Evaluation of

Passive Reduction of Salts and Nitrate from Greenhouse Effluent by Planted Bioreactors

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Greenhouse Effluent

- High levels of nutrients: nitrate.
- Low organic content.

- Untreated discharge:
  - Eutrophication and hypoxia in waters.
  - Health hazard of high nitrate in drinking water.
  - Ontario: Greenhouse Nutrient Feedwater regulation (effective 2015).

- Recirculation and reuse:
  - Lower yield and crop damage caused by salt accumulation.
  - Phytodesalination results in: Fatehi Pouladi et al. 2016:
    - Softstem bulrush: average 7% (max 15%) EC reduction and Na/Cl accumulation.

Woodchip Bioreactors

- On-site treatment of agricultural tile drainage.

- Nutrient reduction strategies along Mississippi river in USA.

- Heterotrophic denitrification by facultative organisms using carbon source.

- Absence of oxygen: NO_3^- reduction → NO_2^- → NO → N_2O → N_2

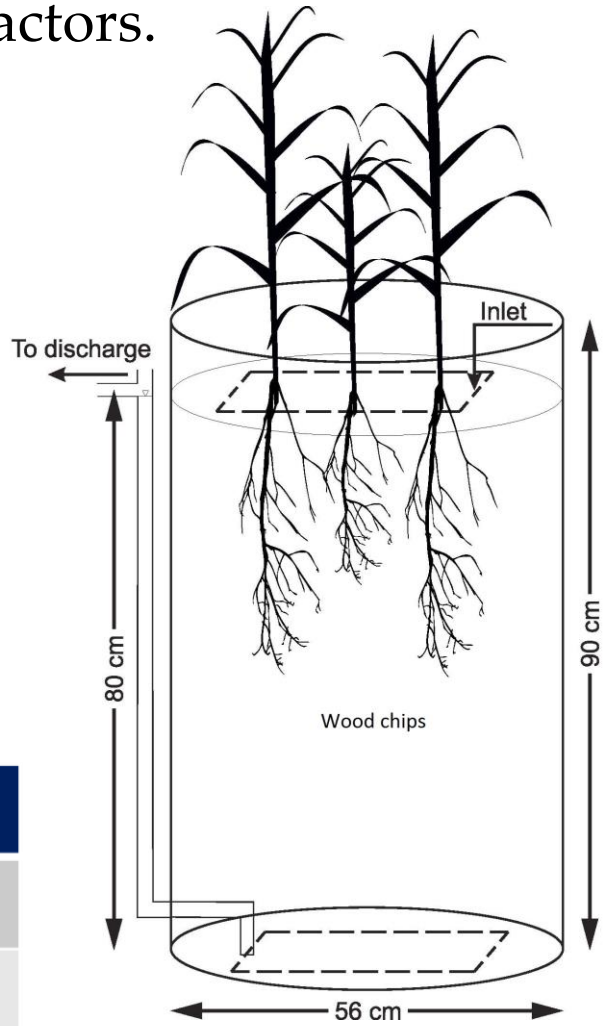
Research Gap & Questions

- Very few studies available on greenhouse effluent.
- Can VF hydraulics provide anaerobic conditions?
- Effects of vegetation on the performance?
- Effects of high and low influent nitrate concentrations?

Experiments – Bioreactors

- Vegetated and control (unplanted) 220-L reactors.
  - Gravel (9.5 mm)
  - Woodchips (2-3 cm)
- 30 L day^{-1} cont. VF (top-bottom)
  HRT: 3.7 days
- Fed by synthetic greenhouse discharge.
- 2 levels of influent loading in woodchip experiment:

Influent (mg L^{-1})	NO_3-N	NH_3-N	PO_4-P	SO_4-S
High Loading	307	8	26	131
Low Loading	202	5.5	16	130



Experiments – Plant Species

- Softstem bulrush (*Schoenoplectus tabernaemontani*)
- Big bluestem (*Andropogon gerardii*)
- Narrowleaf cattail (*Typha angustifolia*
- Canada wildrye (*Elymus canadensis*
- Switchgrass (*Panicum virgatum*
- Prairie cordgrass (*Spartina*)
- Saltgrass (*Distichlis spicata*)

