Removing nitrate from tile drain water using denitrification bioreactors

Collaboration:

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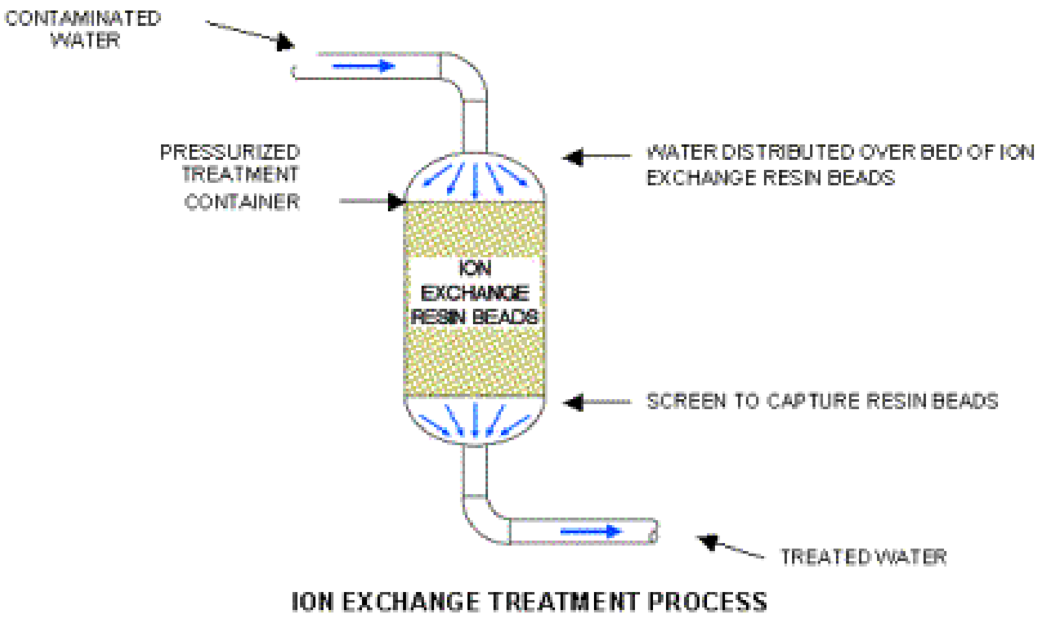
- **Cooperating growers**

Tile drains have high NO_3-N concentration, and can make up a substantial portion of surface flow during the irrigation season

How can NO_3-N be removed from tile drain water?

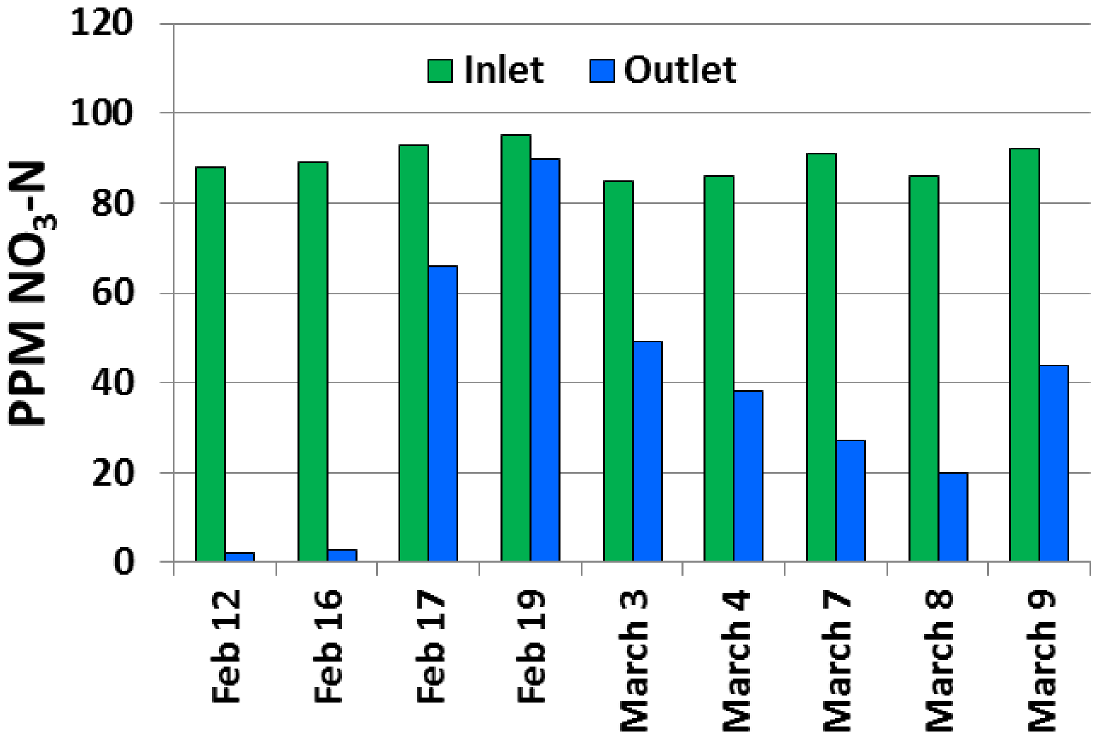
- Ion exchange
- Biological denitrification

