ESTABLISHING NITRITE SHUNT AT FULL SCALE

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ABSTRACT

With an energy neutrality goal for both the Mangere and Rosedale Wastewater Treatment Plants (WWTPs) by 2025, Watercare has started the journey of implementing innovative techniques to existing processes in order to drive down energy consumption. A central focus of this work is on how to improve energy consumption in aeration systems, which can account for more than 40% of total site power consumption.

Mainstream nitrite shunt is an advanced concept that provides shortcut nitrogen removal in activated sludge nutrient removal processes. The objective of nitrite shunt is to minimise the production of nitrate by stopping the nitrification process at nitrite which then is converted to nitrogen gas. This provides a direct energy 'payback' of up to 25% and a 40% carbon requirement reduction for denitrification. It enables the opportunity to focus more heavily on carbon harvest from primary treatment processes.

At Mangere WWTP nitrite shunt process has been implemented at full scale on one of nine MLE step feed reactors (approximately 120,000 EP) followed by a roll out to three other reactors through an approach of reducing reactor sludge retention time and adjusting dissolved oxygen set points through a cascade control loop using online ammonia feedback. After trials with several variations of the control strategy, a successful method was achieved. Ammonia based aeration control was implemented in all aeration zones. Several months of results show that the nitrite shunt reactors out-perform the conventional reactors, in terms of effluent nitrogen parameters. Ammonia was on average less than 1mg/L and total nitrogen was lowered by 2.4 mg/L. Nitrite accumulation was also observed at approximately 0.4 mg/L compared to typical values of under 0.1 mg/L.

Activated sludge wasting is expected to increase by up to 28% which can be a challenge to the downstream thickening processes and needs to be investigated. No detrimental impact on sludge settlability could be observed except higher peak SVI values which could be influenced by several other factors. Using qPCR, there is evidence that the test reactor is accumulating more aerobic ammonia-oxidising bacteria (AOB) than nitrite-oxidising bacteria (NOB) with a ratio of NOB/AOB of 0.33 in the test reactor compared to a ratio of 0.8 in the control reactor. However, this was not evident in the three other reactors where the control strategy was later implemented.

The main challenges for the trial have been how to best adapt a control strategy that works with a plant designed in the 1990s for a conventional process. This paper describes the initial steps to set up the full scale trial, extension of the trial to other reactors, results and provides guidance on how to implement nitrite shunt. This application at the Mangere WWTP is gaining interest with utilities and professionals, who are keen to explore their own nitrite shunt adaptation.

This paper describes the process and challenges of implementing a full scale nitrite shunt process in one of nine step-feed reactor-clarifiers (RCs) and subsequently introducing it to three other RCs.

KEYWORDS

BNR nitrite shunt, carbon, aeration, instrumentation

PRESENTER PROFILE

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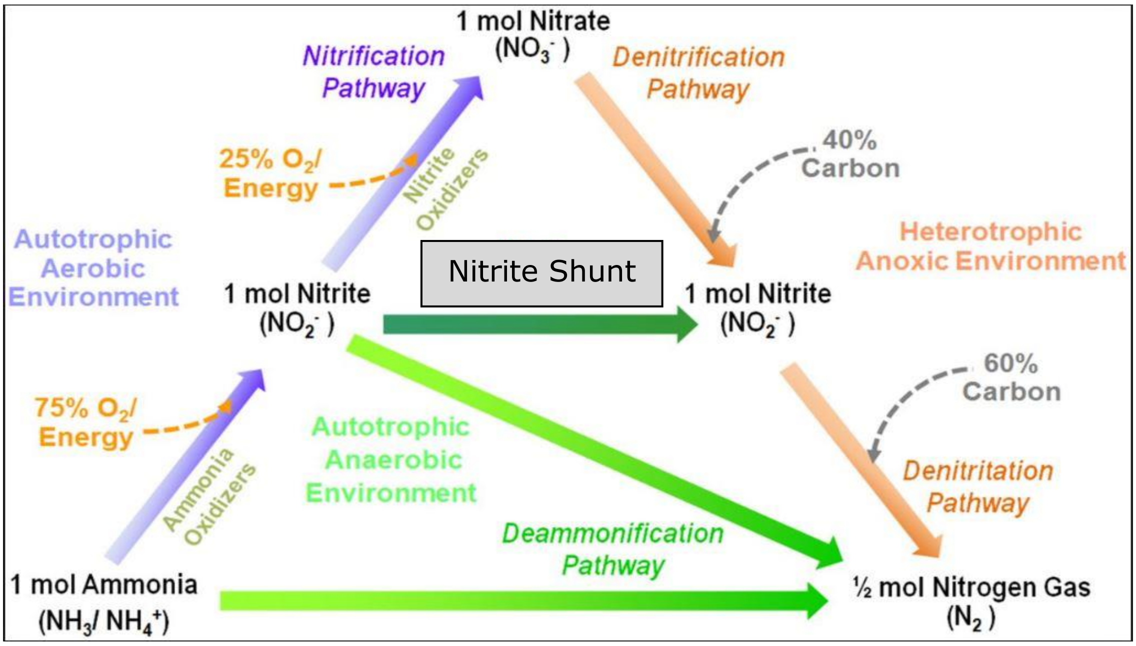
1 INTRODUCTION

With an energy neutrality goal for both the Mangere and Rosedale Wastewater Treatment Plants (WWTPs) by 2025, Watercare has started the journey of implementing innovative techniques to adjust existing processes in order to drive down energy consumption. A central focus of this work is on how to improve energy consumption in aeration systems, which can account for more than 40% of total site power consumption.

Mainstream nitrite shunt is an advanced concept that provides shortcut nitrogen removal in activated sludge nutrient removal processes. This is an economical solution able to save up to 25% of the energy requirements required for conventional nitrogen removal and up to 40% of the carbon requirements for denitrification (Pusker Regmi, 2015). The objective of nitrite shunt is to minimise the production of nitrate by stopping the nitrification process at the nitrite conversion step, which is then converted directly to nitrogen gas. This provides both a direct energy 'payback' and also the opportunity to focus more heavily on carbon harvest from primary treatment processes (*Figure 1*). The key to nitrite shunt is the out-selection of nitrite-oxidising bacteria (NOB) while favouring the growth of aerobic ammonia-oxidising bacteria (AOB).

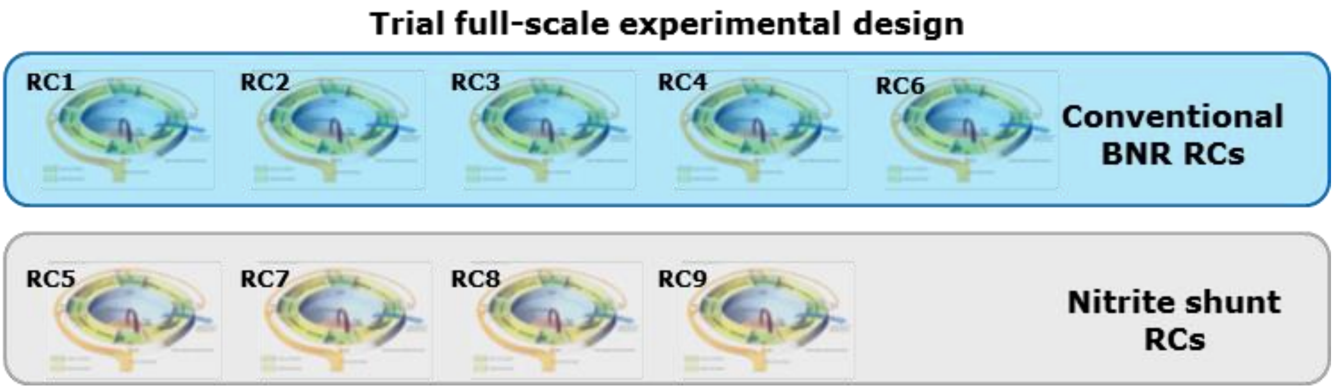
Figure 1: Nitrite shunt process (John L. Willis, 2017).



2 BACKGROUND

At the Mangere WWTP the nitrite shunt process was first implemented at full scale in one of nine step-feed reactor-clarifiers (RCs) in 2016. In January 2018, the 'trial' was extended to three more reactors at the plant (*Figure 2*). RC 5 was the first to be converted followed by RC 7, 8 and 9. Each RC consists of four denitrifying anoxic zones (Zone 1, 3, 5 and 7) interleaved with four conventional nitrifying aerobic zones (Zone 2, 4, 6 and 8). Each RC provides activated sludge treatment for approximately 120,000 PE (Population Equivalent) and holds 31 million litres of primary effluent and mixed liquor.

Figure 2: Strategy for nitrite shunt implementation at Mangere WWTP.



