SSSA Onsite
Wastewater Conference
April 7-8, 2014

The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Project

FOSNRS 5: Quantifying Rates of Denitrification in the Biozone and Shallow Subsurface Within Soil Treatment Units Used for Wastewater Reclamation

April 7, 2014

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COMMITTED TO ENGINEERING EXCELLENCE SINCE 1956

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Presentation Outline

- Review fundamentals
- Denitrification rates
- Measurement methods
- Experimental design
- Results
- Conclusions and recommendations

Nitrogen Fate

Organic N

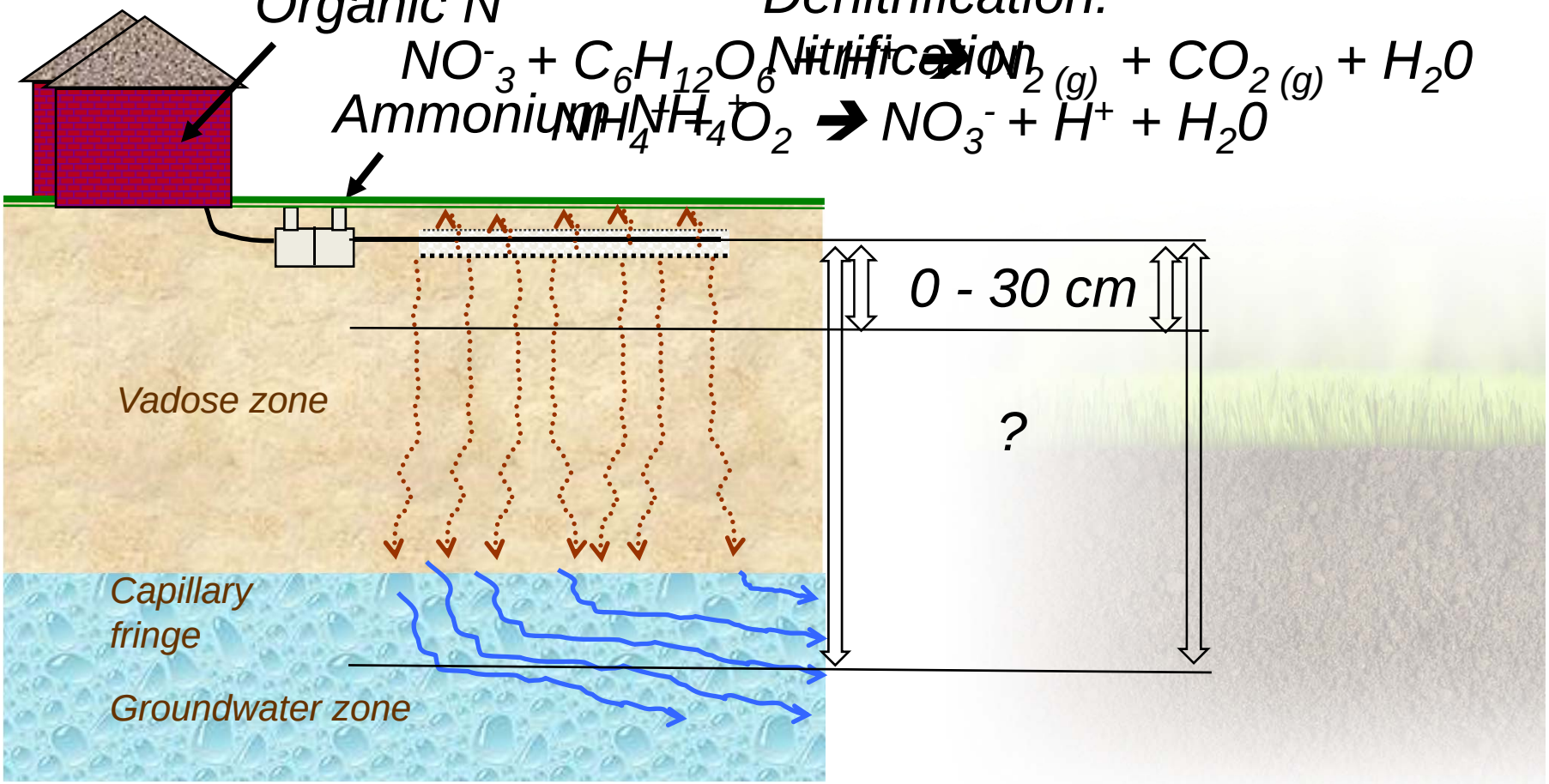
Ammonium

Denitrification:

$NO^-_3 + C_6H_{12}O_6 + H^+ \rightarrow N_{2\,(g)} + CO_{2\,(g)} + H_20$

Nitrification

$NH_4^+ + 4O_2 \rightarrow NO_3^- + H^+ + H_20$



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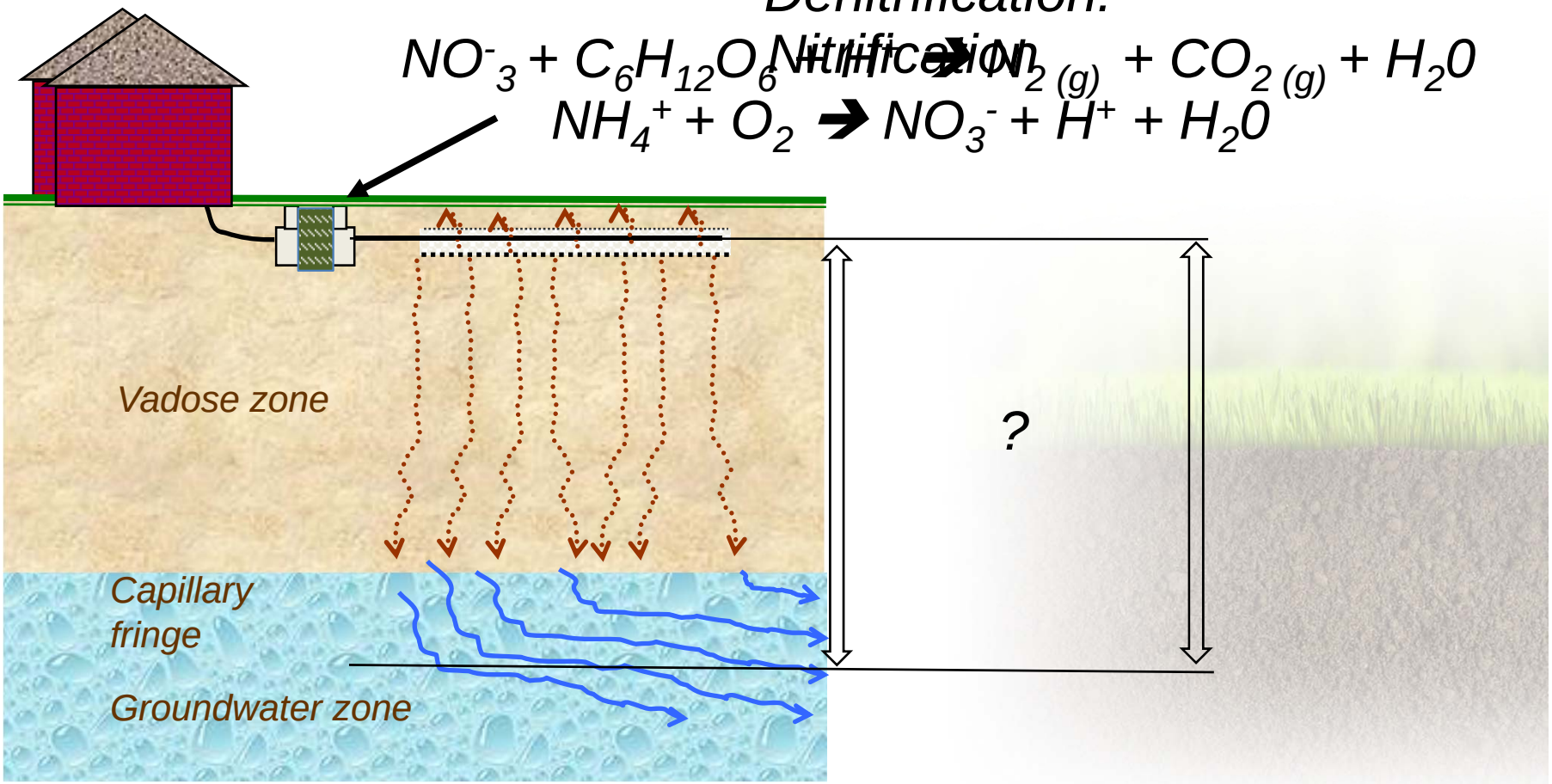

Denitrification Rates

Three primary factors that influence denitrification:

- ***Water Filled Porosity***
- ***Organic Carbon***
- ***Temperature***

Denitrification rates:

- ***Used to quantify denitrification (mg N L^{-1} day^{-1})***
- ***Historically conducted by agricultural soil scientists***
- ***Important input parameter for N fate models***

'Denitrification rates are the result of complex interactions between, physical, hydrological and chemical parameters' Groffman et al, 2006

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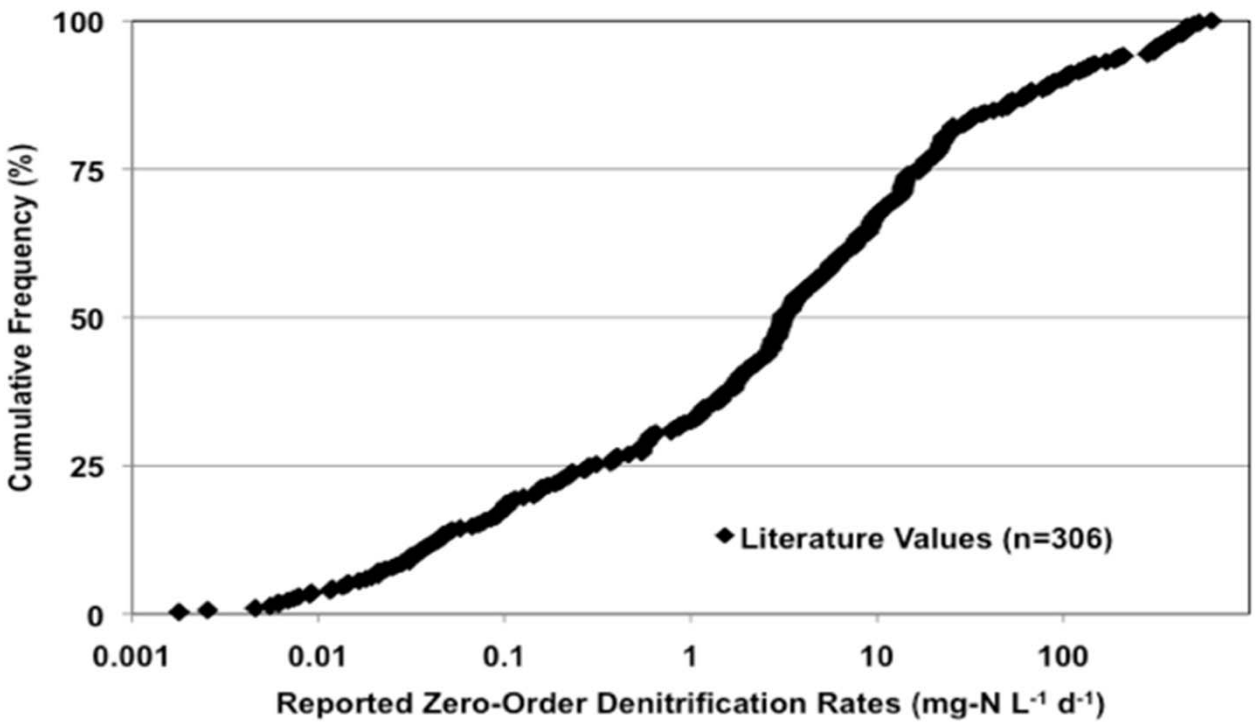
Denitrification Rates



