IAEA-CN-191-42

Denitrifying Bioreactors: Opportunities and Challenges for Managing Offsite Nitrogen Losses

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FAO/IAEA Int'l Symposium on Managing Soils for Food Security and Climate Change Adaptation and Mitigation

Vienna, Austria
July 24, 2012

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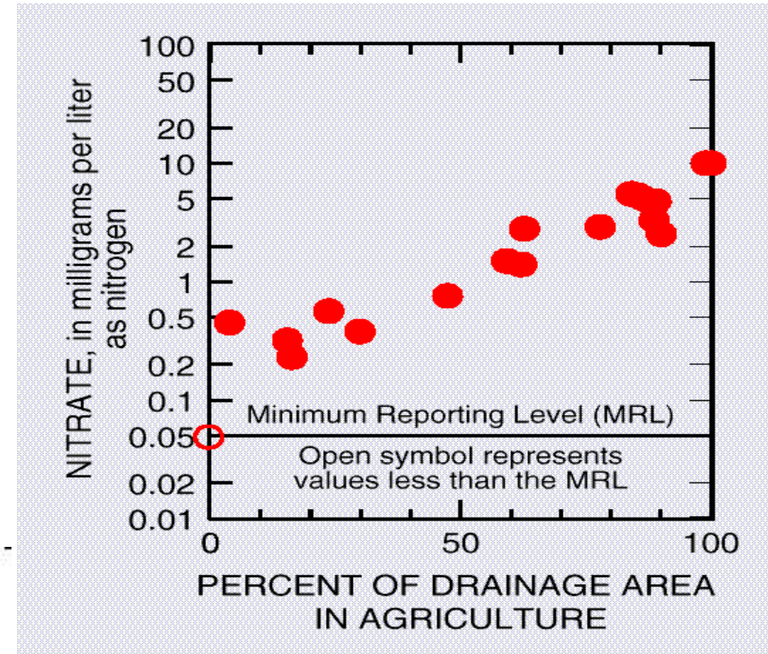
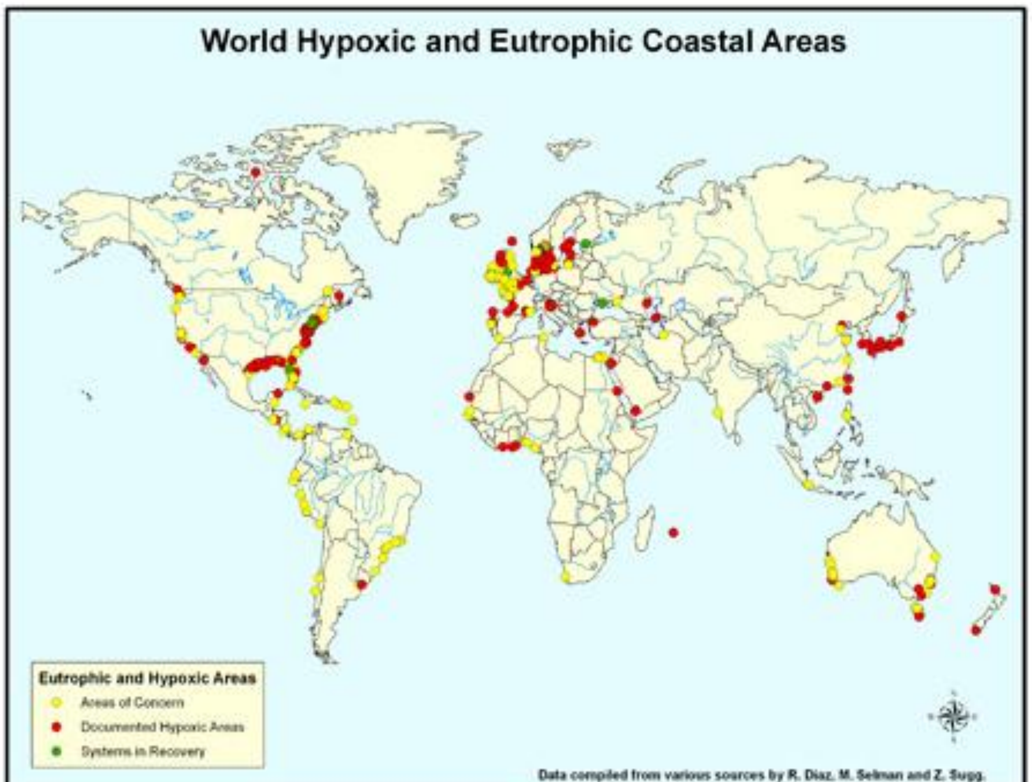




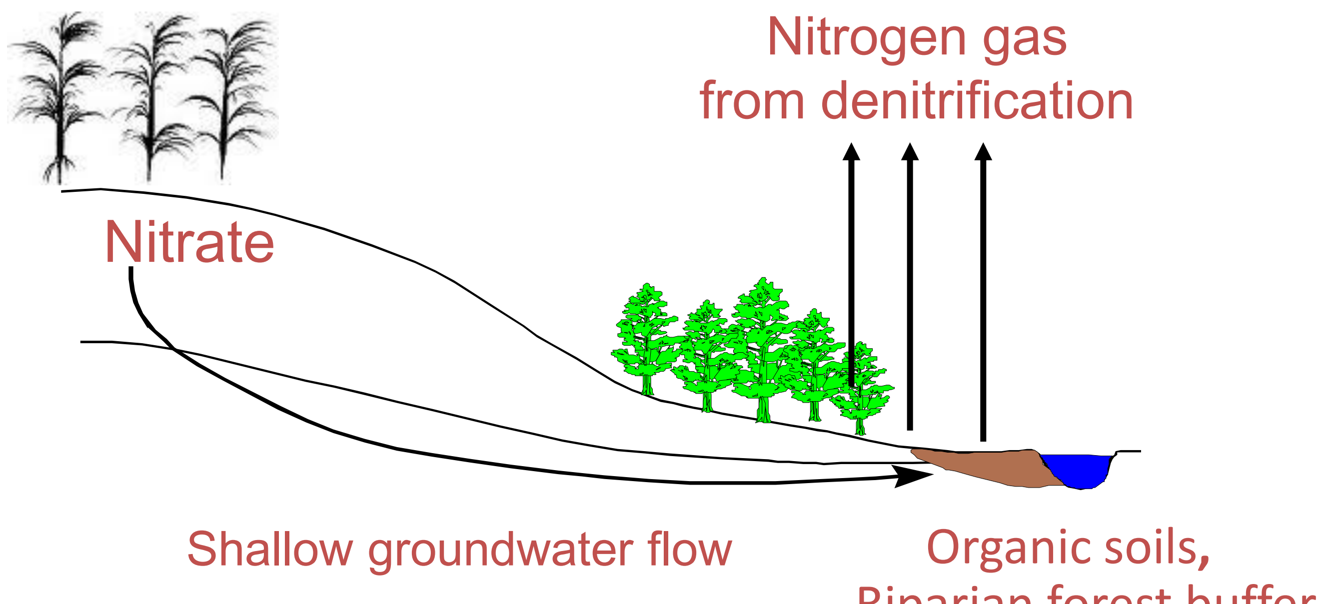
Excess nitrogen from agriculture:

