

Sensors Versus Analyzers: The Case for Ammonia-based Aeration Control

Mark W. Miller^{1*}, Pusker Regmi², Jose Jimenez³

¹Brown and Caldwell, 309 E Morehead Street, Suite 160, Charlotte, NC

²Brown and Caldwell, 4061 Powder Mill Road, Suite 400, Beltsville, MD

³Brown and Caldwell, 2301 Lucien Way, Suite 250, Maitland, FL

*Email: mmiller1@brwncald.com

Main Purpose/Conclusions

The objective of this work was to compare conventional DO control strategies to ABAC and compare the use of sensors or analyzers for monitoring ammonia.

References

Amand, L., Olsson, G., Carlsson, B. (2013) Aeration control – a review. *Water Science Technology*, **67**(11), 2374-2398.

Rieger, L., Jones, R.M., Dold, P.L., Bott, C.B. (2014) Ammonia-based feedforward and feedback aeration control in activated sludge processes. *Water Environment Research* **86**(1), 63-73.

Introduction

The use of advanced aeration controls in water resource recovery facilities (WRRFs), particularly ammonia-based aeration control (ABAC), is becoming more widespread in North America. Compared to conventional dissolved oxygen control, ABAC utilizes the available aeration basin capacity more efficiently by only nitrifying the influent ammonia necessary to obtain a desired effluent ammonia concentration. By allowing ammonia to persist until the end of the aeration basin, a lower than typical (2 mg-O₂/L) operating DO concentration can be achieved thus lowering the total aeration requirements and eliminating excess aeration. Additionally, operating at very low DO concentrations (0.2-0.5 mg-O₂/L) promotes simultaneous nitrification and denitrification resulting in lower effluent total nitrogen and reduce alkalinity consumption. As WRRFs consider the implementation of ABAC, different types of ABAC logic and associated process instrumentation must be considered. Converting from conventional DO control to advanced aeration controllers requires additional process instrumentation and may require a change in the operational culture around their use and maintenance.

There are mainly two types of process instrumentation that are used to measure ammonia (NH₃) or ammonium (NH₄⁺). Ion selective electrode (ISE) sensors are used to measure ammonium directly in the process water (i.e., *in situ*), whereas gas electrode or wet-chemical analyzers pull a filtered sample that is measured *ex situ*. Ammonium sensors have the advantages of lower capital investment and faster response times compared to analyzers, but their minimum detection limits and accuracy are not as good as analyzers. With both sensors and analyzers, routine maintenance and cleaning are critical to ensure stable and accurate results that can be confidently used for process control. The objective of this paper is to determine the value of using ammonium sensors versus analyzers to monitor ammonium for ABAC and determine if the higher capital cost of analyzers can be justified either by improved aeration control or reduced maintenance requirements or both. This paper will include an evaluation of manual DO control, automatic DO control, and ABAC in terms of the aeration energy required. This paper will also present two case studies where ABAC and different process instrumentation were evaluated.

Methods

A wastewater process simulator (EnviroSim BioWin 5.3) was used to model different aeration control strategies to evaluate their impact on energy consumption and effluent quality. Instead of presenting on a specific facility that has its own intricacies and nuances, a BioWin cabinet model was selected to provide results that could be applicable to many facilities. The Modified Ludzack-Ettinger (MLE) cabinet model was modified to compare manual DO control, automatic DO control, and feedback ABAC. Additional control strategies, like feedforward ABAC with feedback trim, will be evaluated for the final paper. The MLE process was chosen because it represents the backbone of most biological nitrogen removal processes. The MLE process configuration that was modeled using BioWin is provided in Figure 1 and the design parameters are provided in Table 1.

Solids treatment was not considered as part of this evaluation. A dynamic influent itinerary based on the influent of a real WRRF was used (Figure 2); however, the default BioWin influent wastewater fractions were used. A constant 65% TSS removal efficiency was assumed for the primary clarifiers. No supplemental carbon or alkalinity was modeled. The default influent alkalinity was sufficient for complete nitrification.

Two case studies will be presented and additional details for each will be provided in the final paper. The first case study is from the Sawgrass WWTP located in Sunrise, Florida. As part of this facilities future upgrades, BioWin was used to compare automatic DO control and feedback ABAC to their existing manual aeration control strategy for their nitrifying activated sludge process. The second case study is from the Central WWTP located in Nashville, Tennessee. This facility is being converted

from a nitrifying activated sludge process with draft tube aerators to the anaerobic/oxic (A/O) process with fine-pore diffused aeration. As part of the upgrades, different aeration control strategies, including feedback and feedforward ABAC, were considered along with several process instrumentation layouts.