Reference: **Tucholke, M (2007)** Statistical Assessment of Relationships Between Denitrification and Easily Measureable Soil Properties

Purpose and Hypothesis

- Develop and implement methods to measure denitrification rates specific to STU
  - Evaluate difference in applying primary vs. secondary effluent to STU

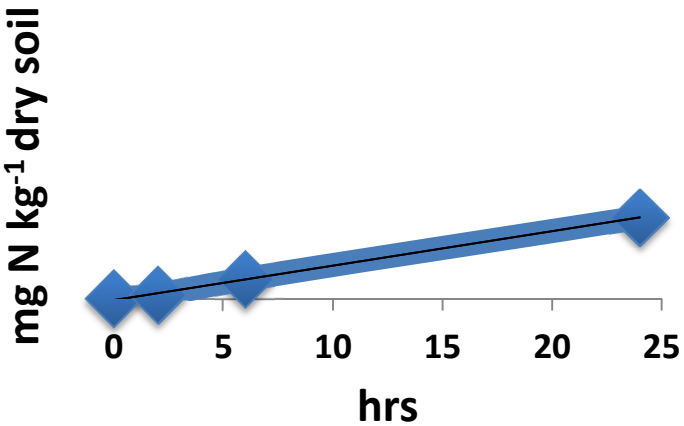
- Application of wastewater will increase the potential for nitrogen removal

Measurement Methods

- Acetylene gas (C_2H_2) inhibits complete denitrification
- $NO_3 \rightarrow NO_2 \rightarrow NO \rightarrow N_2O \not\rightarrow N_2$

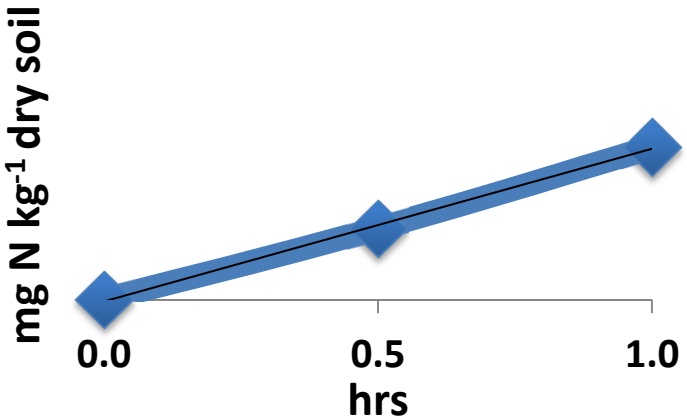
Static Core Acetylene Inhibition

(representative rate)



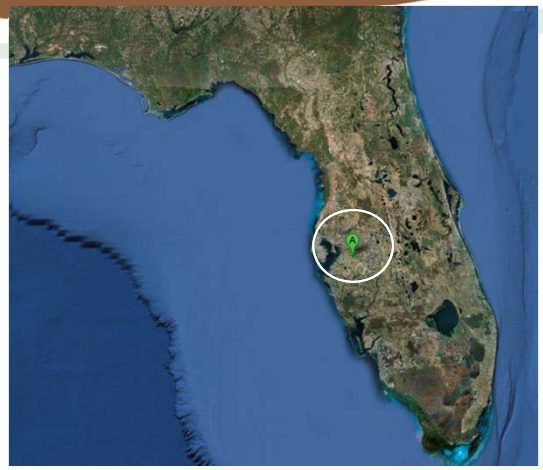
Denitrification enzyme activity (DEA)

(potential rate)



