ETHANOL DOSING OPTIMISATION IN BIOREACTOR

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ABSTRACT

Coombabah sewage treatment plant secondary treatment stage includes a 5 stage Bardenpho configured bioreactor with an ethanol dosing facility that provides an additional carbon source to denitrifying bacteria to further reduce nitrogen in the wastewater. Ethanol dosing optimisation was undertaken as part of the plant-wide optimisation initiatives and results from the trial showed that ethanol dosing was not required to reduce the nitrogen concentration in the mixed liquor in the bioreactor, and that manipulating the internal recirculation rates and aeration set-points was sufficient to reduce nitrogen to within the licence limits. Ceasing ethanol dosing into this bioreactor is estimated to result in considerable cost savings of $181,000 per year.

1.0 INTRODUCTION

Coombabah sewage treatment plant (STP) recently underwent major upgrades to the secondary (biological) and sludge treatment areas undertaken by the Coombabah and Stapylton Program Alliance (CASPA). Biological treatment included the reconfiguration of a previously exisitng aerobic digester to a stage 5 Bardenpho configured bioreactor. The newly reconfigured bioreactor G with a capacity of 14.3 ML/d has biological phosphorus removal capacity in addition to nitrogen, unlike the rest of the existing bioreactors which are carousel type oxidation ditches with nitrogen removal only. Bioreactor G contains anaerobic, anoxic and aerobic zones with diffused aeration with the various zones in a concentric pattern. Figure 1 shows the sequence of zones in which bioreactor G operates.

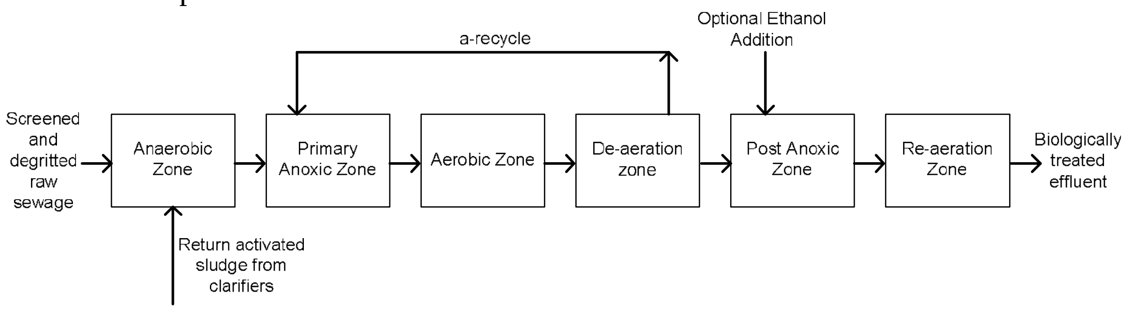

Figure 1: ***The zone sequence of the Bardenpho configured bioreactor G at Coombabah STP***

Figure 1 shows that the return activated sludge (RAS) from the clarifiers enters the bioreactor in the anaerobic zone along with the screened and degritted raw sewage. The a-recycle stream from the de-aeration zone to the primary anoxic zone aids in the further reduction of biologically reduced nitrogen.

The bioreactor G design included an ethanol dosing facility in order to provide an extra carbon source or chemical oxygen demand (COD) for denitrifying bacteria to convert nitrates to nitrogen gas. An additional carbon source was deemed necessary based on the limited nitrate removal capability of bioreactor G compared to that of the other oxidation ditch type bioreactors. These have high nitrogen removal capacity due to their uncommonly high recirculation rates.

The newly constructed ethanol dosing system adjacent to bioreactor G consists of two 10 kL underground ethanol storage tanks, available in a duty/standby configuration. Ethanol is drawn from the duty tank and is dosed into the post anoxic zone of bioreactor G via one of two dosing pumps available. Several dosing control modes are available to operators via the plant SCADA system, which are feed-forward, feed-back, flow paced, fixed flow rate and fixed speed. The current preferred control mode is flow paced dosing. The installation also consists of a circulation pump and associated pipe work that circulates ethanol to prevent vapour locking, as ethanol is highly volatile and flammable.