The trial of the shunt was carried out using two quite different aeration control strategies combined with low solids retention time (SRT). These control strategies followed each other, such that the iterations are termed Stage 1 and Stage 2 respectively. The Stage 2 control strategy was further optimised and the revised approach is referred to as Stage 3. Details of the control approaches are described in the following sections.

2.1 STAGE 1 – AIR ALTERNATION TRIAL WITH AMMONIA BASED AERATION CONTROL

Stage 1 aeration control involved alternating aeration in Zone 2 and Zone 4 between on and off at ten minutes intervals in order to achieve transient anoxia. Zone 8 was operated with ammonia feedback control (ammonia based aeration control). The SRT was also lowered to help wash out NOB. A Biowin model was configured to simulate this scenario. Table 1 summarises the implemented control strategy.

Table 1: Summary of Stage 1 control strategy.

Control Strategy	**RC Zone**	**Set Points**
Air on and off alternation	2 and 4	Ten minutes interval with DO set point of 2 mg/L
Ammonia based aeration control	8	If NH4N<1 mg/L, then DO = 0.5 mg/L If NH4N>1.5 mg/L, then DO = 2 mg/L
SRT	all zones	6 days

2.2 STAGE 2 – AMMONIA BASED AERATION CONTROL

Stage 2 of the trial involved extending the ammonia based aeration control (ABAC) from Zone 8 to all aerated zones. The SRT set point remained the same.

Table 2: Summary of Stage 2a control strategy.

RC Zone	ABAC Set Points – NH_4N, mg/L	ABAC Set Points – DO, mg/L
2 and 4	< 1.5	0.5
	>2	2
6 and 8	<1	0
	>2	2
SRT	all zones	6 days

The above control set points were progressively revised to the following.

Table 3: Summary of Stage 2b control strategy.

RC Zone	ABAC Set Points – NH_4N, mg/L	ABAC Set Points – DO, mg/L
2, 4, 6 and 8	< 1	0
	>2	2

It is important to note that for a DO set point of 0 mg/L, the aeration valve was actually set at a minimum opening position and not fully closed, to prevent solids settling on the ceramic diffusers.

2.3 STAGE 3 – AMMONIA BASED AERATION CONTROL

Stage 3 involved optimisation of the Stage 2 strategy by having a gradual increase in the DO set points through the aeration zones. The theory being to operate the RCs at a constantly low DO environment but have a higher DO set point towards the end of the reaction to polish off the ammonia residual. Biowin modeling was carried out to simulate the parameters and the best predicted parameters were as follows.

Table 4: Summary of Stage 3 control strategy.

RC Zone	ABAC Set Points – NH_4N, mg/L	ABAC Set Points – DO, mg/L
2 and 4	< 1	0.0
	>2	0.5
6	< 1	0.5

	>2	1
8	< 1	1
	>2	1.5
SRT	all zones	Adjusted accordingly to achieve MLSS of 1800 to 2200 mg/L in Zone 8

3 METHODOLOGY

RC 5 was selected as the full scale pilot reactor and RC 4 as the control reactor. RC 5 was selected because it was equipped with air flow meters in three out of the four aerated zones and one ISE ammonium probe in the last aerobic one. Stage 1 started implementation in November 2016 and ended in December 2016. Changes were made one at a time and gradual instead of a drastic step stage. SRT was initially lowered followed by DO set points and aeration alternation.

Moving to Stage 2 was triggered due to the unsuccessful outcome of Stage 1 which is further explained in Section 4.1.1. Stage 2a was applied to RC 5 in February 2017 followed by Stage 2b in April 2017. RC 5 was monitored for over 6 months before Stage 3 was put in place in late September 2017 in order to further optimise the control strategy.

A decision was then made in November 2017 to introduce Stage 3 nitrite shunt control methodology to three other reactors (RC 7, 8, 9) and this phase was termed Stage 4. Gradual changes to the RCs was done in December 2017 and completed within the month. The ammonia based aeration controls (ABAC) are controlled by the ammonium

probe in RC 5. At the time of writing this paper, individual ISE ammonium probes have been commissioned for RC 7, 8 and 9 and will be used for ABAC for each respective reactor.

Several parameters were monitored to determine RC performance and operational set points. Additional laboratory tests were also carried out in order to determine if nitrite shunt was occurring in the reactors. Nitrite-oxidising bacteria (NOB): aerobic ammonia-oxidising bacteric (AOB) concentrations ratio was determined through the quantitative polymerise chain reaction (qPCR) method (Sonthiphand, 2013). In a fully nitrifying system, if all of the nitrite generated from AOB oxidation is in turn converted to nitrate by NOBs then the concentration ratio of NOB:AOB should equal the ratio of the respective yield coefficients that is 0.6 (Peter Dold, 2015) . If a system is exhibiting nitrite shunt, the ratio will be lower than 0.6.

4 TRIAL RESULTS

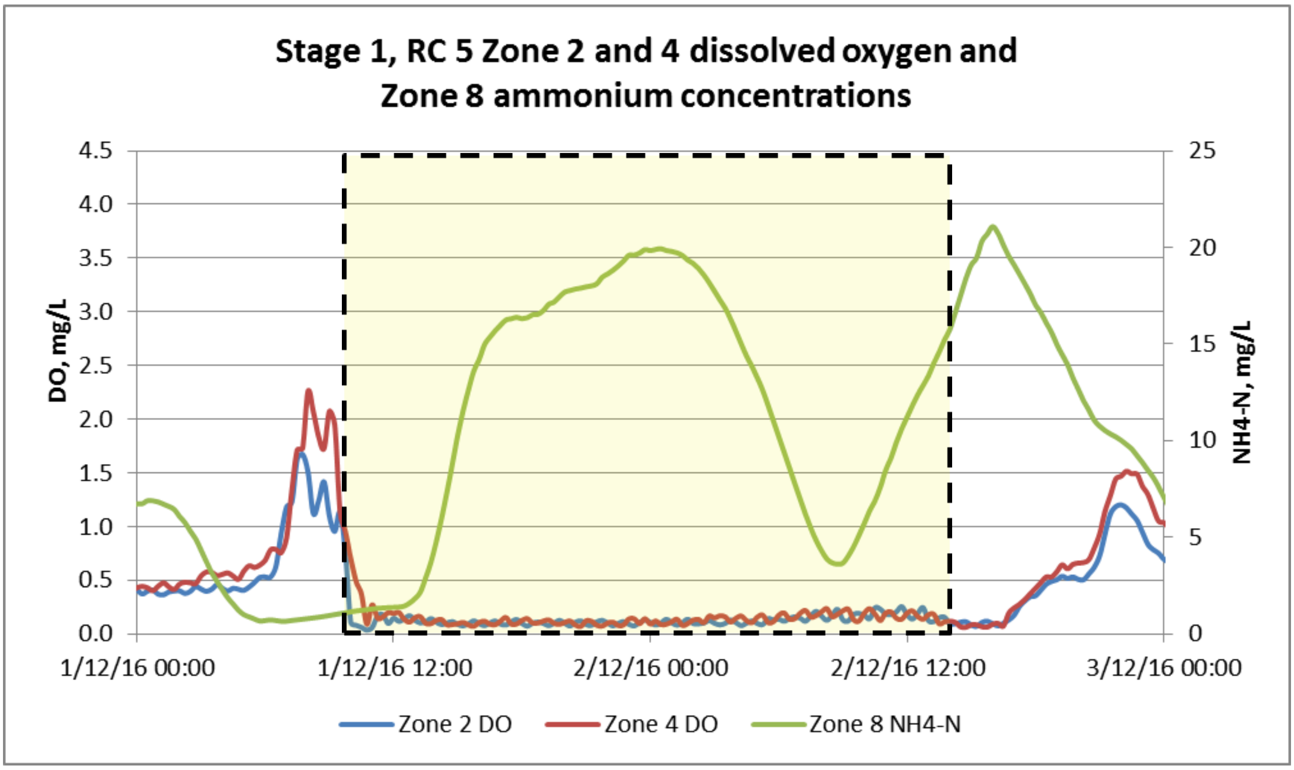
4.1 IMPACT OF AERATION CONTROL STRATEGIES ON REACTOR AERATION DYNAMIC

4.1.1 STAGE 1- AIR ALTERNATION TRIAL OUTCOME

Biowin model predicted an air flow requirement of 35,000 Nm^3/hr for RC 5 Zone 2 and 4. However in reality, these two zones on average received a total flow of only 4,000 Nm^3/hr. The trial did not achieve any of the targeted levels of DO, air flow and ammonia concentration, as the blowers could not ramp fast enough to achieve the target flow rate.