Soil Classification

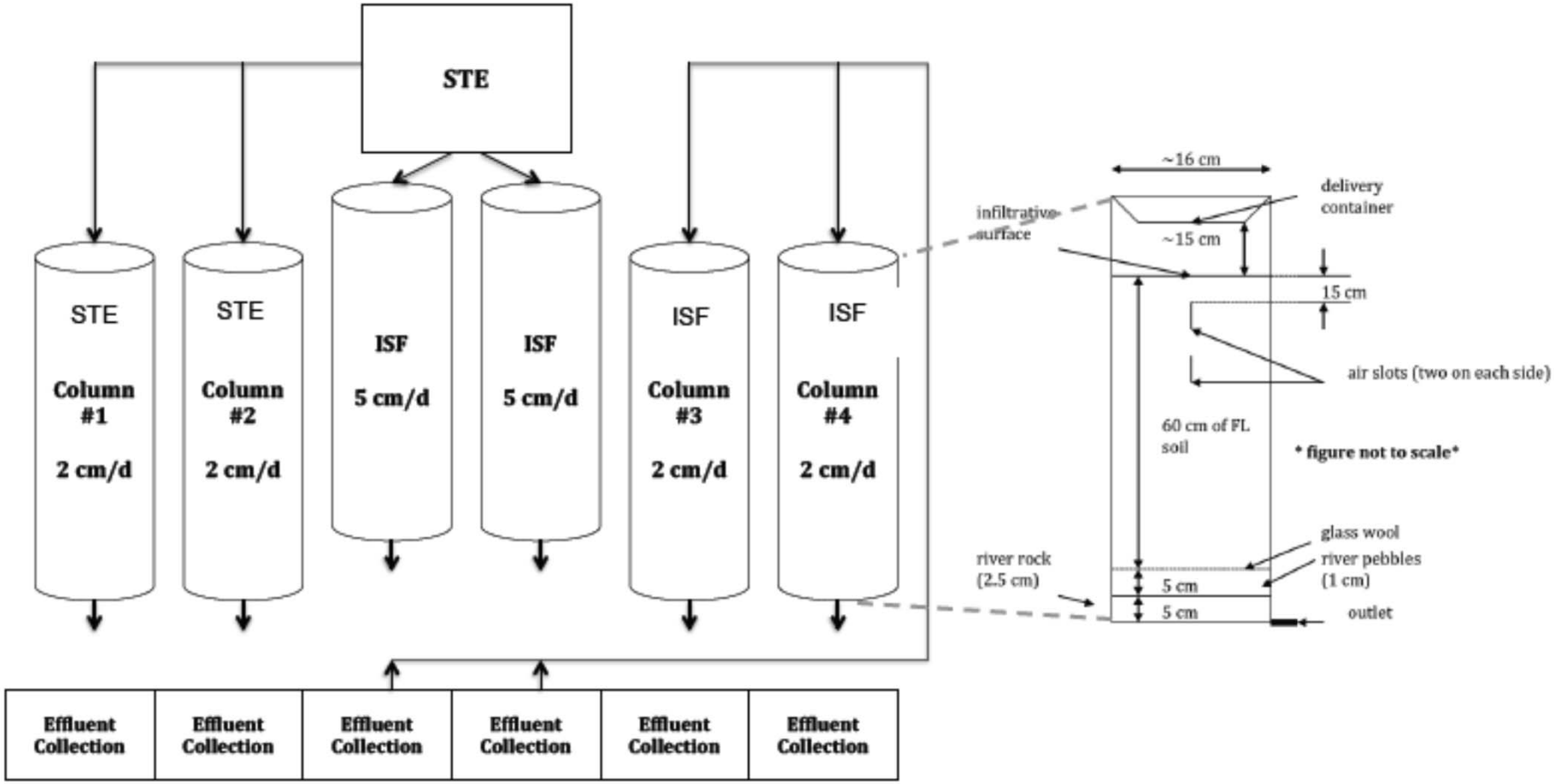
USDA – Soil Survey, Seffner fine sand



Field Dry Bulk Density	1.35 – 1.7 g/cm^3
Average Packed Column Dry Bulk Density	1.57 g/cm^3
pH	5.0
Fraction of Organic Matter (% weight)	0 – 0.05

No DEA potential

Experimental set up



Experimental set up

Effluent Quality

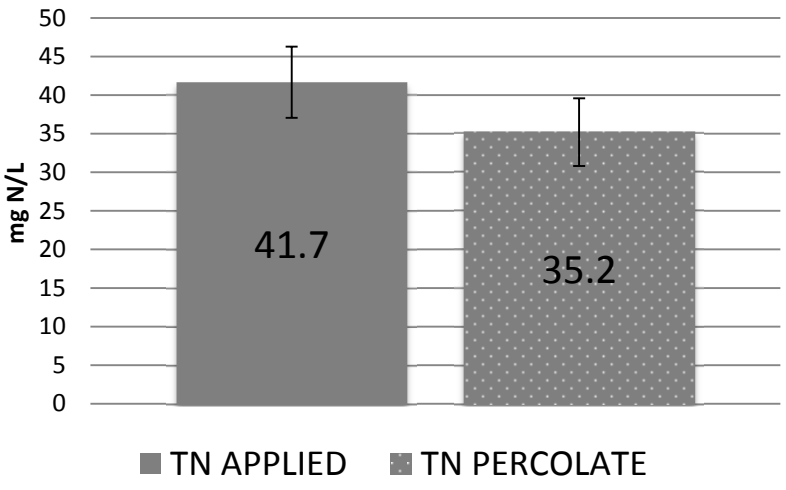
Parameter	Units	Septic tank effluent				Intermittent sand filter effluent			
		Average	S.E.	Range	*n*	Average	S.E.	Range	*n*
pH	-	7.7	0.1	7.1 - 7.9	9	5.6	0.2	4.8 - 6.4	10
Alkalinity	mg $CaCO_3$ / L	181	6.5	164 - 220	9	3	1.7	0 - 14	10
COD	mg / L	128	21	56 - 262	9	8.5	1.7	0 - 16	9
TN	mg N / L	41.7	1.5	33 - 49	9	34.9	1.2	29 - 41	10
NO_3	mg N / L	1.2	0.3	0.4 - 3.4	9	31.4	2.8	15.0 - 39.4	10
NH_4	mg N / L	39.6	2.5	21.4 - 46.2	9	2.7	0.4	0.4 - 4.3	9
DOC	mg C / L	10.4	1.0	8.7 – 12.2	3	4.7	0.8	3.5 – 6.3	3
SUVA[2]	L / mg C	1.4	0.1	1.3 - 1.5	3	1.4	0.1	1.2 – 1.6	3

[1]STE data are for weeks 2 to 10; ISF data are for weeks 1 to 10. [2]SUVA = specific UV absorbance.