Ion exchange for nitrate removal

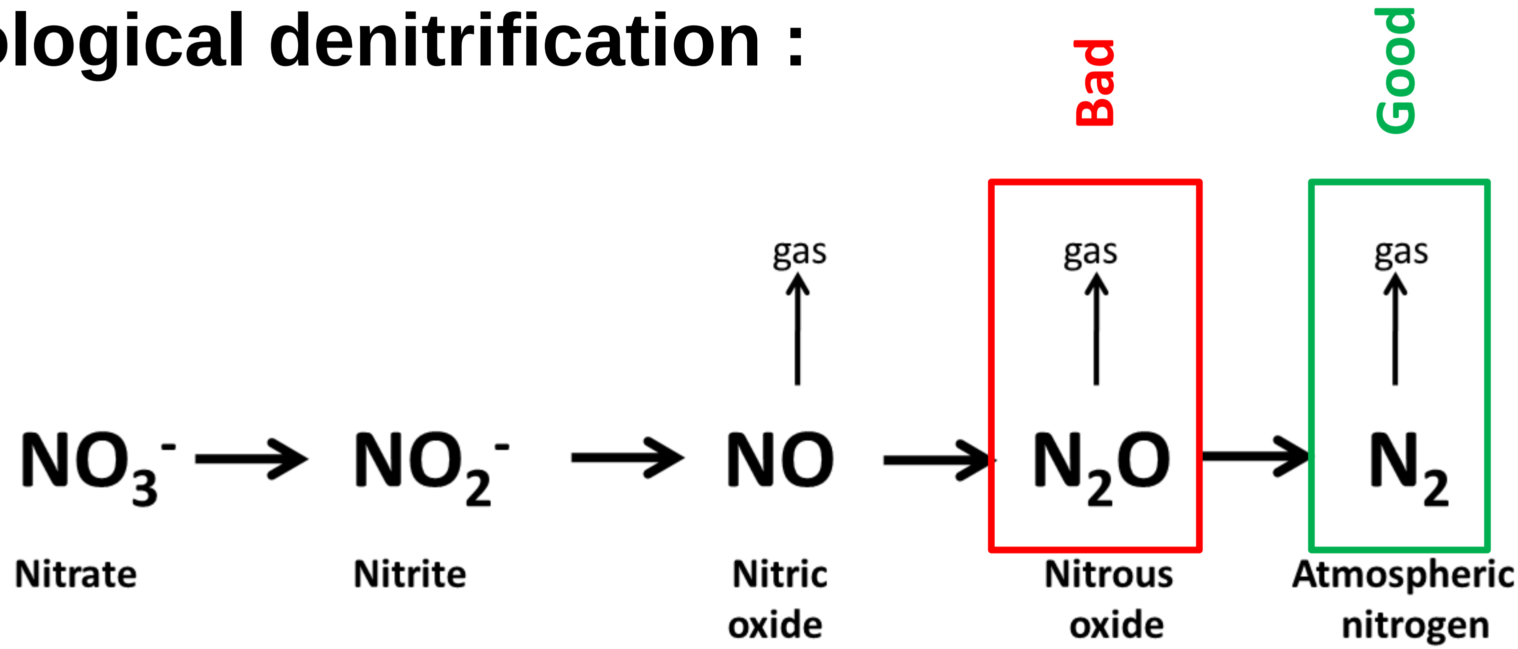


- **Captured NO_3-N can be reapplied as fertilizer**
- **High initial cost, complex operation and maintenance**