- Stimulates algal growth; fishkills; degrades coastal habitats
- Generates a potent greenhouse gas, nitrous oxide (N_2O = 300 CO_2 equivalents)
- Drinking water contaminant

Offsite nitrate losses can be removed within natural denitrification sinks

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

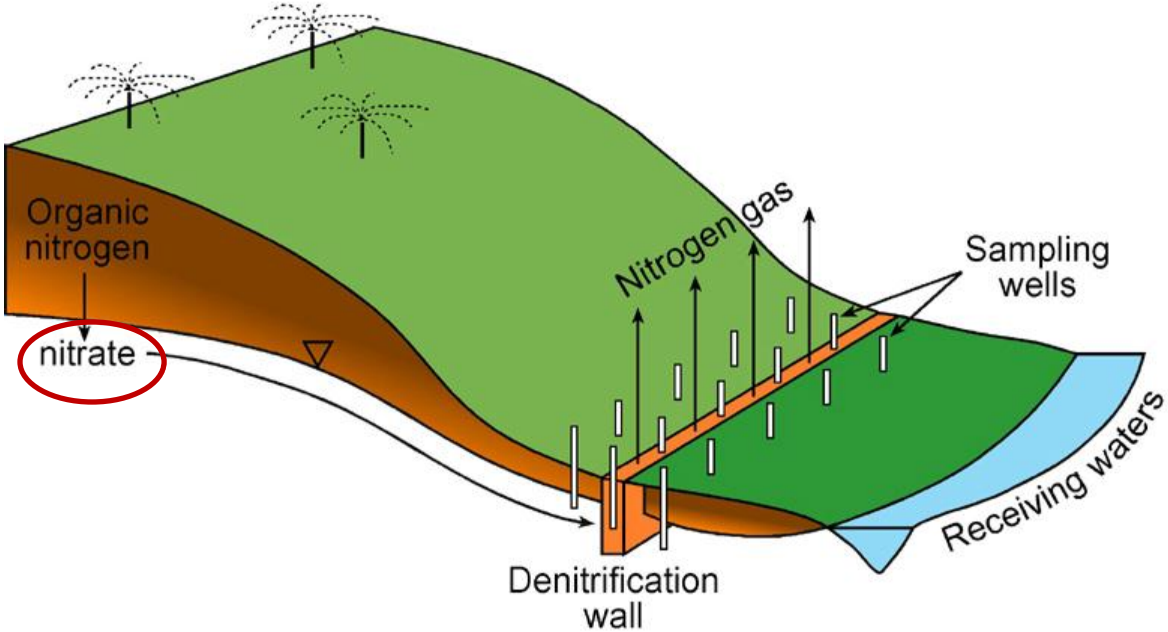
- Electron donor (labile carbon)
- Anaerobic conditions
- Extended retention times
- Appropriate temperatures



Schipper,
U. of Waikato

Where natural sinks are missing, denitrifying bioreactors can treat nitrate-laden waters:

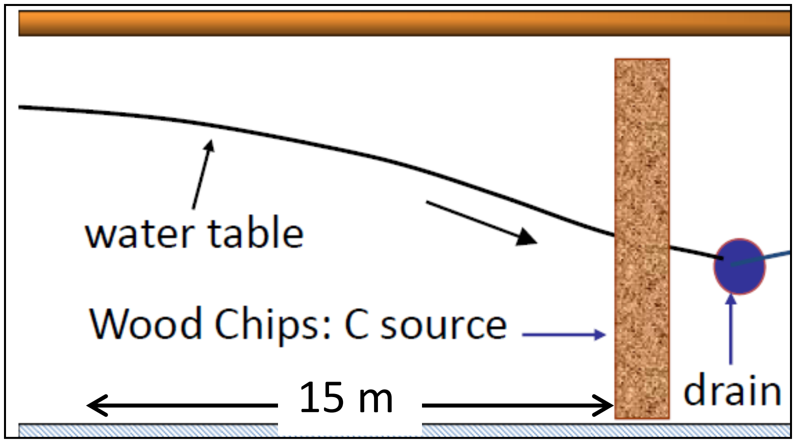
Filling trench box with wood chips



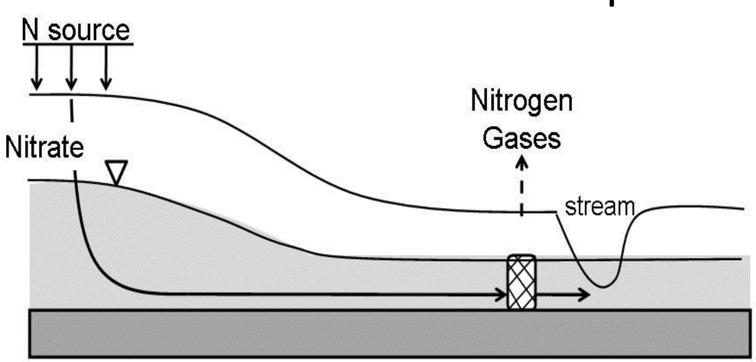
- Requires nitrification in advance of bioreactor
- High nitrate removal rates if designed properly
- Labile C sources induce anaerobic conditions
- Micro-organisms appear to be self-seeding

