as the ratio between NH4-N-N and TKN were reaching 1. Further, particulate TKN were automatically calculated in GPS-X at 0.

The selected concentrations of NH4-N-N used for the raw influent are characterised as low to medium strength.

Based on the scenario increase in ammonia concentrations has an effect on the development and consumption of bacteria within the biofilm. As the concentration of NH4-N increases between 15 to 36 mg-N/L, the development and concentration of NOB's decreases through the biofilm layers in Tank 1. At 15mg-N/L, production of NO3- are found to be higher concentration than NO2-. Similarly, the development of AOB's also follows the decreasing trend in Tank 1, however, not of a significant decrease.

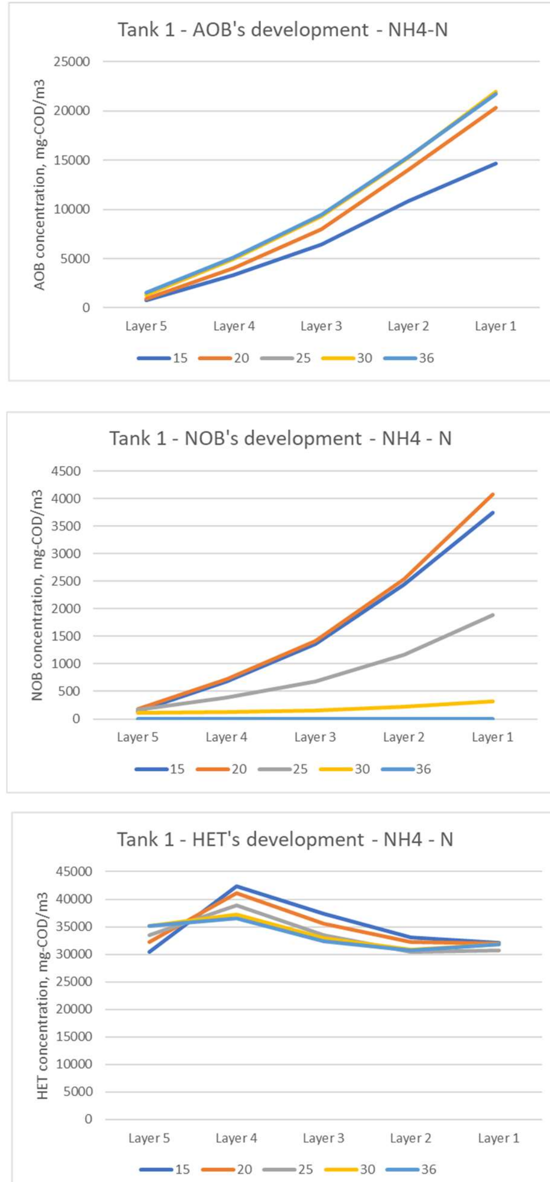


Figure 7 comparison of AOB, NOB and HET communities through the biofilm observed at different ammonia concentrations in tank 1.

Additionally, as NH4-N concentration increases from 15mg-N/L, NO2- production are higher than NO3- concentrations in the biofilm. This could indicate that the second step of nitrification is greatly reduced or negligible due to the increase in NH4-N and additionally, at the constant supply and pressure of oxygen, there is not sufficient oxygen to oxidise NO2- to NO3- in Tank 1 (also indicated by the low NOB's concentration found through the biofilm).

On the other side of the MABR tank, where oxygen supplied was assumed and found from Tank 4, the two- step nitrification occurs until 30 mg-N/L. At 36 mg-N/L, the NOB's development significantly decreases throughout the biofilm. Which indicates that between 30 and 36 mg-N/L, oxidation of NO2- to NO3- is significantly affected and nitrification is not complete. Additionally, the DO profile decreases through the biofilm layers as NH4-N concentration decreases.

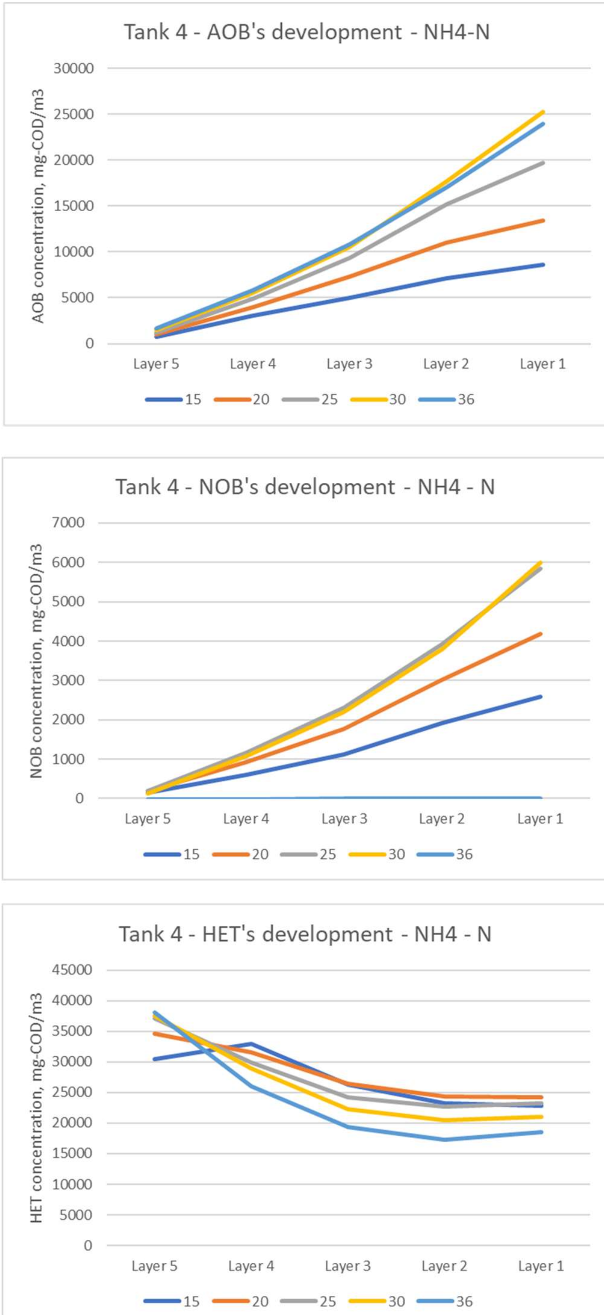


Figure 8 comparison of AOB, NOB and HET communities through the biofilm observed at different ammonia concentrations in tank 4.

HET concentration in the biofilm were observed to be higher and decreases steadily in Tank 1 compared to Tank 4. An inverse relationship was observed in Tank 4, where the HET concentrations were lower and the decrease occurs slightly more significantly.

Further, as hypothesized earlier, the findings show that removal efficiencies of NH4-N in the MABR effluent compared to the raw influent and primary effluent, decreases with an increase in NH4-N concentration (i.e. NH4-N removal efficiency is inversely proportionate to NH4-N concentration). The range of removal efficiencies based on the model conditions ranged between 60 to 71%, with the minimum removal efficiency observed at 36 mg-N/L and the highest at 20mg-N/L.

4.2 Inlet Pressure

To reiterate when observing the concentrations with the increase of inlet pressure, the outlet pressure is kept constant throughout the different scenarios. Further, the O_2 fraction in the membrane process air and total mass transfer were kept constant at 0.21 and 3.33 g-O_2/h/m^2/bar, respectively.

The results from the sensitivity analysis in tank 1 indicated that AOB and HET concentrations spiked at 1.75 bar at 12800 and 207000 mg-COD/L, respectively (between 1.65 and 1.95 bar) prior to reducing and returning to values of 43.5 and 1300 mg-COD/L in the MABR effluent. Conversely, NOB concentrations increased steadily from 5.53 mg-COD/L and increased significantly around 1.8 bar at 9.28 mg-COD/L before the sudden decrease. Consequently, at NOB concentration 2.05 bar, concentrations increased steadily until 3.05 bar where NOB concentrations plateaued.

The overall increase in the inlet pressure provides oxygen to through the biofilm until at most layer 3 (as shown in the oxygen profile in appendix C-2). As expected, with increase in the inlet pressure and increase in pressure difference, simultaneous nitrification and denitrification occurs.

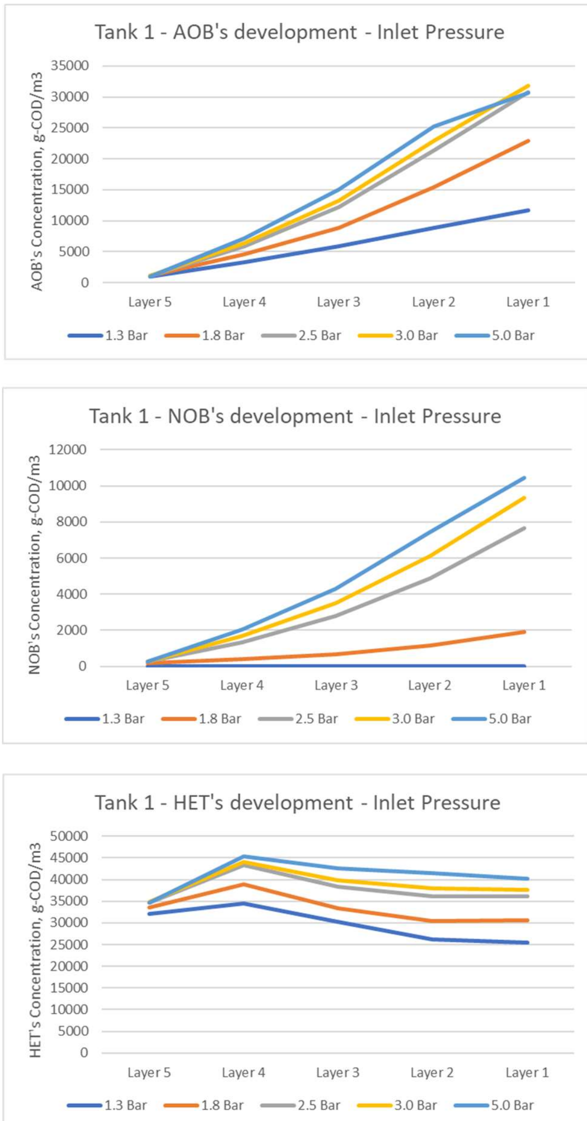


Figure 9 Comparison of AOB, NOB and HET communities through the biofilm observed at different inlet pressure in tank 1

Additionally, the removal of NH4-N concentration has a direct relationship of increase inlet pressure and pressure difference (i.e. the increase pressure in the inlet air from 1.3 bar to 5.0 bar, removal efficiencies were achieved in the range of 56 to 79%). However, with the increase of inlet pressure, NO2- and NO3- production also increases between 0.05 to 0.20 mg-N/L and 0 to 0.72 mg-N/L, respectively, in the MABR effluent.

In tanks 1 and 4, at lower inlet pressure of 1.3 Bar, AOB communities are present more significantly compared to NOB communities through the biofilm. Which indicates that only the initial nitrification occurs (i.e NH4-N oxidation to NO2-). As the inlet pressure increases, NO3- production increases and becomes steadily prominent compared to NO2- even though NOB's are still significantly lower than AOB. Additionally, as the inlet pressure increases, it is observed that AOB concentration plateau in layer 1 and 2 and begins to decrease from 2.5 to 5.0 bar. At 5.0 bar, the NOB concentration steadily increases until layer 1, where the concentrations begin to plateau (from 5291 and 5954 g-COD/m^3 between layer 2 and 1 at 5.0 bar). Additionally, the HET communities indicate denitrification from NO3- can occur.

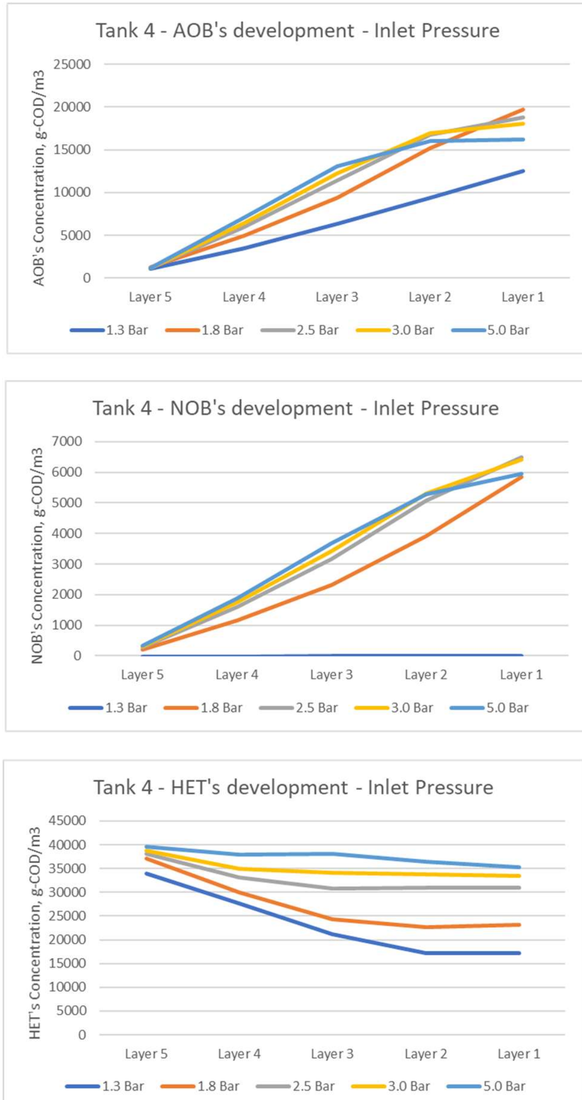


Figure 10 Comparison of AOB, NOB and HET communities through the biofilm observed at different inlet pressure in tank 4.

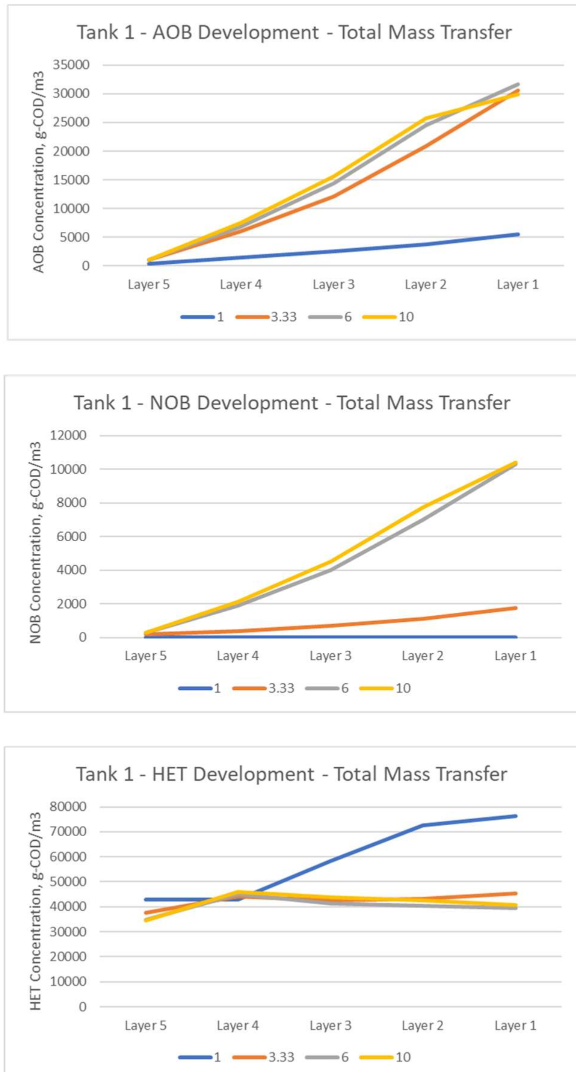


Figure 11 Comparison of AOB, NOB and HET communities through the biofilm observed at different total mass transfer in tank 1.

4.3 Total Mass Transfer

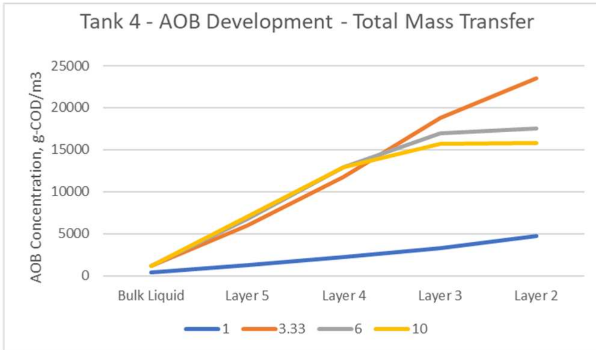
The selected values for total mass transfer were changed within the set pressure difference option in GPS-X. Although not stated in the report, scenario's by changing the values in oxygen mass transfer or oxygen mass transport show significant changes occurring within the biofilm. The total mass transfer coefficient considers the partial pressure compared to the other two options.

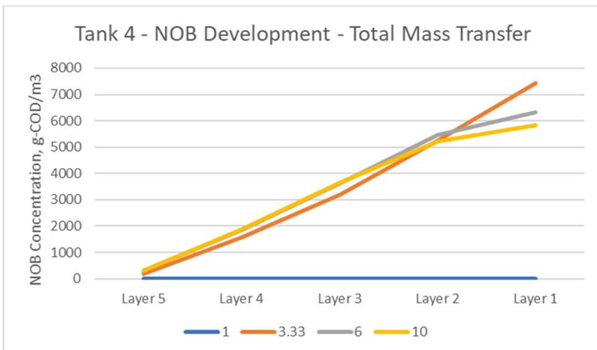
The findings obtained from the sensitivity analysis show that, AOB and NOB concentrations increase significantly between 0 3 g-O_2/h/m^2/bar. Further, by increasing the total mass transfer until about 4 to 6 g-O_2/h/m^2/bar, AOB, NOB and HET concentrations plateau at 39, 10 and 1290 mg-COD/L, respectively, in the MABR effluent. Values obtained to further evaluate the bacteria in the biofilms were selected at 1, 3.33, 6 and 10 g-O_2/h/m^2/bar.

Similar to the inlet pressure, the increase in the total mass transfer, increases the concentration of AOB, NOB and HET in tank 1. Additionally, in tank 4, concentration on biomass were found to be lower compared to tank1. Generally, it was found that in both tank 1 and 4, with the increase total mass transfer, concentrations increased closest to the media.

By increasing the total mass transfer, the second step of nitrification (i.e. the oxidation from NO2- to NO3-) increased which indicates a higher nitrification rate. The increase in total mass transfer rate shows that the transfer of DO concentration increased through the biofilm layers (layer 1 to 3). This could indicate that the increased DO concentration enables NOB to convert NO2- to NO3-. It was observed that as the NO3- concentrations increased, the NO2-concentrations decreased from tank 4 at 3.33 g-O_2/h/m^2/bar and tank 1.

In terms of the NH4-N-N removal efficiencies, by increasing the total mass transfer enables a higher NH-4 removal efficiency was obtained which ranged from 14 to 79% at 1 g-O_2/h/m^2/bar and 10 g-O_2/h/m^2/bar, respectively. However, NO2- and NO3- concentration increased consequently.