Figure 3 shows DO trends in RC 5 Zone 2 and 4 along with Zone 8 ammonium concentration. DO is below 0.5 mg/L for the duration of the trial and ammonium was constantly above 15 mg/L in Zone 8. Although the trial started on the 17/11/2016 as mentioned previously, the trend shown only starts from 1/12/2016. This is because changes were being gradually implemented along with an aeration pipe dropper rupture. RC 5 was only operating in full Stage 1 control strategy from 1/12/2016.

Figure 3: Stage 1 RC 5 Zone 2 and 4 DO and Zone 8 ammonium concentrations.

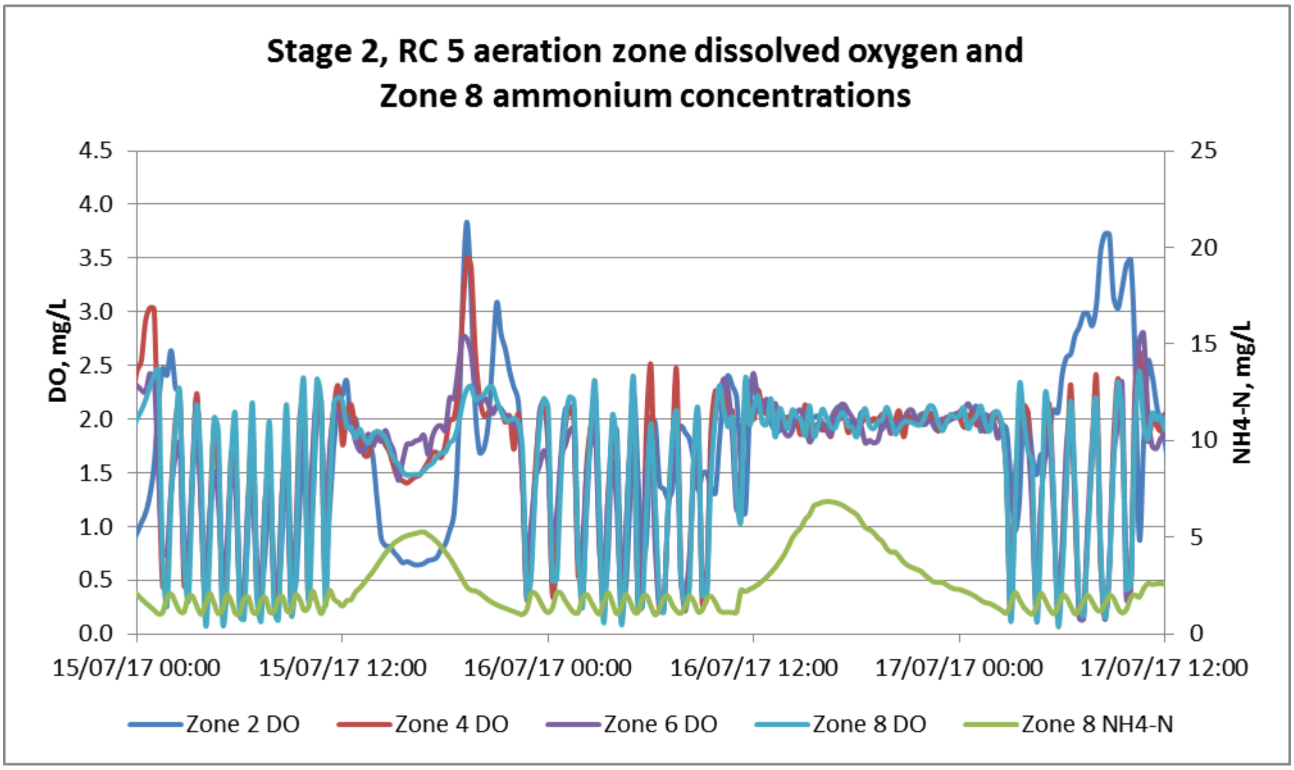


Beside poor process performance, asset failure was also experienced in the form of an aeration pipe dropper rupture. This was due to the aeration switching between on and off which created stress on the ageing asset. A decision was made to not resume the trial with this aeration control strategy but pursue the ammonium based feedback control in all aerated zones.

4.1.2 STAGE 2A AND 2B -AMMONIA BASED AERATION CONTROL OUTCOME

Stage 2a was implemented and after a period of observation Stage 2B was implemented with more aggressive set points in order to further enhance nitrite shunt conditions. Compared to Stage 1, RC 5 aeration zones were able to meet DO set points and there was no detrimental impact on the aeration piping. Ammonium peaked at approximately 7 mg/L but did reach up to 15 mg/L.

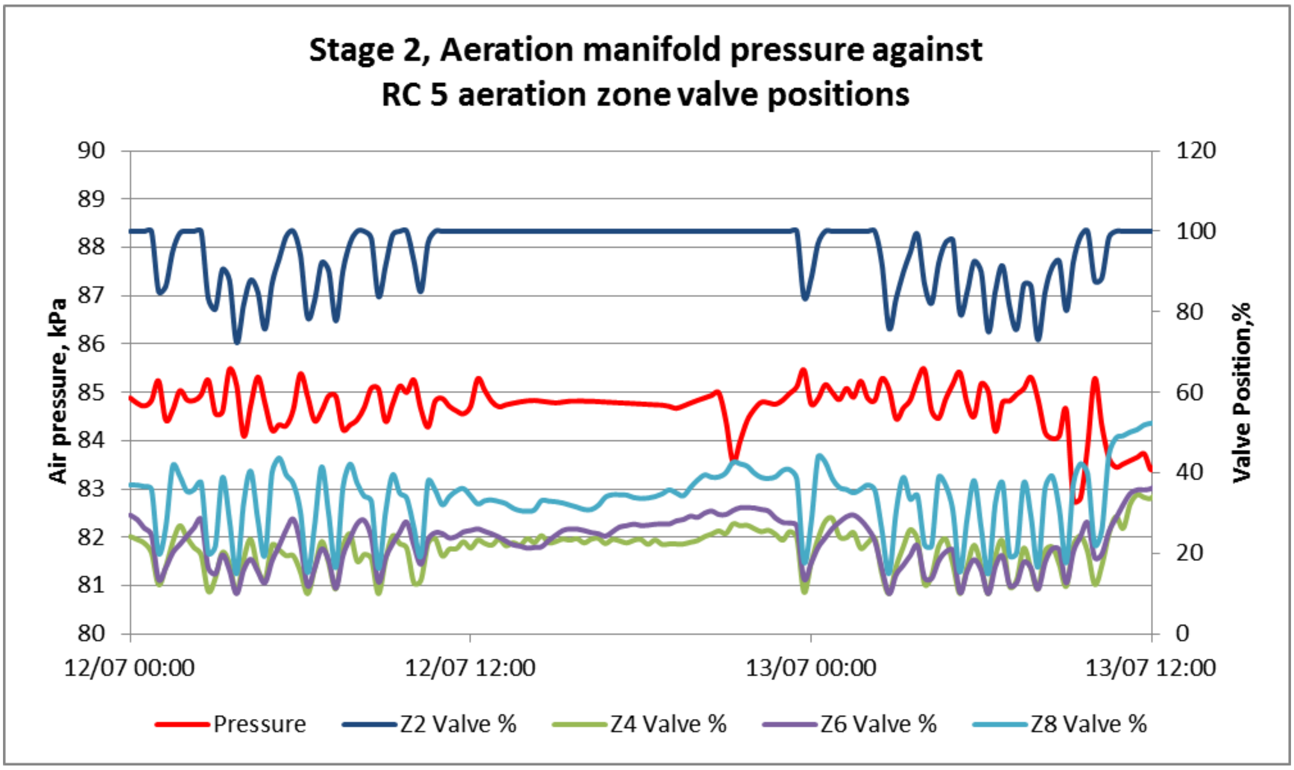
Figure 4: Stage 2 RC 5 aeration zone dissolved oxygen and Zone 8 ammonium concentrations.



It was, however, observed that the blowers' manifold pressure was affected by the aeration valves diurnal modulation of Zone 2 and 4. Manifold pressure and valve position are shown in

Figure 5 which showed similar trends between the parameters.

Figure 5: Stage 2 Aeration manifold pressure against RC 5 aeration zone valves positions.



4.1.3 STAGE 3 – OPTIMISATION OF STAGE 2 AMMONIA BASED AERATION CONTROL OUTCOME

Stage 3 was applied with the aim to further lower DO and inventory while still maintaining compliance. The other objective was to minimise the impact on the blowers' manifold pressure due to the valve modulation.

The rationale behind this Stage 3 strategy was to have lower DO set points (< 0.5 mg/L) in Zone 2 and Zone 4 and gradually increase the set points in Zone 6 and Zone 8. The higher DOs in the later zones were intended to encourage nitrification in order to ensure effluent ammonia compliance. As mentioned, Biowin modelling was used to simulate this in order to obtain the best predicted set points.

DO set points for Zone 2 and 4 were decreased in two step changes while Zone 6 and 8 were done in a single change.

