RTC-N: Modelling Ammonia-Based Aeration Control in Real Time for Deeper Process Control

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Introduction

Traditional forms of modelling and their commercially available systems have been reliable tools for planning large scale projects such as new plant designs or expansions. However, from a unit operation's perspective, these resources can have limitations as process control/optimization tools:

- Limited data set based on composite or average data which may mask diurnal patterns or unique events
- Reliance on past data, which may be up to five years old
- Each model must be built and manually calibrated to the specific unit process
- Models require a sophisticated skill set to properly create and calibrate
- Modelling software can be prohibitively expensive for individual unit process modelling.

In order to overcome these limitations, plant staff are adopting real-time modelling as a means to determine the potential benefits of upgrading and optimizing processes such as nitrification, chemical dosing, and sludge treatment. Manufacturers couple instrumentation and computers for process modelling and control, which provide significant benefits to plant staff over traditional modelling tools:

- Models are pre-created and minimal configuration is required to adapt to the plant
- Self-learning models do not require a sophisticated skillset to calibrate
- Real-time data assists with daily process control operations and decision support
- Outputs can be compared toactual operations in order to enumerate benefits.

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Background

At a 30 MGD water reclamation plant (WRP), the facility uses a design modified Ludzack-Ettinger (MLE) process with an average daily flow of 12.5 MGD. Wastewater enters the plant and flows through a screening and degritting system before flowing into primary clarifiers to reduce total suspended solids (TSS) and biological oxygen demand (BOD) loading. Primary effluent is mixed with the return activated sludge and splits into seven trains. The first section of the train is an anoxic selector for filament reduction and denitrification, followed by an aerobic zone that performs BOD removal and nitrification. Mixed liquor from the end of the aerobic zone is recirculated back to the anoxic zone for denitrification.

Process Issues

The discharge permit for this plant is typical for a reuse facility; the focus is on the concentration of nitrate nitrogen, which must be below 10 mg/L NO_3-N. With the existing process, this objective is easily maintained, however the staff is constantly improving operations and wanted to understand if they could lower dissolved oxygen (DO) in the aeration tank to save energy and achieve simultaneous nitrification and denitrification.

In order to evaluate their system, they chose to use the Hach® Real-Time Control System for Nitrification (RTC-N). Instead of connecting it directly to their existing aeration control system, the WRP would use it to model its system first so it could understand the differences between the current operation and operating under ammonia-based aeration control. The Hach RTC-N is a model-based controller which can be configured to either model a nitrification system, or control it through a variable DO concentration.

Solution and Improvements

To collect the data necessary for the real time modelling system, two AMTAX Ammonia Analyzers, two Filtrax filtration systems, one Solitax suspended solids sensor, and one LDO2 dissolved oxygen sensor were installed. The influent ammonia analyzer is installed in the influent anoxic channel where primary effluent and return activated sludge are mixed and distributed to the trains. The effluent ammonia analyzer was installed at the end of aeration tank 8 so that tank 8 could be modelled separately from the others and potentially operate through ammonia-based aeration control without affecting the other trains. Each ammonia analyzer was fed
0.45 µm filtered sample from a Filtrax system immersed in the mixed liquor. The suspended solids and DO sensor were installed in the middle of the aeration tank. All of these sensors were connected to a Hach SC1000 Controller, located at the middle of the aeration tank.

The real-time modelling system is pre-loaded on an industrial computer and is best located in a PLC cabinet where it is convenient for wiring inputs and outputs. Input to the real-time modelling system is the influent flow rate in gallons per minute as an analog 4-20 mA signal. The industrial PC is connected to the SC1000 controller through a simple twisted pair, communicating with Modbus. The SC1000 controller acts as both the human-machine interface (HMI) for the field sensors as well as the real-time modelling system.

Configuring the real-time modelling system requires scaling the analog input(s), entering limits on measurements and calculations, and populating initial data to seed the model.