The Coombabah development approval (DA) specifies a TN limit of 5 mg/L as a long term 50%ile at the end of the plant effluent lagoon. This means more than 50% of the samples must be under 5 mg/L over 52 weeks. There is also a maximum limit of 10 mg/L. Results above these limits are considered a breach of the DA and would require regulator notification.

Ethanol dosing optimisation was undertaken as part of the plant optimisation process following the completion of the 2013 Coombabah plant upgrades. A major motivating factor for optimising ethanol dosing to bioreactor G was the considerable cost saving of approximately $181,000 per year, if bioreactor G nutrient removal capacity permitted. If the ethanol storage and dosing system was decommissioned, it would also eliminate the requirement of maintaining a hazardous area and associated time consuming and costly maintenance and testing requirements.

2.0 DISCUSSION

Bioreactor G went online in March 2013 and ethanol addition commenced in July 2013, dosed at an average rate of 575 L/d. After approximately 5 months of operation, ceasing ethanol dosing was trialled from 6 December 2013. Several wastewater quality parameters were monitored during the trial to determine the effect of ceasing ethanol dosing.

2.1 Total Nitrogen Concentrations in Effluent Streams

The TN concentrations in several effluent streams were monitored on a weekly basis to determine the imapct of ethanol dosing on nitrogen concentrations. Figure 2 shows the weekly TN trend in plant influent, final effluent (licence sample), bioreactor G and other bioreactors' combined effluent streams for the past two years.

The TN concentration (in mg/L) in the final effluent (licence sample) has comfortably remained under the maximum licence limit of 10 mg/L and the long term median (50%ile) licence limit in the past two years. The graph indicates that there were three TN values in the final plant effluent which exceeded the 5 mg/L limit on the 14/8/12, 8/1/13 and 19/2/13, however, these are not valid exceedences because the long term rolling averge for 52 weeks has not breached the 5 mg/L limit. These higher than usual values were due to disruptions to normal plant operations during the major upgrade works (14/8/12), refurbishment works of air lines (8/1/13) and due to a severe storm event which resulted in using the storm water bypass at Coombabah STP (19/2/13). In this case, the bypassed water is not treated biologically and only undergoes primary treatment with a final disinfection step via chlorination. Therefore, high nutrient content (although dilute) is likely to bypass to the final plant effluent. The TN concentrations for all effluent streams remained well under the long term median and maximum limits post ethanol dosing termination.