Figure 6 and Figure 7 show DO set points were achieved and operating at a lower band as indicated by the shaded yellow box. Ammonium concentration peaks are under 10 mg/L but can on occasion reach up to 17 mg/L. Although there are short bursts of around 1.5 to 2 hours, the average composite ammonia concentration was approximately 0.8 mg/L during that period which is acceptable. Detailed discussion can be found in Section 5.

Figure 6: Stage 3 RC 5 Zone 2 and 4 dissolved oxygen and Zone 8 ammonium concentrations.

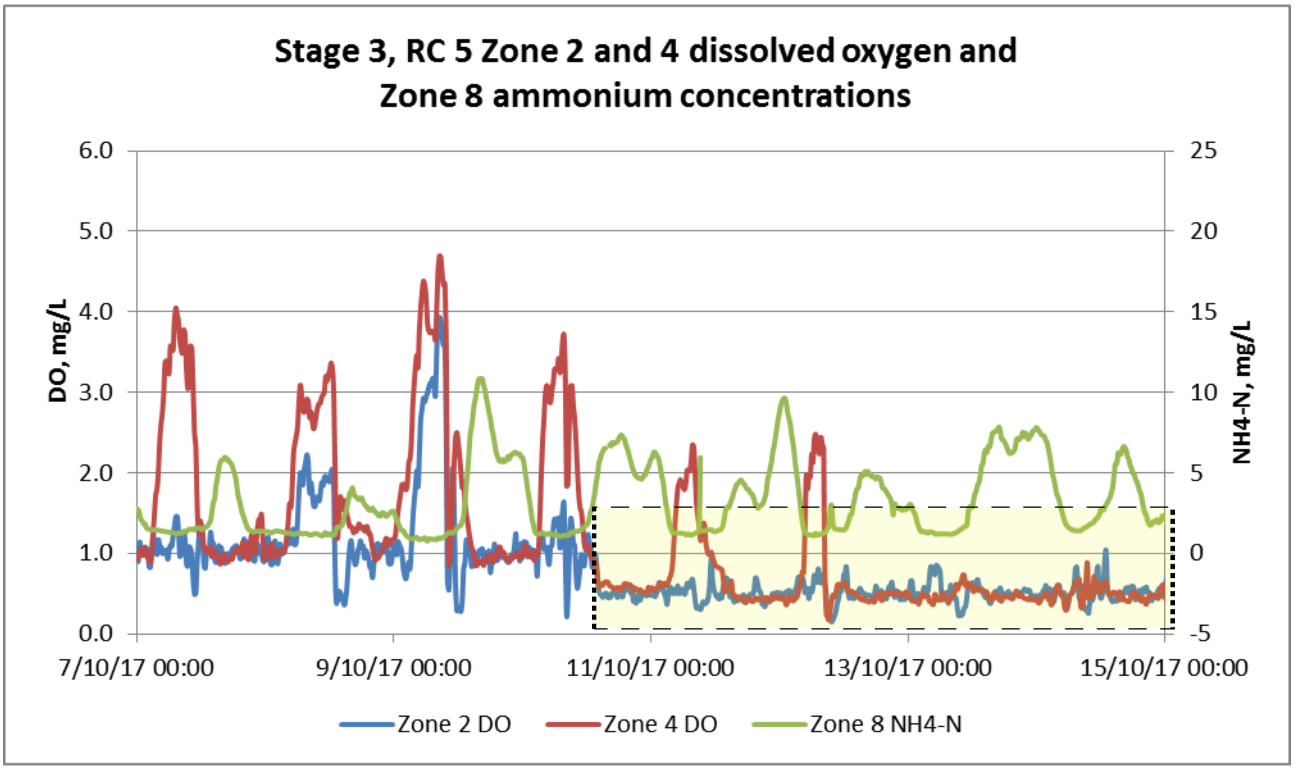
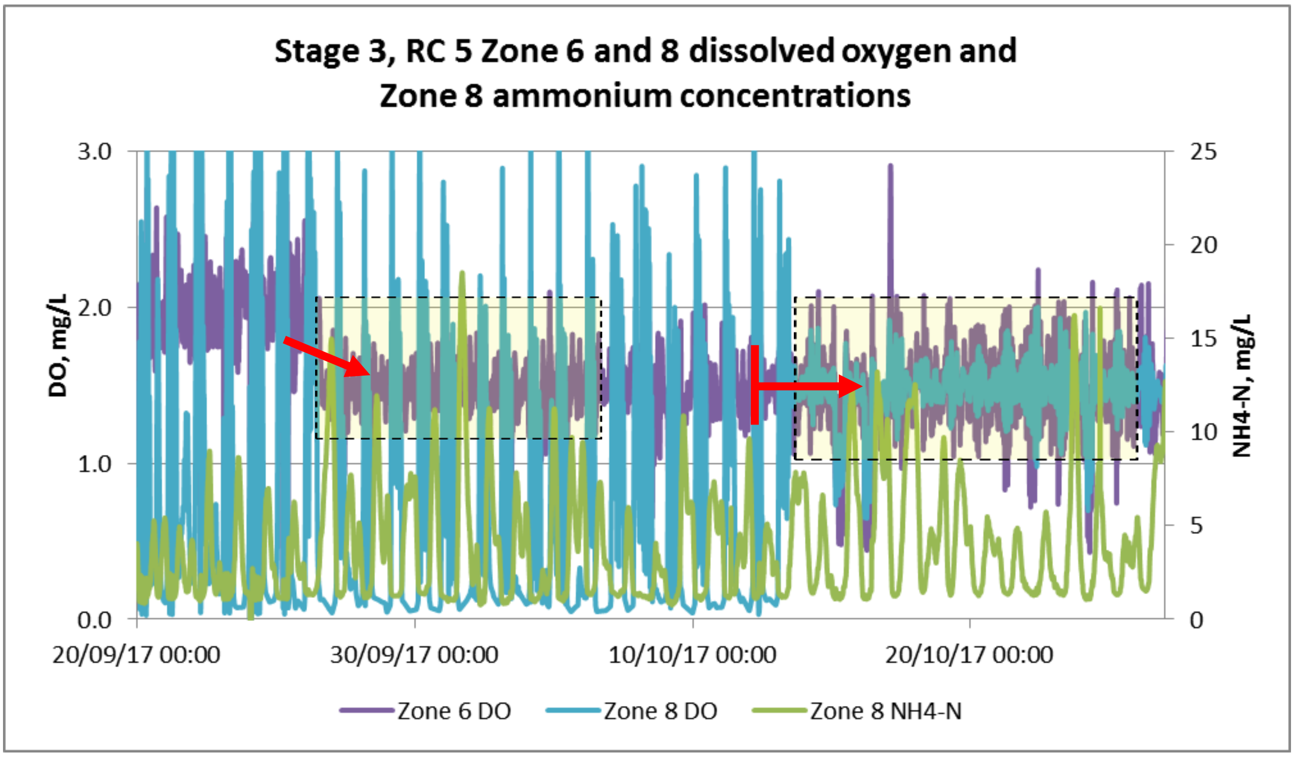
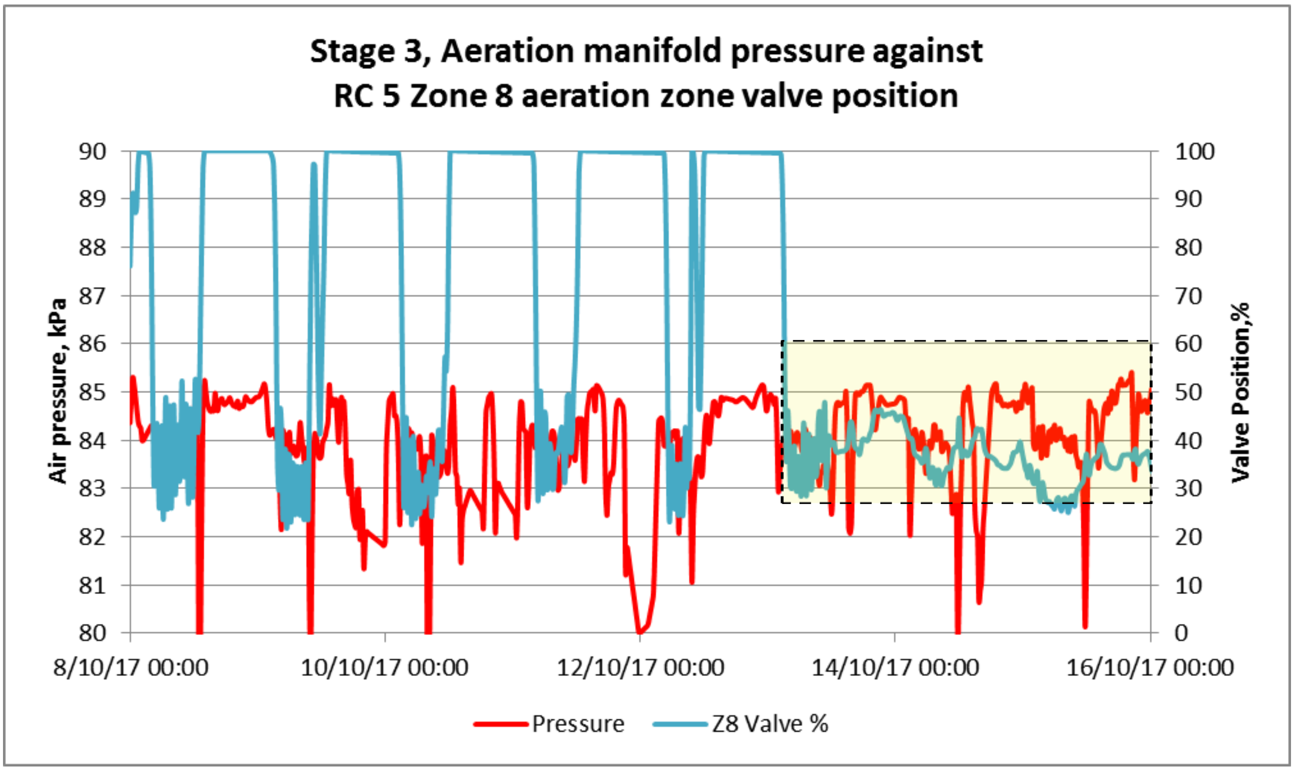