Experiments – Timeline

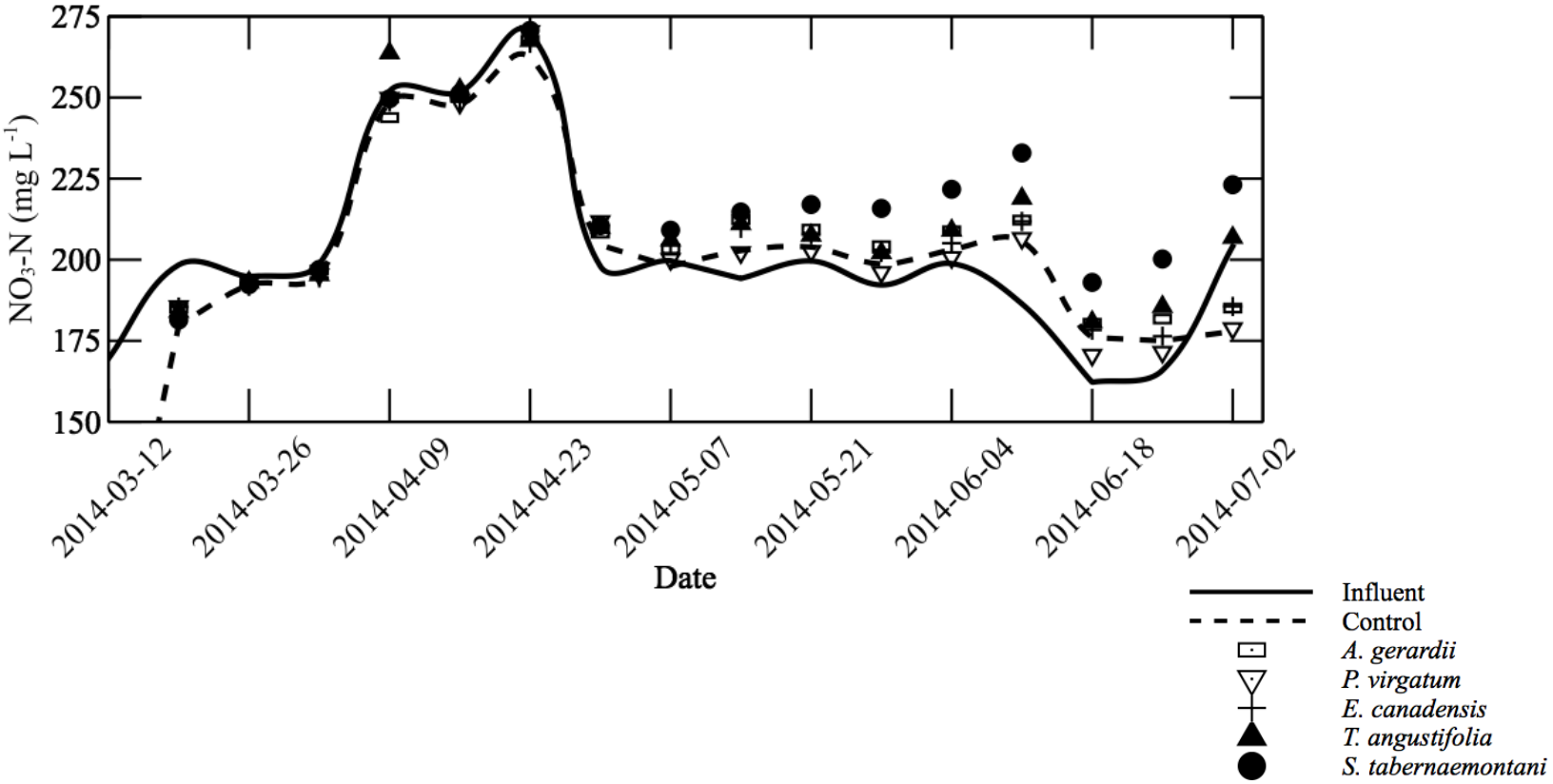
				Operated reactors							
Reactor type	Phase	Operation period		S. tabernaemontani	A. gerardii	T. angustifolia	E. canadensis	P. virgatum	S. pectinata	D. spicata	Control
		From	To								
Gravel	-	Mar 2014	Jul 2014	X	X	X	X	X	--	--	X
Wood-chip HL[1]	Phase 1	Oct 2014	Apr 2015	X	--	X	X	X	--	--	X
	Interim	Apr 2015	Jun 2015	X	--	X	--	--	--	--	X
	Phase 2	Jun 2015	Oct 2015	X	--	X	--	--	X	X	X
Wood-chip LL[2]	-	Oct 2015	May 2016	X	--	X	--	--	X	X	X
[1]High Loading, [2]Low Loading											

X Planted reactor in use.
-- Planted reactor not in use.