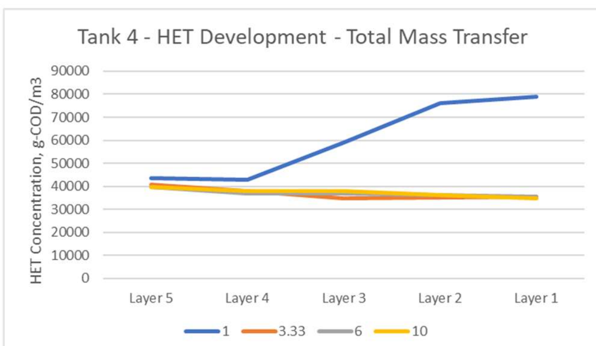


Figure 12 comparison of AOB, NOB and HET communities through the biofilm observed at different total mass transfer in tank 4

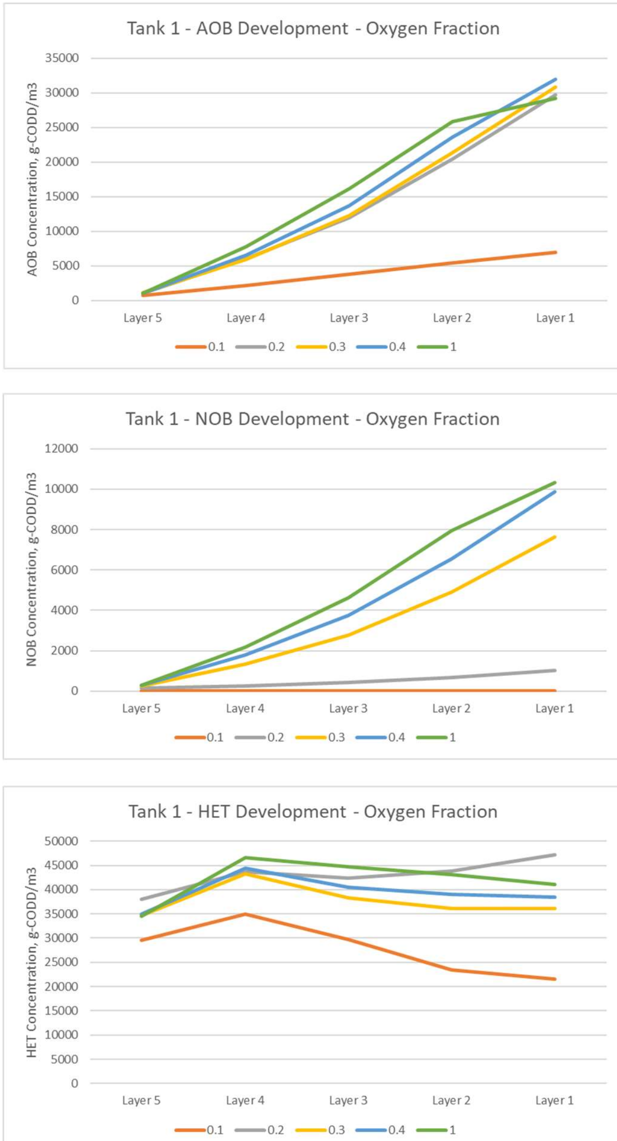


Figure 13 Comparison of AOB, NOB and HET communities through the biofilm observed at different oxygen fraction in tank 1

4.4 Oxygen Fraction

The results from the sensitivity analysis indicated a significant change of biomass concentration in the MABR effluent when the O_2 fraction in the air supplied into the membrane were between 0.1 and 0.3. O_2 fraction 0.1, 0.2, 0.3, 0.4 and 1.0 were further evaluated.

As hypothesised earlier, the fraction of O_2 in the inlet air may suggest an effect to NH4-N-N removal efficiencies. Results from the evaluation within the biofilm show that by increasing of O_2 fraction, the dissolved oxygen allowed nitrification processes (both steps) to occur. As shown in appendix C-4 oxygen profiles, the increase in O_2 fraction in the inlet air show that DO concentration present in layer 1 to 3 in tank 1 and layer 1 to 4 in tank 4. This could suggest that sufficient O_2 fraction (at 0.2 in tank 4) supplied is needed in the inlet air for the second part of nitrification to occur. However, NO2- production were higher than NO3- at O_2 fraction of 0.2 in tank 1, which could indicate that there were insufficient DO concentration transferred for NOB to oxidise NO2- to NO3-. When O_2 fraction of 0.3 were supplied in the inlet air onwards (to 1.0 O_2 fraction), NOB concentrations seem to thrive.

Nevertheless, the NH4-N-N removal efficiencies increased from 39% at 0.1 O_2 fraction to 80% at 1.0 O_2 fraction when the O_2 fraction in the inlet air increased. Consequently, concentrations of NO2- and NO3- increased in the MABR effluent. However, both concentrations in all scenario’s were reported below 1 mg-N/L.

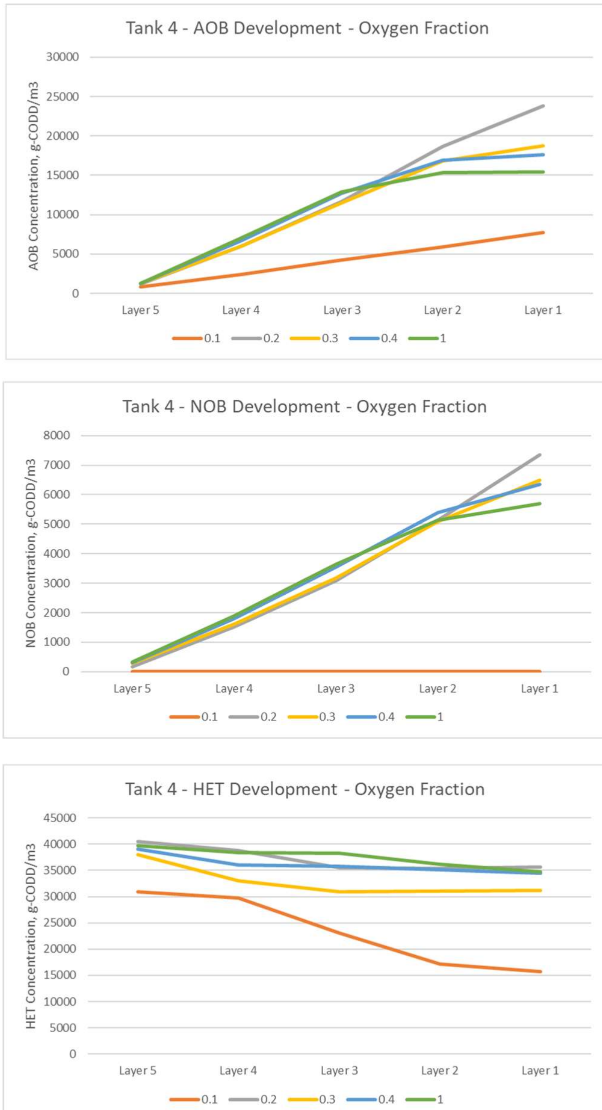


Figure 14 comparison of AOB, NOB and HET communities through the biofilm observed at different oxygen fraction in tank 4.

4.5 Modelling MABR systems and further study recommendation

Modelling the performance of the MABR system involves an in-depth understanding the limitations and assumptions developed for any software. It is critical to understand the boundary conditions and consider the main objectives of the project. The project was to provide a simplified review of the critical performance in the MABR system based on one model provided by GPS-X layout.

Although the performance of the MABR systems modelled are indicated by removal efficiencies, oxygen transfer rate and efficiencies by comparisons of before and after, wastewater microbiology in MABR systems should be considered. Considerations could include the chemical, physical and biological effects on biomass concentrations through the biofilm required for nitrification. As nitrifying and denitrifying bacteria play a critical role in oxidising and removal of nitrogen constituents in wastewater.

Further, only a few critical operational parameters and one uncontrolled parameter were evaluated by OAT analysis, further study suggested can include:

- Modelling with a full set of experimental data to predict and calibrate values based on a realistic pilot or full-scale system
- Additionally, with experimental data, further analysis to determine the optimal parameters could be included
- Include OTE, OTR and Nitrification rate
- Explore the economic cases and feasibility for MABR systems to be implemented

5.0 CONCLUSION

The primary objective of the project was to review the critical parameters and the performance of the MABR system by simulating selected scenarios through a modelling software platform, GPS-X. Based on the one model and the selected simulations, the findings showed that MABR systems performed achieved a NH4-N-N removal efficiency at 70% at low to medium strength NH4-N-N wastewater. Additionally, NH4-N-N removal efficiencies can be achieved at 80% when inlet pressure, total mass transfer coefficient and oxygen fraction were increased.

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Appendix A
GPS-X Default Values: Mass Transport, Model Stoichiometry and Kinetics

Mass Transport	Value	Unit
Solids		
attachment rate	0.5	[m/d]
	0.5	
	0.5	
	0.5	
detachment rate	0.01	[kg/(m2.d)]
	0.01	
	0.01	
	0.01	
anoxic shear reduction factor	1	
	1	
	1	
	1	
internal solids exchange rate	0.00002	[m/d]
	0.00002	
	0.00002	
	0.00002	
Diffusion of Components in Water:		
diffusion constant for dissolved oxygen	0.00002	[cm2/s]
diffusion constant for dissolved hydrogen	0.0000584	[cm2/s]
diffusion constant for dissolved dinitrogen gas	0.000019	[cm2/s]
diffusion constant for dissolved methane	0.00001	[cm2/s]
diffusion constant for soluble inert material	0.00001	[cm2/s]
diffusion constant for colloidal substrate	0.00001	[cm2/s]
diffusion constant for readily degradable substrate	0.0000069	[cm2/s]
diffusion constant for acetate	0.0000124	[cm2/s]
diffusion constant for propionate	0.00001	[cm2/s]
diffusion constant for methanol	0.000016	[cm2/s]
diffusion constant for total ammonia	0.00002	[cm2/s]
diffusion constant for soluble organic nitrogen	0.00001	[cm2/s]
diffusion constant for nitrite	0.0000123	[cm2/s]
diffusion constant for nitrate	0.0000123	[cm2/s]
diffusion constant for ortho-phosphate	0.00001	[cm2/s]
diffusion constant for total soluble inorganic carbon	0.0000196	[cm2/s]
diffusion constant for total calcium	0.00001	[cm2/s]
diffusion constant for total magnesium	0.00001	[cm2/s]
diffusion constant for total inorganic potassium	0.00001	[cm2/s]
diffusion constant for other cation	0.00001	[cm2/s]
diffusion constant for other anion	0.000031	[cm2/s]
diffusion constant for soluble component "a"	0.00001	[cm2/s]
diffusion constant for soluble component "b"	0.00001	[cm2/s]
Effect of Biofilm on Diffusion		
reduction in diffusion constant for dissolved oxygen	0.6	[-]
reduction in diffusion constant for dissolved hydrogen	0.8	[-]
reduction in diffusion constant for dissolved dinitrogen gas	0.8	[-]
reduction in diffusion constant for dissolved methane	0.2	[-]
reduction in diffusion constant for soluble inert material	0.2	[-]
reduction in diffusion constant for colloidal substrate	0.2	[-]
reduction in diffusion constant for readily degradable substrate	0.2	[-]
reduction in diffusion constant for acetate	0.2	[-]
reduction in diffusion constant for propionate	0.2	[-]
reduction in diffusion constant for methanol	0.2	[-]
reduction in diffusion constant for total ammonia	0.6	[-]
reduction in diffusion constant for soluble organic nitrogen	0.8	[-]
reduction in diffusion constant for nitrite	0.8	[-]
reduction in diffusion constant for nitrate	0.8	[-]
reduction in diffusion constant for ortho-phosphate	0.8	[-]
reduction in diffusion constant for total soluble inorganic carbon	0.8	[-]
reduction in diffusion constant for total calcium	0.8	[-]
reduction in diffusion constant for total magnesium	0.8	[-]
reduction in diffusion constant for total inorganic potassium	0.8	[-]
reduction in diffusion constant for other cation	0.8	[-]
reduction in diffusion constant for other anion	0.8	[-]
reduction in diffusion constant for soluble component "a"	0.8	[-]
reduction in diffusion constant for soluble component "b"	0.8	[-]

Model Stoichiometry	Value	Unit
Heterotrophic Biomass		
aerobic heterotrophic yield on soluble substrate	0.666	[gCOD/gCOD]
anoxic heterotrophic yield on soluble substrate	0.533	[gCOD/gCOD]
Methylotrophic Biomass		
aerobic methylotroph yield on methanol	0.45	[gCOD/gCOD]
anoxic methylotroph yield on methanol	0.36	[gCOD/gCOD]
Fermentative Biomass		
yield of fermentative biomass	0.18	[gCOD/gCOD]
Ammonia-Oxidizing Biomass		
ammonia-oxidizer yield	0.18	[gCOD/gN]
Nitrite-Oxidizing Biomass		
nitrite-oxidizer yield	0.06	[gCOD/gN]
Anammox Biomass		
biomass yield on NH4-N	0.168	[gCOD/gN]
Poly-Phosphate-Accumulating Biomass (PAOs)		
aerobic yield on PAO growth	0.639	[gCOD/gCOD]
anoxic yield on PAO growth	0.511	[gCOD/gCOD]
PHA storage yield	0.4	[gP/gCOD]
Xpp storage yield	0.2	[gP/gCOD]
Acetogenic Biomass		
acetogenic yield on propionate	0.04	[gCOD/gCOD]
Hydrogenotrophic Methanogenic Biomass		
methanogenic yield on H2	0.06	[gCOD/gCOD]
Acetoclastic Methanogenic Biomass		
methanogenic yield on acetate	0.05	[gCOD/gCOD]
Unbiodegradable Fraction from Biomass Decay		
unbiodegradable fraction from cell decay	0.08	[gCOD/gCOD]
Soluble Inert COD fraction		
fraction of inert COD during slowly biodegradable organic hydrolysis	0	[gCOD/gCOD]
fraction of inert COD during inert residue hydrolysis	0	[gCOD/gCOD]
fraction of inert COD during inert organic hydrolysis	0	[gCOD/gCOD]

Kinetic	Value	Unit
Absorption of Colloidal COD		
specific adsorption rate	0.1	[1/(gCOD/m3)/d]
saturation/inhibition coefficient for Xs/Xbh	0.05	[-]
Heterotrophic Biomass		
maximum specific growth rate on substrate	3.2	[1/d]
saturation/inhibition coefficient for ss	5	[mgCOD/L]
saturation coefficient for oxygen	0.2	[mgO2/L]
saturation coefficient for nitrogen as nutrient	0.05	[mgN/L]
switching coefficient for using NOx-N as nutrient	0.1	[mgN/L]
saturation coefficient for phosphorus (nutrient)	0.01	[mgP/L]
saturation/inhibition coefficient for Sac	5	[mgCOD/L]
saturation/inhibition coefficient for Spro	5	[mgCOD/L]
reduction factor for denitrification on nitrate-N	0.32	[-]
reduction factor for denitrification on nitrite-N	0.48	[-]
saturation coefficient for nitrite	0.1	[mgN/L]
saturation coefficient for nitrate	0.5	[mgN/L]
oxygen inhibition coefficient for denitrification	0.2	[mgO2/L]
aerobic heterotrophic decay rate	0.62	[1/d]
anoxic reduction factor for decay rate	0.9	[-]
anaerobic reduction factor for decay rate	0.6	[-]
Methylotrophic Biomass		
maximum growth rate for methylotrophs	1.3	[1/d]
methanol saturation coefficient for methylotrophs	0.5	[mgCOD/L]
saturation coefficient of nitrite for methylotrophs	0.1	[mgN/L]
saturation coefficient of nitrate for methylotrophs	0.1	[mgN/L]
oxygen saturation for methylotrophs	0.2	[mgO2/L]
reduction factor for denitrification on nitrate-N	0.4	[-]
reduction factor for denitrification on nitrite-N	0.6	[-]
oxygen inhibition coefficient for denitrification	0.2	[mgO2/L]
aerobic methylotrophic decay rate	0.2	[1/d]
anoxic reduction factor for decay rate	0.9	[-]
anaerobic reduction factor for decay rate	0.6	[-]
Ammonia-Oxidizing Biomass		
maximum growth rate for ammonia oxidizer	0.9	[1/d]
ammonia saturation coefficient for ammonia oxidizer	0.7	[mgN/L]
oxygen saturation for ammonia oxidizer	0.25	[mgO2/L]
inhibition coefficient of FA for ammonia oxidizer	50	[mgN/L]
inhibition coefficient of FNA for ammonia oxidizer	0.2	[mgN/L]
ammonia oxidizer aerobic decay rate	0.17	[1/d]
anoxic reduction factor for decay rate	0.5	[-]
anaerobic reduction factor for decay rate	0.3	[-]
Nitrite-Oxidizing Biomass		
maximum growth rate for nitrite oxidizer	1	[1/d]
nitrite saturation coefficient for nitrite oxidizer	0.5	[mgN/L]
oxygen saturation for nitrite oxidizer	0.68	[mgO2/L]
inhibition coefficient of FA for nitrite oxidizer	1	[mgN/L]
inhibition coefficient of FNA for nitrite oxidizer	0.09	[mgN/L]
nitrite oxidizer decay rate	0.17	[1/d]
anoxic reduction factor for decay rate	0.5	[-]
anaerobic reduction factor for decay rate	0.3	[-]
Anammox Biomass		
maximum growth rate of anammox bacteria	0.0186	[1/d]
ammonia saturation for anammox bacteria	0.73	[mgN/L]
nitrite saturation coefficient for anammox bacteria	0.5	[mgN/L]
oxygen saturation/inhibition for anammox bacteria	0.1	[mgO2/L]
aerobic decay rate of anammox bacteria	0.0058	[1/d]
anoxic reduction factor for decay rate	0.5	[-]
anaerobic reduction factor for decay rate	0.3	[-]