Recent performance:



Biological denitrification :



Requirements for denitrification:

- **Anaerobic conditions**
- **Bacteria capable of reducing NO_3-N**
- **Labile (microbially-available) carbon to support the reaction**

Salinas Valley wood chip denitrification bioreactors (DBRs) built in 2011:

chipped construction waste from Monterey Regional Waste Management District

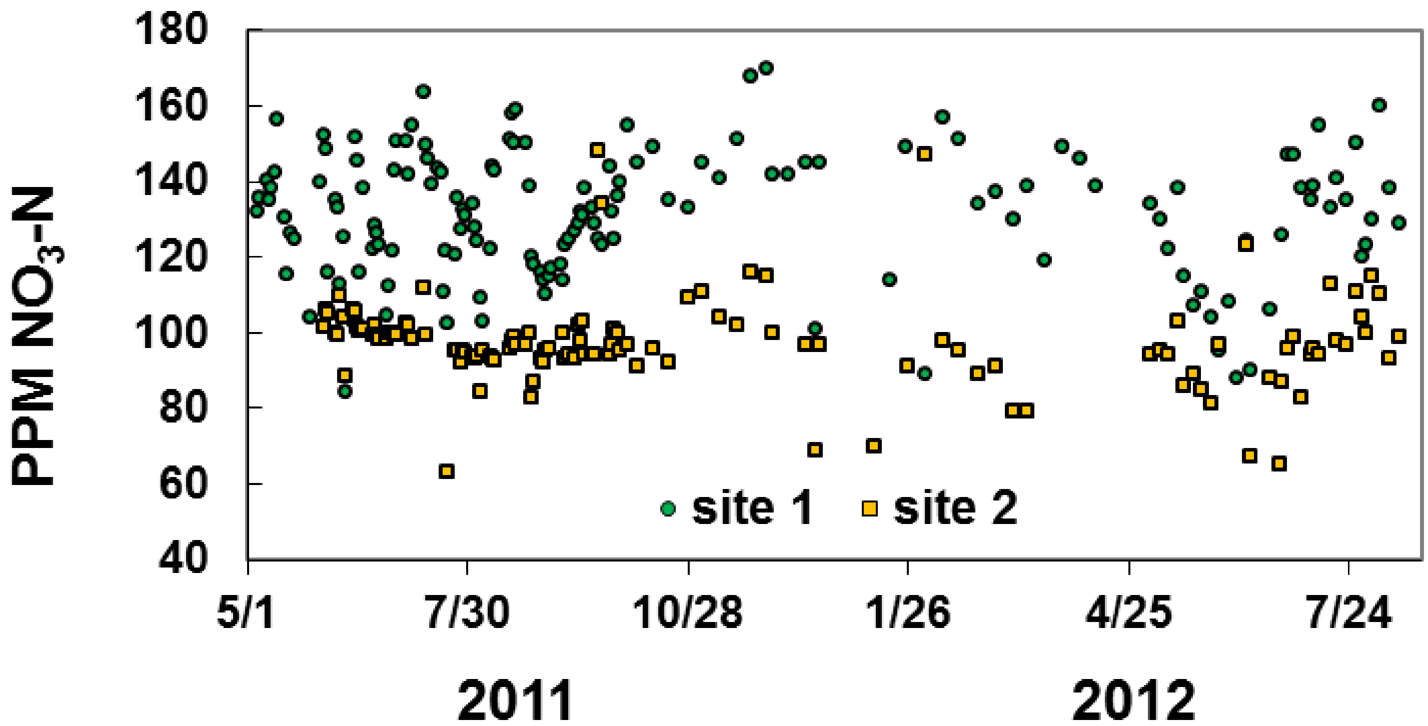
Bioreactor operation :

Continuous pumping into DBRs from the tile drain sump, at a rate to allow about 2 days of residence time

