Effects of drying and rewetting cycles on denitrification and greenhouse gas emissions in saturated ligneous substrate

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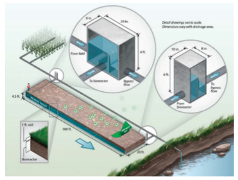
1. Background

- Woodchip bioreactors used to remove excess nitrate from drainage waters via denitrification by maintaining them **saturated**
- Hundreds slated to be installed in the field
- Decrease of nitrate removal efficiency within one to five years from >60% to <20%



Christianson and Helmers, 2011

2. Hypotheses

- We hypothesized that drying and rewetting cycles (DRW) could rejuvenate denitrification in these bioreactors
- Woodchip bioreactors could be seen as a nice **proxy model** to quantify microbial processes in saturated ligneous substrates **undergoing hydric cycle changes**

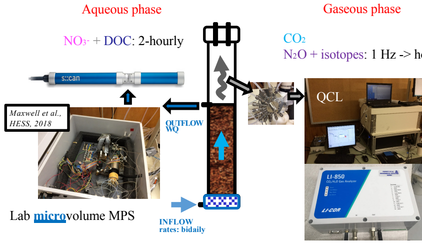
3. Objectives

- Quantify in the lab and in the field the aqueous and gaseous removals and emissions associated with DRW cycles
- Identify drivers using modeling and the microbial pathways using isotopic signatures

4. Methods: instrumentation

- 8 woodchip-filled columns
- 50 cm of saturated woodchip
- Continuous upflow (~8 hr HRT) for 297 days + 105 days
- $[NO_3^-]_{in}$ ~20 mg N/L

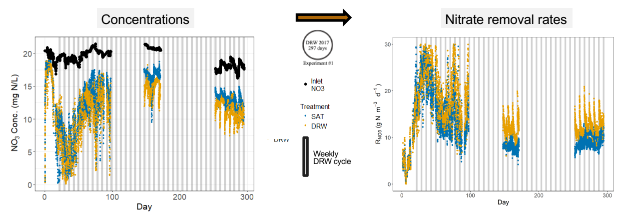
- Use **high resolution instruments** to measure gaseous and aqueous concentrations and removal/emission rates



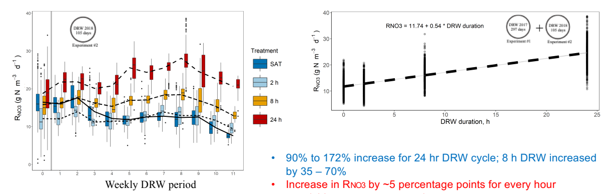
5. Methods: two complementary experiments

- Control: continuously saturated woodchips
- Treatment: weekly unsaturation or DRW cycles lasting 2h, 8h, or 24h

6. Results: DRW cycles enhance denitrification rates

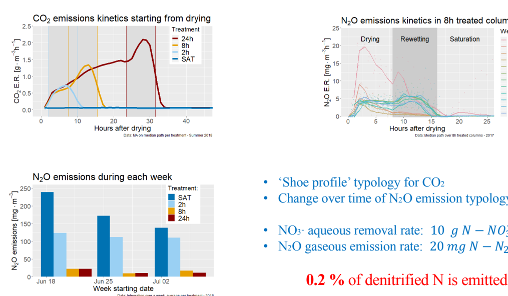


Thousands of removal rate values calculated over ~ 400 experimental days



- 90% to 172% increase for 24 hr DRW cycle; 8 h DRW increased by 35 – 70%
- Increase in R_{NO3} by ~5 percentage points for every hour woodchips were unsaturated

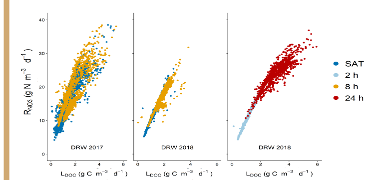
7. DRW cycles enhance respiration and decrease N_2O emissions



- 'Shoe profile' typology for CO_2
- Change over time of N_2O emission typology
- NO_3^- aqueous removal rate: $10\ g\,N - NO_3^-/m^3/day$
- N_2O gaseous emission rate: $20\ mg\,N - N_2O/m^3/day$

0.2 % of denitrified N is emitted as N_2O

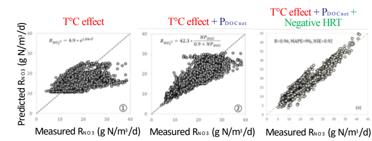
8. DOC, T°C and HRT as main drivers for denitrification



- DOC leaching rates (L_{DOC}) stimulated nitrate removal rates (R_{NO3})
- Non-linear for 24h treatment

- Step modeling approach: **phenolics as inhibitors?**

$$R_{NO_3^-} = R_{ref} * e^{k_{Tem} * \frac{Tem - 10}{10}} * \frac{L_{DOC}}{L_{DOC} + K_{DOC}} * e^{k_{HRT} * (HRT - 8)}$$

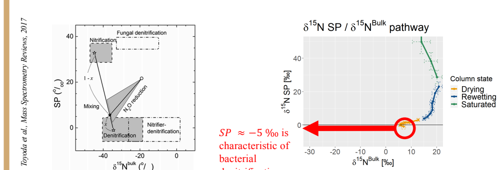


9. Isotopes reveal microbial adjustment to DRW cycles

$^{15}N^{\alpha} = {}^{14}N^{15}N^{16}O$ $\quad$ $^{15}N^{\beta} = {}^{15}N^{14}N^{16}O$

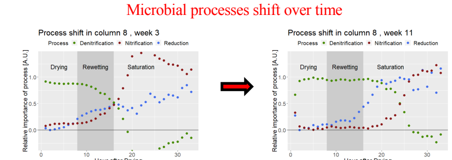
- Bulk ratio: $\delta^{15}N^{bulk} = \frac{\delta^{15}N^{\alpha} + \delta^{15}N^{\beta}}{2}$
- Site preference $^{15}N\ SP = \delta^{15}N^{\alpha} - \delta^{15}N^{\beta}$

N_2O isotopomers α and β



$SP \approx -5$ ‰ is characteristic of bacterial denitrification

Microbial processes shift over time



10. Conclusions

- DRW cycles largely increase respiration and lower N_2O emissions
- Microbial pathway tend to indicate an adaptation of the microbial population in treated columns
- Role of phenolics for respiration in these saturated systems?