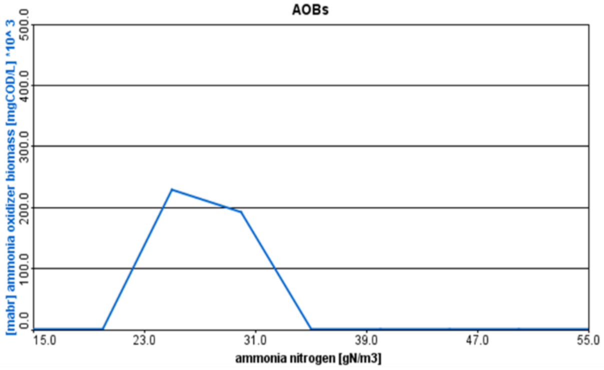
Poly-Phosphate-Accumulating Biomass (PAOs)	
rate constant for storage of PHA	6 [gCOD/gPAO/d]
saturation coefficient of PAO for Sac	4 [mgCOD/L]
saturation coefficient for Xpp/Xbp	0.01 [gP/gCOD]
saturation coefficient of PAO for Spro	4 [mgCOD/L]
maximum growth rate of PAO	1 [1/d]
saturation coefficient for PHA	0.01 [gCOD/gPAOCOD]
saturation coefficient for oxygen	0.2 [mgO2/L]
rate constant for storage of poly-phosphate	2 [gP/gPAO/d]
maximum ratio of Xpp/Xpao	0.34 [gP/gPAO]
inhibition coefficient for Xpp/Xbp	0.02 [gP/gCOD]
P saturation for uptake	0.2 [mgP/L]
reduction factor for denitrification on nitrate-N	0.24 [-]
reduction factor for denitrification on nitrite-N	0.36 [-]
saturation coefficient of nitrite for PAO	0.5 [g-N/m3]
saturation coefficient of nitrate for PAO	0.5 [g-N/m3]
oxygen inhibition coefficient for denitrification	0.2 [mgO2/L]
aerobic decay coefficient for PAO	0.2 [1/d]
anoxic reduction factor for decay rate	0.9 [-]
anaerobic reduction factor for decay rate	0.6 [-]
poly-P lysis coefficient	0.05 [1/d]
PHA lysis coefficient	0.2 [1/d]
Fermentative Biomass	
maximum fermentation rate	3 [1/d]
oxygen saturation for obligate anaerobic biomass	0.1 [mgO2/L]
nitrate saturation for obligate anaerobic biomass	0.1 [mgN/L]
substrate saturation for fermentative biomass	4 [mgCOD/L]
hydrogen saturation/inhibition for acidifier	10 [mgCOD/L]
aerobic decay rate for fermentative biomass	0.133 [1/d]
anoxic reduction factor for decay rate	0.5 [-]
anaerobic reduction factor for decay rate	0.3 [-]
Acetogenic Biomass	
maximum growth rate of propionate degrading bacteria	0.35 [1/d]
undissociated propionate saturation for propionate degrading bacteria	10 [mgCOD/L]
hydrogen inhibition for propionate degrader	5 [mgCOD/L]
aerobic decay coefficient for acetogens	0.067 [1/d]
anoxic reduction factor for decay rate	0.5 [-]
anaerobic reduction factor for decay rate	0.3 [-]
Hydrogenotrophic Methanogenic Biomass	
maximum growth rate of H2-utilizing bacteria	0.368 [1/d]
hydrogen saturation for hydrogenotrophic methanogens	2.5 [mgCOD/L]
aerobic decay coefficient for hydrogenotrophic methanogens	0.033 [1/d]
anoxic reduction factor for decay rate	0.5 [-]
anaerobic reduction factor for decay rate	0.3 [-]
Acetoclastic Methanogenic Biomass	
maximum growth rate of acetate utilizing bacteria	0.15 [1/d]
acetate saturation for hydrogenotrophic methanogens	75 [mgCOD/L]
aerobic decay coefficient for acetoclastic methanogens	0.067 [1/d]
free acetic acid inhibition concentration	1000 [mgCOD/L]
free ammonia inhibition concentration	100 [mgN/L]
anoxic reduction factor for decay rate	0.5 [-]
anaerobic reduction factor for decay rate	0.3 [-]

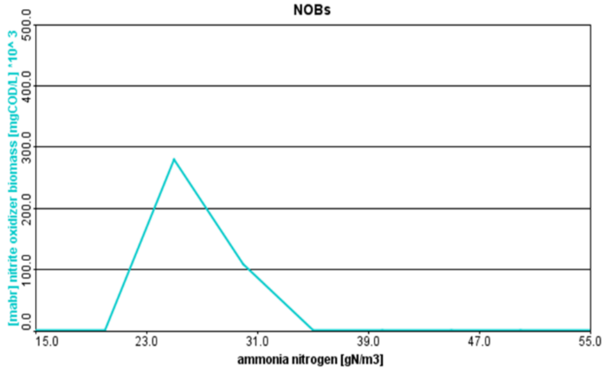
Hydrolysis		
hydrolysis rate constant for xs	3	[1/d]
saturation coefficient for particulate COD	0.1	[-]
anoxic hydrolysis reduction factor	0.28	[-]
anaerobic hydrolysis reduction factor	0.4	[-]
saturation/inhibition coefficient for NOx	0.5	[mgN/L]
hydrolysis rate constant for inert residue	0.03	[1/d]
saturation coefficient for inert residue	1	[-]
hydrolysis rate constant inert organics	0.03	[1/d]
saturation coefficient for inert organics	1	[-]
Ammonification		
ammonification rate	0.08	[m3/gCOD/d]
Precipitation of CaCO3 (Calcite)		
precipitation/dissolution rate for CaCO3	5	[(g-ppt/m3)/((gCa/m3).(gCO3-C/m3).d)]
pKsp of CaCO3	6.45	[-]
switching coefficient for dissolution of CaCO3	1	[g-ppt/m3]
Precipitation of MgNH4PO4 (Struvite)		
precipitation/dissolution rate for MgNH4PO4.6H2O	300	[(g-ppt/m3)/((gMg/m3).(gNH4-N/m3).(gPO4-P/m3).d)]
pKsp of MgNH4PO4.6H2O	13.2	[-]
switching coefficient for dissolution of MgNH4PO4.6H2O	1	[g-ppt/m3]
Precipitation of MgHPO4 (Newberyite)		
precipitation/dissolution rate for MgHPO4.3H2O	0.05	[(g-ppt/m3)/((gMg/m3).(gHPO4-P/m3).d)]
pKsp of MgHPO4.3H2O	5.8	[-]
switching coefficient for dissolution of MgHPO4.3H2O	1	[g-ppt/m3]
Precipitation of Ca3(PO4)2 (Amorphous calcium phosphate)		
precipitation/dissolution rate for Ca3(PO4)2	150	[(g-ppt/m3)/((gCa/m3)3.(gPO4-P/m3)2.d)]
pKsp of Ca3(PO4)2	23	[-]
switching coefficient for dissolution of Ca3(PO4)2	1	[g-ppt/m3]
Precipitation of MgCO3 (Magnesite)		
precipitation/dissolution rate for MgCO3	50	[(g-ppt/m3)/((gMg/m3).(gCO3-C/m3).d)]
pKsp of MgCO3	7	[-]
switching coefficient for dissolution of MgCO3	1	[g-ppt/m3]
Precipitation of AlPO4		
precipitation/dissolution rate for AlPO4	1	[(g-ppt/m3)/((gAl/m3).(gPO4-P/m3).d)]
pKsp of AlPO4	21	[-]
switching coefficient for dissolution of AlPO4	1	[g-ppt/m3]
saturation term for AlOH in AlPO4 precipitation	0.001	[g-ppt/m3]
Precipitation of FePO4		
precipitation/dissolution rate for FePO4	1	[(g-ppt/m3)/((gFe/m3).(gPO4-P/m3).d)]
pKsp of FePO4	26	[-]
switching coefficient for dissolution of FePO4	1	[g-ppt/m3]
saturation term for FeOH in AlPO4 precipitation	0.001	[g-ppt/m3]

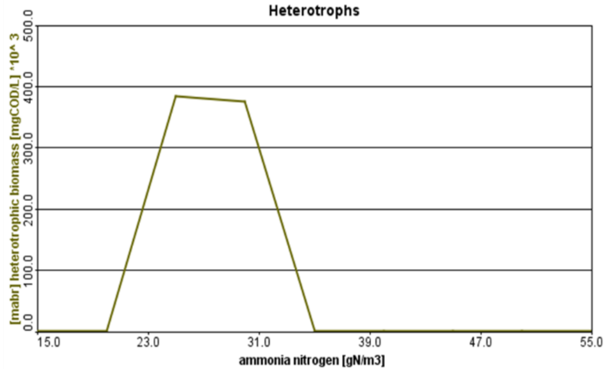
Temperature	
Temperature coefficient for specific adsorption rate	1
Temperature coefficient for maximum specific growth rate on substrate	1.07
Temperature coefficient for aerobic heterotrophic decay rate	1.03
Temperature coefficient for maximum growth rate for methylotrophs	1.11
Temperature coefficient for aerobic methylotrophic decay rate	1.03
Temperature coefficient for maximum growth rate for ammonia oxidizer	1.07
Temperature coefficient for ammonia oxidizer aerobic decay rate	1.03
Temperature coefficient for maximum growth rate for nitrite oxidizer	1.06
Temperature coefficient for nitrite oxidizer decay rate	1.03
Temperature coefficient for maximum growth rate of anammox bacteria	1.1
Temperature coefficient for aerobic decay rate of anammox bacteria	1.03
Temperature coefficient for rate constant for storage of PHA	1.07
Temperature coefficient for maximum growth rate of PAO	1.07
Temperature coefficient for rate constant for storage of poly-phosphate	1.07
Temperature coefficient for aerobic decay coefficient for PAO	1.03
Temperature coefficient for poly-P lysis coefficient	1.03
Temperature coefficient for PHA lysis coefficient	1.03
Temperature coefficient for maximum fermentation rate	1.07
Temperature coefficient for aerobic decay rate for fermentative biomass	1.03
Temperature coefficient for maximum growth rate of propionate degrading bacteria	1.07
Temperature coefficient for aerobic decay coefficient for acetogens	1.03
Temperature coefficient for maximum growth rate of H2-utilizing bacteria	1.07
Temperature coefficient for aerobic decay coefficient for hydrogenotrophic methanogens	1.03
Temperature coefficient for maximum growth rate of acetate utilizing bacteria	1.07
Temperature coefficient for aerobic decay coefficient for acetoclastic methanogens	1.03
Temperature coefficient for hydrolysis rate constant for xs	1.07
Temperature coefficient for hydrolysis rate constant for inert residue	1.07
Temperature coefficient for hydrolysis rate constant inert organics	1.07
Temperature coefficient for ammonification rate	1.07

Appendix B
Sensitivity Analysis: Results and Outputs

Effect on biomass concentrations by different ammonia concentrations

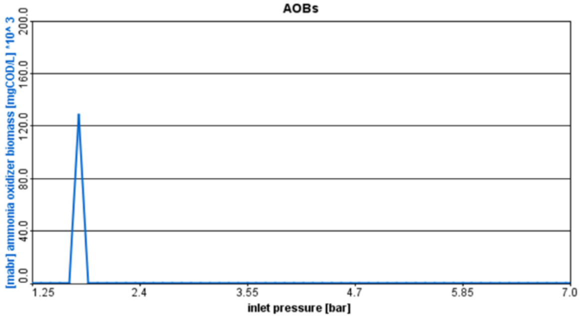


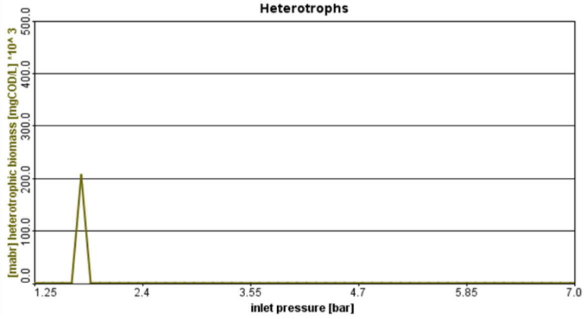


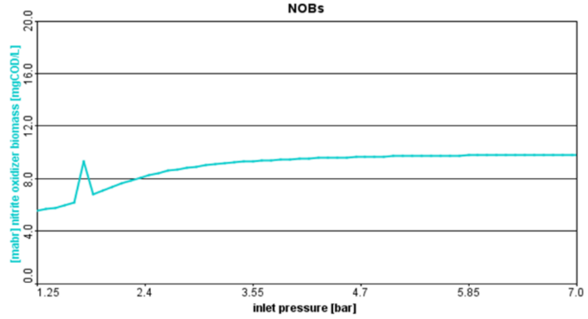


Concentration in MABR effluent			
NH4-N in Raw Influent	**AOB**	**NOB**	**HET**
gN/m3	**mgCOD/L**	**mgCOD/L**	**mgCOD/L**
15	31.4	5.91	1290
20	37.8	7.14	1300
25	230000	280000	384000
30	192000	109000	376000
35	55.9	0.227	1290
40	59.3	0.0000239	1310
45	60.5	0.0000235	1310
50	61.2	0.0000233	1300
55	61.7	0.0000232	1300
Min	31.4	0.0000232	1290
Max	230000	280000	384000
Mean	46929.75556	43223.69745	85455.55556
Std Dev	93502.94291	95829.5413	167002.98

Effect on biomass concentrations by inlet pressure



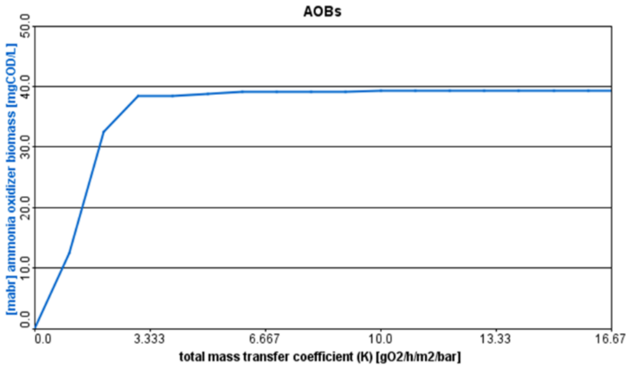


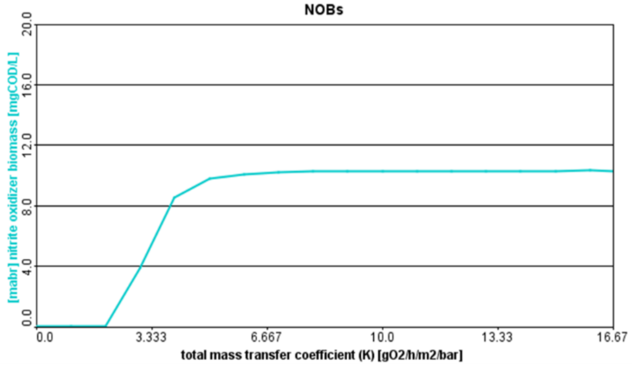


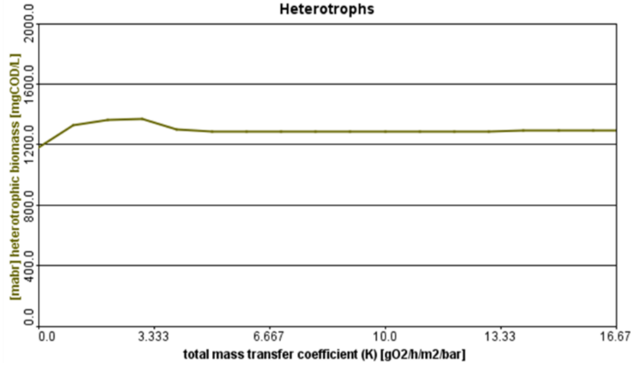
Concentration in MABR effluent			
Inlet Pressure	**AOB**	**HET**	**NOB**
bar	**mgCOD/L**	**mgCOD/L**	**mgCOD/L**
1.25	44.2	1310	5.53
1.55	44.5	1310	5.94
1.75	128000	207000	9.28
2.05	43.5	1300	7.38
2.25	43.1	1300	7.87
2.55	42.6	1300	8.43
2.75	42.4	1290	8.7
3.05	42.1	1290	9
3.25	42	1290	9.16
3.55	41.9	1290	9.32
3.75	41.8	1290	9.41
4.05	41.7	1290	9.5
4.25	41.6	1290	9.55
4.55	41.5	1290	9.62

Concentration in MABR effluent			
Inlet Pressure	**AOB**	**HET**	**NOB**
bar	**mgCOD/L**	**mgCOD/L**	**mgCOD/L**
4.75	41.5	1290	9.65
5.05	41.4	1290	9.69
5.25	41.4	1290	9.71
5.55	41.3	1290	9.74
5.75	41.3	1290	9.76
6.05	41.3	1290	9.78
6.25	41.2	1290	9.79
6.55	41.2	1290	9.8
7	41.1	1290	9.82
Min	41.1	1290	5.53
Max	128000	207000	9.82
Mean	2210.827119	4779.830508	8.962542373
Std Dev	16658.70642	26780.73513	1.205737138

Effect on biomass concentration by total mass transfer

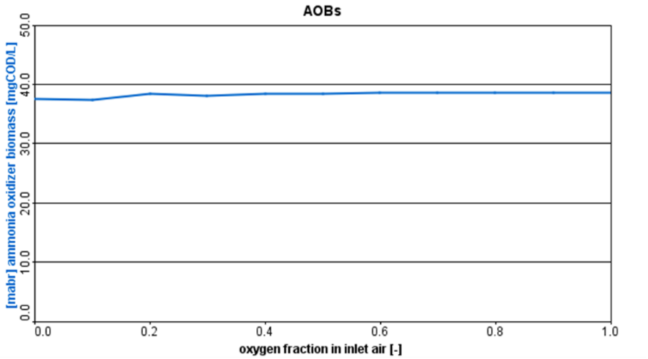


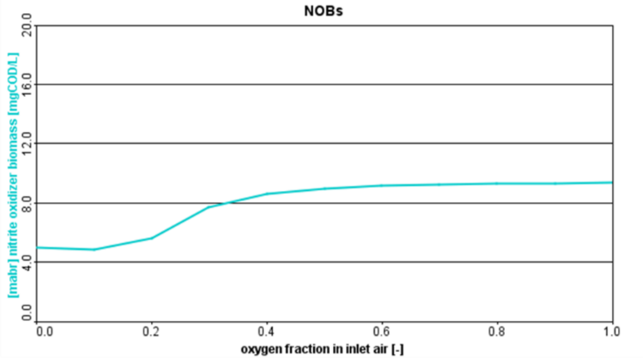


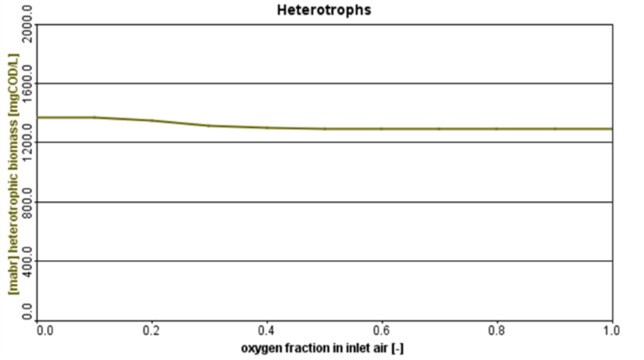


Concentration in MABR effluent			
Total Mass Transfer	**AOB**	**NOB**	**HET**
gO2/h/m2/bar	**mgCOD/L**	**mgCOD/L**	**mgCOD/L**
0	0.0000234	0.0000178	1180
1	12.4	0.0000189	1330
2	32.5	0.0000209	1360
3	38.4	3.87	1370
4	38.4	8.51	1300
5	38.8	9.76	1290
6	39	10.1	1280
7	39.1	10.2	1290
8	39.2	10.2	1290
9	39.2	10.3	1290
10	39.2	10.3	1290
Min	0.0000234	0.0000178	1180
Max	39.3	10.3	1370
Mean	35.06666797	8.074447644	1294.444444
Std Dev	10.82969327	4.014780884	38.22875761