DBR outlet drains into surface ditch

Tile drain NO_3-N concentration is variable, but consistently high

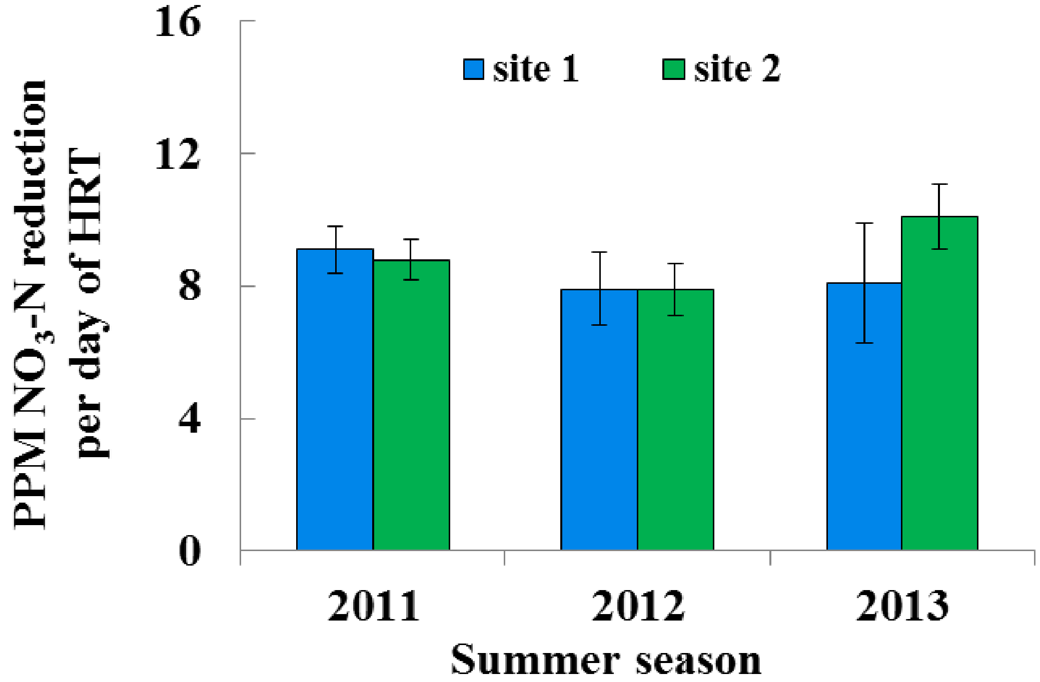
Pattern of NO_3-N in two tile drain systems in the Castroville area:



- **While improved on-farm irrigation and N management can reduce this high N load, consistently achieving < 50 PPM NO_3-N during the irrigation season is unlikely**

Mean denitrification rates achieved during the irrigation season was consistent across the initial years of operation:

- **PPM NO_3-N reduction *per day of residence time*:**



When operated in a 'passive' mode, this technology has significant limitations:

- **The DBR 'footprint' would need to be very large to come close to meeting environmental NO_3-N targets**
- **there is no effective way to handle fluctuations in N load**

Why the difference in performance compared to ‘managed’ systems, in which denitrification rates can reach 10 PPM NO_3-N *per hour* ?

- **‘Managed’ systems inject soluble carbon to speed the denitrification process**
  - **- methanol is commonly used**

2014:

Tested C injection in lab bioreactors:

- **Aged wood chips taken from field bioreactors**
- **Evaluated the effect of methanol enrichment on denitrification rate**

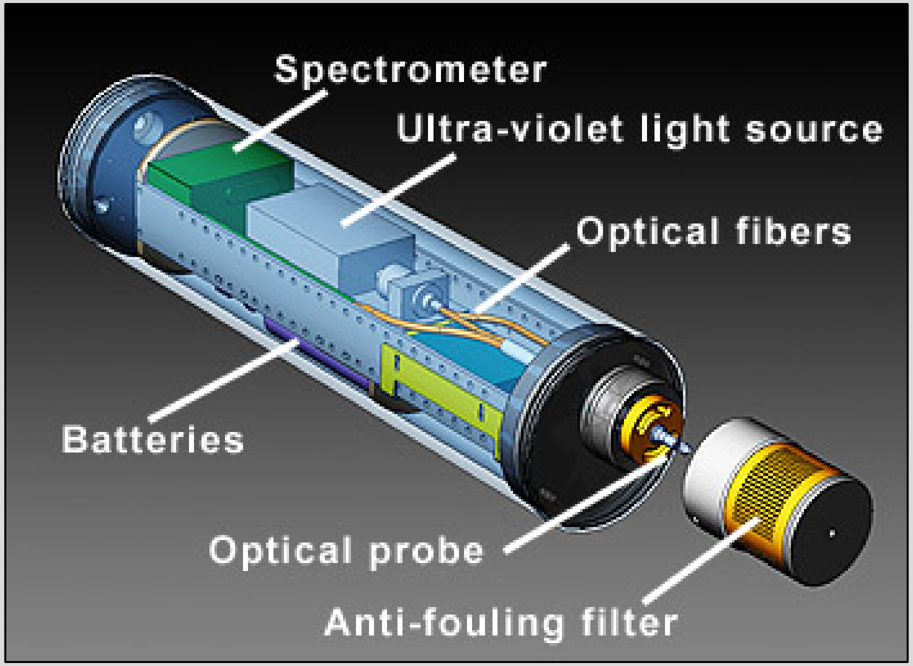
Results:

