OPTIMISATION OF THE MORPETH WWTW BNR PLANT

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2nd Annual WIOA NSW Water Industry Engineers & Operators Conference
Jockey Club - Newcastle
8 to 10 April, 2008

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ABSTRACT

Morpeth Wastewater Treatment Works (WWTW) was constructed under a Design & Construct contract in 2000. Since the plant was constructed up to 12 months ago, the Biological Nutrient Removal (BNR) process has failed to meet the performance requirements incorporated into the D&C contract. Slowly the plant has been optimised to a point where it is now achieving the performance requirements within the D&C specification. However there are still some issues with the reliability of the process to consistently meet the effluent quality objectives.

There have been a range of complex issues that needed to be addressed to optimise the process. Some of these issues related to very simple problems with mechanical or electrical equipment and simple changes were implemented to allow more stable plant operation. There were also a number of complex changes to operation of the plant in which detailed biological modelling was used as a tool to assess the impacts of different changes. Overall a significant improvement in effluent quality from the plant has been observed however there are still some issues that highlight the operational complexity of a BNR process.

The focus of this paper is on the discussion of some of the simple modifications that have been made at the plant that have improved operational flexibility and process reliability.

KEYWORDS
Process optimisation, biological nutrient removal.

1.0 THE MORPETH WWTW

The existing Morpeth WWTW was constructed under a Design and Construct (D&C) contract by the Transfield/Montgomery Watson Joint Venture. Stage 1 (existing), commissioned in the year 2000, has a nominal treatment capacity of 60,000 EP, equivalent to an Average Dry Weather Flow (ADWF) of 14.4 ML/day based on the original design criteria of 240 L/EP/day.

The existing plant consists of an inlet works, one biological nutrient removal activated sludge reactor, two 34 m internal diameter clarifiers, a UV disinfection system, effluent pump station and 2.35 km long MSCL 960 mm discharge pipeline to the Hunter River, and sludge handling facilities including an aerobic digester and lime clarifier. Waste sludge from the activated sludge process is thickened using two parallel gravity drainage decks prior to stabilisation using an aerobic digestion process. After digestion the waste sludge is dewatered using two parallel belt filter press units. Dewatered biosolids are then transported and reused off site by a third party contractor.

The activated sludge process at the Morpeth WWTW has been designed to achieve both biological nitrogen and phosphorus removal. The reactor has been designed with sufficient flexibility to be operated in several different configurations which include the Modified University of Cape Town (MUCT) configuration, a variation on MUCT and the Modified Johannesburg configuration.

Acceptable performance targets for the plant were based on the original EIS and were incorporated into the contract documentation for construction of the existing Morpeth WWTW. Since commissioning the plant has struggled to meet the performance criteria set out in the contract for total nitrogen, total phosphorus and faecal coliforms.

2.0 OPTIMISATION OF THE MORPETH WWTW

Hunter Water has progressively optimised the Morpeth WWTW over the past four years. Initial attempts to optimise the BNR process were unsuccessful as often limitations with mechanical equipment prevented reliable operation of plant in an 'optimised' configuration. It was clear that there were a number of deficiencies with the existing plant that needed to be corrected before further attempts to optimise the biological process would be successful.

The optimisation of the Morpeth WWTW involved sequentially rectifying a range of mechanical problems and assessing the corresponding improvements in process performance. After rectification of the mechanical deficiencies at the plant, further optimisation of the process was undertaken. This first phase of the process optimisation was undertaken as part of a Pollution Reduction Program under the Environment Protection Licence.

2.1 Rectification of Mechanical Equipment

There were a number of issues with mechanical equipment that resulted in low reliability of critical equipment. The RAS pumps and R-recycle pumps installed as part of the contract were dry mounted submersible pumps which were cooled using the pumped liquid (i.e. thickening activated sludge). Accumulation of contamination within the mixed liquor, primarily hair, caused problems with the cooling systems on the pumps and the pumps to fail on a regular basis. The deficiencies were corrected by connecting the cooling systems to the service water system allowing the pumps to operate more reliably. The improved reliability also allowed better control of RAS and R-recycle flows which was critical to optimising the biological process. The cost of this modification was very low, in the order of $600.