Results

The MLE process was modeled assuming a target DO concentration of 2 mg-O₂/L for the manual and automatic DO control strategies. For manual DO control, it was assumed that an operator would check the DO every four hours and adjust the airflow rate based on the DO at that time. This resulted in large swings in the DO from 0.5 to 3.5 mg-O₂/L. The average blower energy requirements per MGD treated are presented in Figure 3. For the manual DO control scenario (baseline), the average energy demand for the blowers was 590 kWh/MGD. Using conventional DO control with a target setpoint of 2 mg-O₂/L, 3% less aeration energy was required than the baseline scenario. While it was expected for the difference to be closer to 10-20% (Amand et al., 2013), true manual DO control is difficult to replicate using a model controller. That is, the controller likely did better at maintaining the DO near 2 mg-O₂/L than what would occur in reality. Feedback ABAC was modeled assuming a target effluent ammonia concentration of 1 mg/L. This resulted in approximately 30% additional energy savings for a total of 33% compared to the baseline scenario as shown in Figure 3.

Case Study 1

The average aeration demand for conventional DO control was 14,700 scfm compared to 8,400 scfm for ABAC or nearly 40% less air required. However, the maximum air required (20,000 scfm) was the same for both scenarios. This was because the peak air demands still need to be met during all scenarios and this drives the total aeration capacity required. One critical aspect for aeration systems that utilize ABAC, is that a full range of aeration must be provided to cover both the minimum and maximum aeration requirements, and this may require either multiple smaller blowers or blowers with adequate turndown. Providing additional blowers or variable speed blowers will likely increase the initial capital cost. The modeling results also showed that supplemental alkalinity would not be required if ABAC was utilized. However, if conventional DO was used, an average of 450 gpd of alkalinity (30% w/w NaOH) would be required. The final paper will include the cost comparison of both scenarios and an evaluation of the instrumentation being considered.

Case Study 2

The evaluation included conventional DO control, feedback ABAC, and feedforward ABAC with feedback trim. Based on the BioWin modeling, it was decided that feedforward ABAC did not provide a substantial enough improvement in terms of reducing effluent ammonia peaks to justify the feedforward controller complexity and additional instrumentation requirements. A simple cost comparison was made between installing ammonium sensors and analyzers that included the initial capital cost and the annual maintenance costs associated with cleaning solutions, reagents, and replacement parts. It was assumed that the instrumentation had useful life of 10 years. To install analyzers, the total cost was \$60,700 after 10 years and to install sensors, the total cost was \$47,800. When considering the cost savings associated with energy reductions, the cost difference between the two types of instrumentation was deemed insignificant. The final paper will include a detailed cost comparison of the capital cost, maintenance costs, and man-hours required for routine maintenance and instrument calibrations.

Conclusions

When compared to manual aeration control, automatic DO setpoint control can potentially net 10-20% aeration energy savings. As with this evaluation, ABAC has been shown to decrease aeration

energy requirements by an additional 20-30% when compared to automatic DO setpoint control. Although difficult to quantify, use of aeration control strategies can reduce labor associated with operators manually monitoring DO concentrations and adjusting air flow valves. However, the additional labor associated with maintaining the DO monitoring equipment and modulating valves should be considered. Depending on the facility specifics, the use of analyzers for accurate ammonia monitoring is comparable in terms of costs and should be considered when utilizing advanced aeration controllers. If the total costs are comparable between sensors and analyzers, the ultimate deciding factor may come down to user preference.