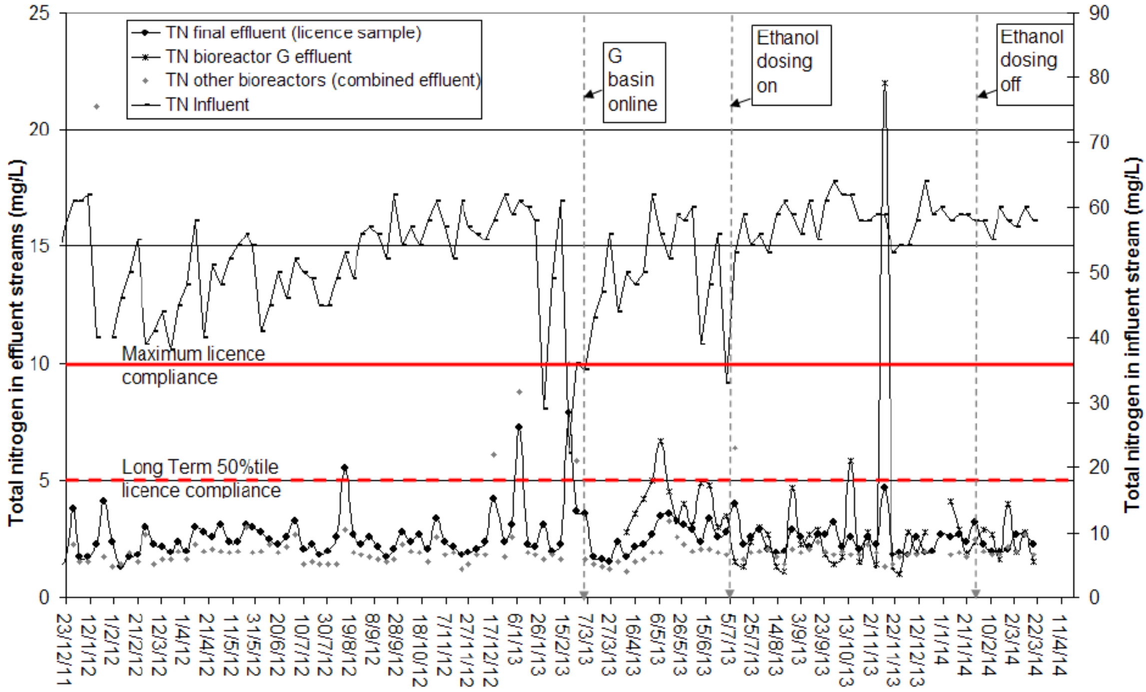

Figure 2: ***The total nitrogen concentrations in plant influent, final effluent, bioreactor G and other bioreactor combined effluent streams.***

2.2 Plant Inflow Rates

Coombabah STP receives varying flow rates of wastewater at the plant inlet with varying nutrient concentrations. The effect of varying nutrient loading rates on the capacity of bioreactor G to reduce nitrogen concentrations must also be considered before ethanol dosing can be turned off. The ethanol dosing during this trial was switched off during the summer period, therefore the seasonal nutrient load variability in the incoming sewage and its effect on the quality of the plant treated effluent was also investigated.

Figure 3 shows the plant inflow rates, TN concentrations in the influent and the ratio of TN to plant inflow rates over the past two years. The plant inflow rate typically varies between 60 to 100 ML/d depending on the water usage in the area and the rainfall patterns during wet and dry periods. TN concentration in the plant inflow varies between 40 and 60 mg/L which falls in the range of TN in typical untreated domestic wastewaters (Metcalf and Eddy, 2003).

During large plant inflow periods, the incoming nutrient load is diluted, therefore the nitrogen concentrations are lower than expected, for example on 29/01/2013, 19/02/2013 and 02/07/2013 (TN of 29, 22 and 33 mg/L, respectively), where the plant inflow rates was over 140 ML/d (due to wet weather conditions). The trend for the ratio of TN to the plant inflow rate shows that the ratio varies between 0.4 and 1 typically except during wet weather conditions when the ratio drops down to approximately 0.2.

It can be concluded that according to this long term data, the TN content in the influent will not change by significant amounts in the next few financial years since the average wastewater generated and received at Coombabah STP does not show a considerable seasonal change and it is not likely to impact from a large population change. High plant inflows due to wet weather events is the major contributor to varied TN concentrations being received at Coombabah STP.