Figure 7: Stage 3 RC 5 Zone 6 and 8 dissolved oxygen and Zone 8 ammonium concentrations.



No distinct pattern could be observed in relation to impact of valve modulations on blowers' manifold pressure but a clear improvement could be seen in Zone 8 in terms of valve operation (Figure 8). Based on the DO trends it was concluded that the control regime had improved and valve modulation on RC 5 did not impact the blowers' manifold pressure.

Figure 8: Stage 3 RC 5 Zone 8 aeration valve position and blowers' manifold pressure.



Attempts to measure savings in aeration could not be made due to technical difficulties with a newly installed air flow meter. The air flow meter installed on RC 5 was intended for the typical flow range. Due to the low DO mode operation, the air flow was under the low flow limit of the meter.

4.1.4 STAGE 4 – IMPLEMENTATION TO THREE MORE REACTORS

With the implementation of Stage 4, four out of nine RCs were on the new control methodology. During this period, one of the other RCs was out of service, resulting in a total of 50% of the reactors under new low DO set point operations. The total plant aeration flow (January to May 2018) showed a reduction of 11% in air flow and 8% in blower power consumption when compared to the average aeration flow data for the same time the previous year.

RC 7, 8 and 9 all met DO set points and the RC effluent ammonia concentration was maintained under 1 mg/L. There was no negative impact on blowers' manifold pressure.

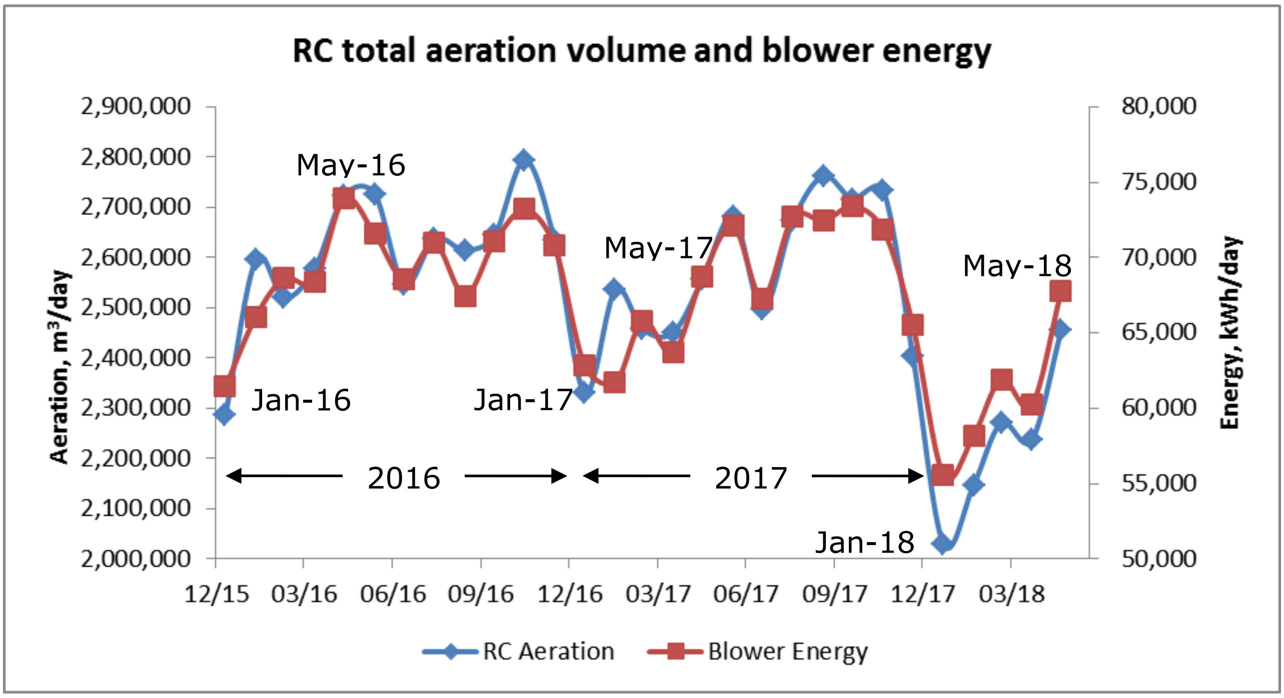
Summary of data is shown in

Table 5 and trends are shown in Figure 9.

Table 5: Average total aeration volume, blower energy consumption, biological oxygen demand removal and ammonia removal over three different periods.

Average	Jan 16 to May 16	Jan 17 to May 17	Jan 18 to May 18 (Stage 4 implemented)	Difference (2018/ Average(2016 and 2017)
RC total aeration, m3/day	2,540,644	2,466,122	2,227,695	89%
RC blower energy, kWh/day	67,685	63,672	60,728	92%
BOD removed, tons/day	87	80	80	-
Ammonia removed, tons/day	13	15	13	-

Figure 9: Total reactor air flow and blower energy consumption.



There was no discernible difference in sewage load characteristics year on year. Therefore, the aeration reduction observed is most likely due to the low DO control strategy implemented and reactors carrying a lower inventory in order to promote nitrite shunt.

5 OPERATIONAL PERFORMANCE

5.1 EFFLUENT NITROGEN CONCENTRATIONS

RC effluent nitrogen concentrations (ammonia, nitrite and nitrate) were monitored as 24 hour composite samples in order to determine the performance of the nitrite shunt. Nitrite is expected to accumulate for nitrite shunt reactors which results in higher effluent nitrite concentrations and lower nitrate levels compared to conventional reactors (Peter Dold, 2015). Total nitrogen concentrations were also compared on several occasions through grab samples. Nitrite, nitrate and ammonia composite results for RC 5, 7, 9 and 4 (Stage 3 and 4) are as shown in the figures below. RC 4 is the control reactor.

Figure 10: Reactor effluent nitrite concentrations for RC 5, 7, 9 and 4 (control RC).