Woodchip Bioreactors

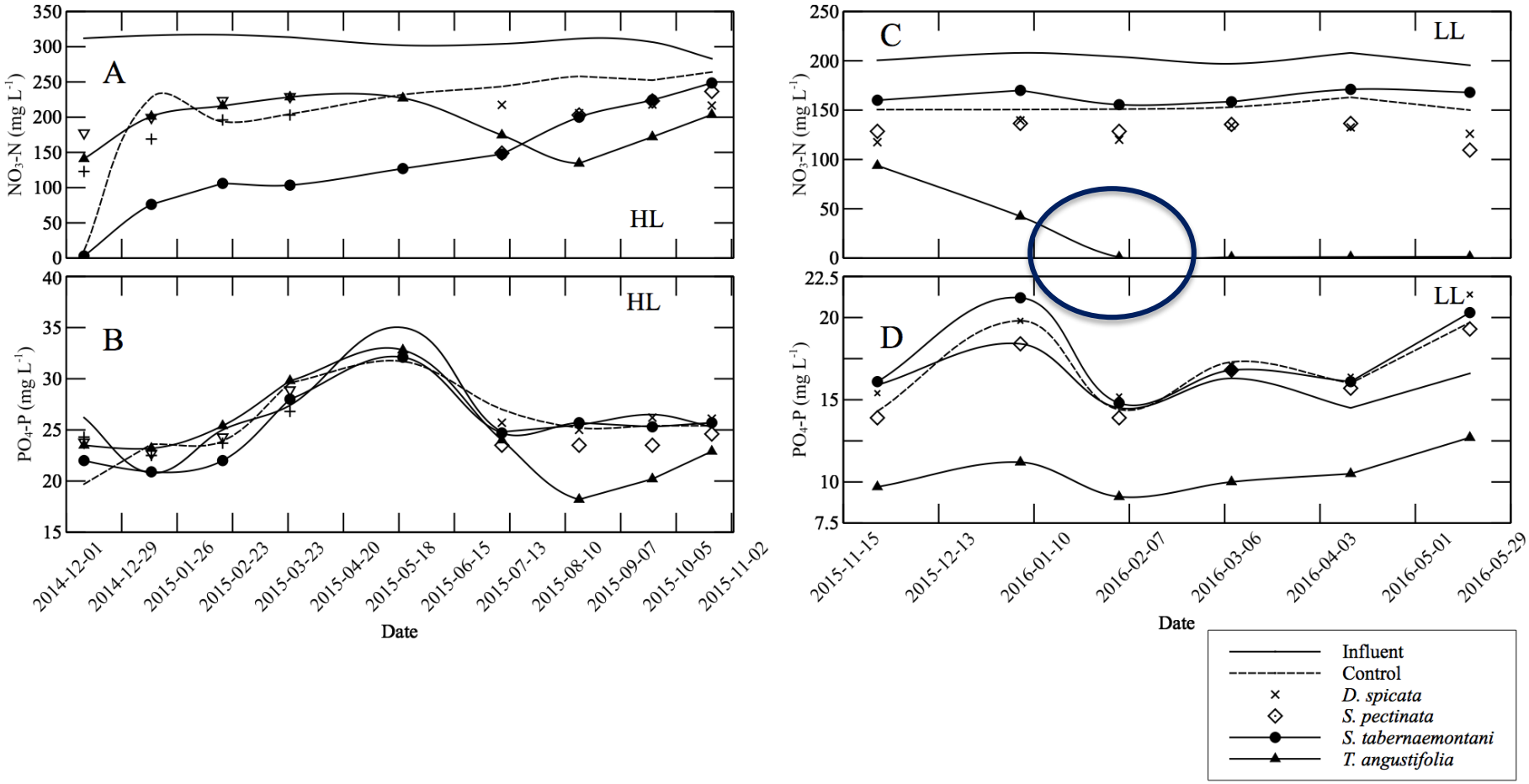
Results - Gravel Bioreactors

- No nitrate reduction.
- Limited organic carbon in outflow (BOD_5<17 mg L^{-1}).



