Reducing Nitrogen Concentrations from Anaerobic Baffled Reactor Effluent using Partial Nitritation-Anammox

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Introduction

The anaerobic baffled reactor (ABR) at the Colorado School of Mines is a pilot-scale reactor anaerobically treating raw domestic wastewater from the Mines Park student residential community. The ABR is capable of removing up to 80% of organics and 95% of total suspended solids (TSS) (unpublished data). The ABR eliminates the cost of energy-intensive aeration utilized in typical wastewater treatment plants (WWTP) and produces energy-rich biogas by converting organic matter to methane and carbon dioxide (Pfluger, 2018). The ABR, however, does not sufficiently address nitrogen removal (Pfluger, 2018).

An additional process is required to treat the ABR's low-carbon, high-ammonium effluent. This unique effluent composition makes a partial nitritation-anammox (anaerobic ammonia oxidation) (PN/A) system a good fit to address nitrogen removal. Through the PN/A process, roughly 50% of ammonium is oxidized to nitrite by ammonium-oxidizing bacteria (AOB) while the resulting nitrite and remaining ammonium, under anoxic conditions, are autotrophically converted into mainly nitrogen gas and some nitrate (Ma, 2014). The goal is to implement a pilot-scale PN/A reactor to remove inorganic nitrogen from the ABR effluent.

Methods

A schematic of the 9-liter pilot-scale moving bed biofilm reactor (MBBR) utilized for the PN/A process is presented in Figure 1. The 9-liter PN/A reactor was fed effluent from the ABR through a 400-micron screen once daily for a 24hr hydraulic retention time (HRT). Reactor samples were collected daily, immediately before and after the volume exchange. Floating plastic media wheels were used, at a 33% bulk volume fill, to increase available surface area and encourage biofilm development. Constant mixing was provided by an overhead mixer and low-shear impeller. The reactor was aerated at a constant rate of 100 mL/min.

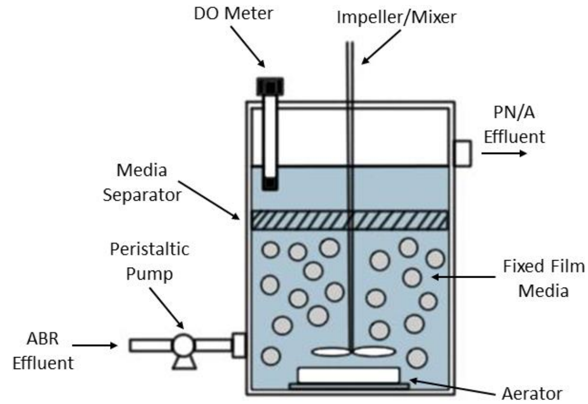

Figure 1 Pilot-scale PN/A Reactor Schematic

A Hamilton Oxysens dissolved oxygen (DO) sensor was utilized to constantly monitor dissolved oxygen. The primary nutrients of interest (ammonium, nitrite, and nitrate) were monitored daily using spectrophotometry. Over the counter aquarium fish kits were used to monitor ammonium and nitrate concentrations, while Hack TNT 839 kits were used to monitor nitrite concentrations. Furthermore, pH, dissolved organic carbon (DOC), and soluble and total chemical oxygen demand (COD) were measured daily, whereas BOD_5 was measured weekly.

Results

The percent removal of ammonium in initial PN/A batches over a two-and-a-half-week period (nine batches) is presented in Figure 2.

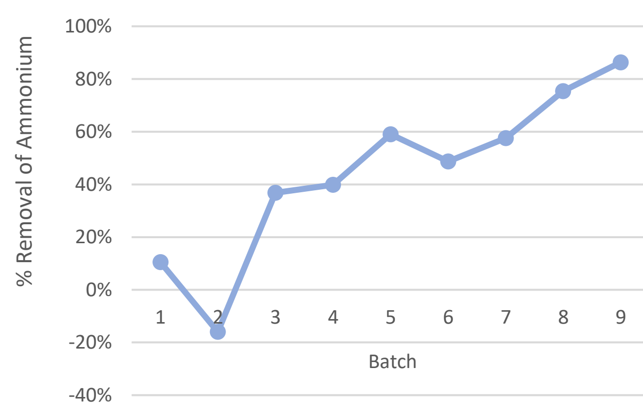

Figure 2 Percent removal of ammonium over nine individual PN/A batch treatments

The results indicate PN/A successfully removed ammonium from the ABR effluent. The stacked bar graph in Figure 3 presents the initial and final concentrations of inorganic nitrogen species across individual batches.

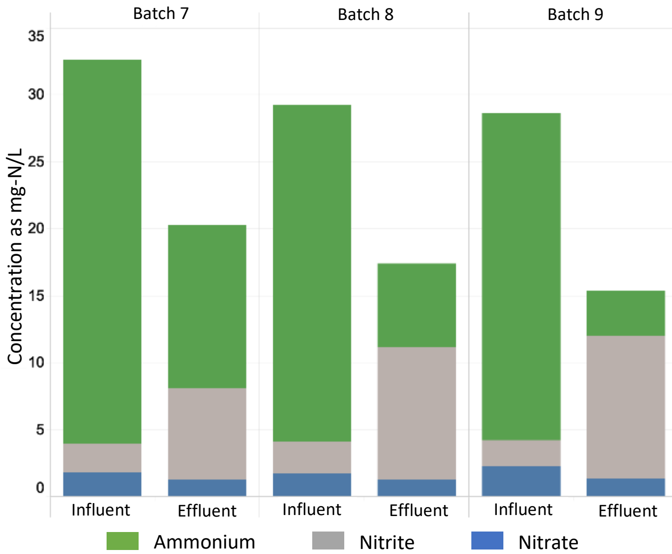

Figure 3 Comparison of initial and final concentration of the nitrogen species of interest over three individual PN/A batch treatments

Along with a reduction in ammonium concentration between each batch, an increase in nitrite and a slight decrease in nitrate was observed. Incomplete or invalid data was collected for nitrite concentrations for previous batches and were therefore excluded.

Conclusions

Though the results show an accumulation of nitrite and a slight reduction in nitrate concentrations, a significant amount of inorganic nitrogen is unaccounted for in the monitored species. The missing nitrogen coupled with the significant reduction in ammonium concentrations across each batch suggests successful anammox in the PN/A reactor. Furthermore, it is likely the reactor underwent a stabilization period, evident by the increase in ammonium concentration observed in Batch 2 and increasing ammonium removal across batches (Figure 2). The biofilm media was gathered from a full-scale anammox reactor treating high concentration ammonium (~1,000 mg/L NH_4^+-N), whereas the PN/A reactor never exceeded 45 mg/L NH_4^+-N during the experimental period. The drastic change in environment for the AOB and anammox bacteria may require further time for the PN/A reactor to stabilize and reach consistent performance.

Future Work

A full time-course study through a batch during one HRT would allow for a better understanding of the kinetics taking place in the system. Implementing DO control could mitigate nitrite accumulation, which may be inhibiting anammox activity. Furthermore, microbial community characterization would investigate PN/A community shifts due to communities present in the ABR effluent which will aid in developing a further understanding of the reactor's performance.

References

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Pfluger, A., Vanzin, G., Munakata-Marr, J., Fiueroa, L. (2018). An Anaerobic Hybrid Bioreactor for Biologically Enhanced Primary Treatment of Domestic Wastewater Under Low Temperatures. Environmental Science: Water Research Technology, 4, 1851-1866.