Transforming denitrifying bioreactor research and applications: unveiling the inside of the blackbox

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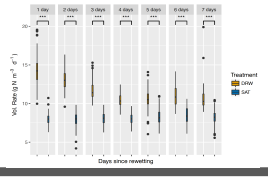
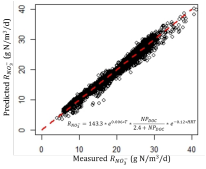
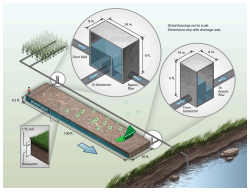
0. Highlights and impacts

- Wetting and drying cycles stimulate N removal and can be used as a practice to maintain nitrate removal efficiencies in denitrification bioreactors
- Replicated high frequency measurements provide fantastic insights on kinetics and internal functioning of bioreactors.





1. Background



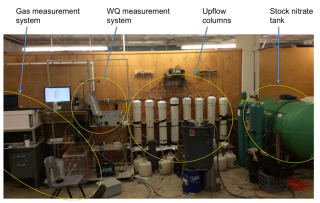
- Bioreactors hold great promise to lower the aqueous N emissions, particularly from agriculture
- Very empirical approaches until now for study and management
- Need for finding 'rejuvenation' techniques to maintain removal efficiencies
- Need for having process-based model to explore new maintenance and design

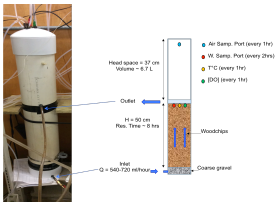
2. Objectives

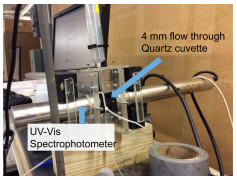
- Describe and quantify the fate of water and N and C inside denitrification beds
- Quantify and model N and C removals and emissions in aqueous and gaseous phases
- Find whether wetting/drying cycles can rejuvinate denitrification bioreactors
- Explore and define novel and optimized design and management guidelines for bioreactors

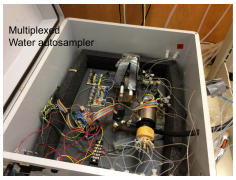
3. Approach - lab

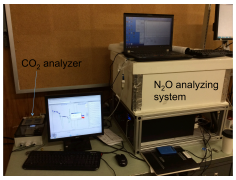
- Experiment to show whether or not wetting and drying cycles can 'rejuvenate' bioreactors to maintain their nitrate removal efficiencies
- High frequency and replicated measurements of $[NO_3^-]$, [DOC], T°C, DO, CO_2, N_2O
- Columns fed with ~15 mg N/L with nitrate
- 8-hr residence time
- 4 columns kept saturated
- 4 columns drained for 8 hours
- 300-day experiment







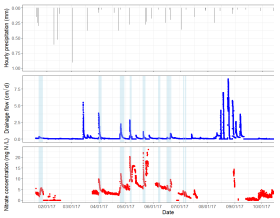




4. Approach - Field

- Capture in space and in time the nitrate concentration variations associated with rainfall events and along bioreactors
- Long term (~months) and short-term experiments
- High frequency measurements of $[NO_3^-]$ and [DOC] at inlet, within, and outlet of NC, IA and NZ bioreactors
- Our system can capture the extreme variability in the field of nitrate and DOC concentrations

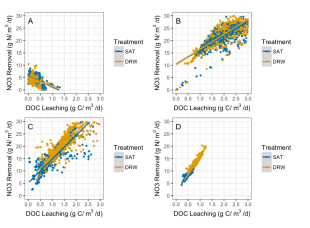
Field setup for Plymouth Bioreactors, NC



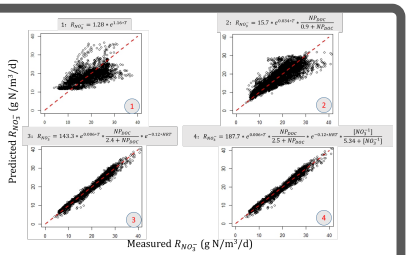
Rainfall, Flow and Nitrate conc. at the inlet of one field bioreactor (Plymouth, NC)

5. Preliminary results from lab measurements

- Nitrate removal rates (R_{NO3}) are highly correlated to DOC net prod. *(NP)*, which are stimulated by drying cycles
- Kinetics were developed for modeling nitrate removal rate in column studies
- NP_{DOC}, temperature, and hydraulic retention time explain 99% of variations of nitrate removal rates



N removal as a function of DOC production (column study)



Four levels of kinetics of simulating nitrate removal rates ($R_{NO_3^-}$) based on temperature (T), net production of DOC (NP_{DOC}), hydraulic retention time (HRT), and influent nitrate concentration ($[NO_3^-]$)