Results - Woodchip Bioreactors

- High Loading (left); Low Loading (right)

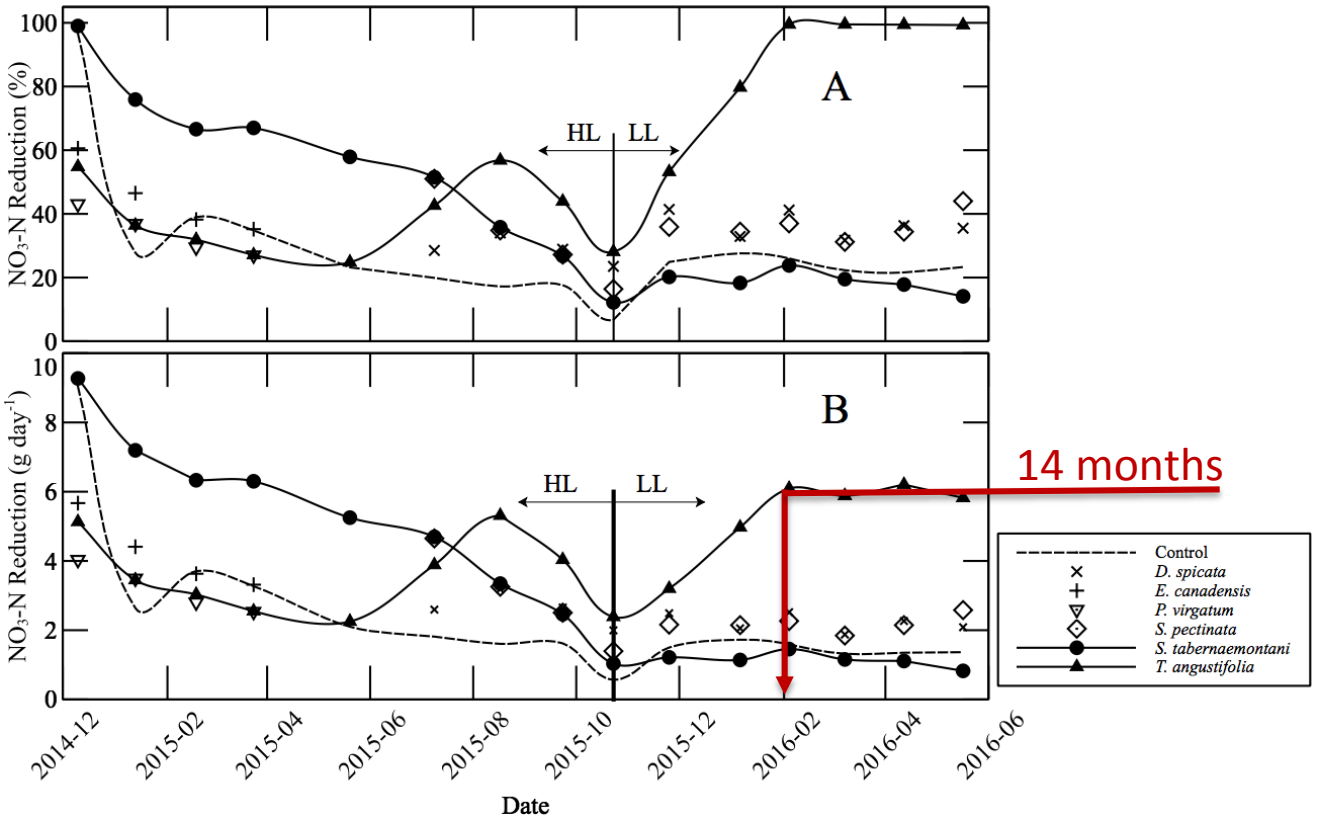


Results - Woodchip Bioreactors

- Nitrate was limiting factor in cattail (*T. angustifolia)* reactor:
  - 14 months after operation started
  - 3 months after reduction in loading