At the WRP, the following data were input into the system:

• Average mass wasted per day:	1341.8 kg
• COD/TKN ratio:	7.6
• Minimum nitrifiers limit:	0.8%
• Maximum nitrifiers limit:	2.0%
• Effluent ammonia setpoint	0.1 mg/L NH_4-N
• Min DO model limit:	1.0 mg/L O_2
• Max DO model limit:	3.0 mg/L O_2
• Inflow minimum:	164.25 L/s
• Inflow maximum:	175.25 L/s
• Return sludge flow minimum	0 L/s
• Return sludge flow maximum	175.25 L/s
• Recirculation flow rate	330 L/s
• Aerobic volume:	3839 m^3

The above data, combined with the real-time data, is entered into the real-time modelling software running on the computer. The modelling software is proprietary software based on ASM1, but it is modified so that it can be used for real-time modelling or real-time control. Suggested analysis trends include suggested DO concentration of the mixed liquor (mg/L), influent ammonia load (kg/h), estimated SRT of the system (days), percentage of the mixed liquor which are nitrifiers (%), maximum nitrification rate of the system (mg/L-h), nitrification rate (mg/L-h) (along with mixed liquor temperature), influent and effluent ammonia concentrations, DO concentration, and suspended solids concentration.

Results

Evaluating the data reveals the benefits of real-time modelling versus a traditional desktop software system. Figure 1 shows the variability of influent ammonia, even though the inflow equalized at 12.5 MGD. It also shows that a majority of the time the effluent ammonia was below detectable limits (<0.05mg/L NH_4-N) with small spikes less than 1.5 mg/L NH_4-N towards the end of the chart.