Effect on biomass concentrations by oxygen fraction in Tank 1

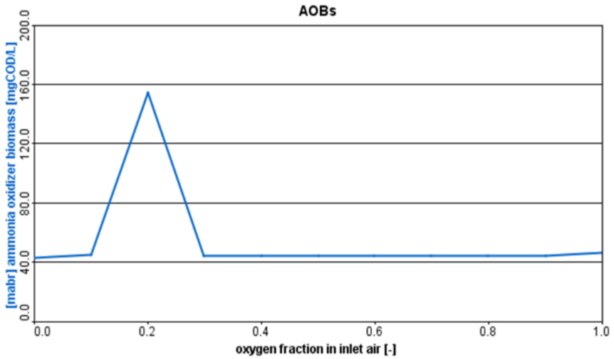


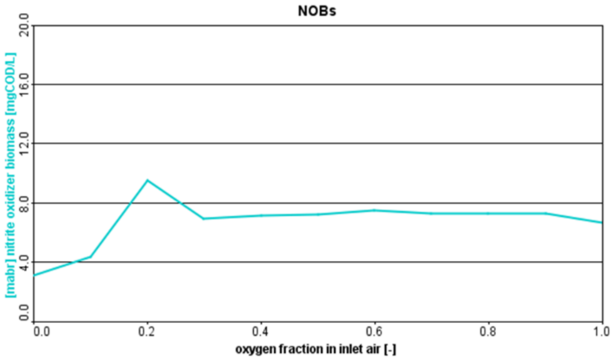


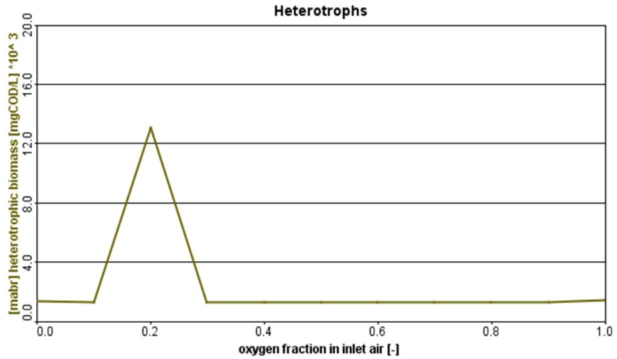


Concentration in MABR effluent			
O2 Fraction in Tank 1	**AOB**	**NOB**	**HET**
-	**mgCOD/L**	**mgCOD/L**	**mgCOD/L**
0	37.5	4.99	1370
0.1	37.3	4.88	1370
0.2	38.3	5.61	1350
0.3	38.1	7.74	1310
0.4	38.4	8.62	1300
0.5	38.5	8.97	1300
0.6	38.5	9.14	1290
0.7	38.6	9.24	1290
0.8	38.5	9.29	1290
0.9	38.6	9.33	1290
1	38.6	9.35	1290
Min	37.3	4.88	1290
Max	38.6	9.35	1370
Mean	38.26364	7.923636	1313.636
Std Dev	0.454473	1.841957	32.94624

Effect on biomass concentrations by oxygen fraction in Tank 4





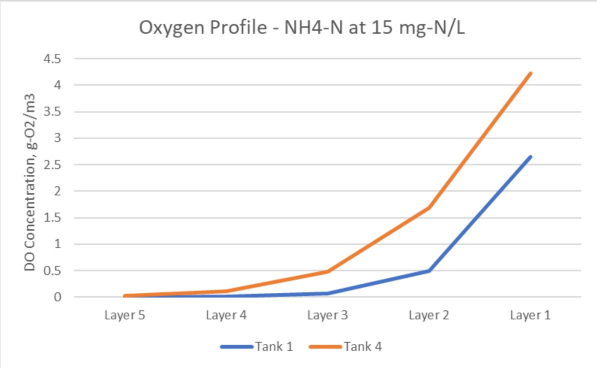


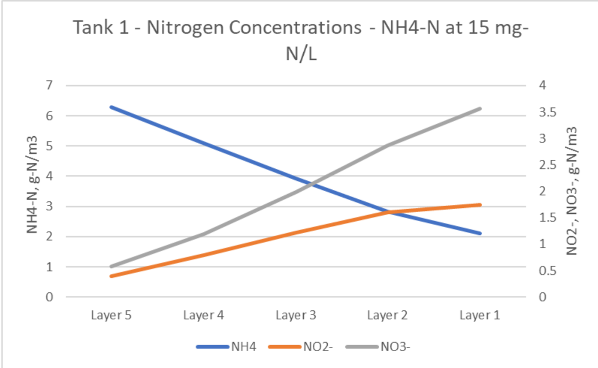
Concentration in MABR effluent			
O2 fraction in Tank 4	**AOB**	**NOB**	**HET**
-	**mgCOD/L**	**mgCOD/L**	**mgCOD/L**
0	43.1	3.09	1340
0.1	44.8	4.34	1310
0.2	154	9.53	13100
0.3	44.1	6.94	1300
0.4	44.1	7.12	1300
0.5	44.1	7.21	1300
0.6	44.5	7.47	1310
0.7	44.1	7.28	1300
0.8	44.1	7.29	1310
0.9	44.1	7.3	1300
1	46.6	6.67	1420
Min	43.1	3.09	1300
Max	154	9.53	13100
Mean	54.32727	6.749091	2390
Std Dev	33.06863	1.694594	3552.284

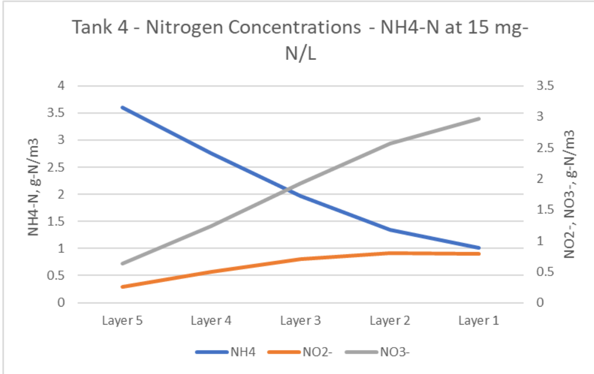
Appendix C
Detailed findings: Tables and graphs for each scenario

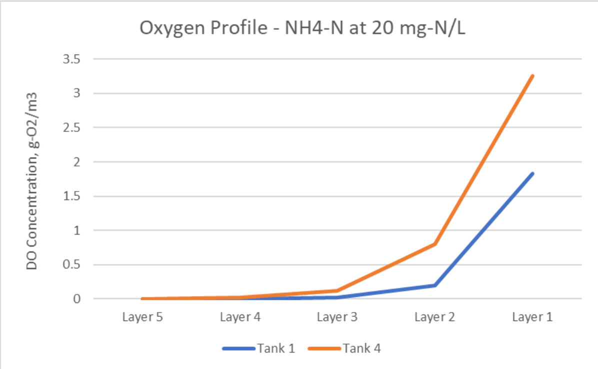
C-1 Increase in NH_4-N concentrations

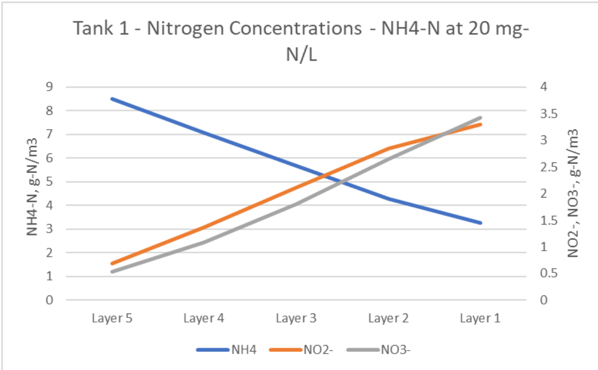
			NH4-N in mg-N/L											
			Tank 1						Tank 4					
Scenario	Parameter	Unit	Bulk liquid	Layer 5	Layer 4	Layer 3	Layer 2	Layer 1	Bulk liquid	Layer 5	Layer 4	Layer 3	Layer 2	Layer 1
	DO	g-O2/m3	6.43E-05	0.002121	0.009851	0.06606	0.4934	2.647	0.0009028	0.02623	0.1047	0.4764	1.68	4.228
	NH4	g-N/m3	7.455	6.278	5.1	3.924	2.82	2.118	4.427	3.594	2.758	1.967	1.346	1.011
	NO2-	g-N/m3	0.05785	0.3919	0.7875	1.222	1.606	1.749	0.03932	0.2568	0.4982	0.7061	0.7961	0.7933
	NO3-	g-N/m3	0.1051	0.585	1.196	1.985	2.871	3.562	0.1209	0.6304	1.238	1.924	2.565	2.966
15	COD	g-COD/m3	3124	71700	92710	80870	70780	71930	3106	71570	74080	59230	53820	54100
	sCOD	g-COD/m3	81.64	61.69	47.88	40.21	36.02	34.02	58.42	48.94	41.36	36.28	33.21	31.78
	AOB's	g-COD/m3	31.41	741.5	3320	6452	10860	14650	31.73	746.7	3025	5031	7168	8634
	NOB's	g-COD/m3	5.919	139.8	682.2	1355	2445	3750	5.999	141.2	610.8	1129	1912	2595
	HET	g-COD/m3	1294	30480	42290	37350	33020	32040	1299	30490	32880	26290	23290	22860
	DO	g-O2/m3	1.58E-05	0.0005472	0.002712	0.02021	0.1957	1.828	0.0001637	0.004684	0.02079	0.1253	0.8041	3.255
	NH4	g-N/m3	9.905	8.495	7.085	5.669	4.281	3.258	5.723	4.655	3.581	2.517	1.583	1.058
	NO2-	g-N/m3	0.09562	0.6856	1.367	2.108	2.845	3.295	0.06239	0.2961	0.5491	0.794	0.9338	0.9032
	NO3-	g-N/m3	0.1102	0.5314	1.085	1.809	2.653	3.419	0.1981	0.8973	1.723	2.656	3.608	4.262
20	COD	g-COD/m3	3107	75210	94270	85330	76280	78890	3089	80490	79410	67160	62380	63860
	sCOD	g-COD/m3	81.25	61.51	48.43	41.27	37.56	35.77	55.91	47.32	41.05	36.94	34.3	32.96
	AOB's	g-COD/m3	37.86	942.4	4056	7996	14040	20290	38.25	1017	3994	7321	11050	13430
	NOB's	g-COD/m3	7.146	177.8	718.7	1411	2533	4081	7.246	192.9	922	1778	3012	4181
	HET	g-COD/m3	1298	32250	41080	35600	32230	31980	1304	34590	31500	26400	24310	24250
	DO	g-O2/m3	9.68E-06	0.0003542	0.00185	0.01468	0.1548	1.659	3.00E-05	0.0008678	0.004027	0.02839	0.2742	2.211
	NH4	g-N/m3	12.6	11.02	9.427	7.829	6.252	5.04	7.449	6.148	4.84	3.529	2.27	1.434
	NO2-	g-N/m3	0.155	1.23	2.487	3.882	5.318	6.402	0.09179	0.3901	0.7082	1.032	1.312	1.336
	NO3-	g-N/m3	0.05704	0.1613	0.3307	0.5991	0.9571	1.316	0.2654	1.131	2.13	3.235	4.406	5.37
25	COD	g-COD/m3	3136	76560	94370	85740	75690	78060	3117	84680	82990	74070	69050	72290
	sCOD	g-COD/m3	79.64	61.49	49.39	42.34	38.53	36.68	53.34	45.82	40.71	37.43	35.52	34.49
	AOB's	g-COD/m3	44.68	1121	4640	8907	15450	22920	45.13	1251	4950	9361	15150	19740
	NOB's	g-COD/m3	6.829	171.2	393.4	680.7	1163	1885	6.933	192.6	1160	2308	3927	5841
	HET	g-COD/m3	1338	33520	38880	33480	30480	30720	1345	37160	29950	24240	22730	23170
	DO	g-O2/m3	8.99E-06	0.0003413	0.00191	0.01574	0.1725	1.788	8.94E-06	0.0002651	0.001278	0.009888	0.1133	1.438
	NH4	g-N/m3	15.8	14.17	12.54	10.89	9.266	8.041	9.797	8.263	6.739	5.214	3.711	2.531
	NO2-	g-N/m3	0.2	1.385	2.825	4.492	6.279	7.672	0.1287	0.6974	1.304	1.926	2.538	2.904
	NO3-	g-N/m3	2.63E-02	2.54E-02	3.84E-02	6.96E-02	1.23E-01	1.84E-01	2.23E-01	1.04E+00	1.98E+00	3.02E+00	4.14E+00	5.17E+00
30	COD	g-COD/m3	3124	80980	95650	88950	76660	76810	3106	86150	84670	76350	71690	75940
	sCOD	g-COD/m3	80.12	62.73	51.18	43.91	39.51	37.14	53.43	46.28	41.61	38.71	37.17	36.48
	AOB's	g-COD/m3	50.7	1351	4947	9292	15290	21920	51.23	1449	5563	10540	17640	25260
	NOB's	g-COD/m3	4.32E+00	114.7	125.3	1.55E+02	218.3	326.1	4.39E+00	124.8	1074	2193	3800	5985
	HET	g-COD/m3	1324	35200	37170	32910	30890	31750	1331	37550	28970	22290	20410	21070
	DO	g-O2/m3	7.52E-06	0.0002957	0.001715	0.01452	0.164	1.761	1.02E-05	0.0003319	0.001766	0.01407	0.1608	1.764
	NH4	g-N/m3	20.7	19.06	17.41	15.74	14.09	12.84	14.31	12.55	10.79	9.027	7.298	5.994
	NO2-	g-N/m3	0.2422	1.432	2.896	4.609	6.473	7.957	0.1812	1.76	3.553	5.482	7.473	9.022
	NO3-	g-N/m3	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.17E-06	1.00E-06	1.00E-06	1.23E-06	1.83E-06	2.81E-06	3.95E-06
36	COD	g-COD/m3	3133	81830	96190	90140	77350	76350	3115	88660	85600	77000	64260	64440
	sCOD	g-COD/m3	81.04	63.64	52.1	44.77	40.21	37.66	55.24	49.07	44.73	41.65	39.65	38.42
	AOB's	g-COD/m3	57.59	1546	5123	9479	15360	21760	58.19	1690	5818	10840	17050	23960
	NOB's	g-COD/m3	2.57E-05	0.0006865	0.0006117	0.0006325	0.0007756	0.001081	2.57E-05	0.0007451	0.001537	0.00257	0.00396	0.006102
	HET	g-COD/m3	1311	35120	36550	32420	30670	31750	1318	38140	26030	19320	17260	18590

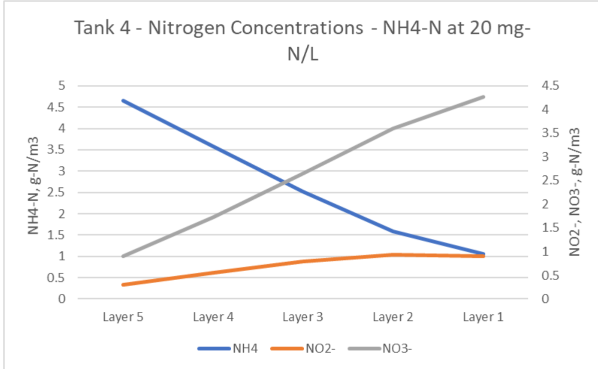

Oxygen Profile - NH4-N at 15 mg-N/L
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

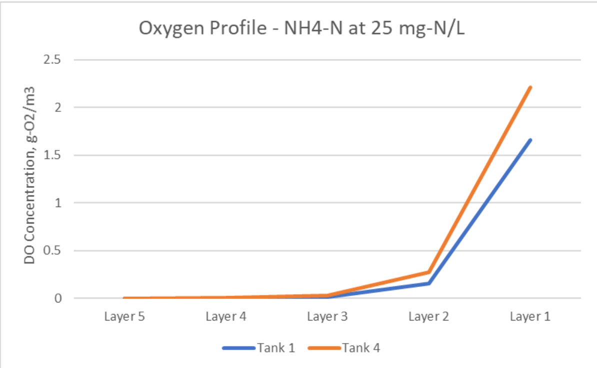

Tank 1 - Nitrogen Concentrations - NH4-N at 15 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

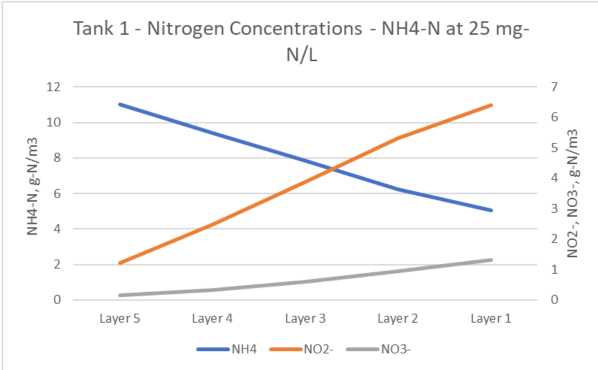

Tank 4 - Nitrogen Concentrations - NH4-N at 15 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

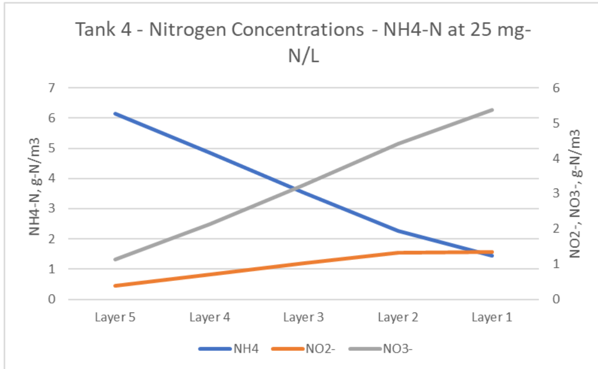

Oxygen Profile - NH4-N at 20 mg-N/L
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

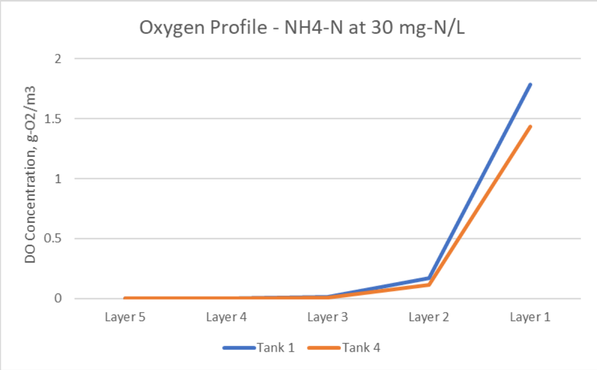

Tank 1 - Nitrogen Concentrations - NH4-N at 20 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