Grab samples collected October 9th - December 10th, 2012

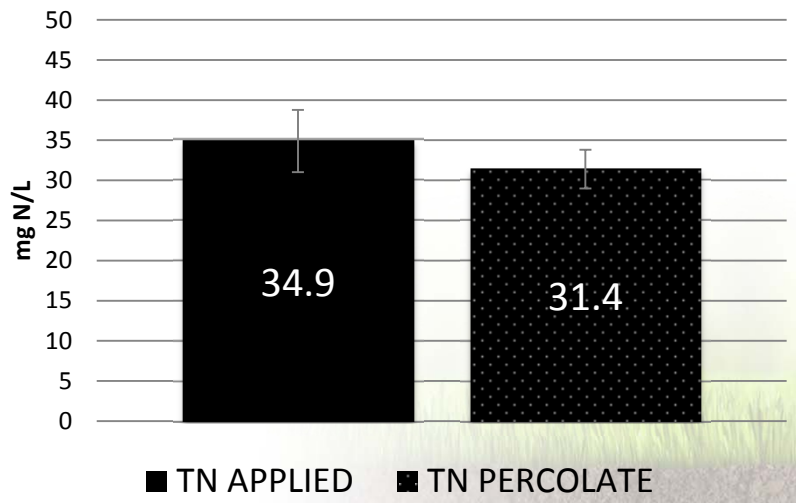
Nitrogen Mass Balance

STE column



- 16%

ISF column



- 10%

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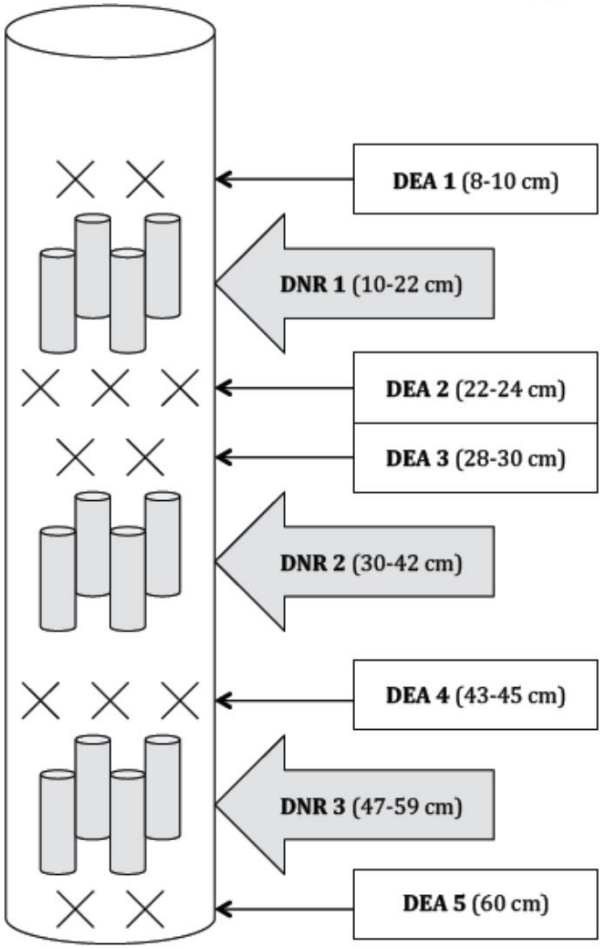
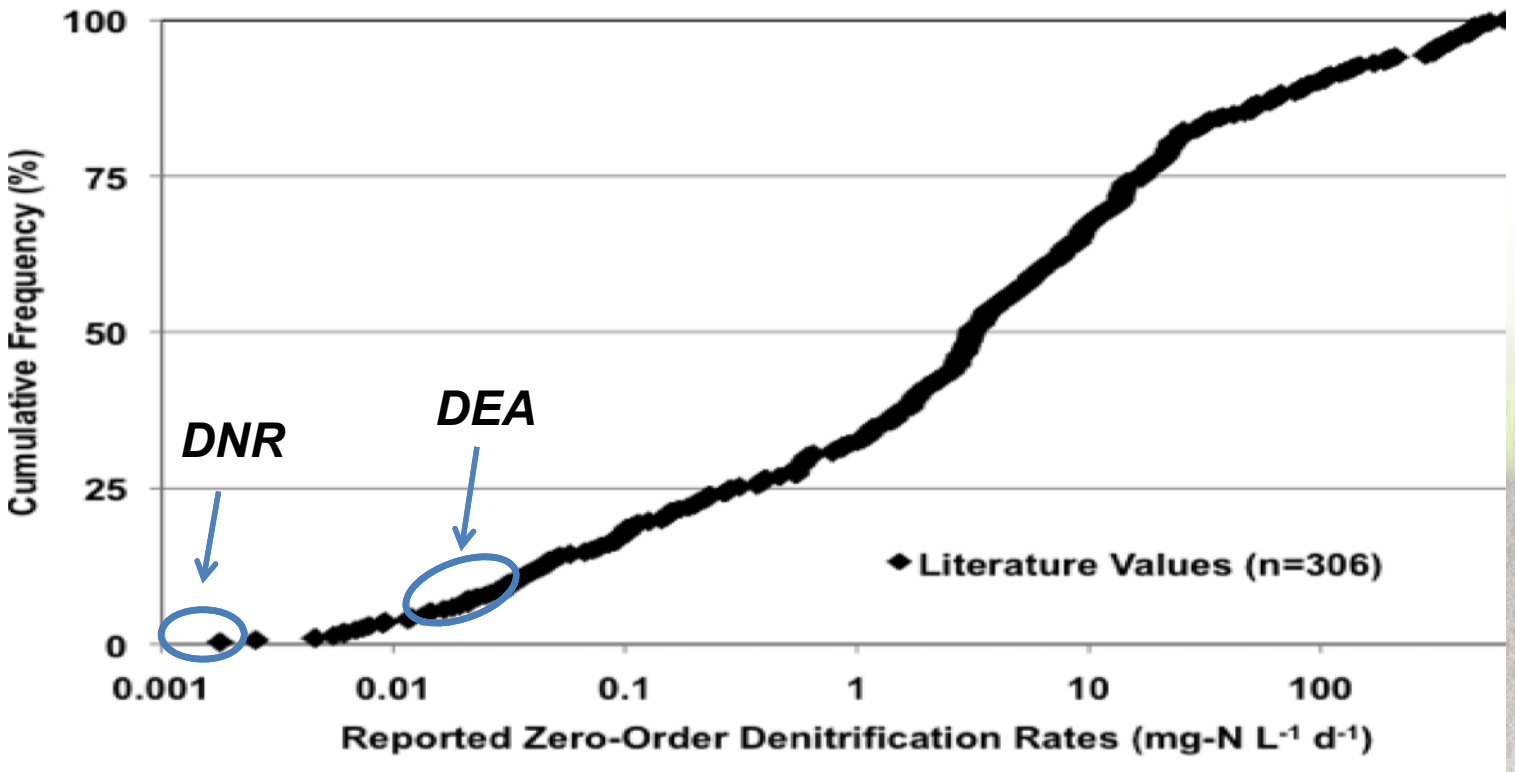
DNR, DEA, qPCR– sample collection