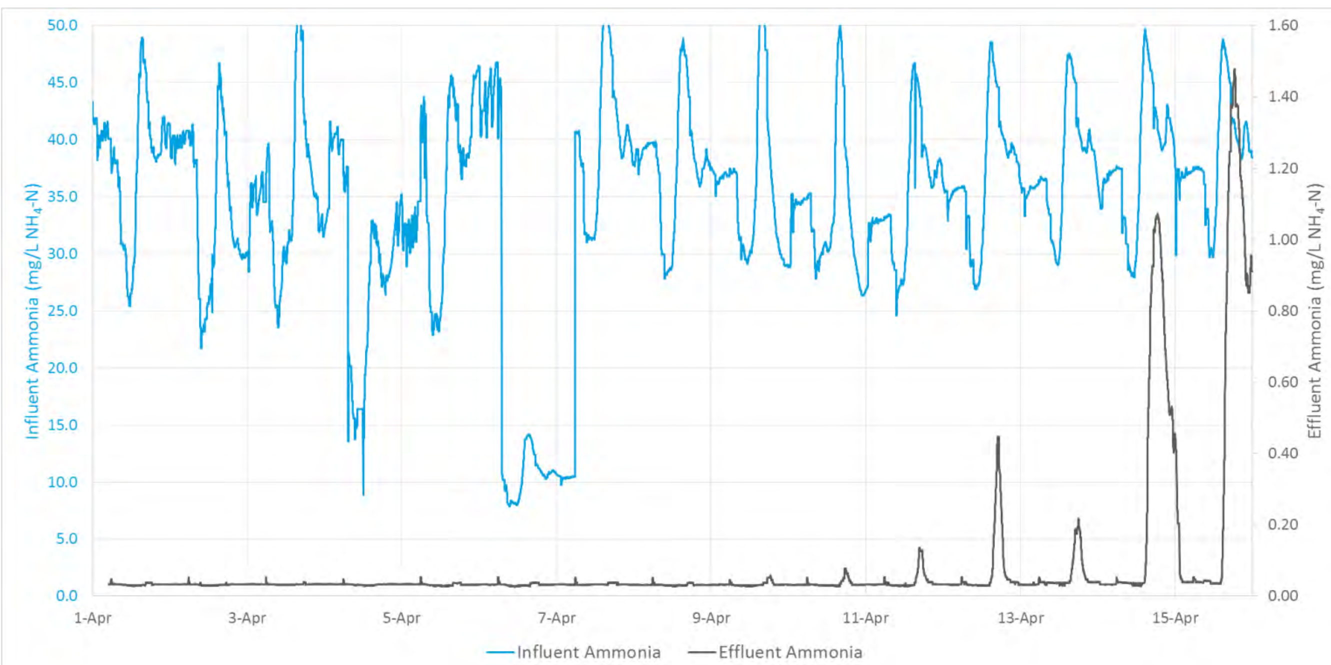

Figure 1: Comparison of influent and effluent ammonia concentrations

Figure 2 shows the second level of real-time modelling, trending the nitrification rate needed to nitrify the incoming ammonia load against the actual nitrification rate of aeration tank 8.

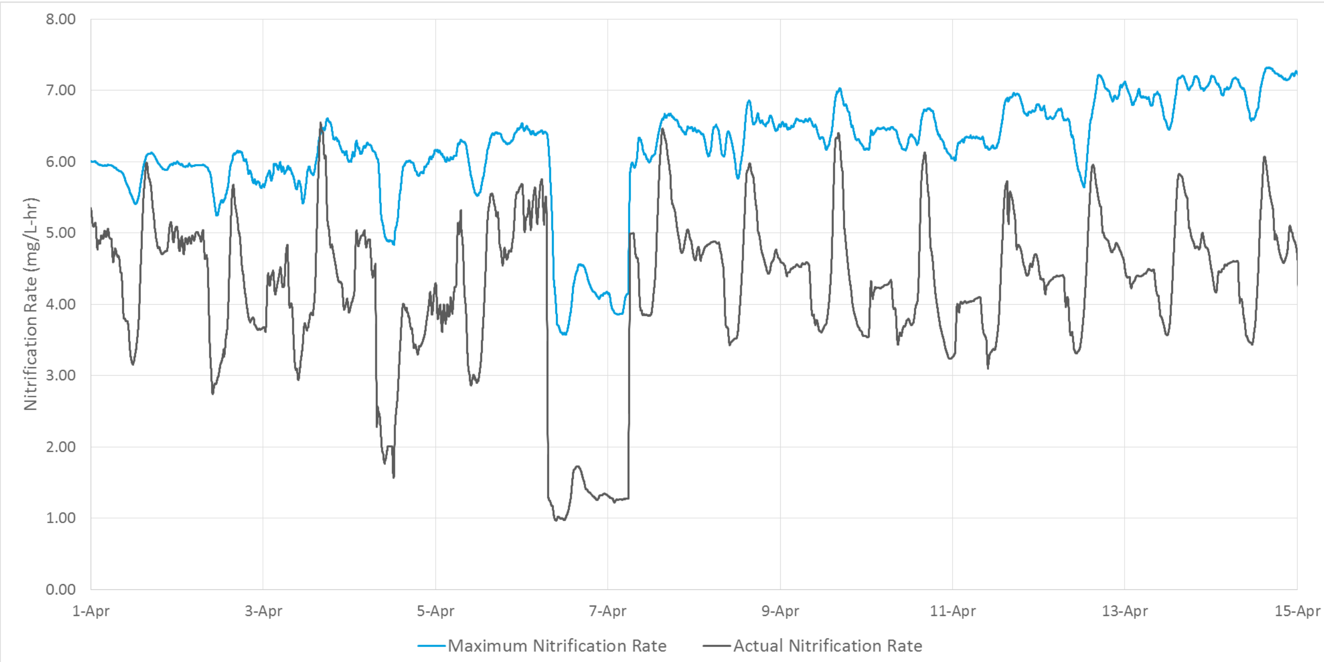

Figure 2: Trending actual real-time nitrification rate and real-time maximum nitrification rate

There are two important operational observations in Figure 2: First, there are times on April 1 and April 3 that the actual nitrification rate spikes near or above the maximum nitrification rate. While this is not evident in the respective effluent ammonia data (see Figure 1), it is evident through these modelled trends. This information is important for real-time operations, especially when deciding to treat sidestreams with high ammonia loads or other factors which could inhibit nitrification. Second, the actual nitrification rate is distant from the maximum rate during the effluent ammonia spikes on April 13, 14, and 15. This means that the spikes in effluent ammonia were not due to a problem from insufficient DO, but most likely were due to a toxic load which inhibited nitrification quickly and briefly.