Denitrifying Walls: Rely on intercepting natural groundwater flow

- Work well close to source

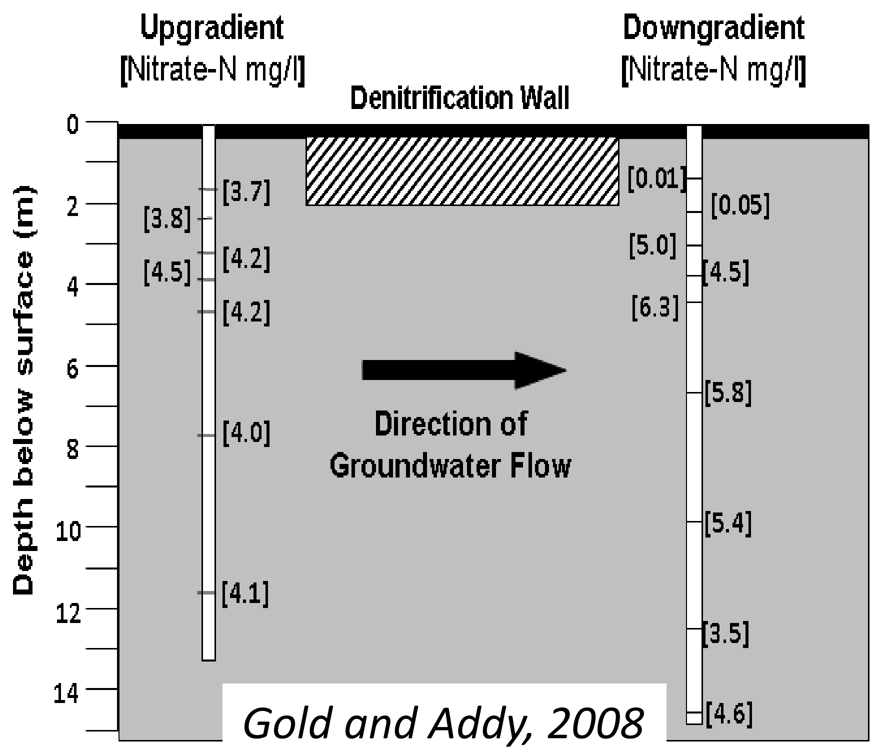


- Work well in shallow aquifers



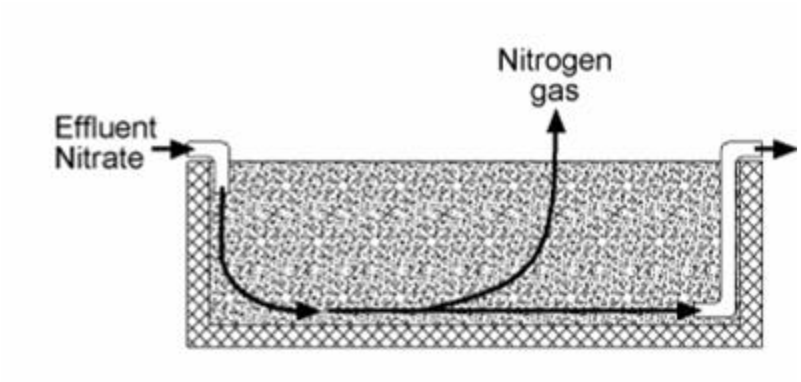
Schipper et al., 2010

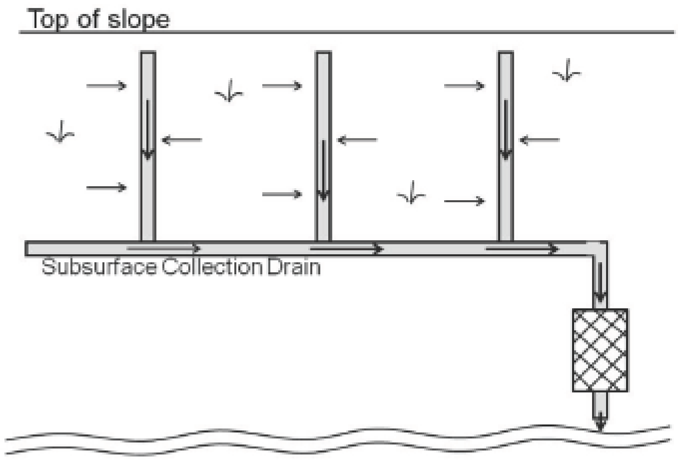
- In deep aquifers, substantial nitrate can bypass wall bioreactor