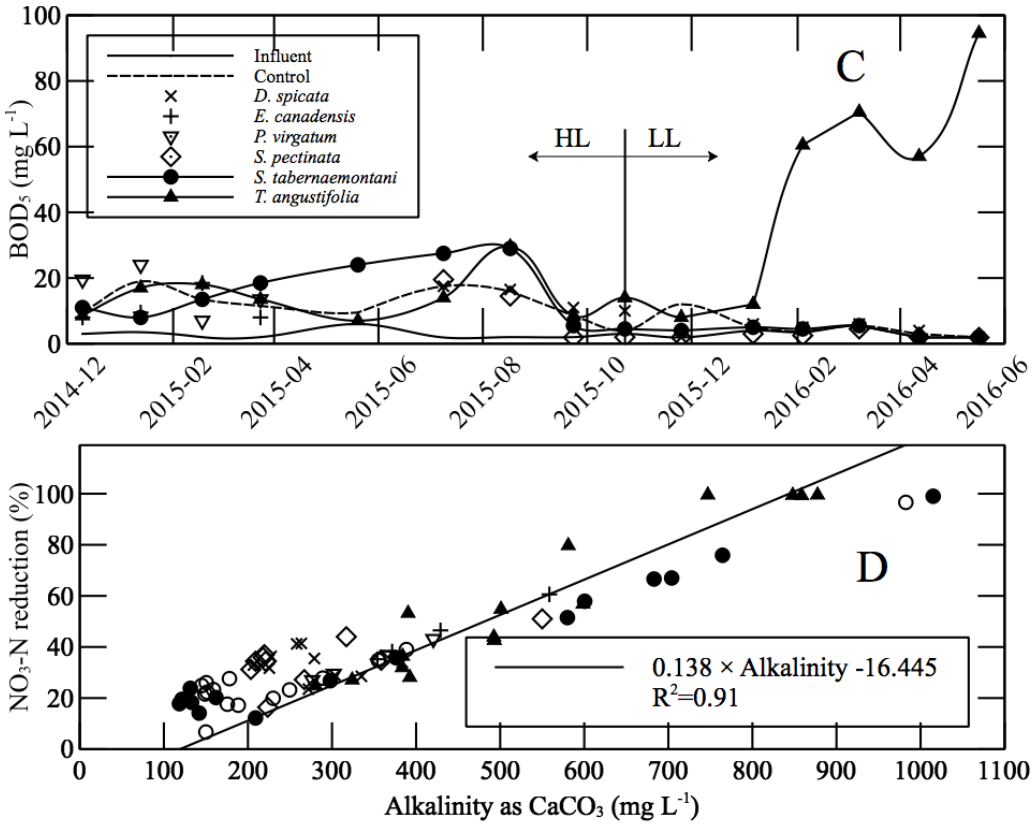
- Nitrate removal
  - HL: 30.2 % – 55.3 %
  - LL: 19.0 % - 88.4 %

- O-phosphate removal
  - HL: 1.9 % - 9.2 %
  - LL: 0 - 34.4 %



Results - Woodchip Bioreactors

- Higher organic carbon resulted in higher denitrification.
- Potential breakdown of woodchips via organisms.