There were also several deficiencies within the existing plant that were identified by operations staff. Phosphorus release through the secondary clarifiers was evident however the cause was not fully understood. It was clear that the secondary release through the two clarifiers was occurring to different levels. On site measurements indicated that the sludge blanket depth was also different between the two clarifiers and the phosphorus release was directly related to the observed sludge blanket depth. The scrapers were modified by changing the height and shape of the scrapers which resulted in a significant reduction in the amount of secondary phosphorus release. The total cost of this modification was relatively low in the order of $5,000.

Attempts to trial different aeration profiles in the biological reactor were hampered by poor aeration control. Investigations revealed that there were errors in the logic which controlled the aeration systems. A new control philosophy was developed and implemented and provided more flexibility for operations staff to refine the control settings and the new aeration profiles could now be trialled. Minor changes were also made to the aeration grid in one of the aerobic zones where over aeration was causing a problem with oxygen carry over in the recycle stream.

Internal resources were used to develop and modify the aeration control philosophy and the cost to implement this change was in the order of $5,000. There was a considerable amount of operator input required to refine the settings and stabilise the DO settings.

Improvements were made to the dewatering equipment to allow the belt press equipment to operate outside of hours during which the plant is manned. As part of a biosolids dewatering improvement program, changes were made to allow the dewatering equipment to operate over a longer period. This allowed better control of the aerobic digestion process to minimise intermittent variation in nutrient loads returned to the main plant. This change cost in the order of $2,000 and has also resulted in an improvement in the dewatered cake solids from the plant.

The issues with mechanical equipment were preventing the plant from being optimised to its full potential. It is clear that the cost to rectify the major mechanical issues that were resulting in process constraints were only very minor (in the order of $10,000). By sequentially identifying and rectifying these mechanical constraints the BNR process could now be optimised to its full potential.

2.2 Optimisation of the Biological Process

A number of key changes were made to the process to improve performance of the plant. The process configuration was converted from the Modified University of Cape Town (MUCT) process configuration to the Modified Johannesburg process configuration. A range of other trials were also conducted to optimise the plant performance such as variations in recycle ratios and optimisation of the digestion process. It was clear that there was a delicate balance between nitrogen and phosphorus removal at the Morpeth BNR plant. A biological model was developed and calibrated using Biowin, a commercially available software package. This biological model was used to predict the impact of changes to the operation of the plant. The model was relatively accurate in predicting the minor changes to effluent quality.

As part of a pollution reduction agreement with the EPA, HWA changed the configuration of the BNR process at the Morpeth WWTW. The configuration was changed from the MUCT process to the Modified Johannesburg process configuration. Due to unreliable operation of the R-recycle pumps the process configuration was changed in an attempt to stabilise the process. At this point issues were identified with the aeration control so changes were made to the control algorithms for the aeration systems. The process appears to be more stable in the Modified Johannesburg process configuration. Future attempts to return to the MUCT process configuration have also been unsuccessful.

Changes were made to the aeration control systems and a number of trials were conducted to determine the impact of different dissolved oxygen profiles on the process performance. It was clear from these trials that a descending DO profile did not result in better performance of the Enhanced Biological Phosphorous Removal (EBPR) process. It was also clear that at dissolved oxygen concentrations less than 2 mg/L the EBPR process was less reliable. Dissolved oxygen concentrations above 2 mg/L (ranging from 2.5 to 3 mg/L) with an increasing DO profile was ultimately selected based on these trials. It was clear that the ascending DO profile was superior for biological phosphorus removal than the other DO profiles trialled. However the ascending DO profile resulted in a reduction in the nitrogen removal performance at the plant.