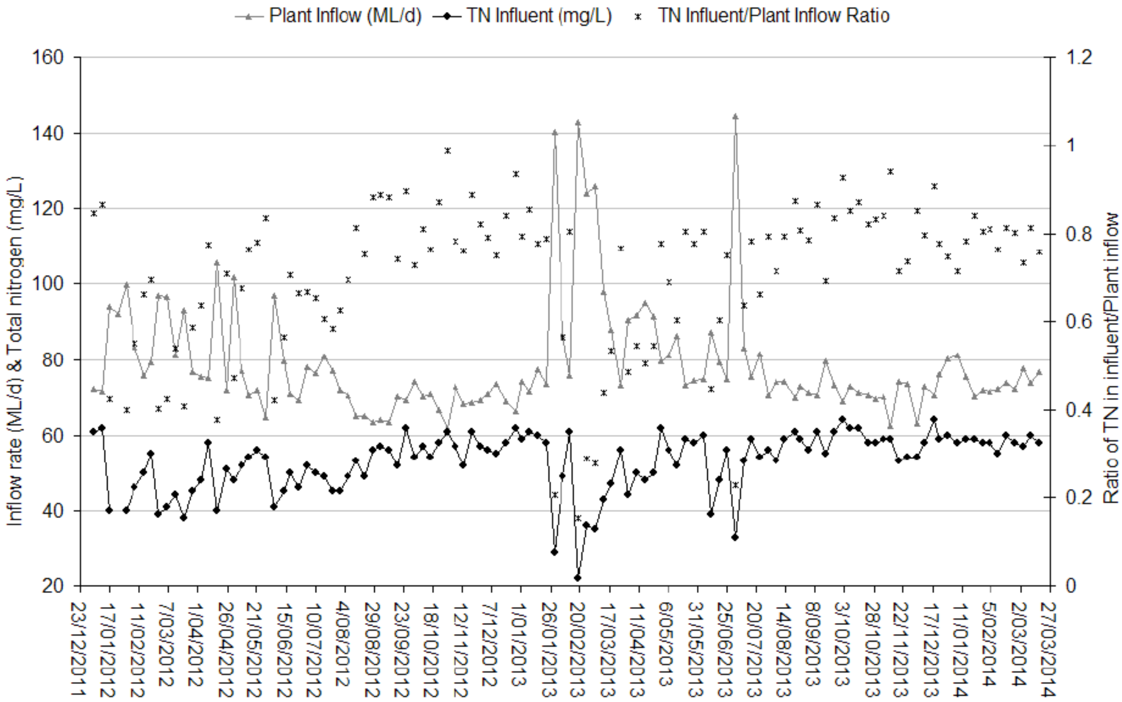

Figure 3: ***The seasonal variation in plant inflow rates and the total nitrogen concentrations.***

The variations in the influent TN concentrations is generally not reflected in the TN concentrations in the bioreactor effluent and final plant effluent streams shown in Figure 2. This indicates that the biological treatment stage at Coombabah STP is able to accommodate variations in the influent nutrient concentrations. The plant nutrient loading in the influent is continually monitored to determine the effect of nutrient loading variations on the biological nutrient removal capacity at Coombabah STP in the long term.

2.3 Sludge Dewatering Filtrate Return Stream

The sludge treatment at Coombabah STP includes sludge dewatering via belt presses. The dewatered biosolids is trucked away while the dewatering filtrate stream is returned to the plant inlet. The recent major upgrade works at Coombabah STP included the installation of mesophilic anaerobic digesters to treat thickened waste activated sludge (TWAS), previously, TWAS was treated via aerobic digestion. The quality of the sludge dewatering filtrate returning to the plant inlet is another factor that can impact the influent TN since the anaerobic digestion process releases signficiantly higher quantities of nitrogen and phosphorus into the sludge compared to aerobic digestion.

Figure 4 shows the TN and total phosphorus (TP) concentration in the sludge dewatering filtrate return stream before and after the installation of anaerobic digestion. According to this data, there is a 13 fold increase in TN in the return stream with anaerobic digestion compared to aerobic digestion.

Comaprisons of the TN concentrations in the plant influent before and after the installation of the anaerobic digestion process does not indicate that the sludge dewatering filtrate stream returning to the plant inlet has affected the inlet TN concentrations, nor the plant's biological capacity to reduce nitrogen to the required limits.

