Nutrient Mitigation And Changes In Hydraulic Parameters Caused By Two Helophyte Species

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1. Background and Objective

Helophytes have been employed in river restoration and in constructed wetlands, for bank stabilization and wastewater treatment[1,2]. Motivated by the concept of aquatic plants as biological engineers[3], we investigated the influence of helophytes *Scirpus lacustris* L. and *Phragmites australis* L. on solute transport and nutrient retention along subsurface flowpaths.

We hypothesize that helophytes affect:

a) solute transport, by modifying the structure of the sediment with their root system, and

b) nutrient retention, because their rhizosphere favors the development of microbial assemblages that take up nutrients from subsurface water.

2. Experimental set-up

- **Urban River Lab (URL)** facility in Barcelona, Spain. (www.urbanriverlab.com)
- 9 flow-through stream mesocosms (flumes)
  L: 12 m, W: 60 cm, H: 40 cm
- End-to-end gravel bed of 25 cm depth
- Receiving treated wastewater
- Subsurface flow, Q~5 L/min
- 3 treatments (3 replicates/treatment):
  - ***i. Scirpus lacustris* L.**
  - ***ii. Phragmites australis* L.**
  - **iii. Unvegetated (Control)**

3a. Methods: Solute transport modeling

Fractional advection-dispersion model[4]

Temporally tempered Levý motion: imposes an exponential cutoff to power-law waiting times in the immobile zone

+

FRACFIT:
Parameter estimation tool, using a weighted nonlinear least squares algorithm[5]

3b. Methods: Solute tracer injections

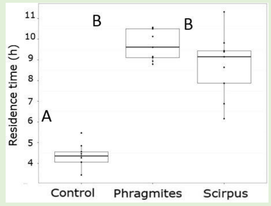
Pulse injections per flume:

- 3 conservative tracer (Cl^-) injections
- one of them coinjected with NH_4^+ and PO_4^{-3}

Collected data from flumes' inlet and outlet:

- Continuous measurements of EC, DO
- Samples over time analyzed for: NH_4^+, PO_4^{-3}, NO_3^-, NO_2^-

4a. Results: Solute transport



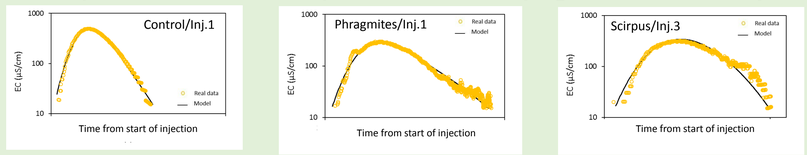
Comparison with ANOVA/Tukey's test, α =0.05

Water residence time (WRT):
Elapsed time from the start of the injection until the last detection of the tracer using Cl^- breakthrough curves.

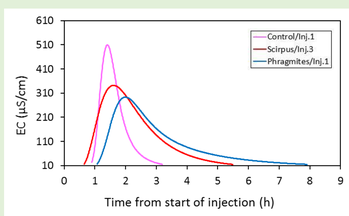
Longer WRT in vegetated treatments compared to unvegetated ones.

Preliminary results of solute transport modeling

Examples of model fits per treatment (logarithmic scale):



Examples of model outputs per treatment (linear scale):

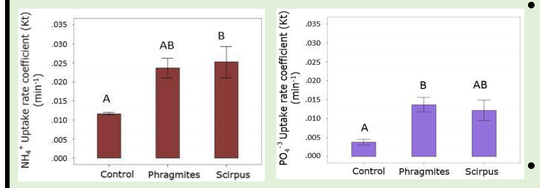


Model outputs illustrate differences in hydraulic parameters other than WRT.

Treatment/BTC	Time-fractional exponent: γ	Average plume velocity: u (m/s)	Capacity coef.: β ($s^{\gamma-1}$)	Fractional dispersivity: D (m^2/s^{γ})	Tempering rate: λ (s^{-1})
Control/Inj.1	0.255	0.00247	0.00254	0.0004	0.00032
Phragmites/Inj.1	0.100	0.00180	0.00180	0.0006	0.00008
Sciprus/Inj.3	0.206	0.00210	0.00290	0.0015	0.00020

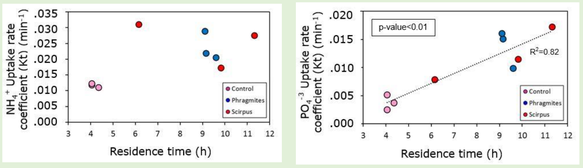
β: long-term ratio of immobile versus mobile particles
λ: governs the transition from anomalous to Fickian transport, by putting an exponential cutoff to the power-law waiting times.

4b. Results: Nutrient retention



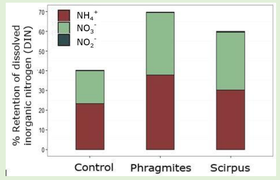
Means and standard errors per treatment. Statistical comparison with ANOVA/Tukey's test, α=0.05

- Higher K_t for both NH_4^+ and PO_4^{-3} in vegetated flumes compared to unvegetated ones.
- K_t for NH_4^+ > Kt for PO_4^{-3} in all flumes.

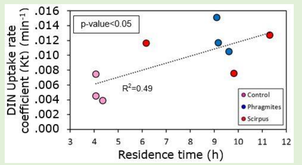


Relationship of Kt for NH_4^+ and PO_4^{-3} with residence time. α=0.05

Linear relationship between residence time and Kt for PO_4^{-3} but not for NH_4^+



Similar contribution of NH_4^+ and NO_3^- retention to total DIN retention in all flumes.



Linear relationship between residence time and Kt for DIN

Relationship of Kt for DIN with residence time. α=0.05

5. Findings and Conclusions

- Helophytes influence hydraulic parameters of solute transport, and their presence results in increased water residence times.
- Flumes with helophytes demonstrate increased nutrient retention in comparison to unvegetated ones.
- Increase in nutrient retention in the vegetated flumes seems to respond to increase in water residence time, with stronger relationship with PO_4^{-3} (R^2=0.80) than with DIN retention (R^2= 0.49).

Bibliography: [1] Bernhardt et al., 2005, Ecology, [2] Vymazal, 2011, Hydrobiologia, [3] Sand-Jensen, 1998, Freshwater Biology, [4] Meerschaert et al., 2008, Geophysical Research Letters, [5] Kelly et al., in press, Water Resources Research.

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