Effects of a Nitrification/Denitrification Inhibition Compound on Biological Wastewater Treatment

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Introduction

Distributed wastewater treatment has the potential to cut energy costs and conserve water by reusing treated water closer to the point of generation. Since distributed water treatment plants traditionally have smaller capacity than their centralized counterparts, pollutants can have a greater effect on effluent quality. This work examines the effects of a known nitrification and denitrification inhibitor on water treatment: sodium azide. In biological wastewater treatment, nitrification and denitrification are necessary processes to convert ammonia in raw wastewater into bioavailable nitrate and subsequently nitrogen gas for complete nitrogen removal. The removal of nitrogen from wastewater is important to prevent damage to receiving ecosystems, and crucial in the case of water reuse to protect the health of consumers.

Experimental Overview

Sodium azide (NaAz) has been studied as a nitrification-inhibitor, in particular a bacteriostatic[3] herbicide[1,2]. If used to treat large swaths of crops, distributed wastewater treatment has the potential to treat the agricultural runoff. Understanding the effects of herbicides on biological wastewater treatment is necessary to prevent an interruption in effluent quality. For these experiments, a pure solution of NaAz was used to induce a biological perturbation in a batch, activated sludge system.

A bench scale jar test with 2 L reactors were initially dosed with return activated sludge from a demonstration-scale sequencing-batch membrane bioreactor (SB-MBR). After 20 minutes of settling, effluent water quality was measured using various Hach 'Test-N-Tube' tests (Hach Company, Loveland, CO), including nitrate, total nitrogen, ammonia, and chemical oxygen demand (COD). Total suspended solids of the activated sludge and conductivity, pH, and alkalinity of the effluent were also measured. In the bench scale tests, the hydraulic residence time was kept at 24 hours by removing 1 L of effluent supernatant water and dosing with 1 L of raw, municipal wastewater every 12 hours. Three main experiments were developed and executed for this project, and are described below.

Pulse Disturbance – The first experiment was conducted as a bench scale jar test, where varying concentrations of NaAz (0, 0.1, 1, 10, 100, 1000 ppm) were dosed a single time in six 2 L jars/bioreactors. This experiment can be used to represent a single disturbance, such as from a storm runoff event.

Press Disturbance – The second experiment conducted manipulated the same bench scale jar test, where NaAz was dosed over the course of 72 hours. This experiment can be used to represent a continual dosing of an herbicide upstream of a wastewater treatment facility.

Sensor Network Test – Ammonium and nitrate probes were tested in one of the 2 L bioreactors during a pulse disturbance to test its functionality.

Results

Experiment 1: Pulse Disturbance

A pulse input of NaAz resulted in near complete inhibition of nitrification at concentrations above 100 ppm. Dosing of the system occurred in the morning of 6/15. This is shown in the increased ammonia levels (Figure 1) and decreased nitrate levels (Figure 2). Qualitatively, at higher concentrations the settleability of bioreactors decreased with increased concentration (Figure 3.)