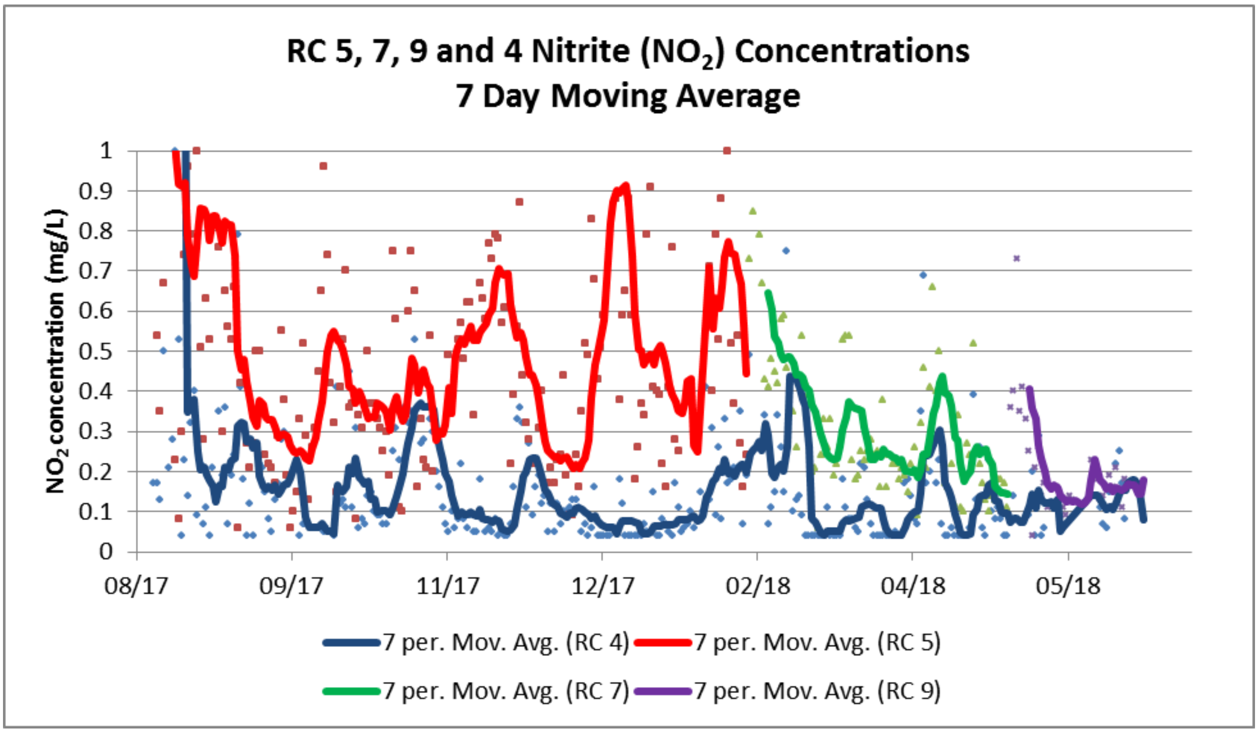


Figure 11: Reactor effluent nitrate concentrations for RC 5, 7, 9 and 4 (control RC).

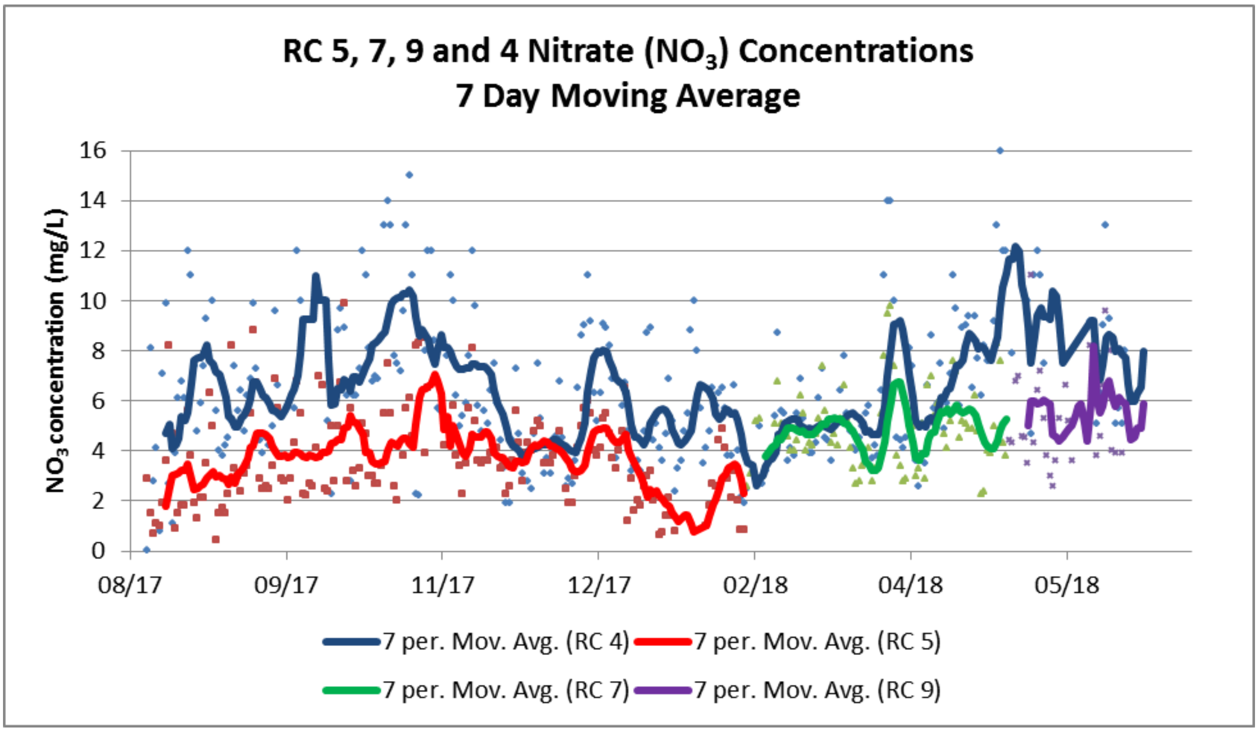
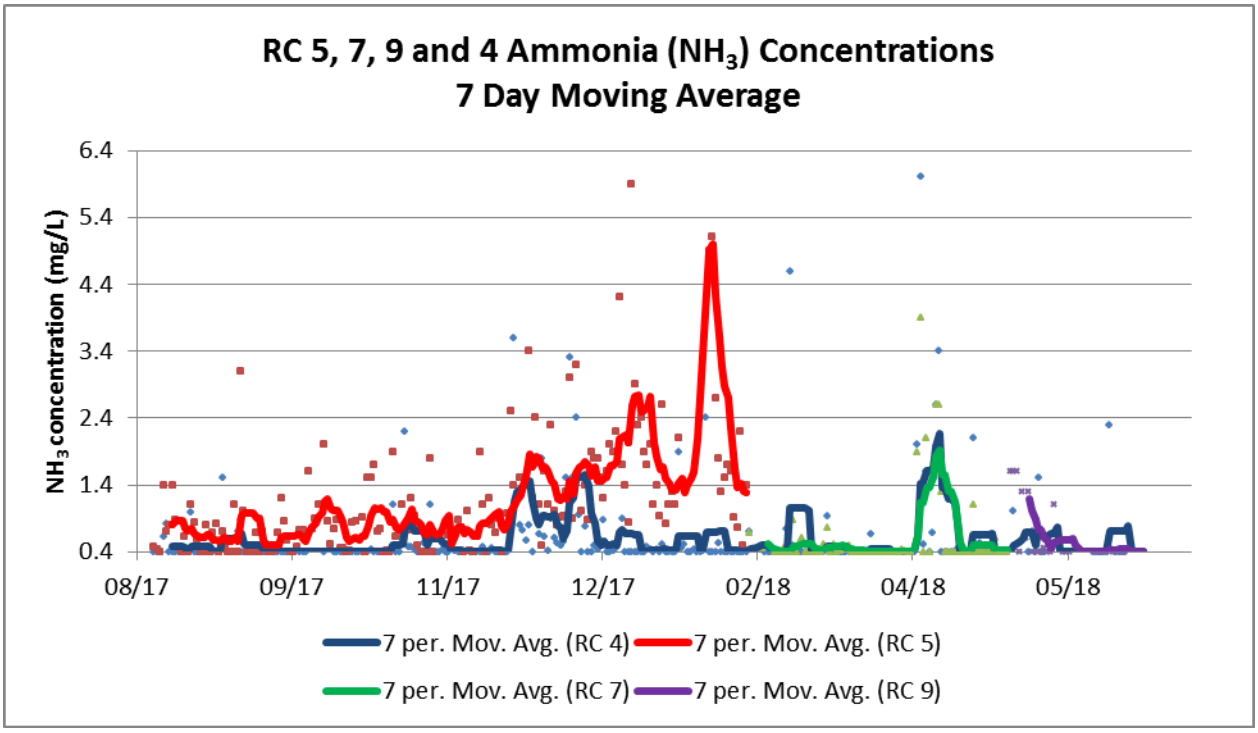


Figure 12: Reactor effluent ammonia concentrations for RC 5, 7, 9 and 4 (control RC).



It can be seen that nitirite levels were overall higher and nitrate concentrations were lower in RC 5, 7 and 9 compared to RC 4 (control reactor). Slightly elevated ammonia levels were observered in RC 5. This is another factor which can promote nitrite shunt. Maintenance of residual ammonia allows aerobic AOB growth rate to be close to the maximum (Pusker Regmi, 2015). However this was not observed in RC 7 and 9. The reason is still being investigated.

Nitrites were higher in RC 5 and 7 compared to the RC 4 while nitrates were lower in the nitrite shunt reactors. Ammonia concentrations were similar to RC 4. Results of RC 9 nitrite is similar to RC 4 and is being investigated at time of writing this paper. Initial analysis shows that due to the small sample set, there were some high values from RC 4 which is skewing the statistical results.