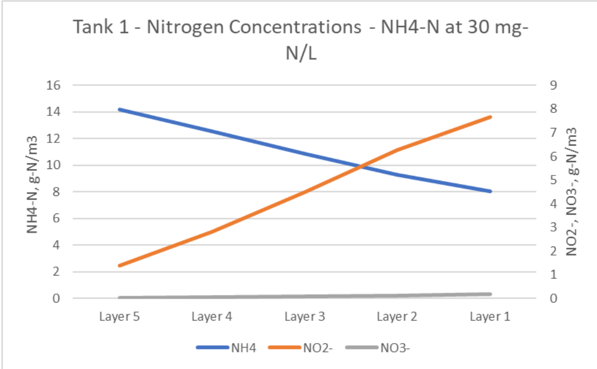

Tank 4 - Nitrogen Concentrations - NH4-N at 20 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

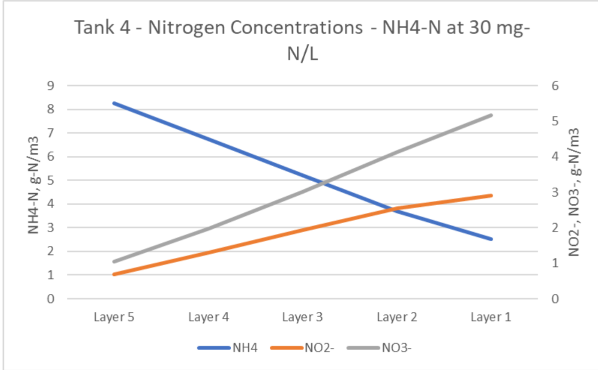

Oxygen Profile - NH4-N at 25 mg-N/L
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

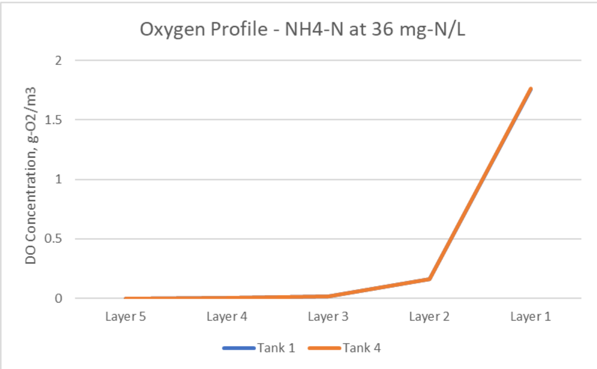

Tank 1 - Nitrogen Concentrations - NH4-N at 25 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

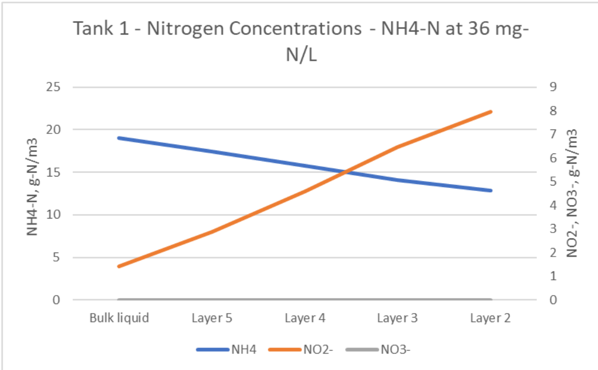

Tank 4 - Nitrogen Concentrations - NH4-N at 25 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

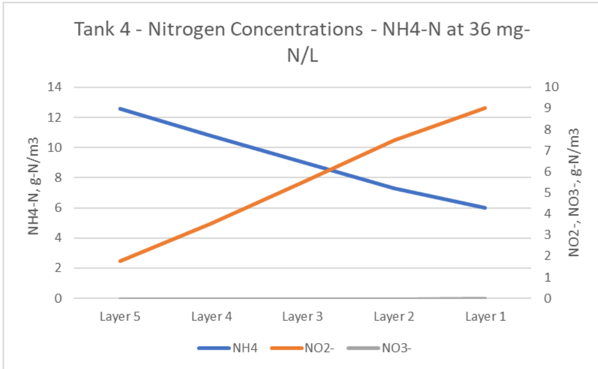

Oxygen Profile - NH4-N at 30 mg-N/L
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4


Tank 1 - Nitrogen Concentrations - NH4-N at 30 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-


Tank 4 - Nitrogen Concentrations - NH4-N at 30 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

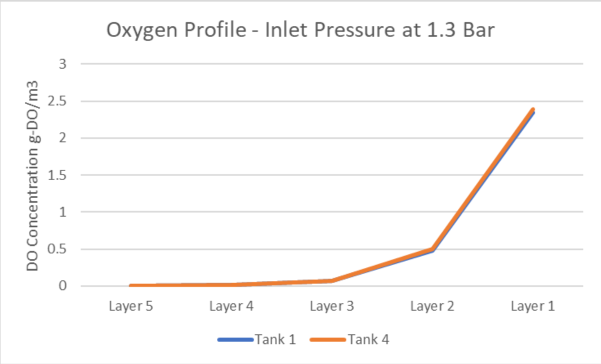

Oxygen Profile - NH4-N at 36 mg-N/L
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

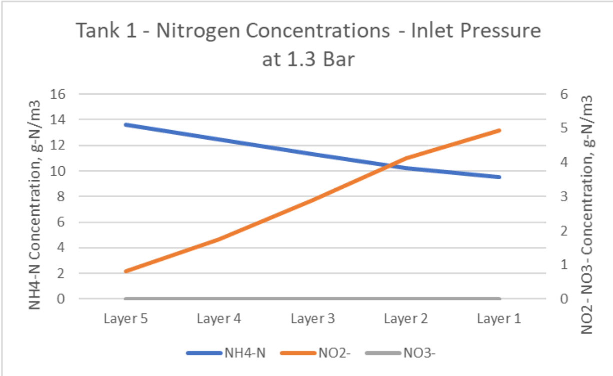

Tank 1 - Nitrogen Concentrations - NH4-N at 36 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Bulk liquid
Layer 5
Layer 4
Layer 3
Layer 2
NH4
NO2-
NO3-

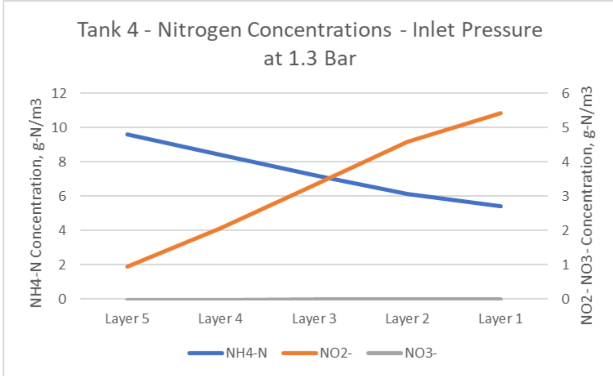

Tank 4 - Nitrogen Concentrations - NH4-N at 36 mg-N/L
NH4-N, g-N/m3
NO2-, NO3-, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4
NO2-
NO3-

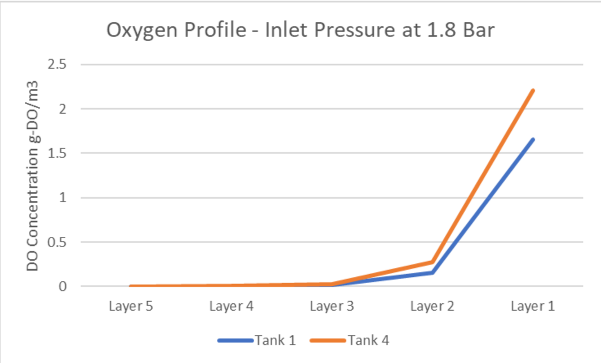
C-2 Inlet Pressure

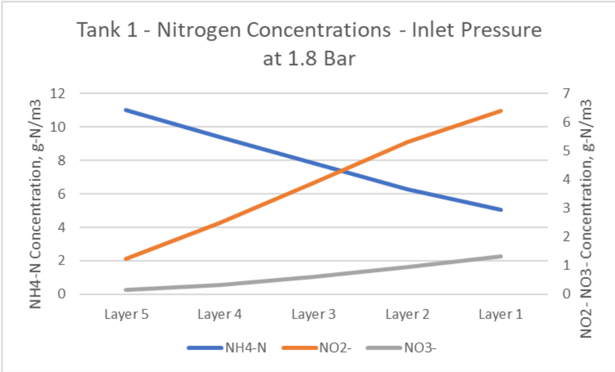
Inlet pressure (bar)														
			Tank 1						Tank 4					
Scenario	Parameter	Unit	Bulk liquid	Layer 5	Layer 4	Layer 3	Layer 2	Layer 1	Bulk liquid	Layer 5	Layer 4	Layer 3	Layer 2	Layer 1
1.3 Bar	DO	g-O2/m3	5.61E-05	0.001965	0.009964	0.06585	0.4771	2.351	7.00E-05	0.002337	0.01173	0.07272	0.5061	2.395
	NH4-N	g-N/m3	14.73	13.59	12.45	11.31	10.23	9.542	10.79	9.6	8.404	7.213	6.112	5.41
	NO2-	g-N/m3	0.08627	0.8045	1.751	2.912	4.128	4.942	0.04701	0.9399	2.055	3.32	4.582	5.41
	NO3-	g-N/m3	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.16E-06	1.35E-06	1.00E-06	1.06E-06	1.65E-06	2.80E-06	4.50E-06	5.99E-06
	COD	g-COD/m3	3153	76240	92840	82540	63180	58500	3138	80830	85820	72550	53260	50020
	sCOD	g-COD/m3	80.29	63.86	52.37	44.78	39.93	37.46	62.19	52.93	46.07	41.37	38.31	36.72
	AOB's	g-COD/m3	42.34	1051	3264	5851	8828	11740	42.79	1126	3540	6346	9357	12500
	NOB's	g-COD/m3	2.67E-05	0.0006606	0.0006102	0.0006449	0.0007969	0.001088	2.68E-05	0.0007038	0.001789	0.003122	0.004903	0.00742
	HET	g-COD/m3	1293	32060	34460	30280	26130	25490	1296	34020	27590	21180	17200	17110
1.8 Bar	DO	g-O2/m3	9.68E-06	0.0003542	0.00185	0.01468	0.1548	1.659	3.00E-05	0.0008678	0.004027	0.02839	0.2742	2.211
	NH4-N	g-N/m3	12.6	11.02	9.427	7.829	6.252	5.04	7.449	6.148	4.84	3.529	2.27	1.434
	NO2-	g-N/m3	0.155	1.23	2.487	3.882	5.318	6.402	0.09179	0.3901	0.7082	1.032	1.312	1.336
	NO3-	g-N/m3	0.05704	0.1613	0.3307	0.5991	0.9571	1.316	0.2654	1.131	2.13	3.235	4.406	5.37
	COD	g-COD/m3	3136	76560	94370	85740	75690	78060	3117	84680	82990	74070	69050	72290
	sCOD	g-COD/m3	79.64	61.49	49.39	42.34	38.53	36.68	53.34	45.82	40.71	37.43	35.52	34.49
	AOB's	g-COD/m3	44.68	1121	4640	8907	15450	22920	45.13	1251	4950	9361	15150	19740
	NOB's	g-COD/m3	6.829	171.2	393.4	680.7	1163	1885	6.933	192.6	1160	2308	3927	5841
	HET	g-COD/m3	1338	33520	38880	33480	30480	30720	1345	37160	29950	24240	22730	23170
2.5 Bar	DO	g-O2/m3	3.81E-06	0.0001375	0.0007338	0.006751	0.09271	1.512	9.19E-05	0.002316	0.01033	0.07761	0.7269	3.76
	NH4-N	g-N/m3	11.86	10.02	8.192	6.354	4.521	3.026	6.268	4.981	3.686	2.396	1.245	0.6511
	NO2-	g-N/m3	0.1833	0.7885	1.448	2.136	2.82	3.241	0.1504	0.3347	0.5209	0.6933	0.746	0.5951
	NO3-	g-N/m3	0.2679	1.153	2.235	3.52	4.937	6.297	0.5213	1.557	2.727	4.002	5.302	6.159
	COD	g-COD/m3	3088	81020	100700	99160	96720	100600	3068	88790	87020	83390	83980	85720
	sCOD	g-COD/m3	81.09	60.06	47.23	40.76	37.59	36.2	52.41	44.72	39.39	35.77	33.35	32.04
	AOB's	g-COD/m3	41.4	1119	5944	12230	21370	30810	41.81	1236	5953	11410	16800	18820
	NOB's	g-COD/m3	9.562	258.4	1348	2772	4883	7639	9.686	286.5	1601	3156	5073	6496
	HET	g-COD/m3	1288	34700	43270	38340	36080	36100	1295	38110	33060	30870	30980	31030
3.0 Bar	DO	g-O2/m3	4.36E-06	0.0001575	0.0008438	0.008107	0.1178	1.907	0.000159	0.003901	0.01721	0.1317	1.13	4.623
	NH4-N	g-N/m3	11.57	9.631	7.697	5.756	3.826	2.318	5.862	4.589	3.306	2.038	0.9827	0.4914
	NO2-	g-N/m3	0.1886	0.6039	1.047	1.503	1.944	2.083	0.1685	0.3366	0.5045	0.6485	0.6212	0.4572
	NO3-	g-N/m3	0.3799	1.598	3.035	4.687	6.473	8.134	0.5988	1.657	2.849	4.144	5.418	6.168
	COD	g-COD/m3	3085	81640	102600	102700	101300	105300	3064	90260	89100	87920	89820	90790
	sCOD	g-COD/m3	80.89	59.48	46.51	40.05	36.91	35.47	51.72	43.94	38.53	34.83	32.27	30.94
	AOB's	g-COD/m3	40.33	1100	6395	13260	22940	31840	40.73	1226	6416	12270	16940	18090
	NOB's	g-COD/m3	10.03	273.6	1670	3482	6098	9336	10.15	305.7	1737	3421	5313	6424
	HET	g-COD/m3	1286	34930	44140	39770	38010	37700	1293	38700	34920	34050	33840	33420
5.0 Bar	DO	g-O2/m3	1.29E-05	0.0004687	0.002502	0.02564	0.3837	4.114	0.0004632	0.0109	0.04682	0.3454	2.15	6.26
	NH4-N	g-N/m3	11	8.842	6.689	4.53	2.441	1.176	5.184	3.949	2.706	1.515	0.6801	0.3353
	NO2-	g-N/m3	0.2188	0.4835	0.7514	1.013	1.202	0.9657	0.2035	0.3606	0.5155	0.6136	0.4804	0.3255
	NO3-	g-N/m3	0.572	2.263	4.191	6.346	8.617	10.37	0.7211	1.789	2.986	4.27	5.398	5.967
	COD	g-COD/m3	3086	81210	103400	103900	104300	107300	3065	92210	91010	93680	95810	95920
	sCOD	g-COD/m3	79.94	58.07	44.73	38.13	34.84	33.17	50.07	42.47	37.12	33.32	30.74	29.48
	AOB's	g-COD/m3	39.19	1064	7223	15090	25300	30700	39.56	1216	7046	13070	16020	16190
	NOB's	g-COD/m3	10.25	278.2	2037	4291	7453	10460	10.36	318.6	1885	3681	5291	5954
	HET	g-COD/m3	1287	34760	45400	42530	41580	40130	1294	39560	37960	38070	36420	35200

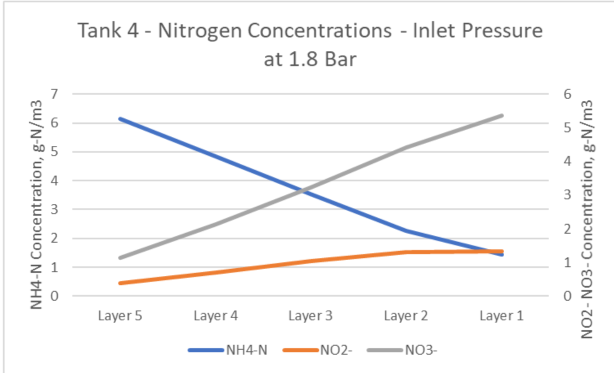

Oxygen Profile - Inlet Pressure at 1.3 Bar
DO Concentration g-DO/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

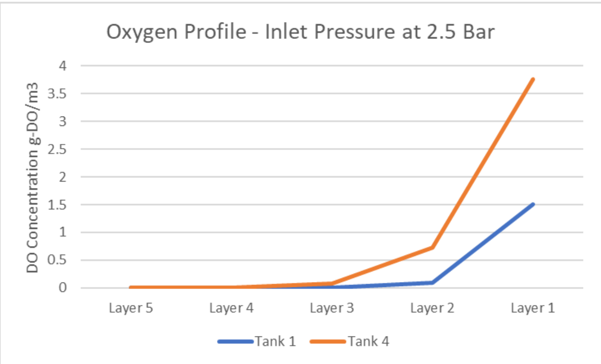

Tank 1 - Nitrogen Concentrations - Inlet Pressure at 1.3 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

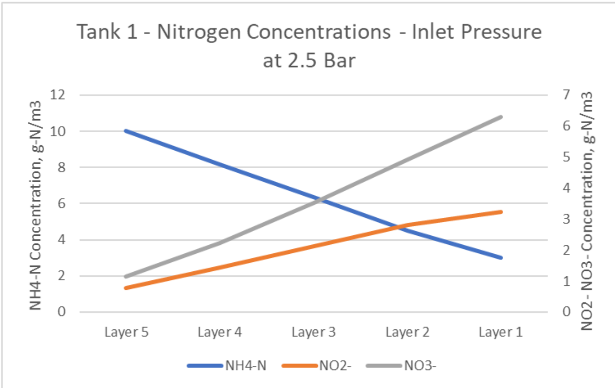

Tank 4 - Nitrogen Concentrations - Inlet Pressure at 1.3 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

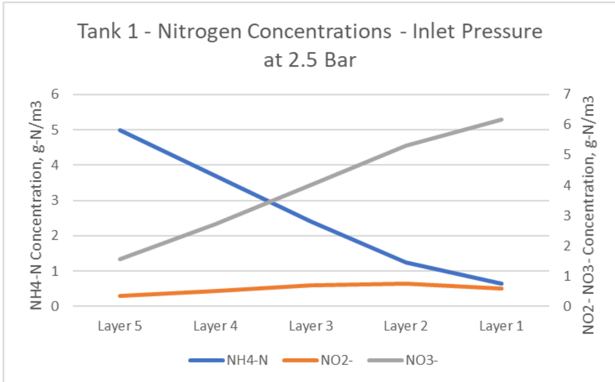

Oxygen Profile - Inlet Pressure at 1.8 Bar
DO Concentration g-DO/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