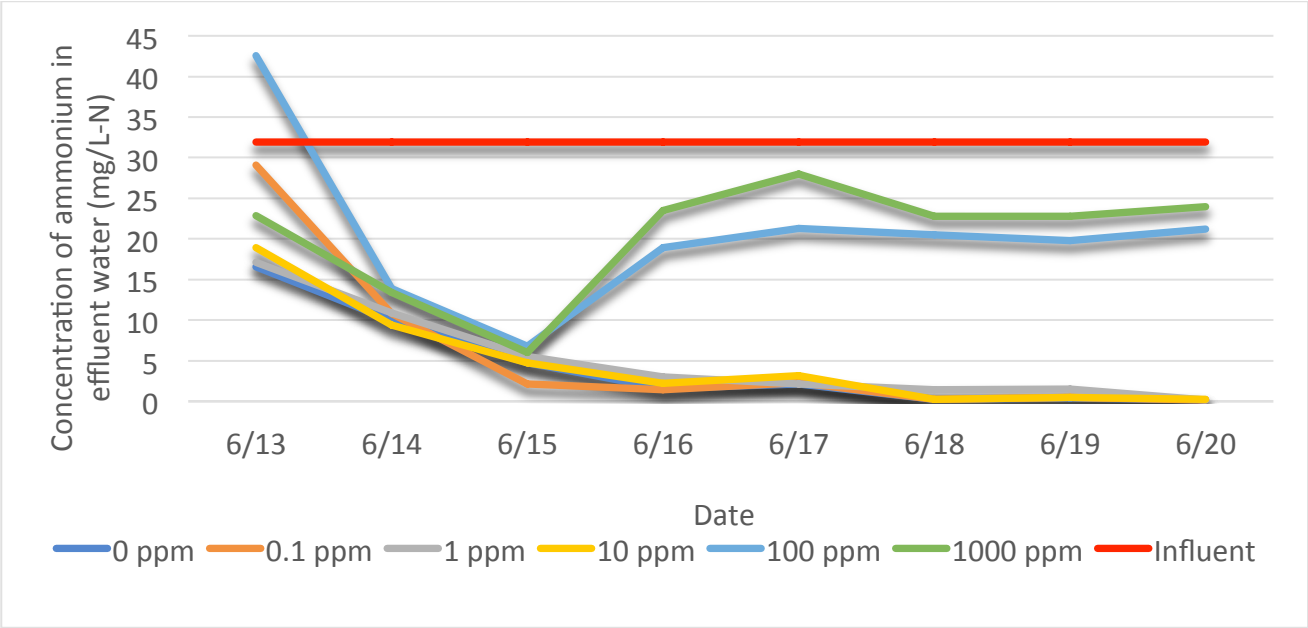

Figure 1: Ammonia concentrations of effluent water during a pulse disturbance of NaAz

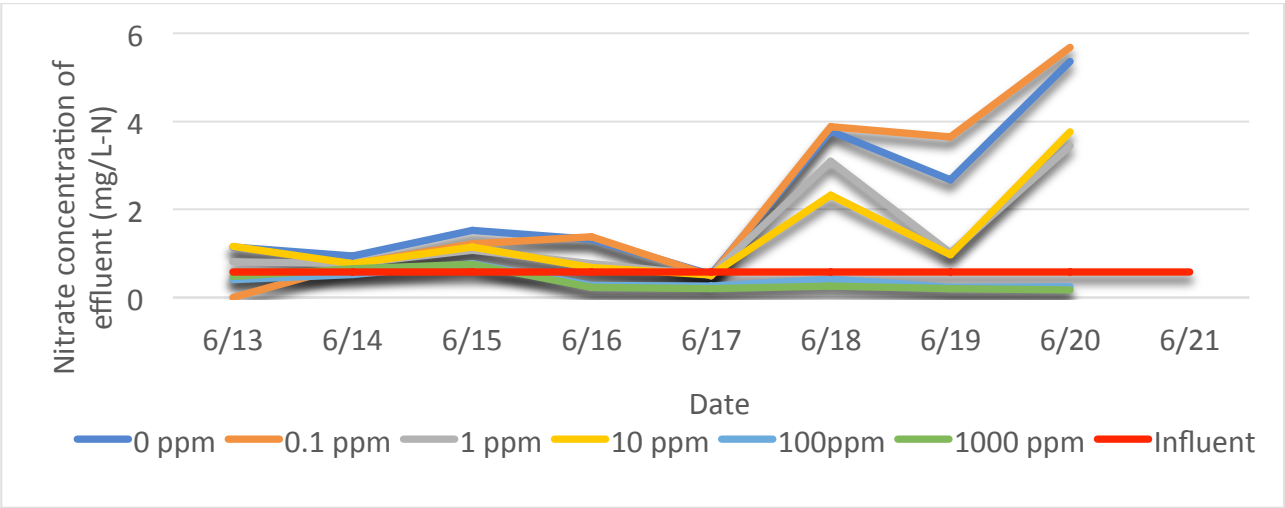

Figure 2: Nitrate concentrations of effluent water during a pulse disturbance of NaAz

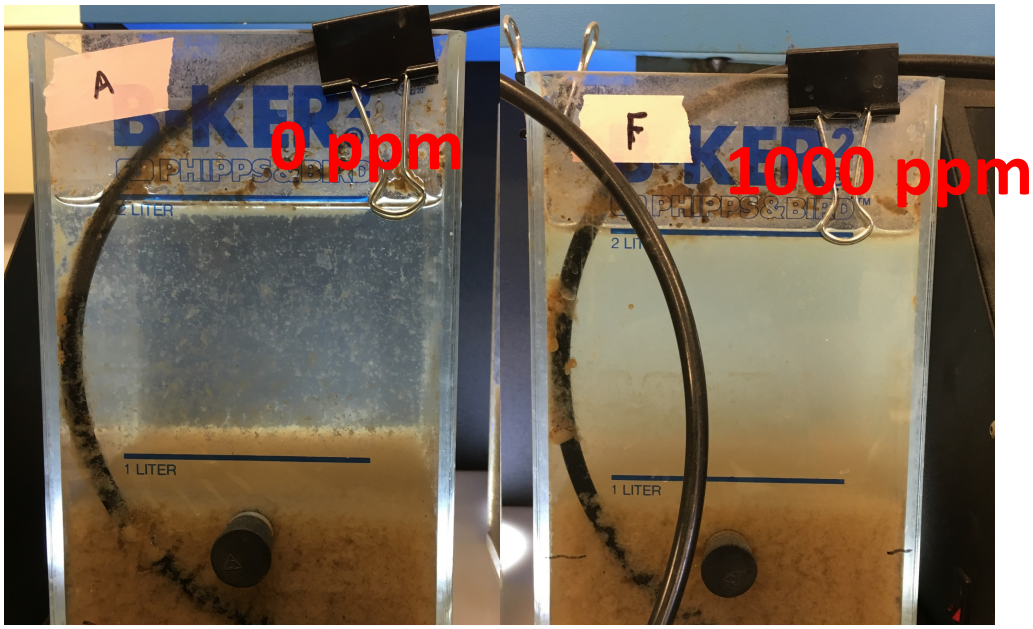

Figure 3: Qualitative differences in settleability of bioreactors dosed during a pulse disturbance at 0 and 1000 ppm

