Tertiary Biological Activated Filter (BAF) with Partial Denitrification Anammox (PdNA) for Transitioning to Water Reuse

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Introduction

Partial denitrification anammox (PdNA) implementation can combat some of the most difficult challenges facing water resource recovery facilities (WRRFs). PdNA can alleviate strains caused by population growth and nutrients, while offering long-term budgetary benefits. Rather than using traditional nitrification and denitrification for nitrogen removal, PdNA can be implemented to achieve lower energy consumption, carbon demands, and greenhouse gas emissions. In PdNA, influent ammonium is oxidised to nitrate. This nitrate is then reduced to nitrite (partial denitrification), and the reduction of nitrite to nitrogen gas (full denitrification) is limited. The nitrite produced from partial denitrification and the remaining influent ammonium can then be reduced to nitrogen gas via anammox bacteria.

PdNA offers utilities a promising pathway towards a circular economy in the water industry by expanding nutrient removal capacity and enabling the development of water reuse programs. From a reuse perspective, water and wastewater quality management basin plans highlight the critical link between WRRF effluent quality and the resulting source water quality for downstream drinking water treatment plants. In the US, drinking water regulations limit nitrate to 10 mg NO_3-N/L. For both indirect and direct potable reuse, planners and water treatment plant operators typically prefer

WRRF effluent nitrate concentrations to align with existing source water quality to minimise treatment modifications at water treatment plants. This often requires WRRF effluent nitrate levels below 5 mg NO_3-N/L which can be challenging to achieve for many utilities, and PdNA provides an attractive solution in this context. Retrofitting PdNA into existing concrete infrastructure is particularly advantageous for facilities with limited footprint, as it avoids major construction. Alternatively, implementing PdNA as a stand-alone tertiary process in a biological aerated filter (BAF) enables utilities to achieve stringent nitrate and total suspended solids (TSS) limits while minimising disruption to upstream processes. Using a BAF for intensified nitrogen removal is particularly advantageous in applications without total phosphorus limits. While BAFs typically provide worse particulate phosphorus removal than conventional denitrifying filters, they have considerably higher nitrogen removal rates which makes them ideal for intensified nitrogen removal prior to reuse.

This presentation will provide an overview of a US$4 million U.S. Department of Energy (DOE) PdNA study that is implementing PdNA in six WRRFs across the United States and will focus on design considerations for PdNA implementations that focus on water reuse. The presentation will highlight pilot-scale results for a tertiary PdNA BAF.

Methods

The Linda County Water District WRRF in California, USA, has a design capacity of 5 million gallons per day (MGD) and typically treats 2.5 MGD. The facility operates a Modified Ludzack-Ettinger (MLE) process with tertiary filtration to achieve an effluent quality of 2.9 mg NH3-N/L and 10 mg NO3-N/L. To evaluate opportunities for enhanced nitrogen removal, a tertiary PdNA BAF pilot is being tested to demonstrate simultaneous TSS removal and nitrate reduction to 4 mg NO_3-N/L. A photo of the pilot is provided in Figure 1. The pilot treats tertiary influent (settled secondary effluent) at a flow rate of 3.8 L/min, and supplemental ammonium chloride is dosed to achieve an ammonium-to-nitrate ratio of 0.5. Glycerol was added at a fixed carbon-to-total nitrogen ratio and will be controlled by a feedforward with feedback trim control strategy in the next three months. Samples are collected from the pilot influent and effluent three times per week and analysed for BOD, tCOD, sCOD, TN, NH_4-N, NO_2-N, NO_3-N, TSS, and VSS.

RESULTS AND DISCUSSION

The pilot experienced some variability in performance immediately after startup. During stable periods, the pilot consistently reached ammonium (Figure 2) and nitrate (Figure 3) removals over 95%. Nitrate removal has remained relatively stable and was able to reach the target effluent nitrate concentration of less than 5 mg NO_3-N/L. Ammonium removal has been more variable which has consequently resulted in variable total inorganic nitrogen removal (Figure 4). This variability is linked to the constant ammonium and glycerol loadings combined with fluctuations in influent nitrate concentrations, and the variability became more pronounced during later stress testing periods. Implementing the feedforward glycerol dosing strategy with feedback trim is expected to improve effluent nitrate consistency and overall reactor performance.

Future implementations can be optimized with a dynamic ammonium to nitrite+nitrate (AvN) influent control strategy to maintain tight effluent ammonium, nitrate, and total nitrogen compliance. Further optimization can be achieved by using primary effluent as a source of both ammonium and carbon which can reduce supplemental carbon and increase overall secondary treatment capacity. By diverting a portion of the primary effluent to the tertiary process, the secondary process can accommodate higher flows.

CONCLUSION

PdNA offers a cost-effective method for expanding capacity, reducing operation and maintenance costs, and transitioning to water reuse making it a valuable solution for utilities to achieve a circular economy.

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