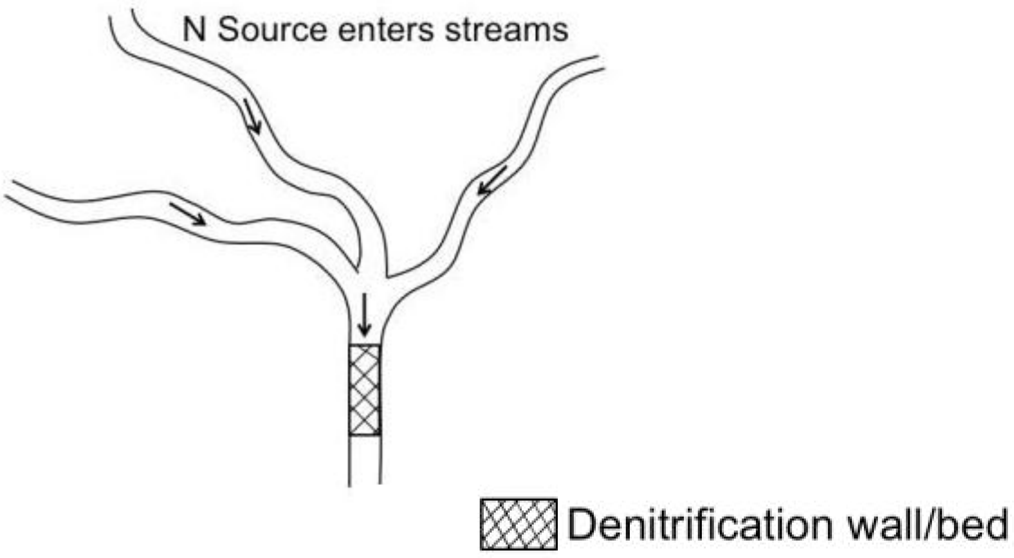
Gold and Addy, 2008

Denitrification beds:
Intercept nitrate from concentrated flows



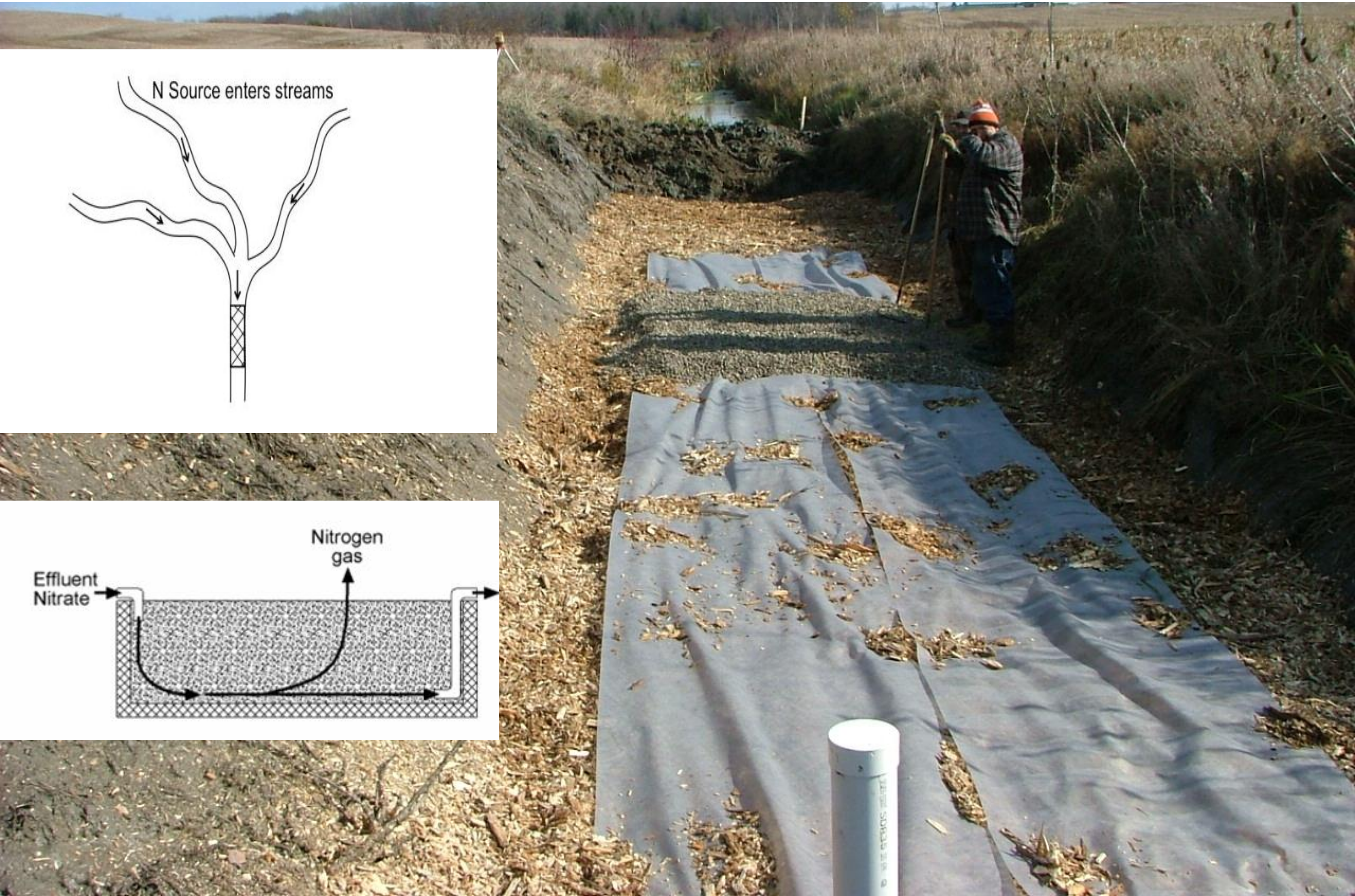


Schipper, et al. 2010. Ecol. Engin.



Wood chip denitrifying bed placed into channel

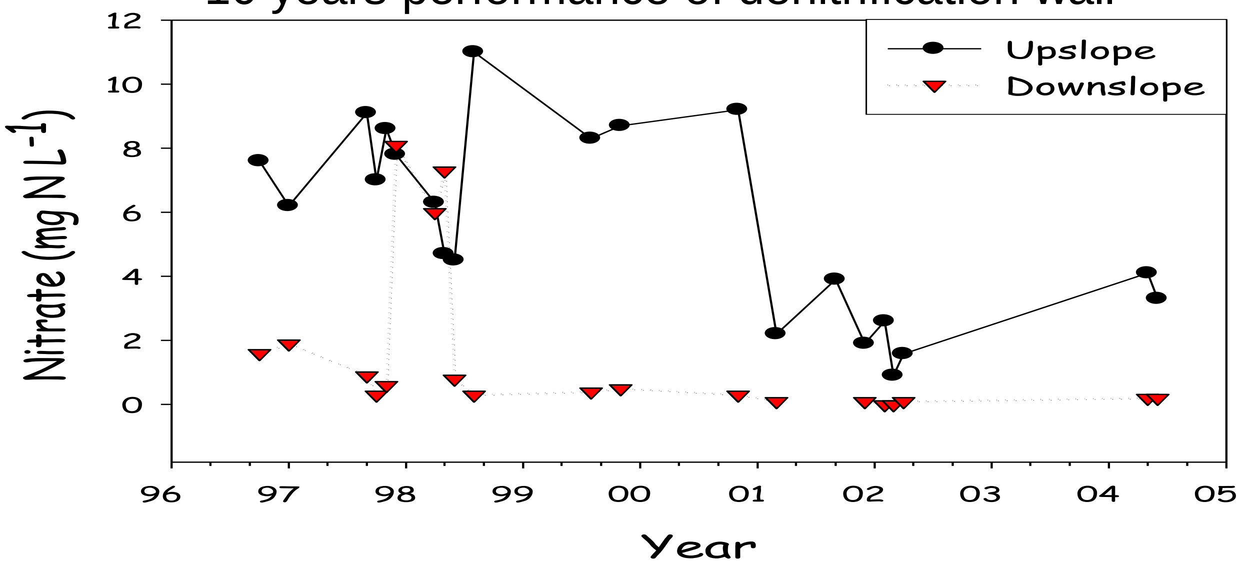
(Robertson et al. 2009)