Grab samples were taken on two separate occasions consisting of 14 samples for each set to compare total nitrogen concentrations. Statistical results are shown in the table below. RC 7 was 0.5 mg/L lower in total nitrogen compared to RC 4 while RC 9 was 2.4 mg/L.

Table 6: RC 7, 9 and 4 (control RC) total nitrogen concentrations comparison.

TN, mg/L	**RC 4**	**RC 7**		**RC 4**	**RC 9**
median	6.5	6		11	8.6
95^{th} percentile	8.75	8.32		14.8	12.4
5^{th} percentile	5.33	4.65		6.08	4.68

5.2 SLUDGE INVENTORY AND WASTING

Sludge retention time (SRT) was lowered during Stage 1 to wash out NOBs. The overall SRT was progressively decreased to 6 days from a typical 9 to 10 day set point. In practice, although the total SRT was set to 6 days through mass wasting control, the actual SRT was between 7 and 8 due to the limitation of the waste activated sludge pump. This will impact on the ability to washout NOBs. In terms of operations monitoring, the target is to operate the RC between 1,800 to 2,200 mg/L. This range was selected based on Biowin modeling which indicated nutrient removal performance of the RC is more likely to be compromised if MLSS was under 1,800 mg/L during high loads.

Overall the solids inventory for RCs with nitrite shunt control strategy is approximately 59 tons compared to 74 tons for conventional RC during the period of January to June 2018. The amount of reactor wasting did not change for RC 7, 8 and 9 after lowering the SRT set point. RC 5 showed an increase in wasting (Table 7 and Table 8). RC 1 and 2 are not shown as they were offline for long periods within the data range.

Table 7: Daily activated sludge wasted (WAS) before and after Stage 4.

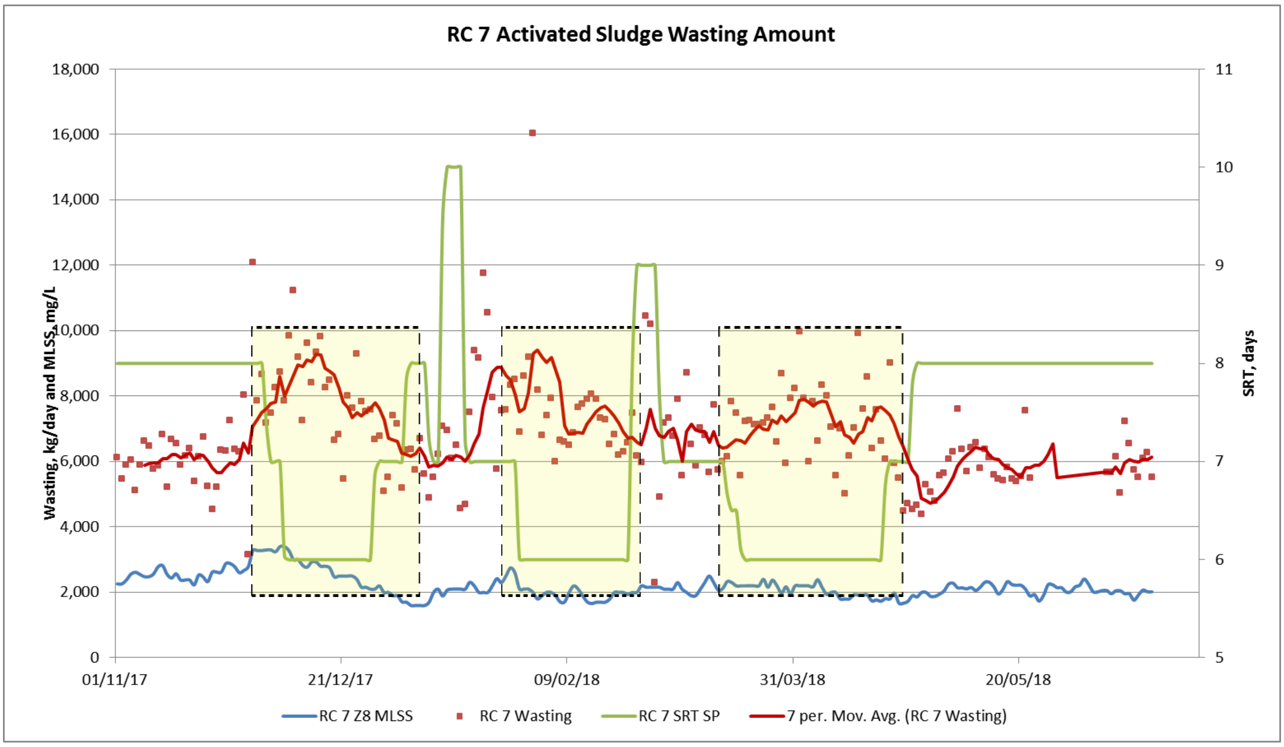
	Before Stage 4 1/3/2017 to 31/10/2017	**After Stage 4** 1/1/2018 to 18/6/2018	
	Waste activated sludge, kg/day	Waste activated sludge, kg/day	Difference
RC 3	7783	7822	101%
RC 4	7117	7534	106%
RC 6	7484	7569	101%
RC 5 (nitrite shunt)	7891	8718	110%
RC 7 (nitrite shunt)	7076	6815	96%
RC 8 (nitrite shunt)	7137	6882	96%
RC 9 (nitrite shunt)	6709	6790	101%

Table 8: Reactor solid inventories before and after Stage 4.

	Before Stage 4 1/3/2017 to 31/10/2017	**After Stage 4** 1/1/2018 to 18/6/2018	
	Solid Inventory, ton	Solid Inventory, ton	Difference
RC 3	82	71	86%
RC 4	72	73	102%
RC 6	68	69	101%
RC 5 (nitrite shunt)	58	64	110%
RC 7 (nitrite shunt)	71	57	80%
RC 8 (nitrite shunt)	70	58	84%
RC 9 (nitrite shunt)	68	58	86%

To further investigate the observed difference in wasting between RC 7, 8, 9 and 5, further analysis was done. The investigation showed wasting did increase during certain periods (2 to 4 weeks) when SRT was lowered to 6 days in order to maintain the desired MLSS operating range. The reason for the increase in wasting amount from RC 5 is because the SRT has been maintained at 6 days since Stage 1. Figure 13 shows the wasting trend of RC 7. Higher wasting was observed during low set point periods as highlighted. Sludge wasting is expected to increase in order to maintain MLSS operating target but this maybe for a defined period or prolong period like RC 5. For the RCs at Mangere WWTP, this can be up to 28% increase.

Figure 13: RC 7 activated sludge wasting amount.



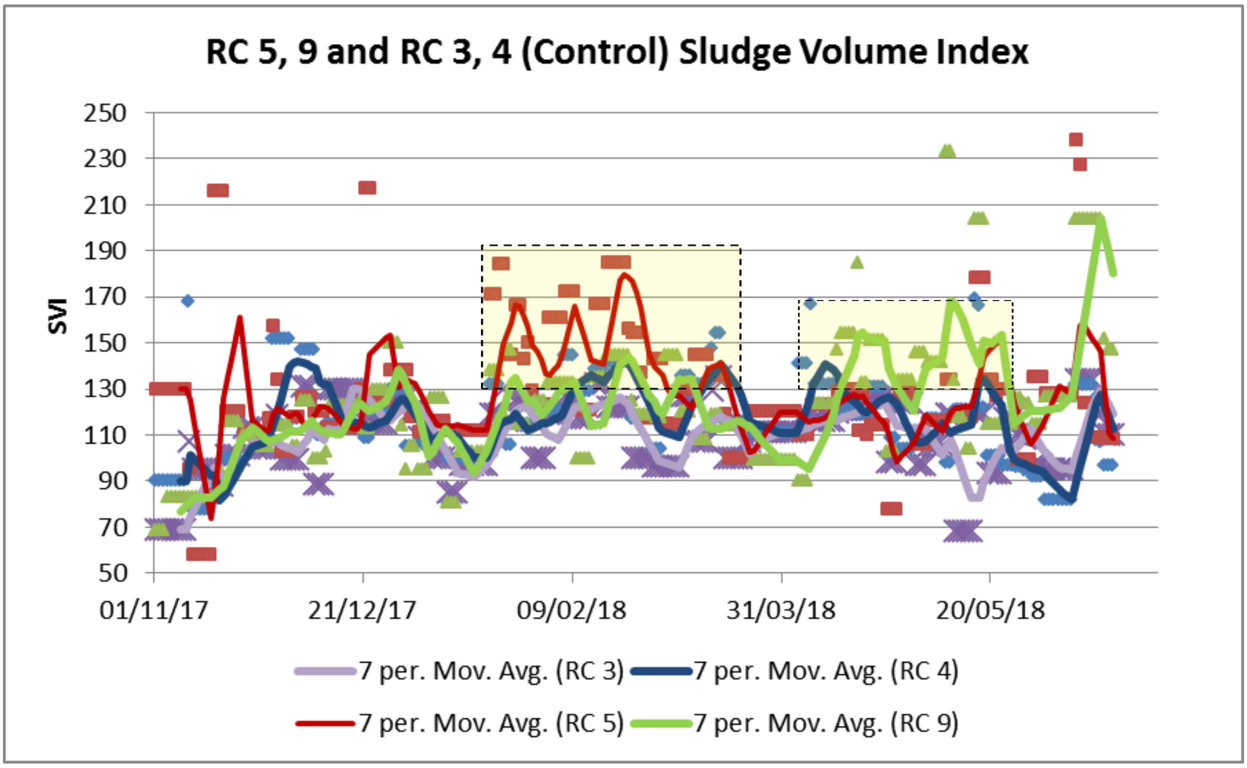
5.3 SLUDGE SETTLING

An operational concern was whether the low DO condition would impact on sludge settlability. Sludge volume index is used as a measure of sludge settleability. Based on the results shown in Table 9, RC 5, 7, 8 and 9 does show higher SVI compared to conventional reactors but the median difference is not significant. RC 2 is not shown as it was out of service.