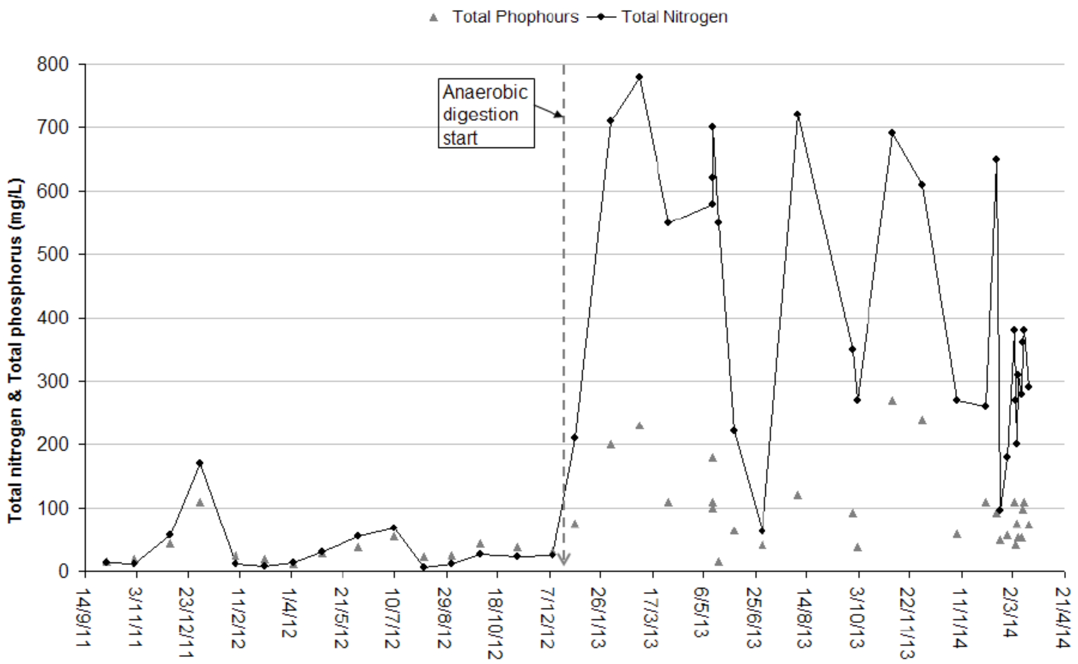

Figure 4: ***Total nitrogen and total phosphorus in the sludge dewatering return stream at Coombabah STP.***

2.4 Internal Recirculation Rates and Aeration Set-points

During the trial where ethanol dosing was ceased, several other initiatives were also taken to optimise the nitrogen reduction process in bioreactor G. A major factor that affects the nitrogen removal is the internal recirculation rate in the bioreactor which recycles mixed liquor from the deaeration zone to the primary anoxic zone in order to utilise the COD in the primary anoxic zone to further aid the denitrifying process that commenced in the deaeration zone.

Other initiatives that aid in the denitrifying process was ensuring that aeration setpoints were optimum such that ammonia in the wastewater was converted to nitrates, however the aeration setpoint was not overly high that dissolved oxygen breakthrough events to the anoxic zones in the bioreactor G occured.

The graph in figure 5 shows the trend in the ammonia and nitrate concentrations in the bioreactor G effluent. The graph shows that during the ethanol dosing period the nitrate concentrations remained low after the initial ethanol dosing period from July to August. A few high nitrate concentrations were seen in September which are similar to the concentrations prior to ethanol dosing. These high nitrate concentrations values can be attributed to the very low ethanol flow rates.

An immediate increase in the nitrate concentrations could be seen when the ethanol dosing was ceased in December 2013. However, the nitrate concentration decreased in the next few months following the initial increase. During early March 2014, the recirculation rate of watewater from the deaeration zone to the primary anoxic zone was increased by approximately a third of the previous recirculation flow rate. As a result, the nitrate concentrations decreased further.