Denitrifying bioreactors: Factors controlling nitrate removal rates and denitrification

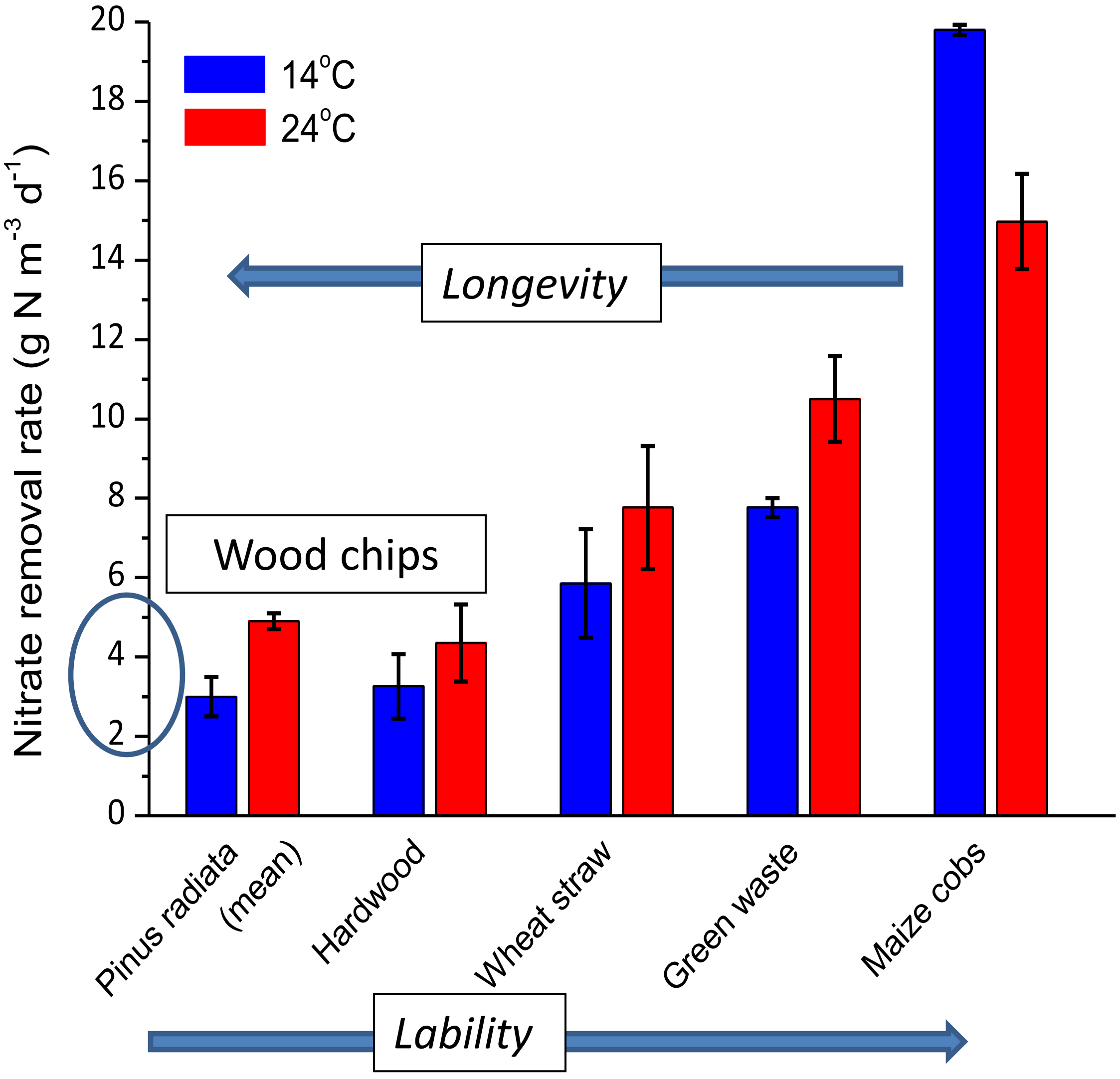
- N source : Nitrification must precede bioreactor
- Retention time: Variations in flow rate must be considered (minimum recommended > 0.25 days)
- Temperature (rates increase with high temperatures)
- Carbon source: Lability; longevity; porosity

10 years performance of denitrification wall



Schipper and Vojvodic-Vukovic (2001)