It was clear that this is primarily due to oxygen returned to the anoxic zones in the A-recycle. A DO profile was selected that balanced both the nitrogen removal and the phosphorus removal.

The last cell in the aerobic zone was converted to a low DO zone (i.e. low dissolved oxygen setpoint) to minimise the return of dissolved oxygen in the A-recycle stream. Diffusers were also removed from the aeration systems in the last cell to further minimise the potential for dissolved oxygen leakage in the A-recycle stream. Ultimately the aeration system in the last cell was restricted by manually closing the actuated valve to the desired level.

At all times there was significant phosphorus release in the order of 3.5 to 1 at the end of the anaerobic zone and it was clear that the EBPR process was operating effectively. However during and immediately after periods high flow due to wet weather, the phosphorus release was significantly reduced as low as 1.5 to 1 and the performance of EBPR process was significantly reduced. It would then take up to 14 or 15 days (i.e. one sludge age) for the process to recover and consistently meet the required effluent quality. There were a number of other smaller changes to the plant to try to improve this stability however again either nitrogen removal or phosphorus removal was affected.

Consultation with the original plant designer (Peter Griffiths), lead to another trial where the final aerobic cell was converted to a de-aeration zone. This provided lower DO leakage in the A-recycle and improved nitrogen removal performance. The phosphorus removal performance of the process was also improved. The theory provided was that the secondary release will only occur in low DO environments and by converting the last cell to a de-aeration zone restricted the secondary phosphorus release. The plant is now meeting its target effluent quality for nutrients on a consistent basis.

The disadvantage with the process configuration adopted is that the aerobic mass fraction of the plant has been reduced (i.e. one of the aerobic cells has been converted to a de-aeration zone). To ensure the nitrification requirements are satisfied the sludge age of the plant has been increased. The increase in sludge age has consumed some of the capacity at the plant, currently equivalent to 10,000 EP. There has also been an impact on the settling velocity of the sludge. The observed settling velocity of the sludge has decreased in the order of 30% since the changes were made.

A further trial is now being conducted to assess the impact of a lower sludge age. Previous trials where the sludge age of the process has been reduced have resulted in unstable performance of the plant. However it was not clear whether or not this unstable operation was a result of lower sludge age or process upsets (i.e. impacts on the digester and nutrient return streams).

3.0 KEY OUTCOMES

A number of general outcomes from this experience should be noted:

- Operational issues with plant and equipment can have repercussions throughout the remainder of the plant, address these issues first however minor they may appear
- It is important to work closely with the plant designers and allow sufficient resources (including access to relevant trades personnel) and time to optimise these types of processes

- It is important for water authorities and regulators to work closely together to allow the flexibility to trial and optimise BNR processes
- Ensure your designers allow sufficient flexibility to operate the plant at higher sludge ages (i.e. always encourage a larger reactor/clarifiers, or designers always be conservative in your reactor sizing)
- When optimising BNR processes, ensure you give adequate consideration to the supplementary processes that control return streams back to the BNR process.

A number of process specific observations that were made for the BNR process at the Morpeth WWTW include:

- High dissolved oxygen concentrations were required to ensure the EBPR phenomenon was observed
- An ascending DO profile in the aerobic fraction of the activated sludge reactor results in better EBPR performance
- Wet weather has a significant impact on the performance of a BNR plant and variations in effluent quality are often observed during the period immediately after wet weather. Variations in wet weather performance of the plant need to be considered for the biological process.
- Secondary phosphorus release did not occur in the de-aeration zone (anoxic zone) this philosophy is potentially a control measure to ensure nitrogen removal performance is enhanced.

4.0 ACKNOWLEDGEMENTS

To the operators at the Morpeth WWTW who have been involved in optimisation of the process.
To Peter Griffiths, the original designer of the plant, for his continued support and informal advice on the implementation of improvements works at the Morpeth WWTW.