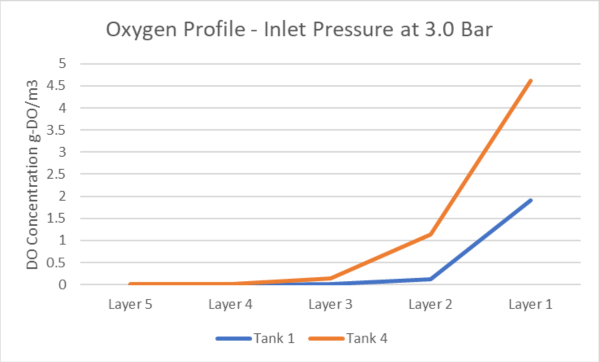

Tank 1 - Nitrogen Concentrations - Inlet Pressure at 1.8 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

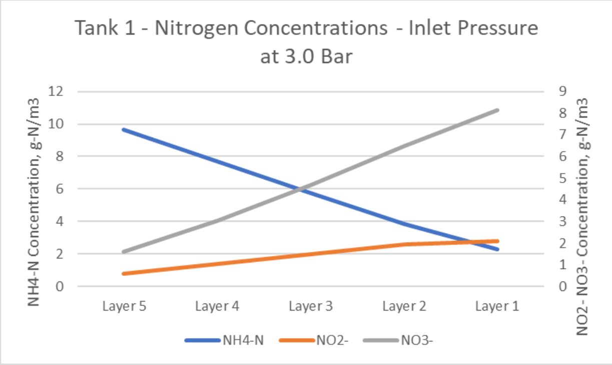

Tank 4 - Nitrogen Concentrations - Inlet Pressure at 1.8 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

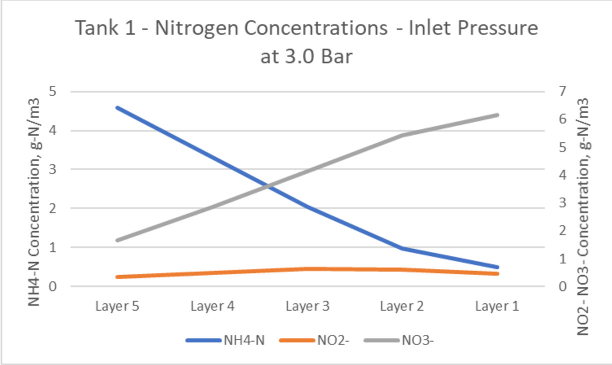

Oxygen Profile - Inlet Pressure at 2.5 Bar
DO Concentration g-DO/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

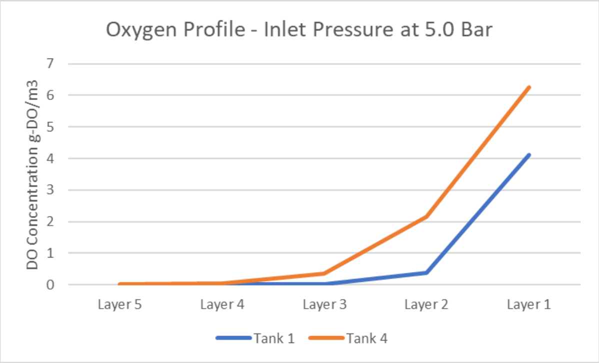

Tank 1 - Nitrogen Concentrations - Inlet Pressure at 2.5 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

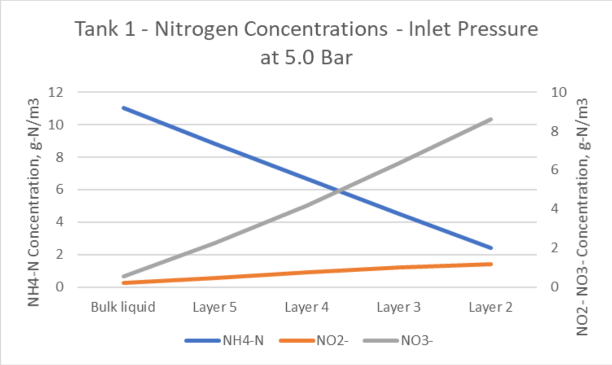

Tank 1 - Nitrogen Concentrations - Inlet Pressure at 2.5 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

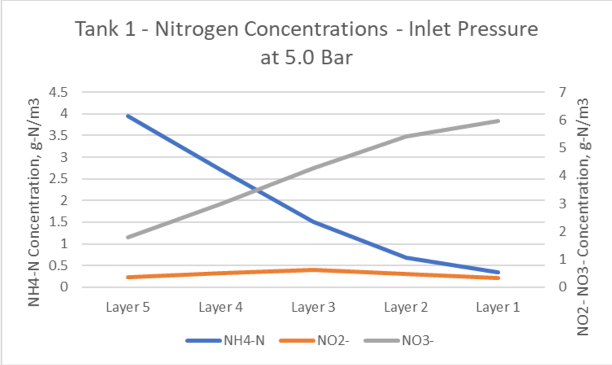

Oxygen Profile - Inlet Pressure at 3.0 Bar
DO Concentration g-DO/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4


Tank 1 - Nitrogen Concentrations - Inlet Pressure at 3.0 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-


Tank 1 - Nitrogen Concentrations - Inlet Pressure at 3.0 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

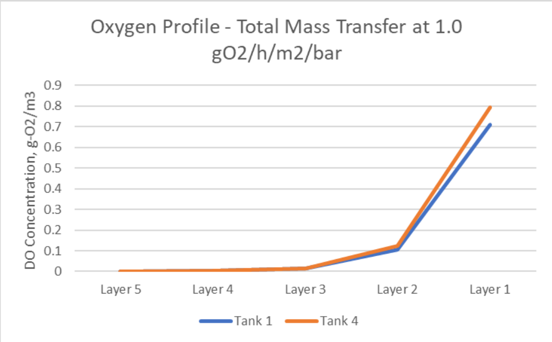

Oxygen Profile - Inlet Pressure at 5.0 Bar
DO Concentration g-DO/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

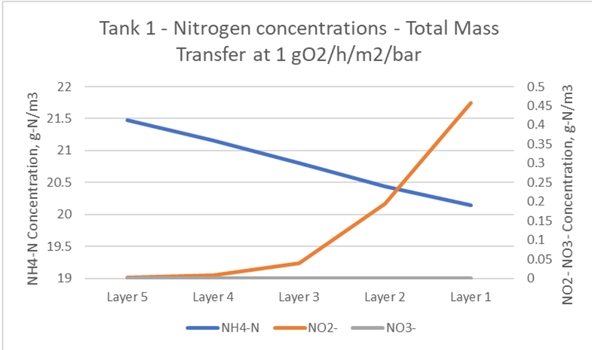

Tank 1 - Nitrogen Concentrations - Inlet Pressure at 5.0 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Bulk liquid
Layer 5
Layer 4
Layer 3
Layer 2
NH4-N
NO2-
NO3-

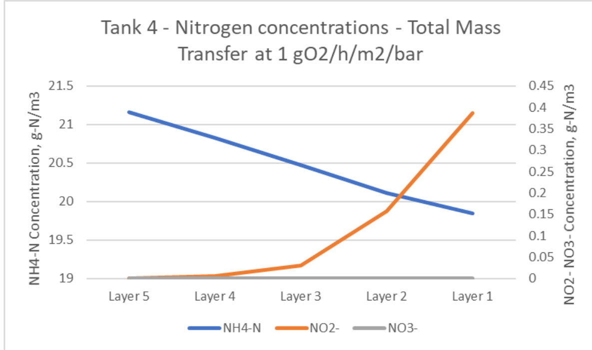

Tank 1 - Nitrogen Concentrations - Inlet Pressure at 5.0 Bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

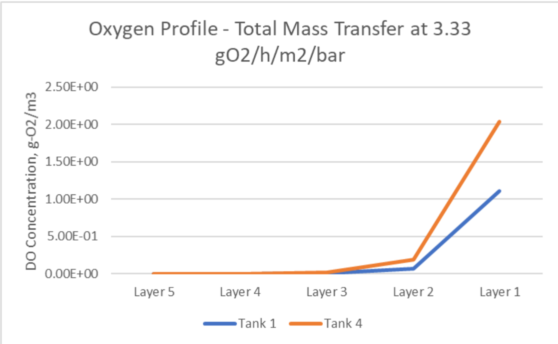
C-3 Total Mass Transfer

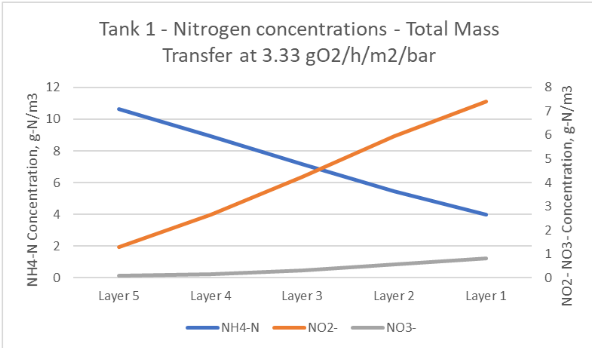
Total Mass Transfer (gO2/h/m2/bar)														
Scenario	Parameter	Unit	Tank 1						Tank 4					
			Bulk Liquid	**Layer 5**	**Layer 4**	**Layer 3**	**Layer 2**	**Layer 1**	**Bulk Liquid**	**Layer 5**	**Layer 4**	**Layer 3**	**Layer 2**	**Layer 1**
	DO	g-O2/m3	1.13E-05	0.000349	0.002082	0.0135	0.106	0.71	1.24E-05	0.0004004	0.002474	0.01603	0.1243	0.7948
	NH4-N	g-N/m3	21.77	21.48	21.16	20.81	20.44	20.15	21.47	21.16	20.83	20.47	20.11	19.84
	NO2-	g-N/m3	0.002207	0.001518	0.007292	0.04005	0.1957	0.4569	2.41E-05	0.0008262	0.00534	0.03032	0.1578	0.3866
	NO3-	g-N/m3	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
1	COD	g-COD/m3	2856	89180	82420	96850	107200	109100	2845	90600	80140	94620	108000	109900
	sCOD	g-COD/m3	88.33	73.89	60.91	47.88	37.63	33.19	85.66	74.29	61.38	47.94	36.82	32.09
	AOB's	g-COD/m3	12.42	401.3	1404	2540	3813	5486	12.54	412.9	1267	2238	3308	4728
	NOB's	g-COD/m3	1.89E-05	0.0006086	0.0004288	0.0002931	0.0001893	0.000158	1.89E-05	0.0006195	0.0004325	0.0002901	0.0001791	0.0001441
	HET	g-COD/m3	1329	42790	42940	58360	72610	76160	1325	43480	42750	58850	75990	79100
	DO	g-O2/m3	2.85E-06	9.90E-05	0.0005361	0.00497	0.0675	1.113	1.48E-05	0.0004256	0.00205	0.01659	0.1949	2.036
	NH4-N	g-N/m3	12.35	10.64	8.919	7.187	5.456	3.986	7.008	5.715	4.417	3.114	1.845	0.9885
	NO2-	g-N/m3	0.1336	1.283	2.668	4.252	5.944	7.403	0.07568	0.3033	0.5451	0.7904	1.003	0.9504
	NO3-	g-N/m3	0.03744	0.07983	0.1632	0.315	0.5464	0.8263	0.2546	1.116	2.132	3.279	4.517	5.584
3.33	COD	g-COD/m3	752900	20750	54710	103500	165000	244400	1863000	33250	64360	111100	171100	249900
	sCOD	g-COD/m3	13790	13710	13620	13540	13460	13400	18330	18250	18170	18090	18010	17950
	AOB's	g-COD/m3	38.32	1076	6040	12170	20900	30620	38.7	1172	6023	11780	18800	23460
	NOB's	g-COD/m3	5.815	162.8	383.4	678.6	1126	1731	5.912	179.8	1559	3183	5263	7430
	HET	g-COD/m3	1343	37560	44160	42590	43140	45400	1349	40640	37850	34870	35130	35500
	DO	g-O2/m3	7.30E-06	0.0002632	0.001406	0.01406	0.2112	2.923	0.0002394	0.005721	0.02505	0.1925	1.5	5.268
	NH4-N	g-N/m3	11.26	9.189	7.123	5.05	3.008	1.592	5.496	4.251	2.996	1.766	0.8098	0.3941
	NO2-	g-N/m3	0.2013	0.5082	0.8258	1.144	1.424	1.311	0.1821	0.3408	0.4985	0.6223	0.5406	0.3767
	NO3-	g-N/m3	0.4898	2.005	3.752	5.723	7.824	9.631	0.6514	1.702	2.886	4.169	5.385	6.046
6	COD	g-COD/m3	3080	81570	103500	104300	103800	107600	3059	92360	91840	93280	96180	96800
	sCOD	g-COD/m3	80.5	58.77	45.56	39	35.79	34.2	50.95	43.18	37.78	34.03	31.42	30.1
	AOB's	g-COD/m3	39.03	1066	6874	14340	24510	31700	39.39	1215	6784	12900	16930	17540
	NOB's	g-COD/m3	10.08	275.3	1907	4007	6990	10300	10.19	314.5	1840	3622	5452	6340
	HET	g-COD/m3	1285	34920	44940	41410	40300	39330	1292	39630	36820	36880	36320	35530
	DO	g-O2/m3	2.04E-05	0.0007423	0.003956	0.0413	0.6053	5.128	0.0005318	0.01242	0.05304	0.3836	2.261	6.38
	NH4-N	g-N/m3	10.86	8.645	6.431	4.214	2.115	0.9648	5.066	3.849	2.624	1.457	0.6548	0.3253
	NO2-	g-N/m3	0.2295	0.4738	0.7173	0.9494	1.069	0.7915	0.209	0.3636	0.5159	0.6061	0.4678	0.3169
	NO3-	g-N/m3	0.6232	2.428	4.473	6.747	9.115	10.77	0.7362	1.792	2.977	4.243	5.339	5.886
10	COD	g-COD/m3	3088	80920	103200	103600	104800	107000	3067	92400	90720	93550	95550	95600
	sCOD	g-COD/m3	79.65	57.64	44.17	37.54	34.16	32.46	49.69	42.22	36.94	33.15	30.6	29.36
	AOB's	g-COD/m3	39.22	1060	7500	15680	25700	29890	39.58	1219	7035	12950	15700	15820
	NOB's	g-COD/m3	10.29	278.3	2125	4489	7754	10420	10.4	320.3	1880	3659	5210	5832
	HET	g-COD/m3	1288	34640	45980	43710	42480	40700	1295	39650	38100	38080	36250	34950

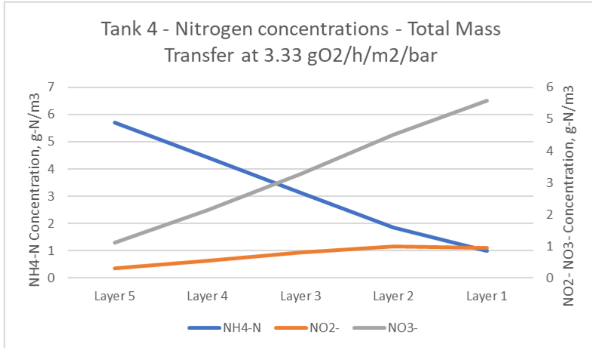

Oxygen Profile - Total Mass Transfer at 1.0 gO2/h/m2/bar
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

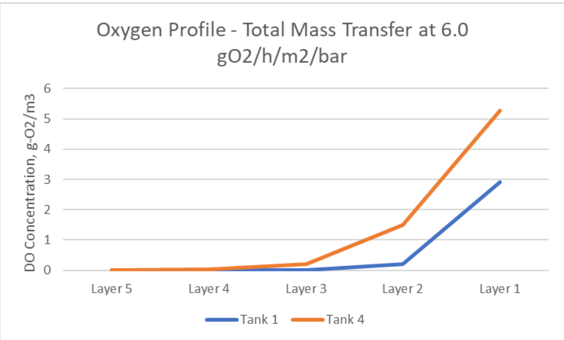

Tank 1 - Nitrogen concentrations - Total Mass Transfer at 1 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

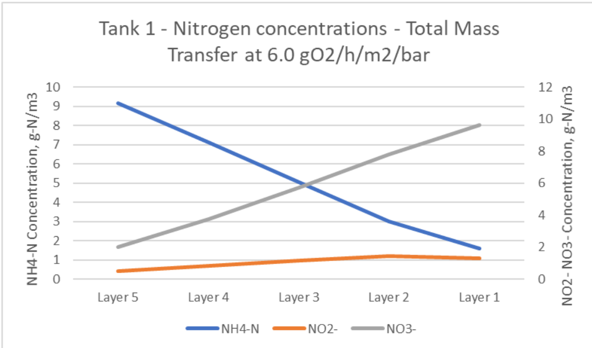

Tank 4 - Nitrogen concentrations - Total Mass Transfer at 1 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

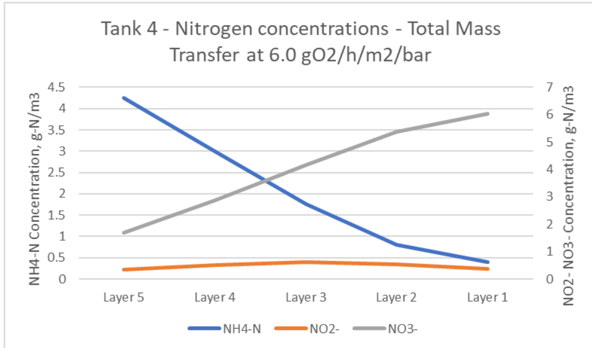

Oxygen Profile - Total Mass Transfer at 3.33 gO2/h/m2/bar
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

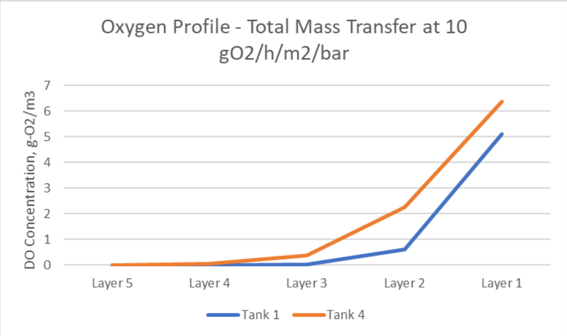

Tank 1 - Nitrogen concentrations - Total Mass Transfer at 3.33 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

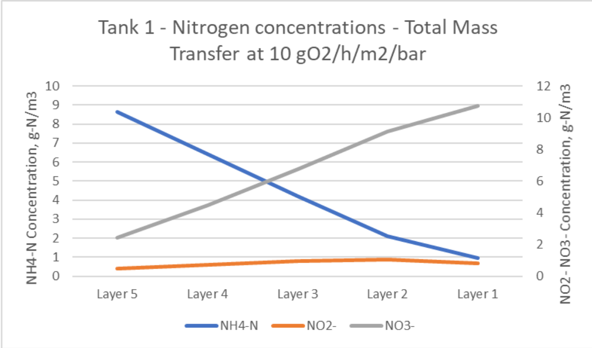

Tank 4 - Nitrogen concentrations - Total Mass Transfer at 3.33 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