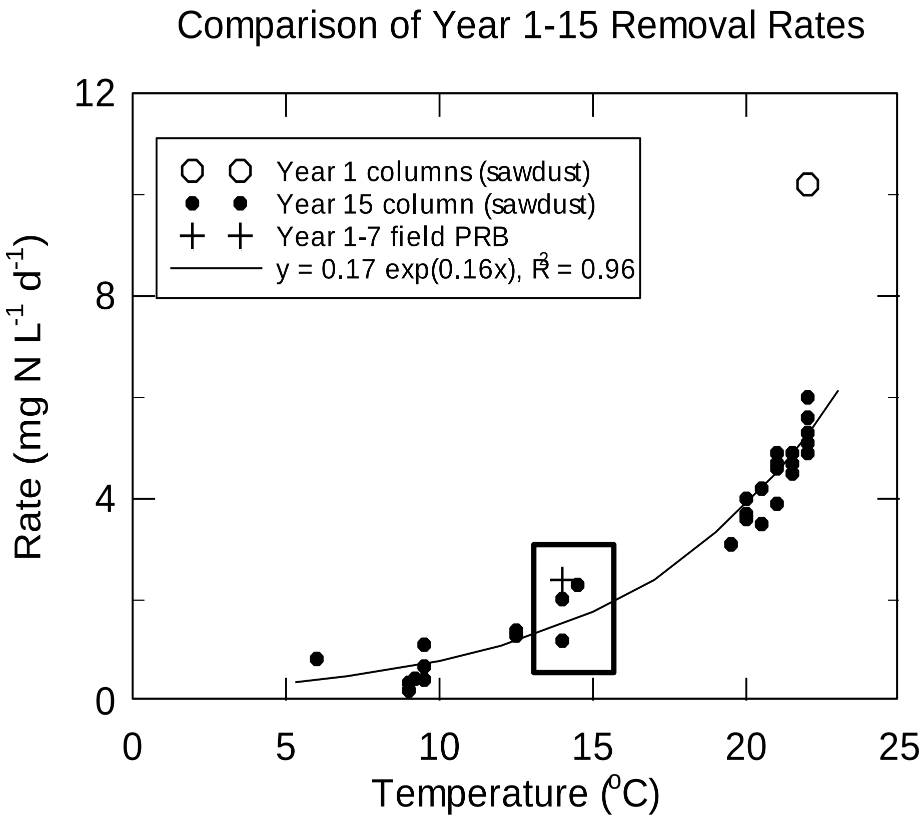
Nitrate removal rates with different carbon sources



Note that temperature generally increases removal rates

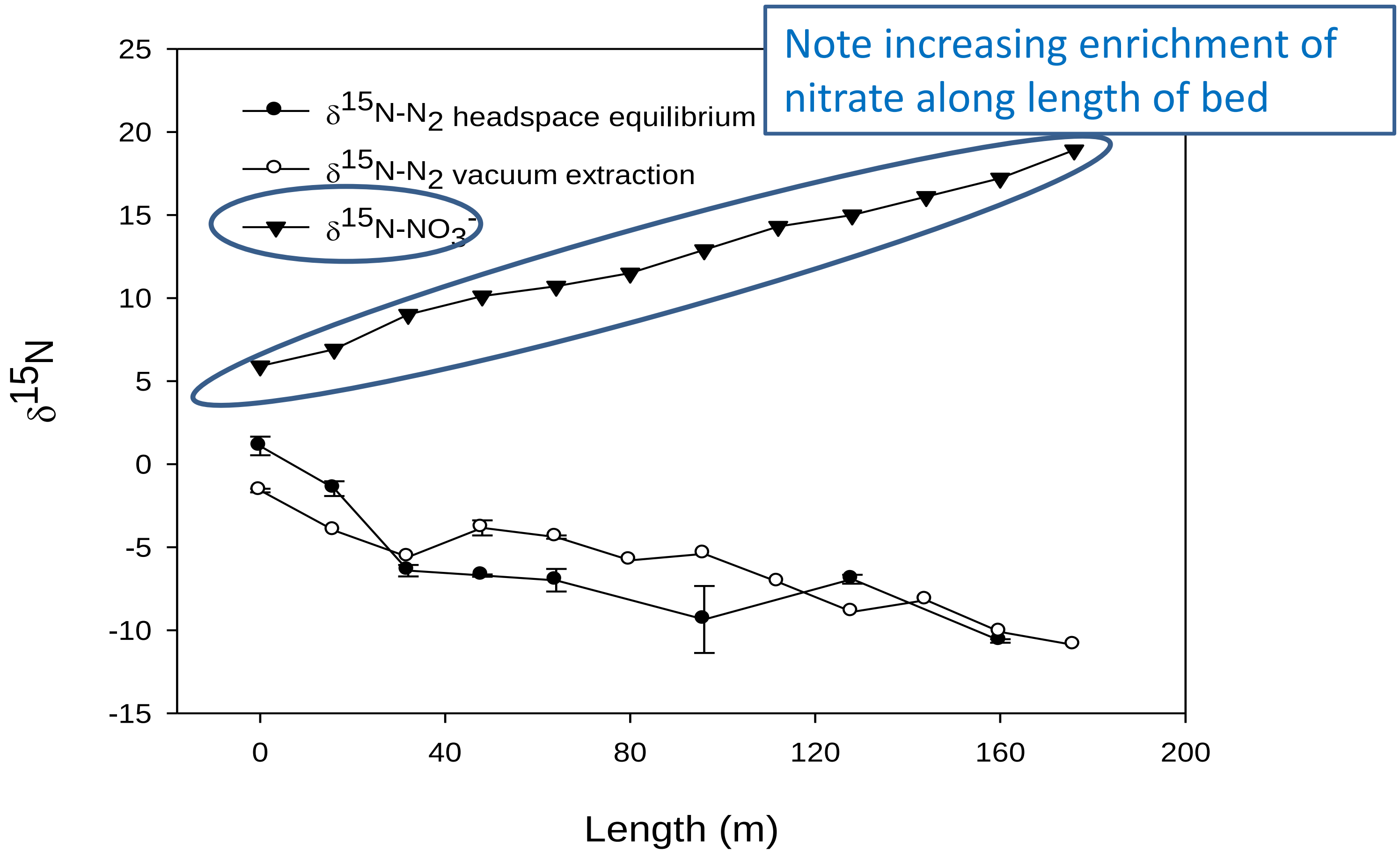
Cameron and Schipper, 2010

Wood chip longevity: Little decline in rates over 15 years of observation



Robertson, 2010.