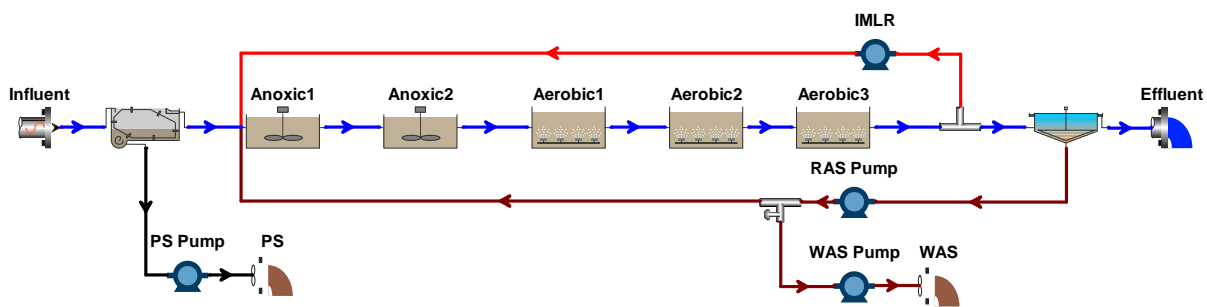


Figure 1 – BioWin MLE Flowsheet

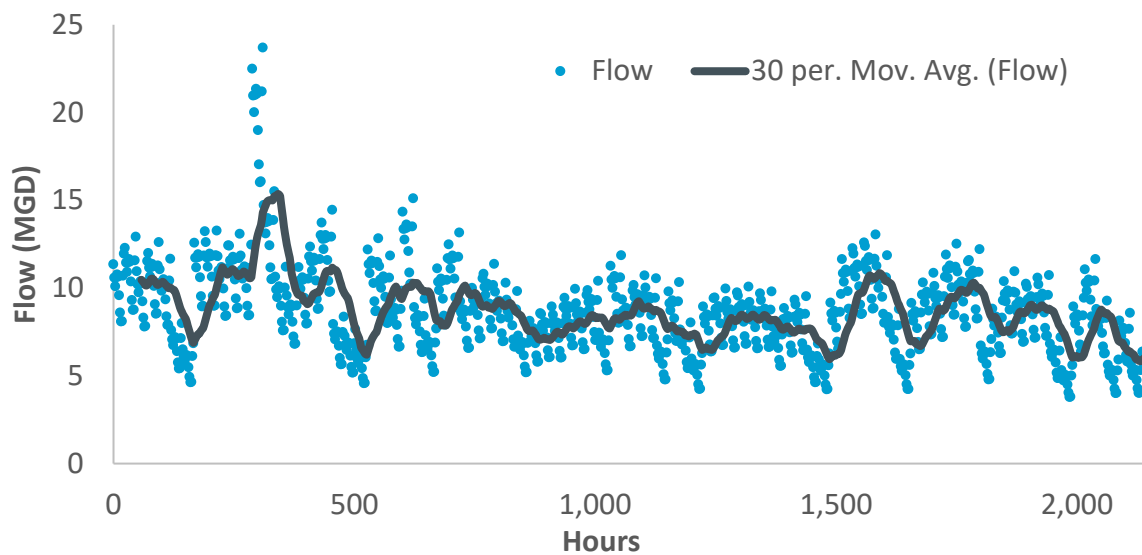


Figure 2 – Influent Flow Itinerary

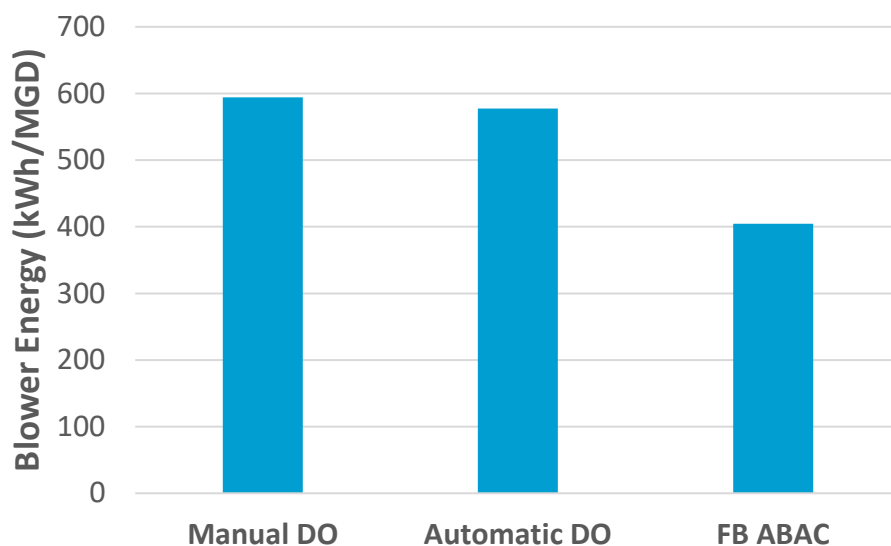


Figure 3 – Average Blower Energy Requirements

Table 1 – BioWin MLE Process Design Parameters

Parameter	Design Value
Flow	
Annual Average	8 MGD
Maximum Month	10 MGD
Peak Hour	24 MGD
Primary Clarifiers	2x 65 ft diameter
BNR Basins	4
Total Anoxic Volume	1.5 Mgals
Total Aerobic Volume	2.25 Mgals
Aerobic SRT	8 days
IMLR	100-400% Qin (Max 50 MGD)
Final Clarifiers	4x 80 ft diameter
RAS	60% Qin (Max 10 MGD)

Table 2 – Case Study 2: Simple Cost Comparison

Scenario	Capital	Annual Maintenance	10-yr
FB ABAC with Sensors	\$41,680	\$1,900	\$60,700
FB ABAC with Analyzers	\$28,010	\$2,000	\$47,800