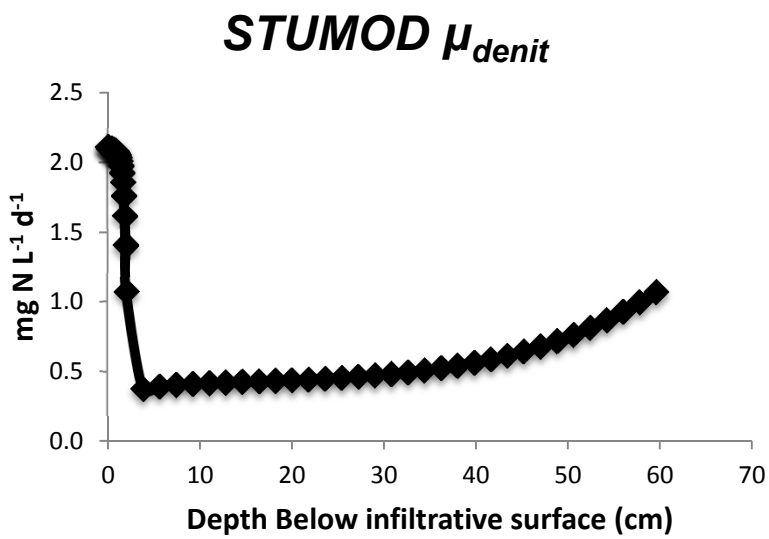


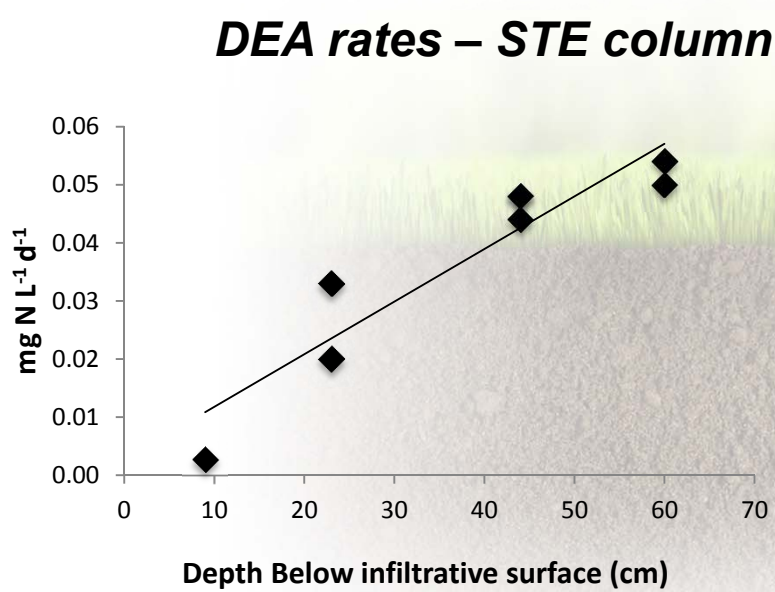
Comparison of rates



STUMOD

$$\mu_{denit} = \mu_{denit,\max}\left(\frac{C_{NO3}}{K_{m,NO3} + C_{NO3}}\right) f_t f_{sw,dn} f_z$$





Sampling - Round 2

GOAL:

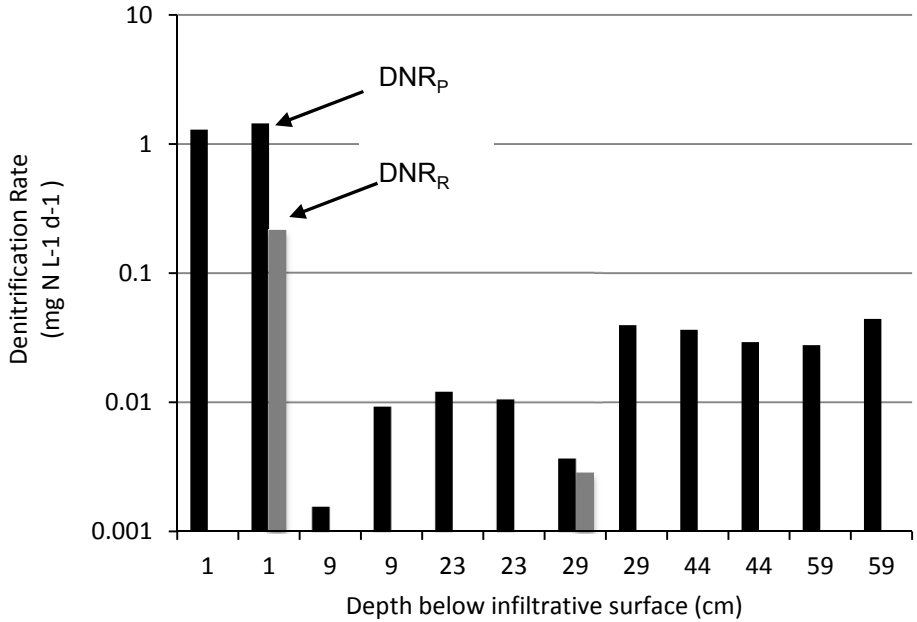
- Focus on biozone (0-1 cm)
- Sample at 28 weeks

WATER QUALITY RESULTS:

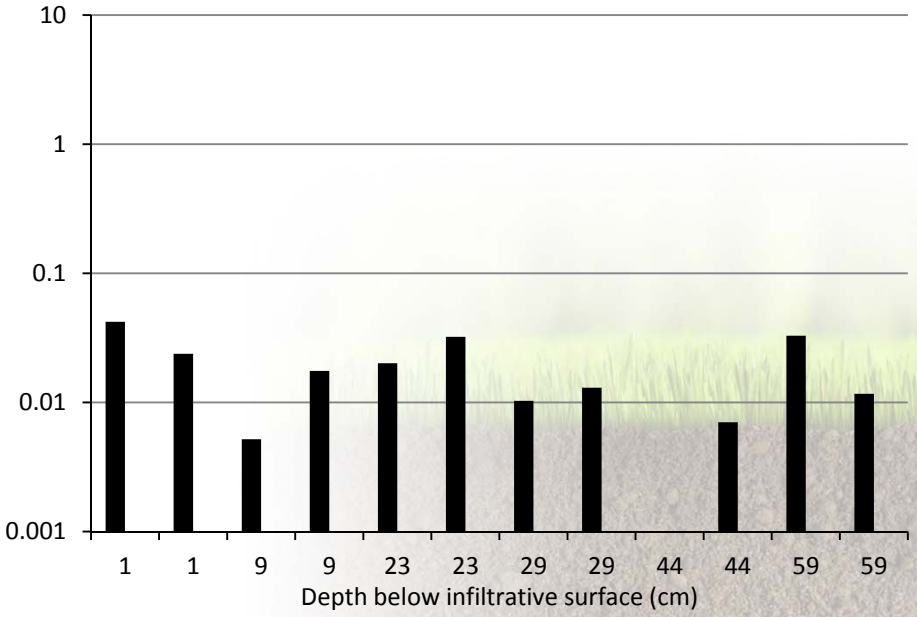
- No change in nitrogen removal
- Effluent and percolate quality remained representative of 0-10 weeks
- WFP similar

Results

STE column



ISF column



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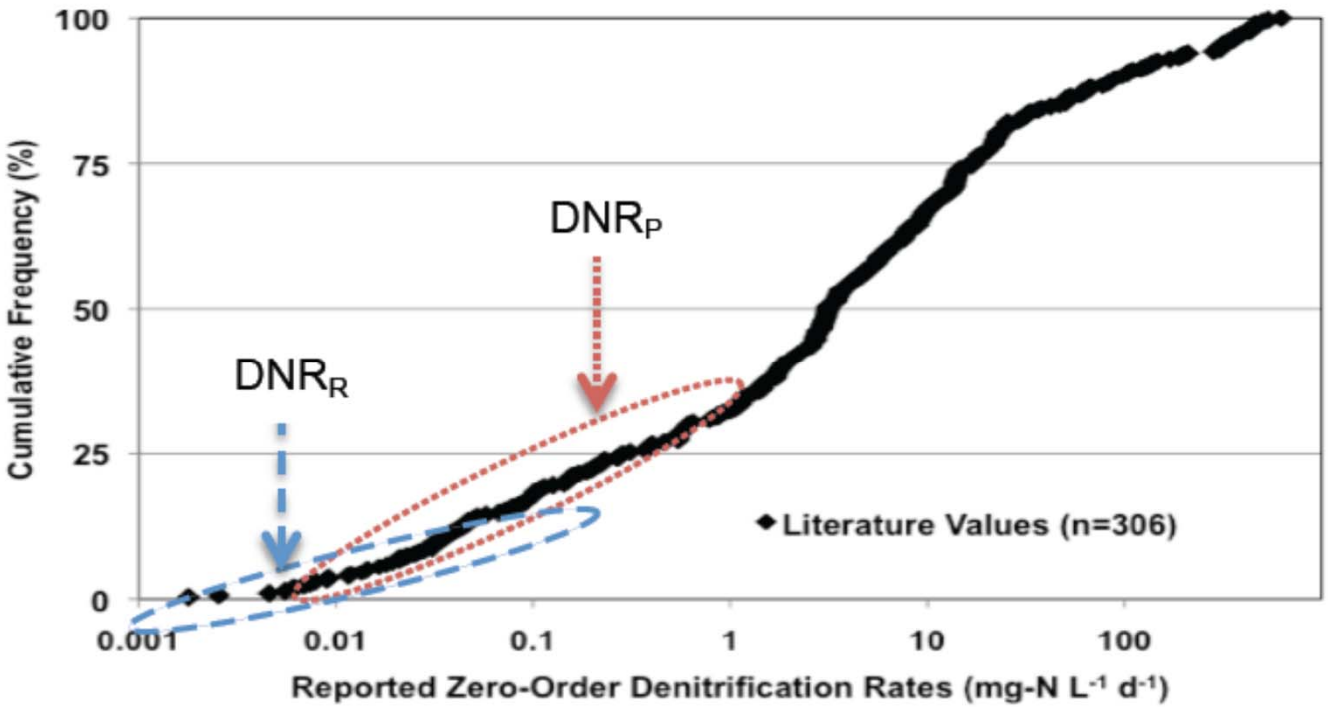
Measured rates compared to literature