- **Regardless of NO_3-N concentration, methanol carbon injected at a ratio of 1.4 (w/w basis) completely denitrified NO_3-N in less than 2 days of residence time**

2015:

Optimizing field bioreactor management:

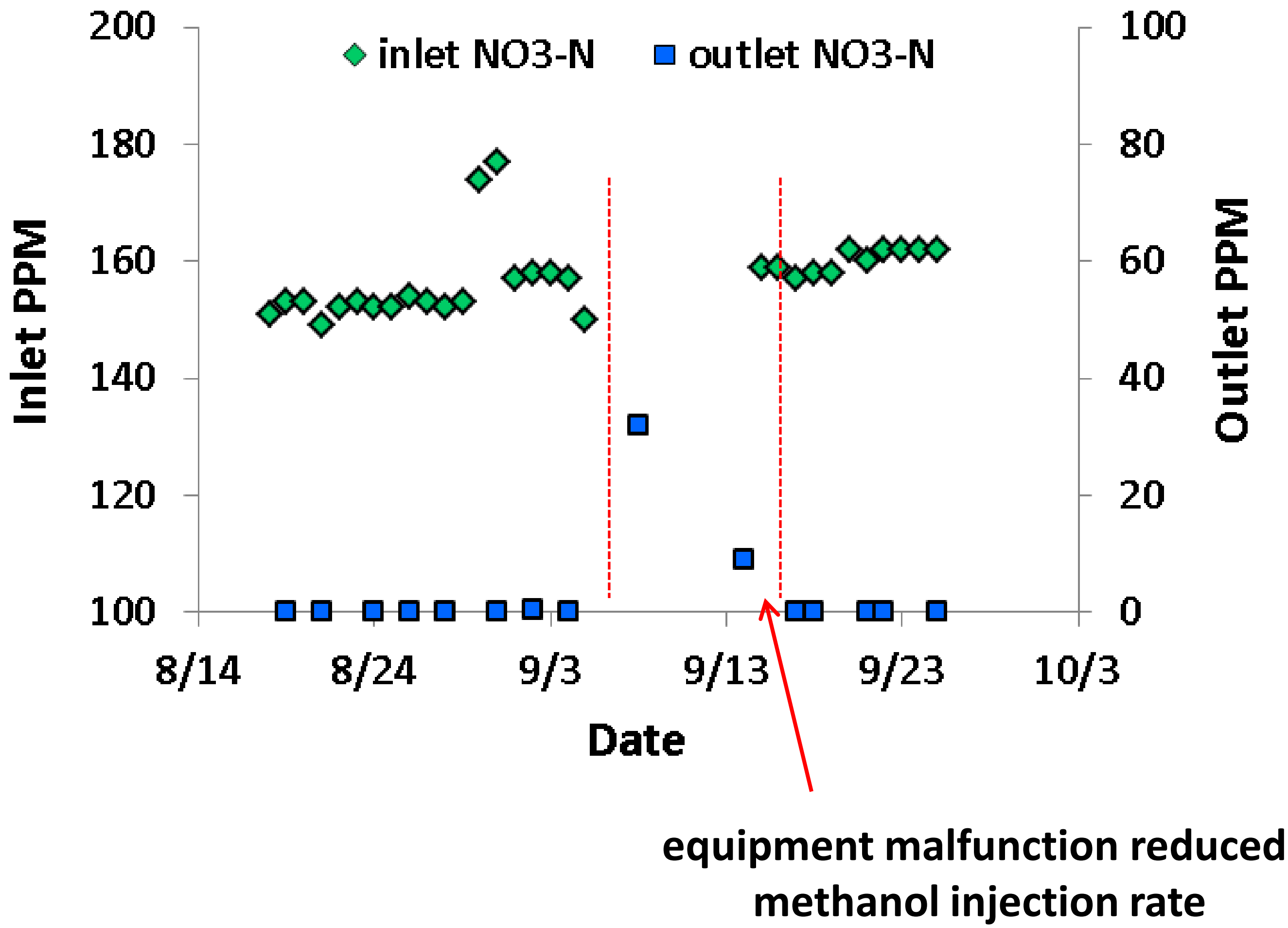
- **Continuously adjust carbon enrichment to the real-time NO_3-N load**



