Monitoring Bioreactors Using Improved Techniques

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Introduction

Woodchip bioreactors are an effective tool for reducing nitrate in tile drainage leaving farm fields. Bioreactors are a recognized tool in the Iowa Nutrient Reduction Strategy to reduce total nitrogen loads by 45 percent. Decades of field and lab experiments have helped determine major factors driving bioreactor performance including residence time, temperature, and age. Reported removal rates across and within experiments varies significantly, in the range of 2–22 g $N/m^3/d$.

Traditional methods of measuring bioreactor performance have relied on infrequent sampling at the bioreactor inlet and outlet. Biweekly or flow-weighted sampling of field bioreactors provides low resolution data on nitrate concentrations, introducing uncertainty when estimating performance. Observing internal processes can help improve bioreactor design for increased efficiency.

A novel sampling system coupled with state-of-the-art field sensors was used for the first time to obtain high-frequency *in-situ* nitrate measurements in a field bioreactor at the Northeast Research and Demonstration Farm in Nashua, Iowa.

Materials and Methods

Previously published articles detail the performance of the Nashua field bioreactor and can be referenced for a more in-depth description of the site. Inlet and outlet flow measurements were recorded every minute using HOBO pressure transducers V-notch weirs. Six pairs of sampling wells inserted in the woodchip media are spaced evenly along the bioreactor length. At each well pair, shallow and deep wells are screened at 15–30 and 31–60 cm from the bioreactor bottom.

A novel multiplexed sampling system was used to continuously monitor all 12 sampling wells and the bioreactor inlet and outlet June 2–12, 2018. This automated sampling system delivers samples from multiple locations using an onboard micro-controller and peristaltic pump. The micro-controller selects one valve of a 12-valve manifold to open and close to determine from which location to pump. Sample volumes (<100-200 mL) are consecutively pumped to a field spectrophotometer capable of accurate estimates of nitrate concentrations. Two sampling systems were used in order to monitor all 14 sampling locations over the 120 ft bioreactor length. Water temperature and dissolved oxygen (DO) were measured daily at the inlet and outlet. With each sampler pumping from seven locations, nitrate measurements were obtained at each location every 40 minutes. An additional rinse cycle with tap water was used after sampling all seven wells in order to regularly rinse the 10 mm quartz cuvette insert used for the spectrophotometer. The field spectrophotometer was calibrated using a statistical regression of absorbance values

from the probe with samples collected in the field and analyzed later in the lab.

Results and Discussion

Over 350 measurements were taken at each sampling location over the 10-day period. Nitrate concentrations declined over the length of the bioreactor, with median concentrations of 16.7 and 11.5 mg N/L at the inlet and outlet, respectively, or a 31 percent reduction in nitrate. Decreases in nitrate concentrations were marginal within the first 11.6 m of the bioreactor, declining by only 0.6–0.9 mg N/L. Nitrate decreased by only 1.3–2.1 mg N/L in the first 17.7 m (~48% bioreactor length). From 17.7 m to the outlet, nitrate decreased more quickly by 3.1–3.9 mg N/L. Apart from the first two well nests at 5.2 and 11.6 m, nitrate concentrations in deep wells were significantly lower than shallow wells. The DO decreased from 8.2-8.9 mg/L at the inlet to 0.1-0.3 mg/L at the outlet. Flow was relatively stable (0.13 – 0.21 L/s) over the monitoring period despite no rainfall at the site. The 128.1 m^3 bioreactor was partially saturated (1.5 ft water table depth) with volumetric removal rates of 1.2–1.9 g $N/m^3/d$, greater than rates seen previously at this site and at the low end of reported removal rates (2-22 g $N/m^3/d$). High-frequency measurements provided increased confidence in removal rate estimates. Future experiments in April 2018 will examine internal hydraulics and effect of flow rate on treatment efficiency.

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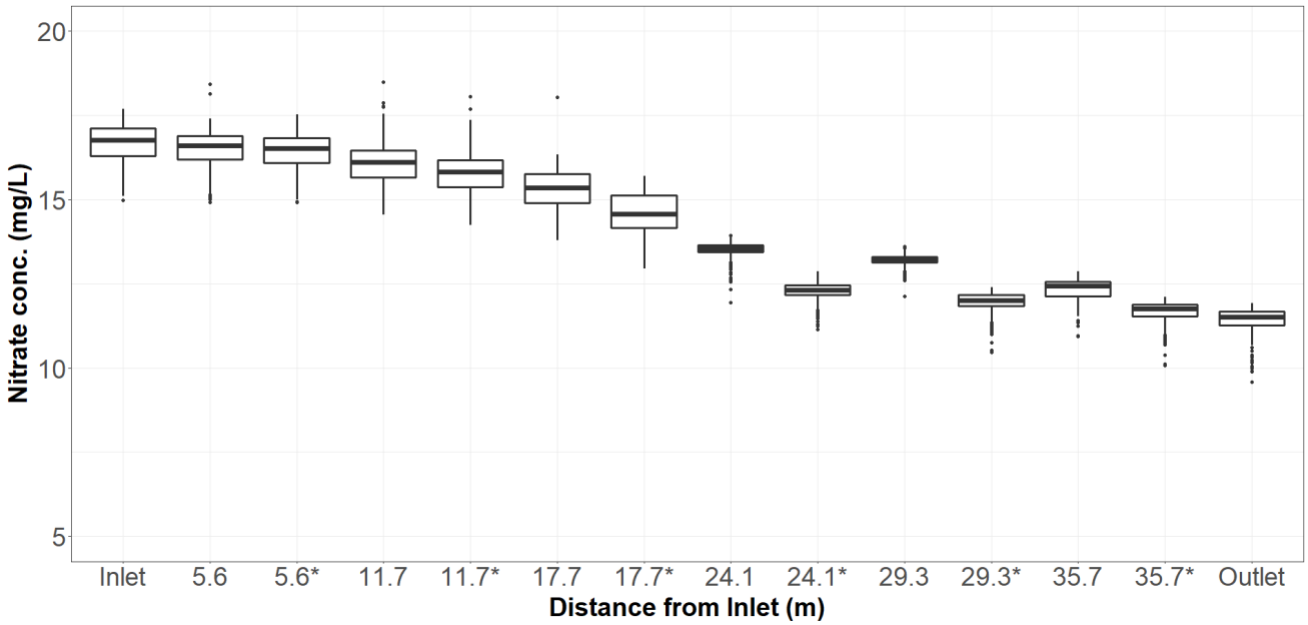

Figure 1. Nitrate concentrations were measured at inlet, outlet, and all 14 sampling wells along the bioreactor length every 40 minutes. Nitrate decreases were more significant in the second half of the bioreactor, with little treatment in the first 11.7 m.

***Indicates measurements taken at deep wells.**