Results - Woodchip Bioreactors

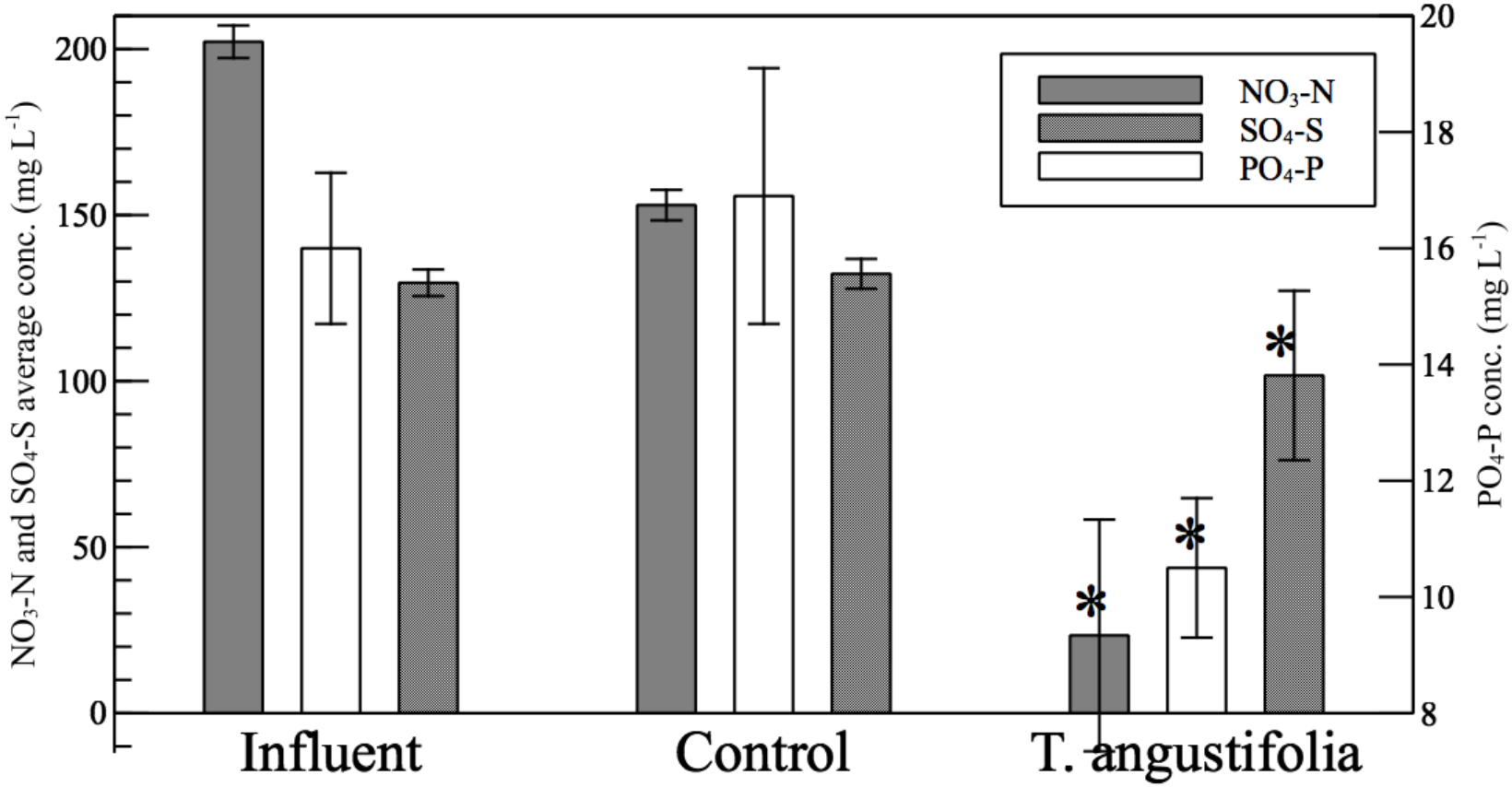
- Low Loading

Parameter (unit)		Control	S. taber.	S. pectinata	D. spicata	T. angustifolia
NO_3-N (mg L^{-1})	Red.	24.3 %	19.0 %	36.1 %	36.5 %	**88.4 % ***
NO_2-N (mg L^{-1})	Red.	--	8.3 %	8.3 %	16.7 %	**8.3 %**
NH_3-N (mg L^{-1}	Red.	90.9 %	83.6 %	100.0 %	96.4 %	**20.0 % ***
TKN (mg L^{-1})	Red.	72.7 %	69.7 %	78.8 %	66.7 %	**--**
PO_4-P (mg L^{-1})	Red.	--	--	--	--	**34.4 % ***
SO_4-S (mg L^{-1})	Red.	--	--	--	--	**21.5 % ***
BOD_5 (mg L^{-1})	Out	5.2 [3.3]	3.8 [1.4]	2.6 [0.9]	4.1 [1.7]	**50.4 [31.0]***
COD (mg L^{-1})		30.5 [3.8]	36.6 [3.2]	24.5 [3.4]	51.6 [3.3]	**181.6 [77.0]***
pH		7.4 [0.0]	7.1 [0.1]*	7.5 [0.0]	7.3 [0.1]	**7.4 [0.1]**

*** Data with significant difference from the control reactor (p-value < 0.05).**

Results - Woodchip Bioreactors

- Cattail (*T. angustifolia*):



Summary

- *T. angustifolia* woodchip bioreactor: average nitrate removal: 22.5 g N m^{-3} day^{-1} (up to 99% treatment).
- System overloaded in High Loading and organic source limiting.
- Nitrate became the limiting factor in Low Loading.
- Potential development of organisms capable of decomposing wood.
- 21 % sulfate reduction. Caution: potential production of CH_3Hg^+.
- 34% P removal (plant uptake, other biological pathways).
- Additional treatment may be required for high BOD.

Future steps

- Analyze anaerobic microbial community using Community Level Physiological Profiling (CLPP).
- Quantify denitrifying genes (NirS, NirK) using qPCR.
- Apply woodchip cells in a pilot-scale CW.

Thank you!

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