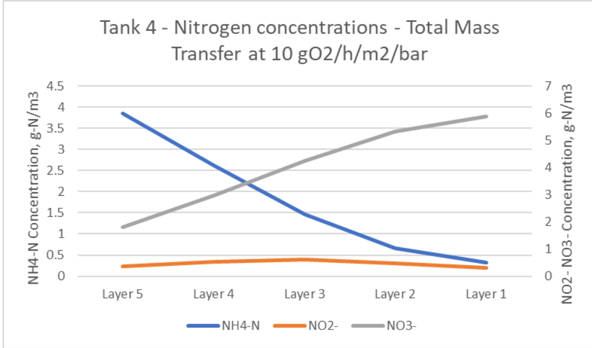

Oxygen Profile - Total Mass Transfer at 6.0 gO2/h/m2/bar
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4


Tank 1 - Nitrogen concentrations - Total Mass Transfer at 6.0 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-


Tank 4 - Nitrogen concentrations - Total Mass Transfer at 6.0 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

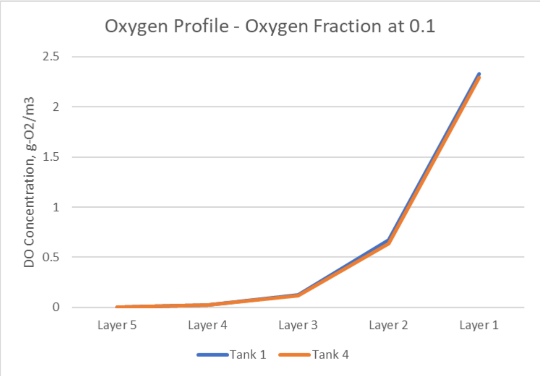

Oxygen Profile - Total Mass Transfer at 10 gO2/h/m2/bar
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

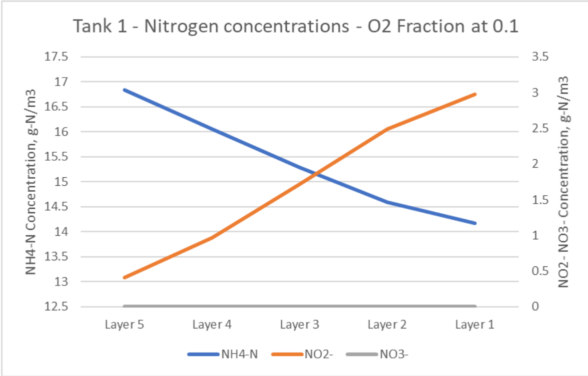

Tank 1 - Nitrogen concentrations - Total Mass Transfer at 10 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

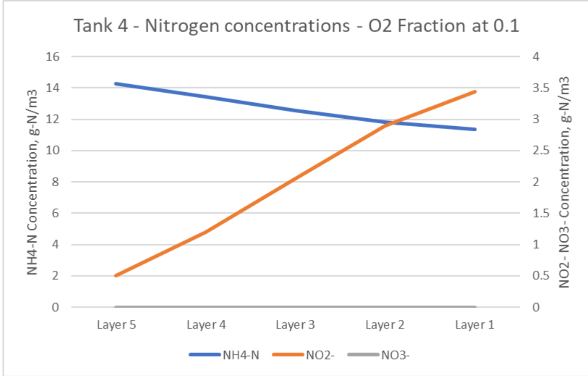

Tank 4 - Nitrogen concentrations - Total Mass Transfer at 10 gO2/h/m2/bar
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

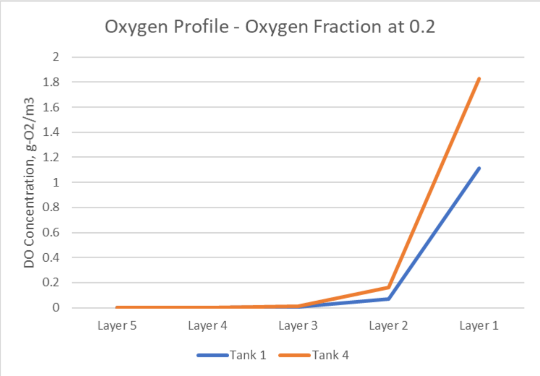
C-4 Oxygen fraction

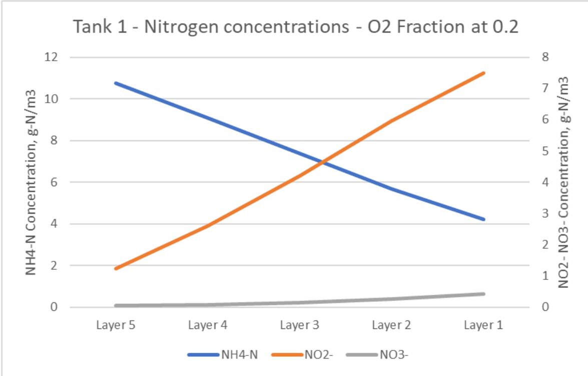
Scenario	Parameter	Unit	O2 fraction											
			Tank 1						Tank 4					
			Bulk liquid	Layer 5	Layer 4	Layer 3	Layer 2	Layer 1	Bulk liquid	Layer 5	Layer 4	Layer 3	Layer 2	Layer 1
0.1	DO	g-O2/m3	0.0001476	0.004794	0.02241	0.1272	0.6695	2.33	0.0001402	0.004532	0.02164	0.1195	0.6377	2.291
	NH4-N	g-N/m3	17.61	16.84	16.06	15.28	14.59	14.17	15.13	14.27	13.42	12.57	11.81	11.35
	NO2-	g-N/m3	0.03826	0.406	0.9647	1.718	2.487	2.979	0.02035	0.507	1.199	2.053	2.899	3.439
	NO3-	g-N/m3	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.01E-06	1.06E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.06E-06	1.14E-06
	COD	g-COD/m3	3161	72780	93350	80900	57660	49790	3149	76330	89170	75050	51420	44130
	sCOD	g-COD/m3	81.62	64.84	52.88	45.06	40.23	37.9	68.01	56.62	47.89	42.03	38.43	36.7
	AOB's	g-COD/m3	31.4	742.3	2213	3816	5420	6966	31.73	786.7	2416	4207	5939	7715
	NOB's	g-COD/m3	2.23E-05	0.000525	0.0004024	0.000328	0.0003176	0.0003739	2.23E-05	0.0005504	0.000446	0.0003959	0.0004106	0.0005091
	HET	g-COD/m3	1249	29500	34990	29770	23370	21600	1250	30940	29700	23000	17090	15740
0.2	DO	g-O2/m3	2.92E-06	0.0001015	0.0005532	0.005118	0.0689	1.112	1.17E-05	0.0003481	0.0017	0.01384	0.1639	1.83
	NH4-N	g-N/m3	12.44	10.76	9.069	7.368	5.667	4.227	7.154	5.862	4.566	3.265	1.991	1.096
	NO2-	g-N/m3	0.1211	1.233	2.602	4.206	5.957	7.498	0.06627	0.3077	0.5686	0.8362	1.078	1.068
	NO3-	g-N/m3	0.02798	0.04046	0.07554	0.1477	0.2693	0.4287	0.2178	1.033	2.006	3.115	4.321	5.391
	COD	g-COD/m3	3022	82620	100900	103500	103500	107200	3003	88010	96230	97380	97500	100500
	sCOD	g-COD/m3	79.68	62.17	50.34	42.65	37.91	35.38	55.35	46.28	39.99	35.88	33.48	32.21
	AOB's	g-COD/m3	38.35	1081	6008	12000	20420	29740	38.35	1161	5951	11640	18690	23820
	NOB's	g-COD/m3	5.246	147.2	260.4	420.1	669.4	1011	5.338	160.8	1510	3095	5134	7353
	HET	g-COD/m3	1353	37970	43660	42400	43890	47140	1358	40540	38760	35570	35400	35710
0.3	DO	g-O2/m3	3.81E-06	0.0001375	0.0007329	0.006741	0.09259	1.51	9.57E-05	0.00241	0.01073	0.08065	0.7512	3.82
	NH4-N	g-N/m3	11.85	10.02	8.185	6.347	4.515	3.021	6.246	4.959	3.664	2.373	1.226	0.6396
	NO2-	g-N/m3	0.1834	0.7878	1.446	2.133	2.816	3.237	0.1518	0.3348	0.5196	0.69	0.7371	0.5847
	NO3-	g-N/m3	0.2689	1.155	2.237	3.522	4.939	6.299	0.5275	1.567	2.741	4.02	5.32	6.171
	COD	g-COD/m3	3089	80790	100600	99120	96740	100600	3069	88560	86880	83430	84170	85880
	sCOD	g-COD/m3	81.08	60.07	47.23	40.76	37.59	36.2	52.37	44.69	39.34	35.73	33.29	31.98
	AOB's	g-COD/m3	41.39	1115	5944	12240	21370	30820	41.8	1232	5978	11460	16810	18770
	NOB's	g-COD/m3	9.588	258.2	1349	2775	4888	7644	9.712	286.5	1608	3172	5090	6493
	HET	g-COD/m3	1288	34590	43220	38330	36090	36120	1295	38000	33070	30990	31110	31140
0.4	DO	g-O2/m3	5.24E-06	0.0001891	0.001013	0.009907	0.1465	2.263	0.0002149	0.005204	0.02283	0.1753	1.404	5.123
	NH4-N	g-N/m3	11.42	9.425	7.437	5.442	3.463	1.98	5.659	4.392	3.117	1.864	0.87	0.4282
	NO2-	g-N/m3	0.1938	0.5497	0.9247	1.307	1.665	1.685	0.1783	0.3418	0.5045	0.636	0.5692	0.4041
	NO3-	g-N/m3	0.4314	1.787	3.368	5.168	7.103	8.853	0.6366	1.702	2.901	4.201	5.446	6.139
	COD	g-COD/m3	3084	81700	103100	103600	102600	106600	3063	91040	90280	90580	92830	93470
	sCOD	g-COD/m3	80.7	59.15	46.1	39.61	36.46	34.96	51.29	43.49	38.07	34.32	31.73	30.41
	AOB's	g-COD/m3	39.81	1087	6603	13730	23640	31920	40.19	1221	6671	12700	16890	17660
	NOB's	g-COD/m3	10.12	276.4	1787	3738	6534	9867	10.24	311	1803	3548	5390	6349
	HET	g-COD/m3	1285	34960	44470	40430	38970	38410	1292	39050	36000	35720	35160	34480
1	DO	g-O2/m3	2.93E-05	0.001068	0.005685	0.06018	0.8544	5.961	0.0006448	0.01496	0.06345	0.4477	2.449	6.624
	NH4-N	g-N/m3	10.76	8.497	6.242	3.988	1.906	0.8406	4.953	3.747	2.534	1.39	0.6243	0.3126
	NO2-	g-N/m3	0.2382	0.4713	0.7017	0.9158	0.9757	0.688	0.2164	0.369	0.5187	0.5978	0.452	0.3054
	NO3-	g-N/m3	0.6605	2.541	4.662	7.015	9.433	11	0.7584	1.812	2.992	4.248	5.308	5.83
	COD	g-COD/m3	3090	80710	103100	103400	105100	106700	3068	92510	90440	93520	95320	95270
	sCOD	g-COD/m3	79.39	57.28	43.72	37.08	33.63	31.94	49.33	41.96	36.72	32.93	30.42	29.2
	AOB's	g-COD/m3	39.3	1059	7733	16170	25860	29250	39.66	1222	7069	12860	15360	15400
	NOB's	g-COD/m3	10.31	278.1	2188	4631	7947	10320	10.42	321.2	1885	3653	5132	5702
	HET	g-COD/m3	1290	34570	46560	44760	43060	41040	1297	39720	38470	38260	36140	34730

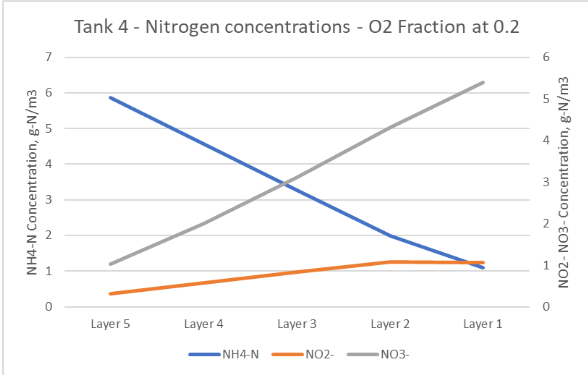

Oxygen Profile - Oxygen Fraction at 0.1
DO Concentration, g-O2/m3
2.5
2
1.5
1
0.5
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

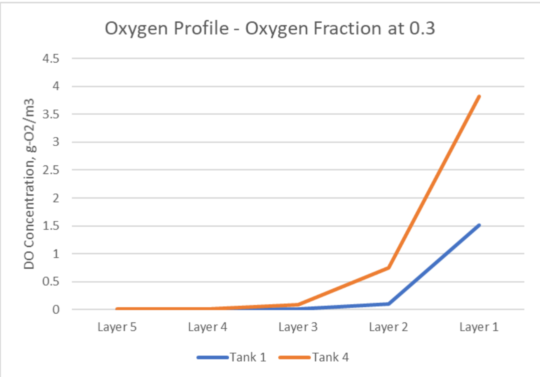

Tank 1 - Nitrogen concentrations - O2 Fraction at 0.1
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
17.5
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
3.5
3
2.5
2
1.5
1
0.5
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

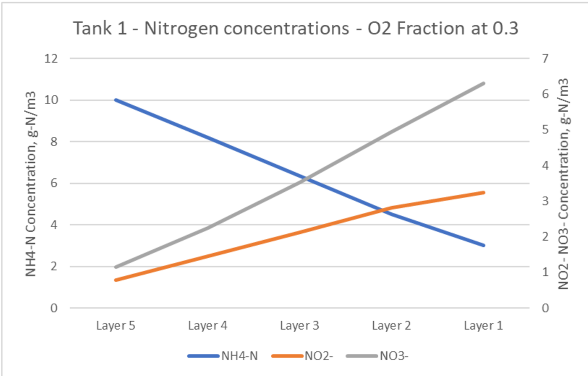

Tank 4 - Nitrogen concentrations - O2 Fraction at 0.1
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
16
14
12
10
8
6
4
2
0
4
3.5
3
2.5
2
1.5
1
0.5
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

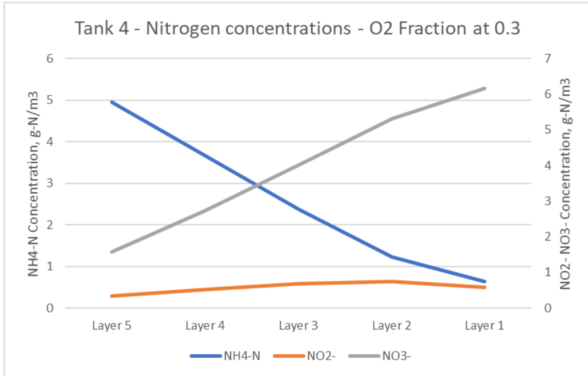

Oxygen Profile - Oxygen Fraction at 0.2
DO Concentration, g-O2/m3
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

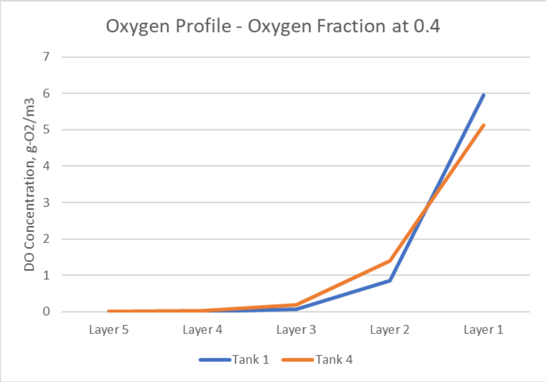

Tank 1 - Nitrogen concentrations - O2 Fraction at 0.2
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
12
10
8
6
4
2
0
8
7
6
5
4
3
2
1
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

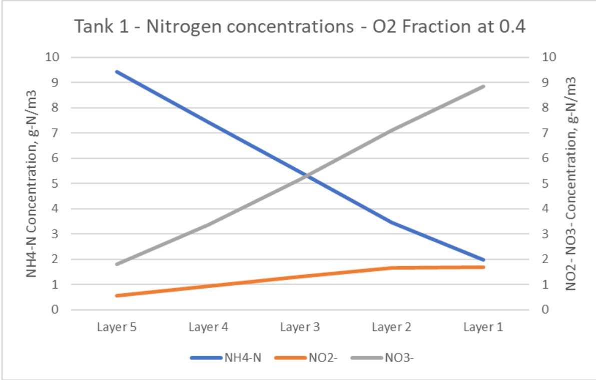

Tank 4 - Nitrogen concentrations - O2 Fraction at 0.2
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
7
6
5
4
3
2
1
0
6
5
4
3
2
1
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

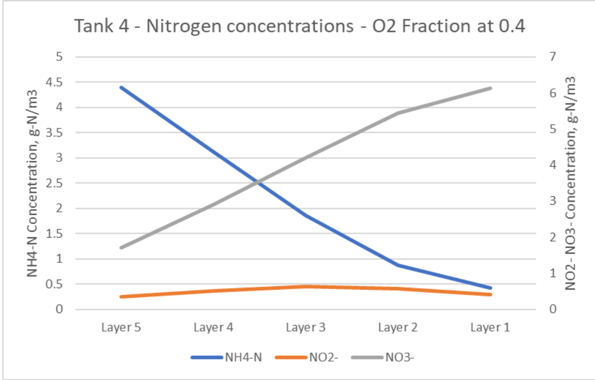

Oxygen Profile - Oxygen Fraction at 0.3
DO Concentration, g-O2/m3
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

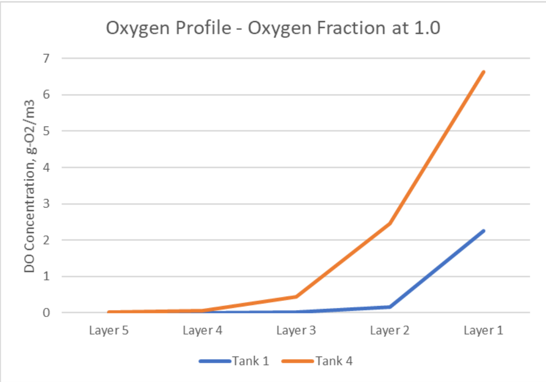

Tank 1 - Nitrogen concentrations - O2 Fraction at 0.3
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
12
10
8
6
4
2
0
7
6
5
4
3
2
1
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