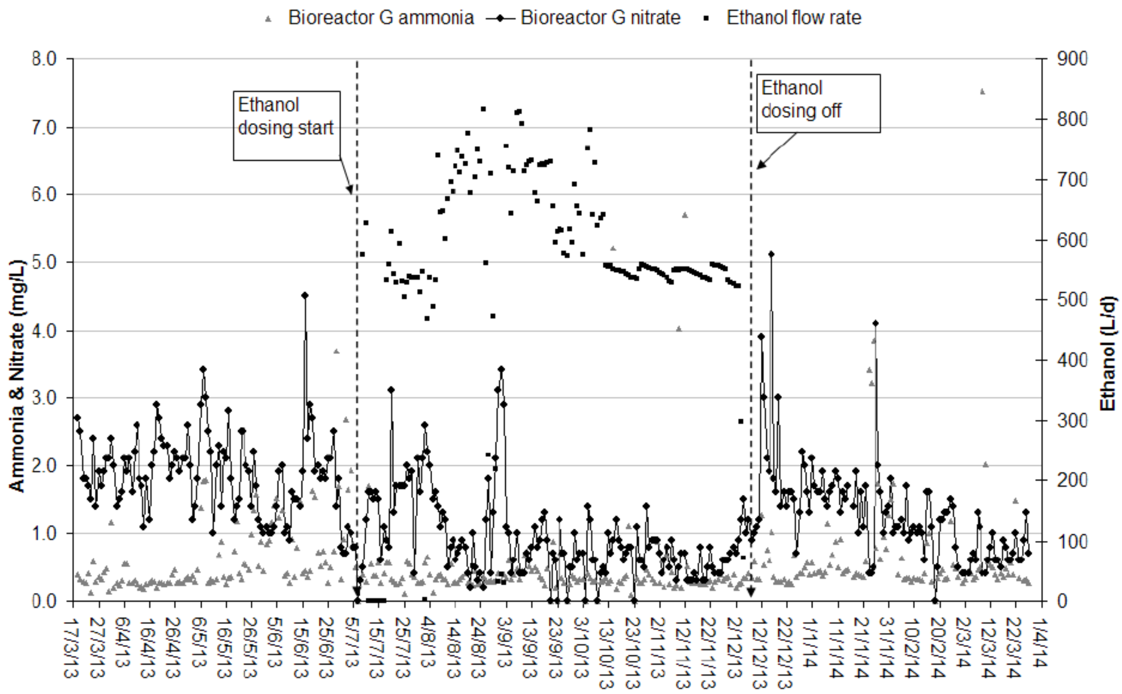

Figure 5: ***Concentration of ammonia and nitrate in bioreactor G effluent, and daily ethanol flow rate during the ethanol dosing period.***

3.0 CONCLUSION

Ethanol dosing optimisation in bioreactor G at Coombabah STP was undertaken in order to reduce the chemical usage on site and optimise the biological nutrient removal process via other means such as optimising the internal recirculation rate and aeration setpoints. A trial was undertaken where ethanol dosing was completely ceased and the bioreactor G and plant effluent streams were closely monitored to determine the effect of ceasing ethanol dosing. Results from the trial showed that bioreactor G can perform within the plant's licence criteria without the addition of ethanol as an extra carbon source for the denitrifying bacteria in the deaeration zone of the bioreactor. Ceasing ethanol dosing did not have an appreciable effect on the the final plant effluent for the duration of the trial. Varying concentrations in the plant influent and the varying nurtient loads to the plant also did not affect the ability of bioreactor G to reduce nitrogen concentrations in the wastewater to acceptable levels. It was concluded that ethanol dosing was not required to reduce the nitrogen concentration in the mixed liquor and that manipulating the internal recirculation rates and aeration set-points was sufficient to reduce nutrients to within the licence limits. Ceasing ethanol dosing into the bioreactor is estimated to result in considerable cost savings of $181,000 per year to the operation and management of Coombabah STP.

4.0 ACKNOWLEDGEMENTS

I would like to take this opportunity to thank Ian Coyne, Todd Chapman, Mark Richardson, Wayne Bleakley and Clinton Schneider.

5.0 REFERENCES

Metcalf & Eddy 2003, *Wastewater engineering treatment and reuse*, 4th Edn, McGraw Hill, New York