DYNAMICS OF WATER AND SOCIETAL SYSTEMS AN INTERDISCIPLINARY RESEARCH PROGRAM AT THE VIRGINIA TECH STREAM LAB

Designing the Next Generation of Denitrifying Bioreactors (DNBRs):

Coupling of Biological and Physiochemical Processes to Remove Nitrogen and Phosphorus

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Biological Systems Engineering

Justification

- Stroubles Creek, a local stream listed as "impaired" by the Environmental Protection Agency (EPA), receives both agricultural and urban runoff, resulting in high nutrients.
- A denitrifying bioreactor (DNBR) is a best management practice (BMP) that reduces nitrate levels by providing a source of carbon for naturally present denitrifying bacteria.
- Literature suggests DNBRs can also improve phosphate levels through incorporation of biochar with carbon media.

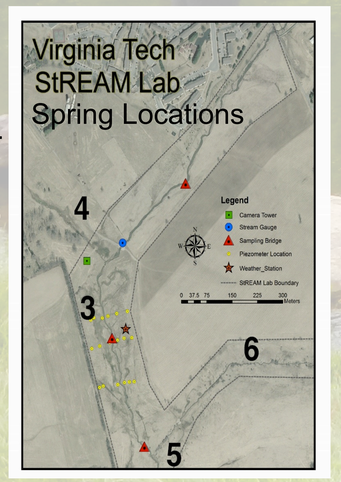
Objectives

- Collect snapshot values of nitrogen and phosphorus levels in local ponds and springs.
- Determine the best location for installation of a DNBR.
- Assess removal rate efficiency of various media (woodchips, biochar).
- Evaluate whether or not pre-inoculation of DNBR with denitrifying bacteria enhances denitrification rates.

Phase 1: Nutrient Assessment

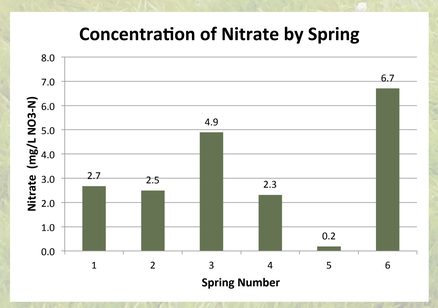
Methodology:

- Samples were collected from 4 springs within the StREAM Lab (see map on right), 2 headwater springs, and 10 local ponds (8 urban and 2 agricultural). Focus is primarily on spring data.
- Sonde data (temperature, pH, %DO, specific conductivity) collected.
- Samples were filtered, then analyzed for nitrate, phosphate, carbon, and iron content.



Results:

High nitrate levels and ease of accessibility make Spring 3 the optimal location for DNBR installation and the chosen source of water for DNBR influent.

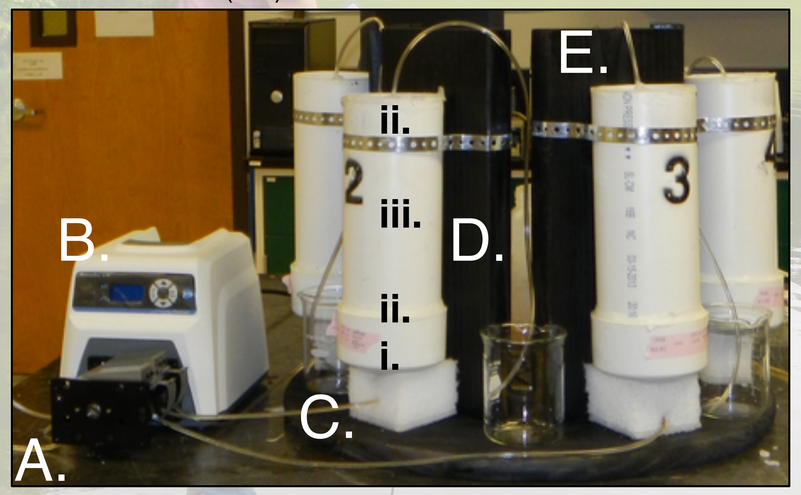


Phase 2: Lab Scale DNBR

Methodology:

The system is composed of four water-sealed 4" diameter, 1' long PVC tubes with approximate 10 hour residence times and the following media mixtures (by volume):

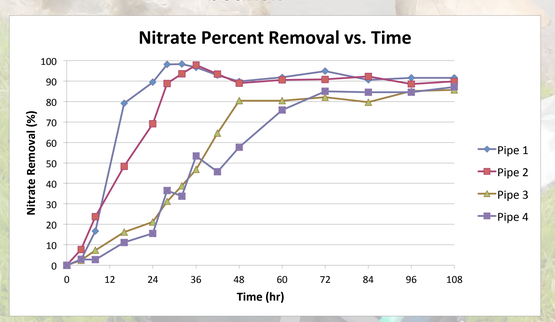
1. Woodchips (95%), active pond sediment (5%)
2. Woodchips (75%), biochar (20%), active pond sediment (5%)
3. Woodchips (95%), sterilized pond sediment (5%)
4. Woodchips (75%), biochar (20%), sterilized pond sediment (5%)



A. To influent bucket of filtered water from Spring 3, with average nitrate value of 7.0 mg/L NO_3-N.
B. Peristaltic pump with 4 channels providing constant flow of 4 mL/min to bottom of pipes.
C. Pipe Influent
D. Pipe Cross Section
   i. Mesh Screen
   ii. Steel Wool
   iii. Carbon Media
E. Effluent collected from tubing at top of each pipe into collection beaker.

Results:

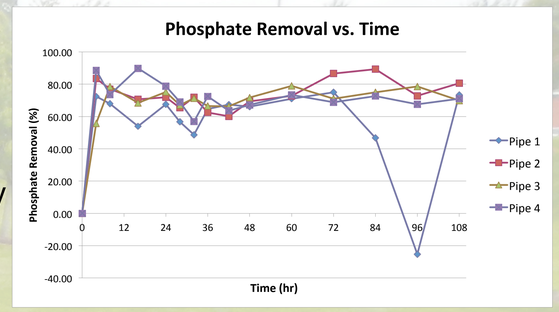
- Nitrate removal of all pipes settled between 85.8% and 91.6% after 108 hours of testing.
- Inoculated pipes more quickly reached nitrate removal equilibrium.

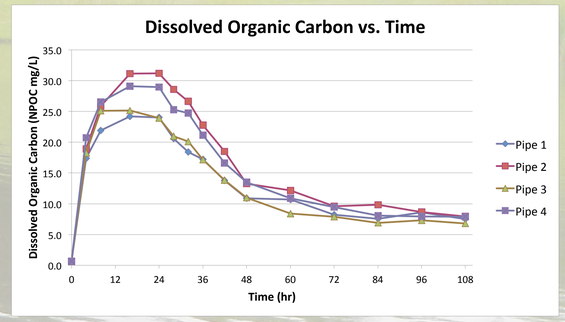


- Biochar systems saw suppressed nitrate removal efficiency compared to the woodchip systems.

Results continued:

- Biochar systems saw slight improvement in phosphate removal efficiency relative to woodchip systems.





- After initial peak, carbon losses decreased significantly in all systems.
- Marked increases of carbon in effluent were correlated with biochar systems.

Conclusions

- Inoculation with biologically active pond sediment decreases time required for systems to reach equilibrium nitrate removal rate due to denitrification from existing bacterial populations.
- Addition of biochar increases the time required to reach equilibrium nitrate removal. Physical adsorption of phosphate to biochar increased removal efficiency notably.
- Inconsistencies and a singular negative removal efficiency of phosphorus in Pipe 1 require further investigation.
- Future research should include spiking of phosphorus samples to improve measurability, quantification of greenhouse gas emissions, and long-term efficiency testing.

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References

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