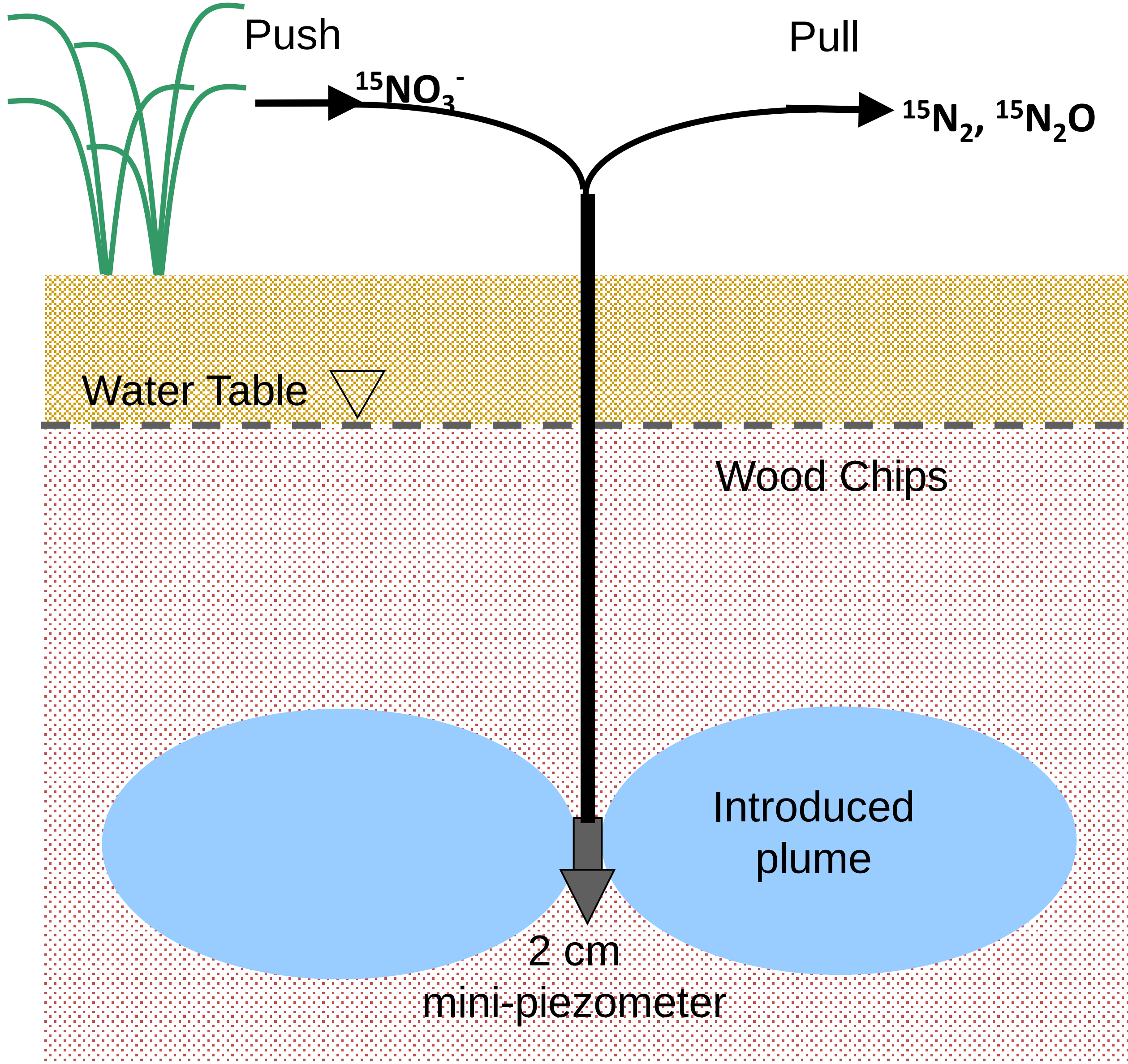
^{15}N studies to determine mechanism of NO_3^- removal: Natural abundance



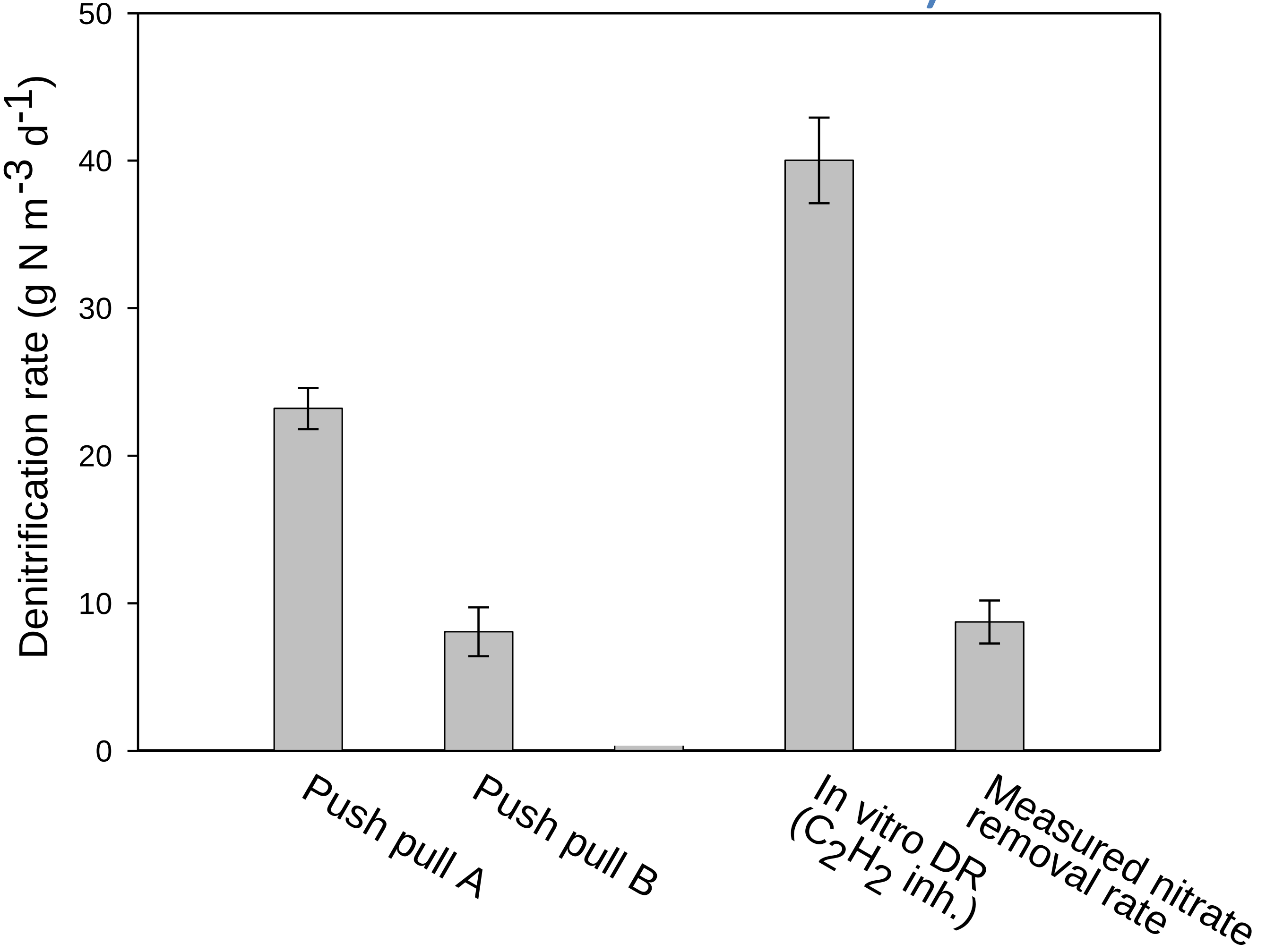
Push-Pull Method: In situ denitrification capacity through $^{15}NO_3^-$ enrichment