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Quantitative PCR

- Quantify the genes that code for denitrification enzymes

nirS and nirK ***nosZ***

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

- Analysis conducting at National University Of Ireland - Galway

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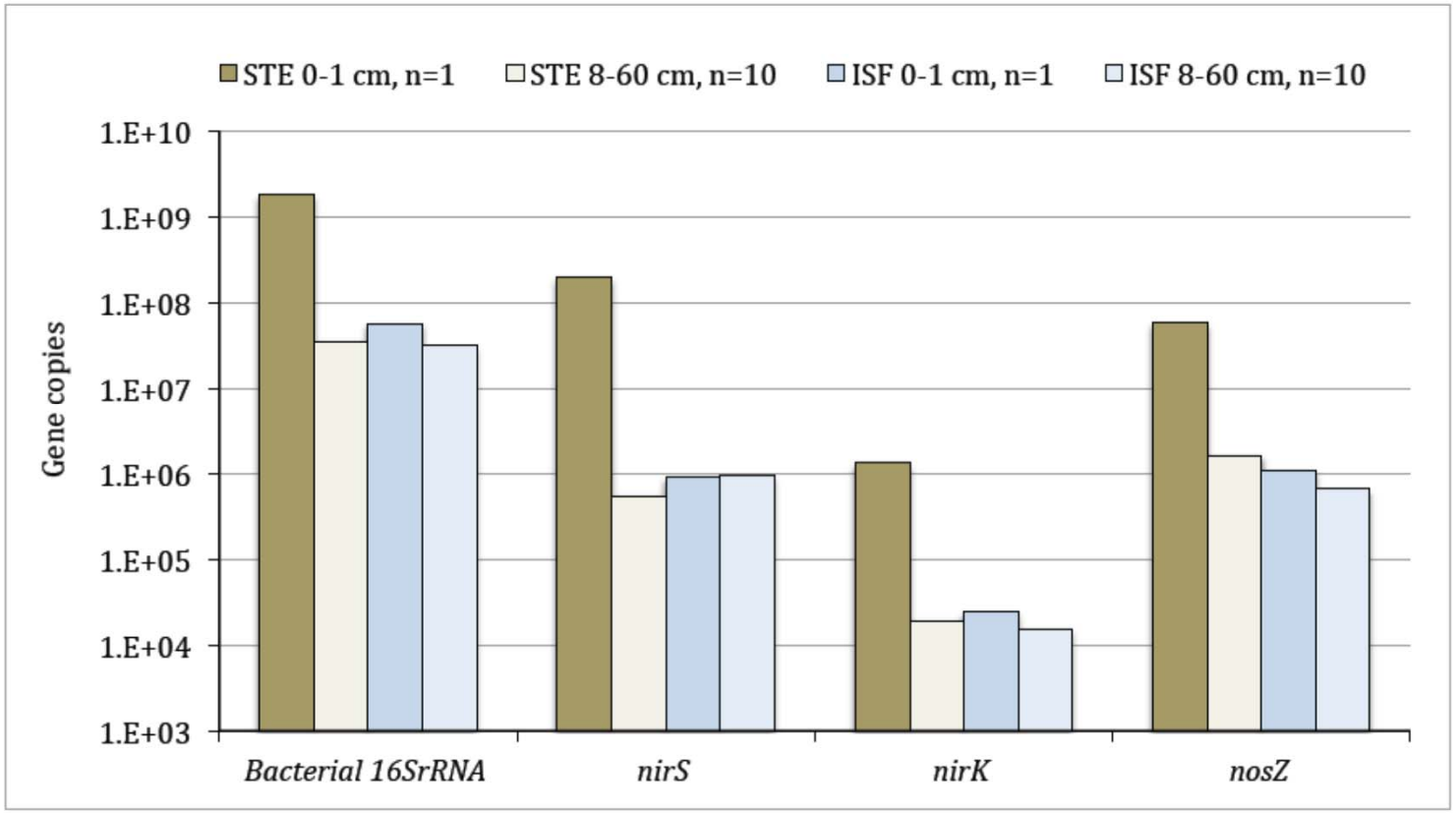
Quantitative PCR - results



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Conclusions

- Denitrification rates increase with wastewater effluent application
- Rates are more elevated in soil receiving STE compared to ISF
- Microbial coexistence near infiltrative surface, nitrification and denitrification
- Focus on biozone (0-1 cm bis) for deintirifcation
- Five lines of evidence: DEA, DNR, *nir*S, *nir*K, *nos*Z identify the same trend

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Acknowledgements

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