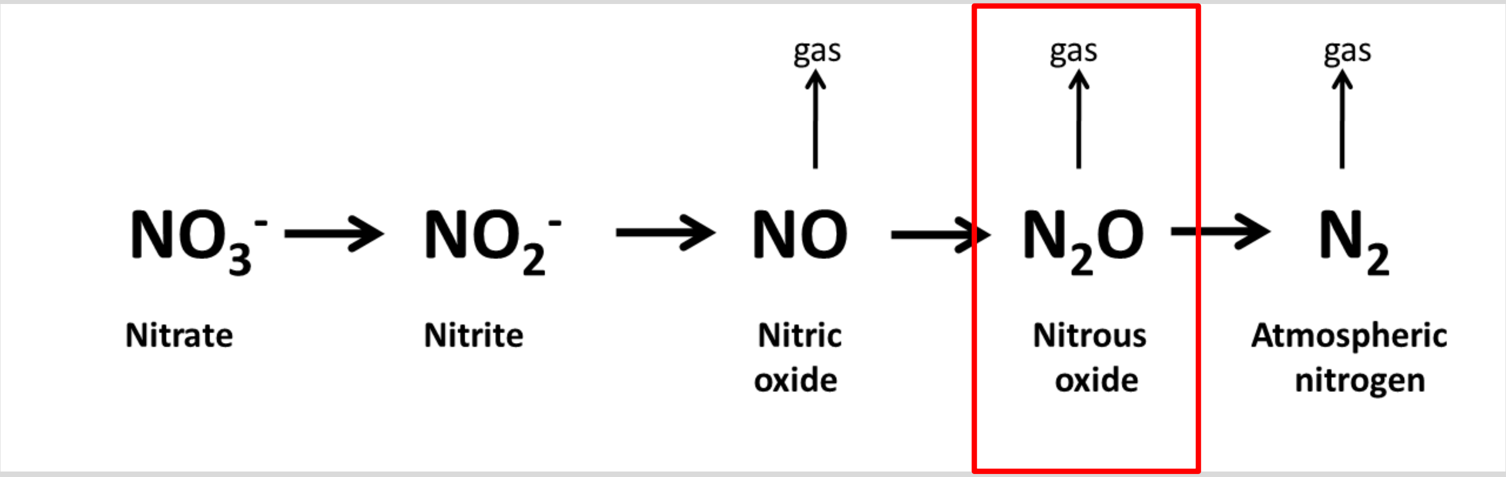
ISUS (in-situ ultraviolet spectrophotometer)

Results:

- **Injection ratio of ≈1.4 PPM C to 1 PPM NO_3-N gave complete nitrate removal in as little as 1.5 days of residence time**