The third level of real-time modelling addresses solids retention time, nitrifier concentration, maximum nitrifier growth rate, and decay rate (see Figure 3). The maximum nitrifier growth rate is compensated for temperature, and used with the similarly temperature compensated decay rate with other variables to determine the percentage of the mixed liquor that are nitrifiers. While these trends do not appear to vary much, they are expected to change seasonally and can provide plant-specific insight as to the activity of the nitrifying organisms.

The solids retention time is based mainly on the mixed liquor suspended solids concentration, but also includes other variables. On April 12, the SRT dropped significantly, as did the concentration of nitrifiers. This drop is correlated with the decrease in the maximum nitrification rate in Figure 2, and also the first significant spike of effluent ammonia in Figure 1. This means that the effluent ammonia spike on April 12 was caused by a different condition than the subsequent spikes on April 14 and 15, and therefore it would have harmed operations to assume that they had the same root cause.

Lastly, in Figure 4 the real-time modelling system highlights the biggest benefit of all: The actual DOconcentration as compared to the optimal dissolved oxygen concentration and the potential energy savings of performing ammonia based aeration control. The optimal DO concentration is calculated in order to match the nitrification rate to the given load, therefore ensuring complete
nitrification of the load while attaining some effects from simultaneous nitrification/denitrification and ensuring limited endogenous respiration in the aeration tank.

This suggests that the DO concentration could be significantly reduced in order to reduce the nitrification rate and also save energy. Based on this limited set of data, the reduction in energy usage by switching to ABAC would be approximately 65.8% (see Table 1).

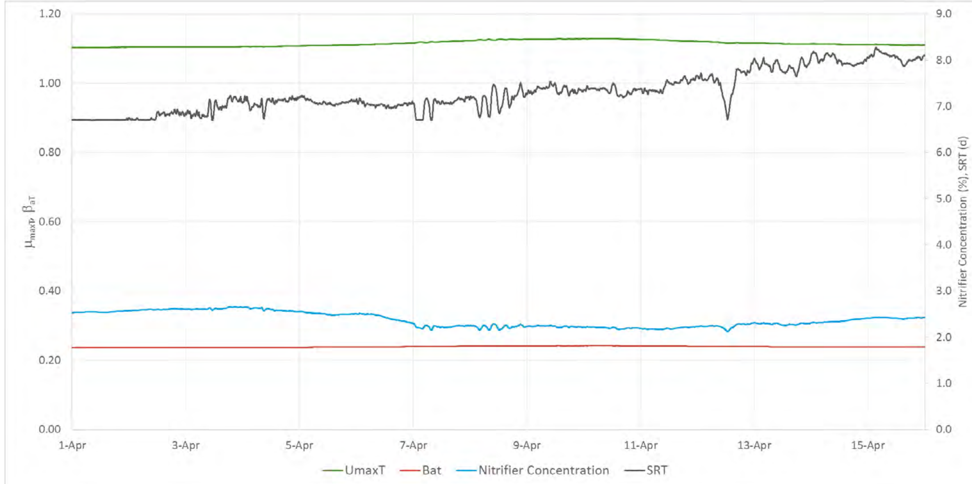

Figure 3: Trends of SRT, nitrifier concentration, maximum growth rate, and decay rate

Figure 4: Trends of optimal and actual DO concentration, and potential energy savings

Table 1: Average DO and modelled energy savings during the study period

Average actual DO concentration (mg/L)	4.27
Average optimal DO concentration (mg/L)	1.22
Average potential energy savings (%)	65.8%

Conclusion

The real-time modelling system is an effective tool for evaluating current operations and presenting how operations can be improved and optimized through ammonia based aeration control. The differences between the current state operations and the improved operations could be used to justify upgrades to an existing aeration system or other projects in order to perform ammonia based aeration control.

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