Table 9: SVI results for RCs.

SVI, 1/11/2017 to 18/6/2018	RC 1	RC 3	RC 4	RC 6	RC 5	RC 7	RC 8	RC 9
Median	107	111	115	116	121	123	125	119
95th percentile	142	131	150	185	185	215	169	204
5th percentile	66	69	82	80	99	83	83	83

Figure 14: Sludge volume index for RC 3 and 4 (control) and RC 5 and 9 (nitrite shunt).



Biomass examination was carried out on multiple occasions for RC 3, 4, 5 and 9. The report concluded that filamentous bacteria presence was common across all four RCs but no more prevalent than non-shunt reactors. Of these filaments, two were primarily associated with long sludge age - low food to microorganism conditions (Type 0041/0675 and Type 1851) and a third type was Thiothrix, most commonly associated with septicity. Filaments specifically associated with low DO conditions were not observed in any of the biomass samples suggesting that DO are not significantly suppressed in the nitrite shunt RCs. The reason for this could possibly be due to the higher DO operational levels in Zone 6 and 8. Retention time in each zone is relatively short hence low DO levels in Zone 2 and 4 won't effectively have time to alter the biomass characteristic.

5.4 ANALYSIS OF NOB:AOB RATIO

A way to determine if nitrite shunt is occurring in a reactor is by quantifying the population of NOB and AOB. A conventional reactor should have a value of 0.6. Values significantly lower than that will indicate washing out of NOB which leads to occurrence of nitrite shunt within the reactor.

Table 10 shows the NOB:AOB ratio median during the test periods for the various RCs.

Table 10: NOB:AOB ratios of RC 5, 7, 8, 9, 3 (control) and 4 (control).

	RC 5	**RC 7**	**RC 8**	**RC 9**	**RC 3 Control**	**RC 4 Control**
NOB:AOB Median	0.30	0.75	0.80	0.56	0.67	0.66

The control reactors RC 3 and 4 have values similar to the theoretical level of 0.6, which indicates the reactors are in conventional mode. NOB:AOB ratios for RC 7 to 9 indicate that the reactors are still in conventional mode and not stable nitrite shunt. RC 5 has a ratio of 0.3 which is an indication of the nitrite shunt shifting the biology of the reactor.

Even though the ratios for RC 7 to 9 did not indicate the reactors are in full nitrite shunt biological conversion, RC effluent nitrogen concentrations showed results which are different from the control RC 4 (Section 5) and with nitrite accumulation. It is likely that the sludge age may be different compared to RC 5 which has a SRT of 6 days. An interesting observation to note is that with the continuous six days wasting for RC 5, MLSS was still maintained at the same range to RC 7, 8 and 9. Therefore SRT should also be considered as an operating parameter to maintain on top of MLSS. Further trials will be carried out to determine this relationship.

6 TRIAL CHALLENGES

6.1 TRIAL SETUP

One of the main challenges for this full scale implementation is the limited knowledge of what is expected from a full scale trial of nitrite shunt. Mangere WWTP, like most modern plants, is subject to tight discharge consents. One method used to minimise risk is simulating the process changes through modeling and using the identified parameters as a starting point.

Another challenge faced was instrumentation capability. The existing RC 5 flow meters (of an annubar type) on individual zones were installed when the reactor was commissioned and operating in a conventional mode. The minimum air flow on the flow meter range was higher than what it would be in nitrite shunt mode. With the implementation of lower aeration, the flow through each zone is below the minimum instrument range and therefore cannot be utilized for data analysis. In the future the installation of thermal dispersion type meters will more accurately measure the airflow for each RC off the main plant aeration header.

Establishment of the qPCR method to quantify NOB:AOB ratio was complex and new for Watercare. Method development and calibration required personnel to be trained in molecular biology which is not always available in treatment plants. Also proper sample preservation is key to ensure results accuracy. For instance sludge samples taken during a 3 month period in early 2018 were compromised due to temperature fluctuations of the storage freezer. AOB gene copies were almost undetectable in these samples. This issue was overcome by performing the extraction of DNA from sludge samples on the same day of sample collection.

6.2 FULL PLANT IMPACTS

The main benefit of nitrite shunt process lies with partial nitrification and COD savings associated with denitrification. Therefore, there is no net theoretical oxygen requirement savings with nitrite shunt as long as sufficient COD is present. COD that is not oxidised for denitrification will be oxidised using oxygen that must be supplied to the process (Pusker Regmi, 2015). The long term goal of this project is therefore maximizing carbon harvest from the primary sedimentation tanks at the Mangere and Rosedale WWTPs. Chemical dosing trials are currently being carried out at Mangere on two of the primary sedimentation tanks. The full benefit of this work will be realised when carbon harvest and nitrite shunt are optimised.

Short term benefits have been observed due to the immediate benefit of operating at much lower DO setpoints. Aeration requirement have been reduced by 22% and power by 16% if applied across the full treatment plant. Another benefit expected is that during the low carbon period in summer acetic acid is dosed to aid with denitrification. Reactor effluent total nitrogen for nitrite shunt RCs have shown lower figures compared to conventional RCs and is likely to not require supplementary carbon dosing.

A limitation to achieving lower SRTs and implementing nitrite shunt on all RCs at this stage is the sludge handling capacity. Analysis has shown that the capacity of the downstream thickening unit processes will need to be monitored and possibly augmented. Activated sludge wasting could be up to 28% higher by volume, which can be a challenge to the downstream solids handling processes and needs to be investigated.

Lastly, nitrite shunt creates a new set of guidelines for the operational staff to be aware of and act accordingly. In a conventional process, a low DO for a sustained period of time is critical and triggers the operation team to increase aeration on swing zones. With nitrite shunt, sustained periods of low DO is intentional and ammonia is the critical variable to monitor. It can be confusing as both methods of operation are being operated currently on the site.

7 CONCLUSIONS

After several variations of control strategies were trialed at the Mangere WWTP, ammonia based aeration control was identified as the best method to promote a nitrite shunt. There was no negative impact on RC performance or blower operation. The trial has shown total aeration volume is approximately 22%, corresponding to a real world power saving of 16% in blower energy consumption. Reactors with the new control strategy had nitrite concentrations ranges of 0.16 - 0.41 mg/L compared to 0.08 - 0.14 mg/L. Nitrate concentrations were also lower with measurements between 3.4 - 4.7 mg/L against 5.5 - 8.5 mg/L. Total nitrogen concentration was 0.5 - 2.4 mg/L lower than the control reactor. Ammonia concentrations were similar at approximately 0.4 mg/L.

No detrimental impact on sludge settlability could be observed except for higher peak SVI values which could be influenced by several other factors. Biomass examination indicated there were no signs of increased prevalence of low DO filamentous bacteria and the filamentous bacteria observed were similar for the two conventional and two nitrite shunt reactor samples. A key method to determine nitrite shunt occurrence is by measuring NOB:AOB ratios. A conventional reactor is expected to have a value of 0.6. Values lower than 0.6 indicate the nitrite shunt mechanism. RC 5 had a value of 0.3 while RC 7, 8 and 9 were over 0.6. A limitation to achieving lower SRTs and implementing nitrite shunt on all reactors could be the installed sludge handling capacity, with considerably higher sludge volumes needing processing.

To conclude, even though occurrence of nitrite shunt could not be categorically proven for three of the four reactors, all are behaving differently compared to the conventional reactors. Lower total nitrogen concentrations along with decreased aeration suggest these reactors are transitioning to nitrite shunt. Further trials and optimisation are required to roll out nitrite shunt nitrogen removal process to the remaining reactors and the NOB:AOB ratio will continue to be monitored.

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