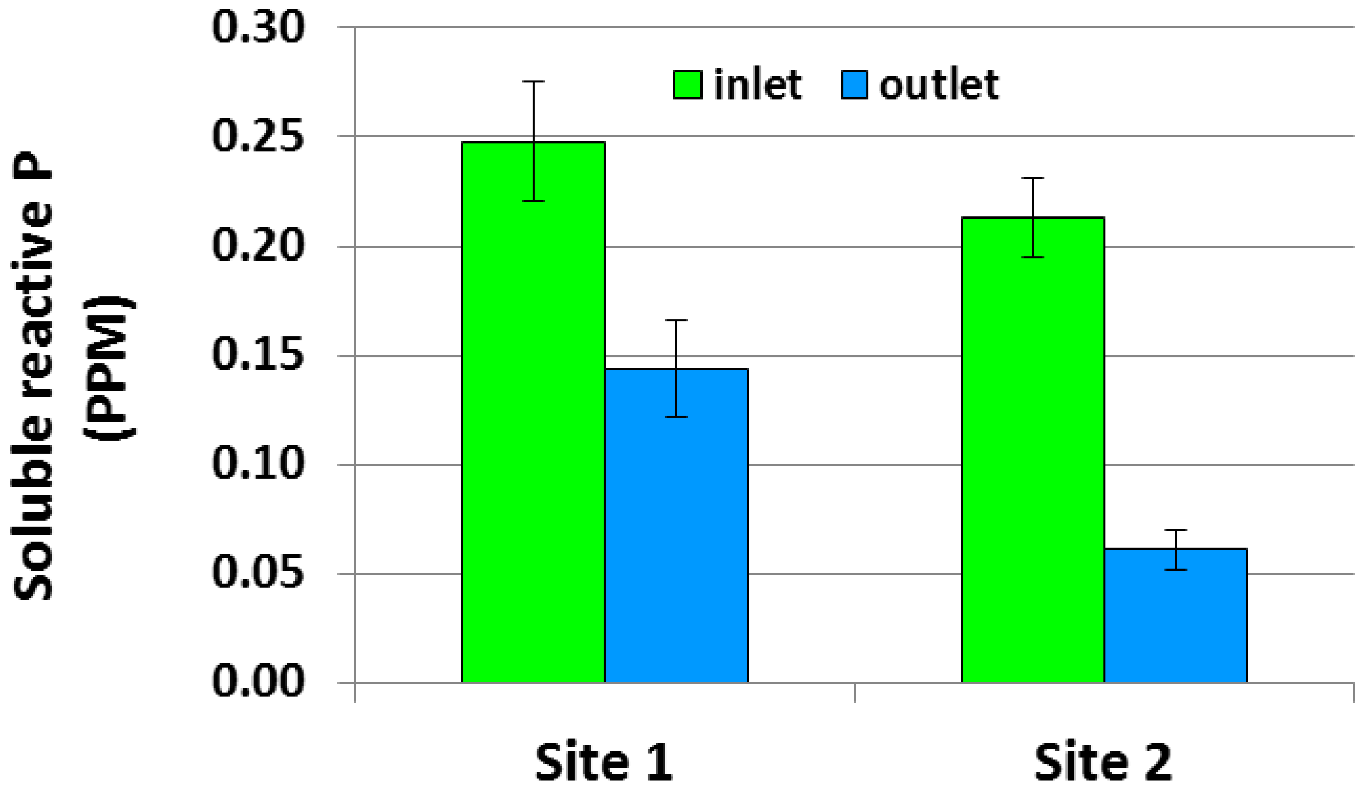
What about N_2O emission?



Dissolved N_2O release

	Dissolved N_2O release (% of N removed)
Unenriched, or insufficiently enriched	> 4%
Methanol enriched @ 1.4 C:N ratio	< 0.2%

Do bioreactors affect phosphorus concentration?



Bioreactor costs

Example:

- **ranch of 100 farmed acres**
- **35,000 gallons of tile drainage daily over 8 month irrigation season**
- **To retain 2 days of typical tile drain flow, a bioreactor would need to be about 100’ long x 20’ wide x 6’ deep**
- **methanol @ $1.00-1.30/lb C**

Cost:

- **≈ $1.50-1.80/lb NO_3-N denitrified, not including the NO_3-N sensor/C injection system (about $20K)**

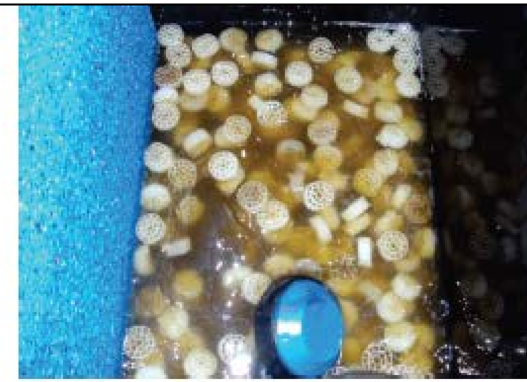
Conclusions:

- Passively operated bioreactors are severely limited:
  - overwhelmed by high inlet NO_3-N concentration
  - inflexible in the face of highly fluctuating N loads
- Controlling sediment is difficult in surface water treatment
- Carbon enrichment improves performance, but brings other issues
  - added up-front cost
  - chemical storage / permitting
  - requires active management


Could remediation technologies be combined?
Could they be deployed on a regional scale?

More intensive denitrification approaches?

- **Modular treatment systems**



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