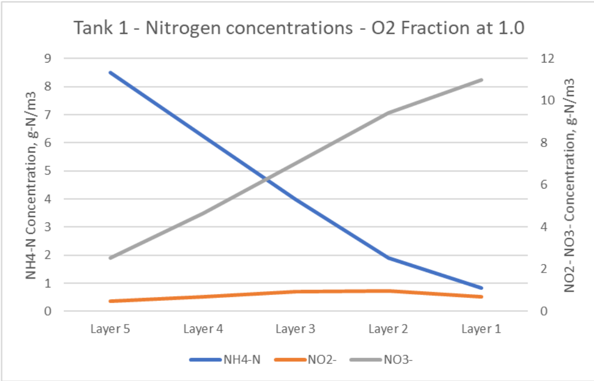

Tank 4 - Nitrogen concentrations - O2 Fraction at 0.3
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
6
5
4
3
2
1
0
7
6
5
4
3
2
1
0
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

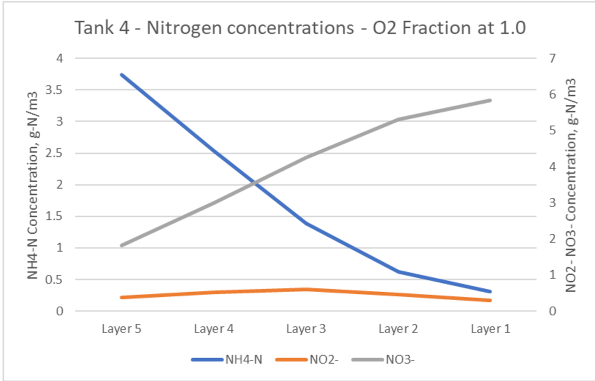

Oxygen Profile - Oxygen Fraction at 0.4
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4


Tank 1 - Nitrogen concentrations - O2 Fraction at 0.4
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

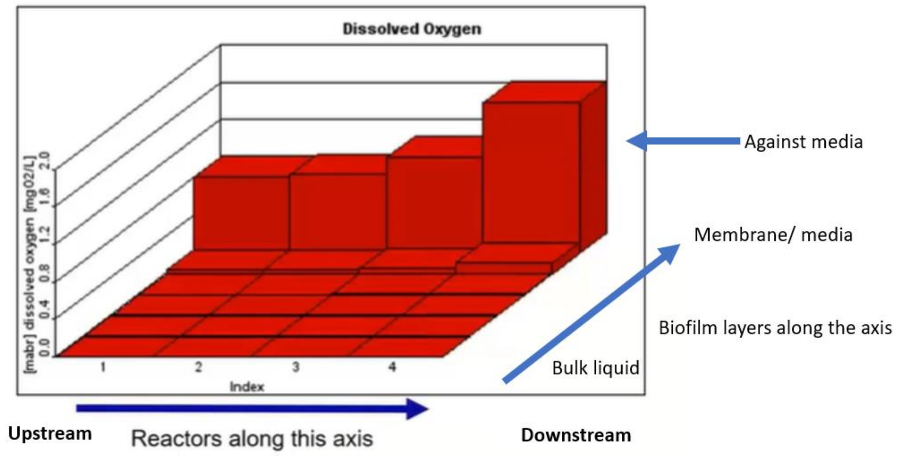

Tank 4 - Nitrogen concentrations - O2 Fraction at 0.4
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-


Oxygen Profile - Oxygen Fraction at 1.0
DO Concentration, g-O2/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Tank 1
Tank 4

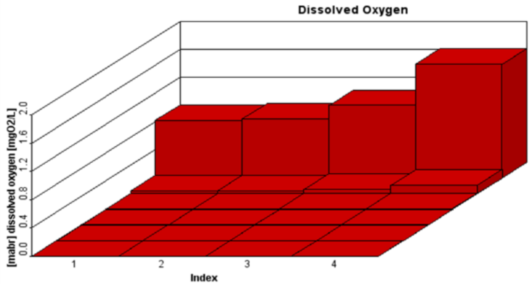

Tank 1 - Nitrogen concentrations - O2 Fraction at 1.0
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

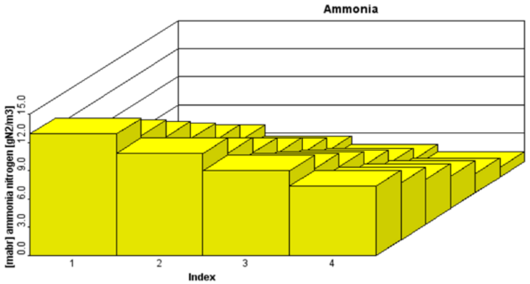

Tank 4 - Nitrogen concentrations - O2 Fraction at 1.0
NH4-N Concentration, g-N/m3
NO2- NO3- Concentration, g-N/m3
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
NH4-N
NO2-
NO3-

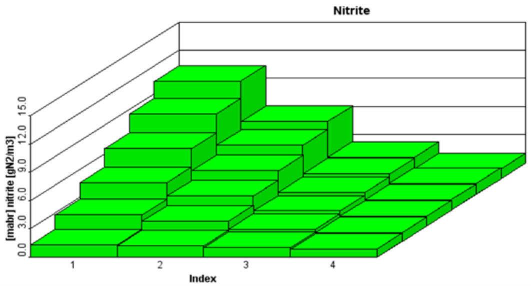
Appendix D
GPS-X Output Layout – Base Model

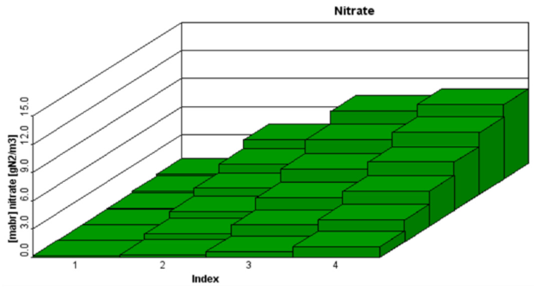


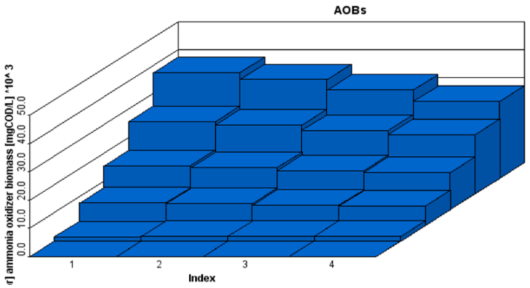
Dissolved Oxygen
[mabr] dissolved oxygen [mgO2/L]
0.0
0.4
0.8
1.2
1.6
2.0
1
2
3
4
Index
Against media
Membrane/ media
Biofilm layers along the axis
Bulk liquid
Upstream
Reactors along this axis
Downstream

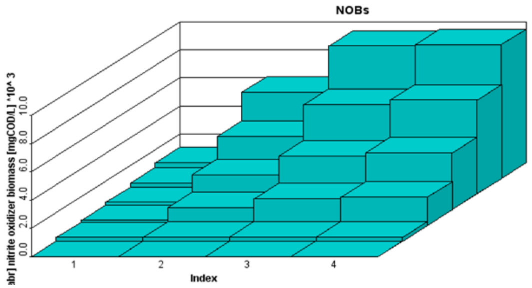

Dissolved Oxygen
[mabr] dissolved oxygen [mgO2/L]
0.0 0.4 0.8 1.2 1.6 2.0
1 2 3 4
Index

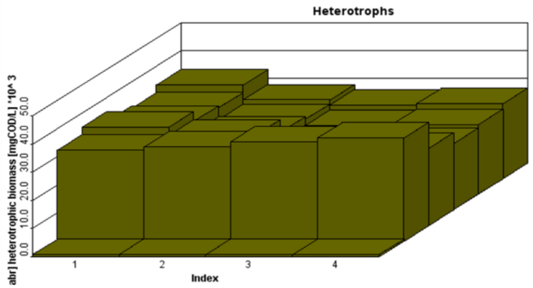

Ammonia
[mabr] ammonia nitrogen [gN2/m3]
0.0 3.0 6.0 9.0 12.0 15.0
1 2 3 4
Index


Nitrite
[mabr] nitrite [gN2/m3]
0.0 3.0 6.0 9.0 12.0 15.0
1 2 3 4
Index


Nitrate
[mabr] nitrate [gN2/m3]
0.0 3.0 6.0 9.0 12.0 15.0
1 2 3 4
Index


AOBs
r] ammonia oxidizer biomass [mgCOD/L] *10^ 3
0.0 10.0 20.0 30.0 40.0 50.0
1 2 3 4
Index

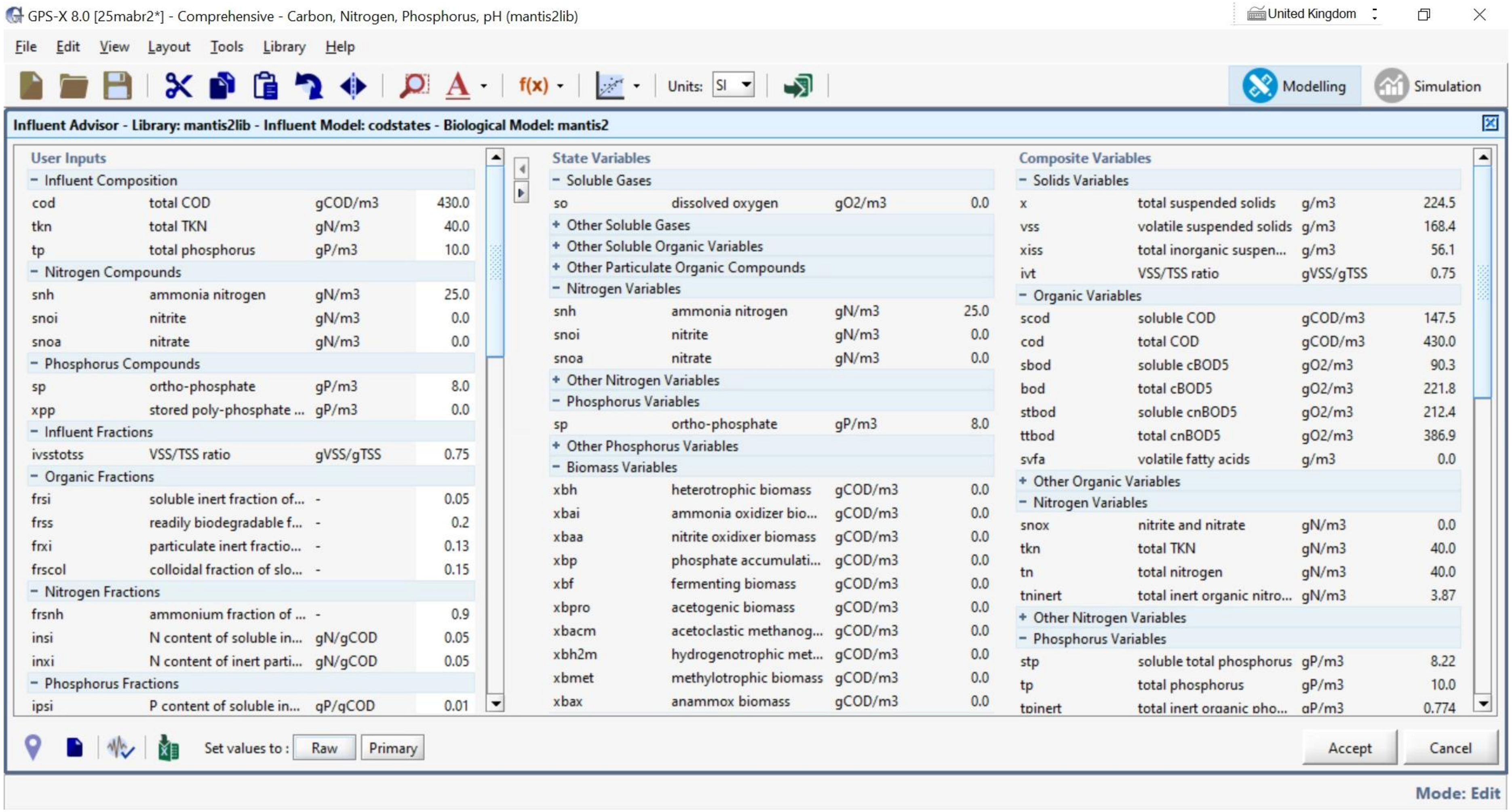

NOBs
abr] nitrite oxidizer biomass [mgCOD/L] *10^ 3
0.0 2.0 4.0 6.0 8.0 10.0
1 2 3 4
Index


Heterotrophs
abr] heterotrophic biomass [mgCOD/L] *10^ 3
0.0 10.0 20.0 30.0 40.0 50.0
1 2 3 4
Index

Appendix E
MABR Nitrogen concentration performance

Scenario's	Unit	NH4-N (mg-N/L)				NO2- (mg-N/L)			NO3- (mg-N/L)			Comments
		Raw Influent	Primary Effluent	MABR Effluent	Removal efficiency	Raw Influent	Primary Effluent	MABR Effluent	Raw Influent	Primary Effluent	MABR Effluent	
Increase in NH4-N concentrations												
15	mg-N/L	15	14.768	4.427	70%	0	0.012	0.039	0	0.006	0.121	NH4-N:TKN (ratio) = 0.35
20	mg-N/L	20	19.681	5.722	71%	0	0.017	0.062	0	0.009	0.198	NH4-N:TKN (ratio) = 0.5
25	mg-N/L	25	24.601	7.449	70%	0	0.025	0.092	0	0.011	0.265	NH4-N:TKN (ratio) = 0.625
30	mg-N/L	30	29.533	9.797	67%	0	0.036	0.129	0	0.007	0.223	NH4-N:TKN (ratio) = 0.75
36	mg-N/L	36	35.488	14.306	60%	0	0.048	0.181	0	0.000	0.000	NH4-N:TKN (ratio) = 0.9
Inlet Pressure												
1.3	Bar	25	24.663	10.764	56%	0	0.0281	0.0466	0	0.000	0.000	Pressure difference = 0
1.8	Bar	25	24.601	7.447	70%	0	0.0249	0.0942	0	0.011	0.270	Pressure Difference = 0.5
2.5	Bar	25	24.583	6.268	75%	0	0.0198	0.1504	0	0.018	0.521	Pressure difference = 1.25
3	Bar	25	24.577	5.862	76%	0	0.0186	0.1685	0	0.020	0.599	Pressure difference = 1.75
5	Bar	25	24.566	5.184	79%	0	0.0175	0.2035	0	0.022	0.721	Pressure difference = 3.75
Total Mass Transfer (Ki)												
1	gO2/h/m2/bar	25	24.894	21.473	14%	0	0.0029	0.0000	0	0.000	0.000	
3.33	gO2/h/m2/bar	25	24.598	7.008	72%	0	0.0199	0.0757	0	0.008	0.255	
6	gO2/h/m2/bar	25	24.572	5.496	78%	0	0.0176	0.1821	0	0.020	0.651	
10	gO2/h/m2/bar	25	24.564	5.066	79%	0	0.0174	0.2090	0	0.022	0.736	
Oxygen Fraction in Air												
0.1	-	25	24.757	15.133	39%	0	0.018	0.020	0	0.000	0.000	
0.2	-	25	24.600	7.154	71%	0	0.020	0.066	0	0.007	0.218	
0.3	-	25	24.583	6.246	75%	0	0.020	0.152	0	0.018	0.527	
0.4	-	25	24.574	5.659	77%	0	0.018	0.178	0	0.020	0.637	
1	-	25	24.562	4.953	80%	0	0.017	0.216	0	0.023	0.758	

Appendix F
GPS-X CODStates library


GPS-X 8.0 [25mabr2*] - Comprehensive - Carbon, Nitrogen, Phosphorus, pH (mantis2lib)
United Kingdom
File Edit View Layout Tools Library Help
f(x)
Units: SI
Modelling
Simulation
Influent Advisor - Library: mantis2lib - Influent Model: codstates - Biological Model: mantis2
User Inputs
− Influent Composition
cod total COD gCOD/m3 430.0
tkn total TKN gN/m3 40.0
tp total phosphorus gP/m3 10.0
− Nitrogen Compounds
snh ammonia nitrogen gN/m3 25.0
snoi nitrite gN/m3 0.0
snoa nitrate gN/m3 0.0
− Phosphorus Compounds
sp ortho-phosphate gP/m3 8.0
xpp stored poly-phosphate ... gP/m3 0.0
− Influent Fractions
ivsstotss VSS/TSS ratio gVSS/gTSS 0.75
− Organic Fractions
frsi soluble inert fraction of... - 0.05
frss readily biodegradable f... - 0.2
frxi particulate inert fractio... - 0.13
frscol colloidal fraction of slo... - 0.15
− Nitrogen Fractions
frsnh ammonium fraction of ... - 0.9
insi N content of soluble in... gN/gCOD 0.05
inxi N content of inert parti... gN/gCOD 0.05
− Phosphorus Fractions
ipsi P content of soluble in... gP/gCOD 0.01
State Variables
− Soluble Gases
so dissolved oxygen gO2/m3 0.0
+ Other Soluble Gases
+ Other Soluble Organic Variables
+ Other Particulate Organic Compounds
− Nitrogen Variables
snh ammonia nitrogen gN/m3 25.0
snoi nitrite gN/m3 0.0
snoa nitrate gN/m3 0.0
+ Other Nitrogen Variables
− Phosphorus Variables
sp ortho-phosphate gP/m3 8.0
+ Other Phosphorus Variables
− Biomass Variables
xbh heterotrophic biomass gCOD/m3 0.0
xbai ammonia oxidizer bio... gCOD/m3 0.0
xbaa nitrite oxidixer biomass gCOD/m3 0.0
xbp phosphate accumulati... gCOD/m3 0.0
xbf fermenting biomass gCOD/m3 0.0
xbpro acetogenic biomass gCOD/m3 0.0
xbacm acetoclastic methanog... gCOD/m3 0.0
xbh2m hydrogenotrophic met... gCOD/m3 0.0
xbmet methylotrophic biomass gCOD/m3 0.0
xbax anammox biomass gCOD/m3 0.0
Composite Variables
− Solids Variables
x total suspended solids g/m3 224.5
vss volatile suspended solids g/m3 168.4
xiss total inorganic suspen... g/m3 56.1
ivt VSS/TSS ratio gVSS/gTSS 0.75
− Organic Variables
scod soluble COD gCOD/m3 147.5
cod total COD gCOD/m3 430.0
sbod soluble cBOD5 gO2/m3 90.3
bod total cBOD5 gO2/m3 221.8
stbod soluble cnBOD5 gO2/m3 212.4
ttbod total cnBOD5 gO2/m3 386.9
svfa volatile fatty acids g/m3 0.0
+ Other Organic Variables
− Nitrogen Variables
snox nitrite and nitrate gN/m3 0.0
tkn total TKN gN/m3 40.0
tn total nitrogen gN/m3 40.0
tninert total inert organic nitro... gN/m3 3.87
+ Other Nitrogen Variables
− Phosphorus Variables
stp soluble total phosphorus gP/m3 8.22
tp total phosphorus gP/m3 10.0
tpinert total inert organic pho... gP/m3 0.774
Set values to : Raw Primary
Accept Cancel
Mode: Edit