Experiment 2: Press Disturbance

Bioreactors were dosed over the course of 72 hours with NaAz in concentrations ranging from 0 to 100 ppm. Total suspended solids or TSS (Figure 4) decreased over time during the dosing period for bioreactors dosed above 50 ppm, which correlates with a decrease in microbial activity.

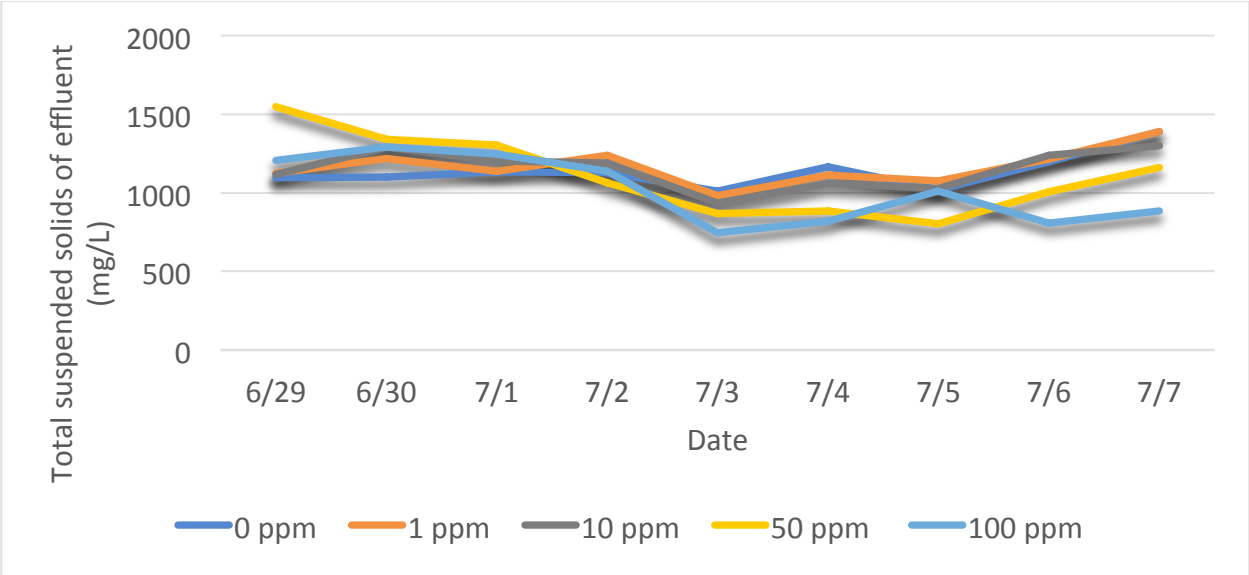

Figure 4: Graph of total suspended solids or TSS (mg/L) during a pulse disturbance where bioreactors were dosed for 72 hours with NaAz

Experiment 3: Sensor Network

Nitrate and ammonium probes (Vernier Technology and Software, Beaverton, Oregon) were placed in a 2 L bioreactor that underwent a pulse disturbance at 75 ppm. Data was collected every second over multiple days using an Arduino microprocessor. A buildup of a biofilm and formation of air bubbles under the membranes of the probes showed that sensors in an activated sludge system must be maintained properly to ensure accurate readings over time.

Conclusions

- NaAz completely inhibits nitrification at concentrations above 100 ppm, in both a pulse and press disturbance
- NaAz and other related agricultural products have the potential to seriously harm the microbial ecology of biological wastewater treatment systems
- Sensor networks in activated sludge systems will need more bench scale testing to determine a maintenance/calibration schedule in order to improve performance
- COD, pH, alkalinity, and conductivity are not as beneficial to detect perturbation events because of their ability to recover to steady state values, compared to nitrate and ammonium levels which are more permanently changed

Future Work

- Applying an inhibition compound to the pilot scale sequencing batch membrane bioreactor (SB-MBR) located at Mines Park
- Examining the effects of a commercial grade herbicide/fertilizer as a nitrification inhibitor to understand the effect of a more complex matrix
- Further development and implementation of the fault detection program and sensor network

References

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