- Pump groundwater
- **Amend with $^{15}NO_3^-$**
- Push (inject) into well
- Incubate
- Pull (pump) from well
- Analyze samples for **$^{15}N_2$ and $^{15}N_2O$** (products of microbial denitrification)

Addy et al. 2002, JEQ



Push-Pull ^{15}N method shows denitrification is the main mechanism for nitrate removal (Acetylene-block overestimated rates)



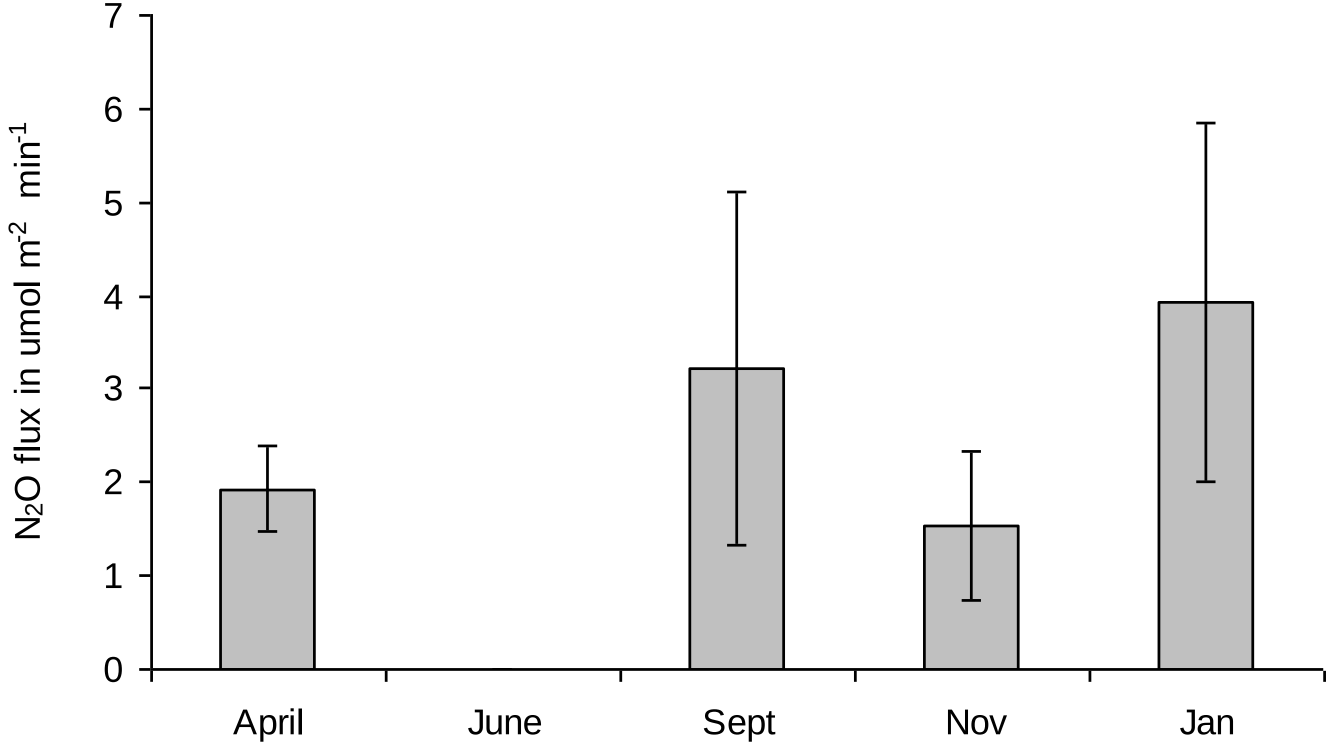
Warneke, et al. 2011

Adverse effects?

- Can generate greenhouse gases N_2O, CH_4, CO_2
- Dissolved carbon leaving bed – problem at start up
- H_2S – possible health hazard
- Methyl mercury

Managing adverse effects: Requires balancing NO_3^- load with retention time

Denitrifying Bioreactor: Nitrous oxide emission



On average < 0.9 % of NO_3^--N removed emitted as N_2O gas emissions
(IPCC: Groundwater N_2O gas emissions as high as 1.5% of NO_3^-–N leached)

Warneke et al., 2011. Ecol. Engin.

Future Directions and Challenges

Opportunities to combine carbon bioreactors with wetlands for food or fiber

Woodchip/wetland bed, H. *Leverenz, UC Davis*

Acknowledgements:
This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2011-51130-31120.

Contribution from Joint FAO/IAEA CRP*: "Strategic placement and area-wide evaluation of water conservation zones in agricultural catchments for biomass production, water quality and food security"*

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