Laboratory of Soil Ecology and Microbiology

Gone with the Wind: Rethinking How Water-Filled Pore Space Affects Gaseous Nitrogen Production in Soil-Based Wastewater Treatment

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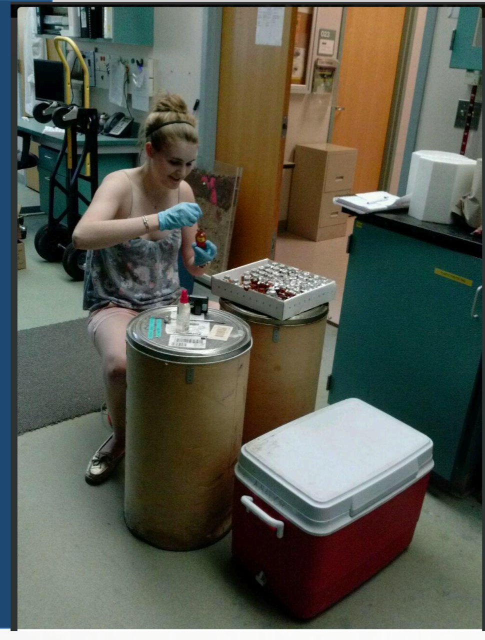


Why do we need to re think this?

- A quarter of U.S. homes rely on onsite wastewater treatment systems (OWTS) to treat wastewater
- Treatment takes place as wastewater moves through drainfield soil
- Zero to 30% of N in wastewater is removed in soil via microbial processes as N_2 and N_2O
- N removal by microorganisms is affected by water-filled pore space (WFPS)

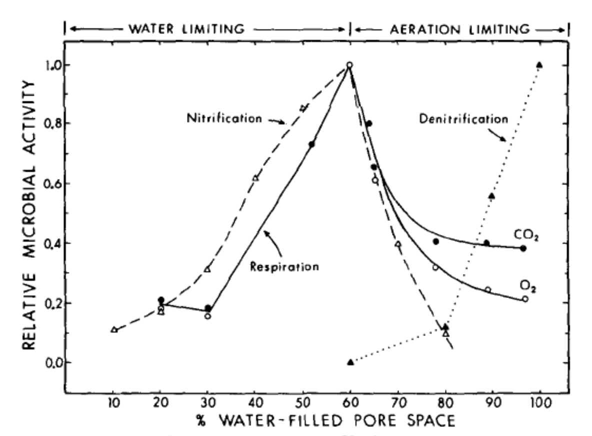
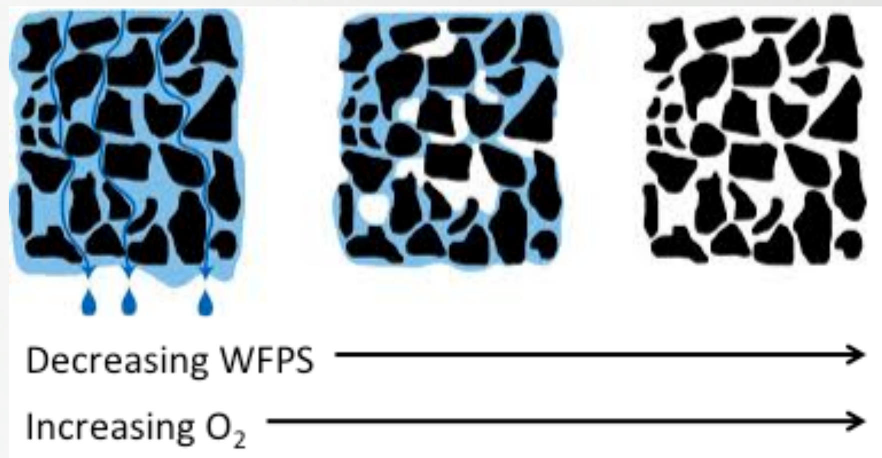


Fig. 1—The relationship between water-filled pore space and relative amount of microbial nitrification (after Greaves and Carter, 1920), denitrification (after Nommik, 1956), and respiration [O_2 uptake (○-○) and CO_2 production (●-●) as determined in this study]. Data for nitrification originally expressed as percentage water-holding capacity.

From: Linn, D. M., and J. W. Doran. 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. Soil Sci. Soc. Am. J. 48:1267-1272.

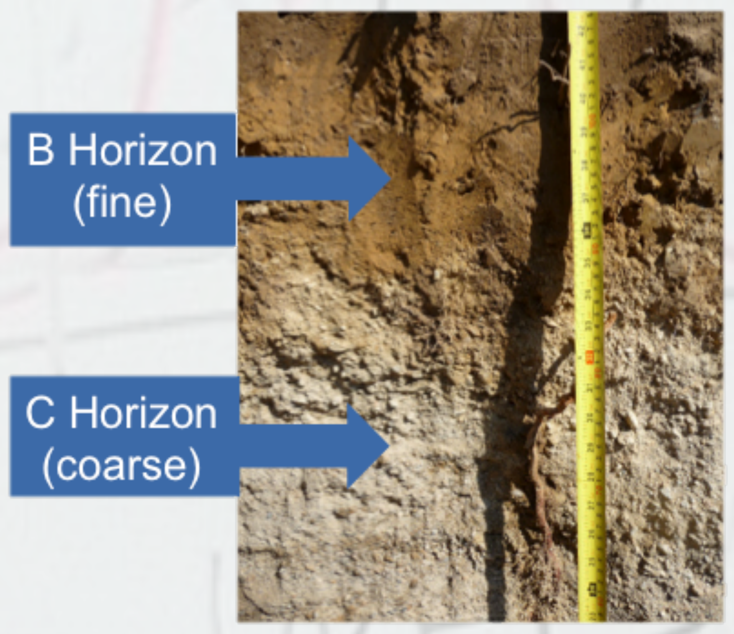


- Current understanding of effects of WFPS on microbial N removal is based on long-term incubations using surface agricultural soils and clean, oxygenated water.
- **But: the drainfield is installed in subsurface horizons; wastewater has high levels of inorganic N and organic C, and little or no dissolved O_2 (DO); water spends a short time in soil.**
- Poor understanding of how WFPS affects N removal affects ground and surface water quality, public health.

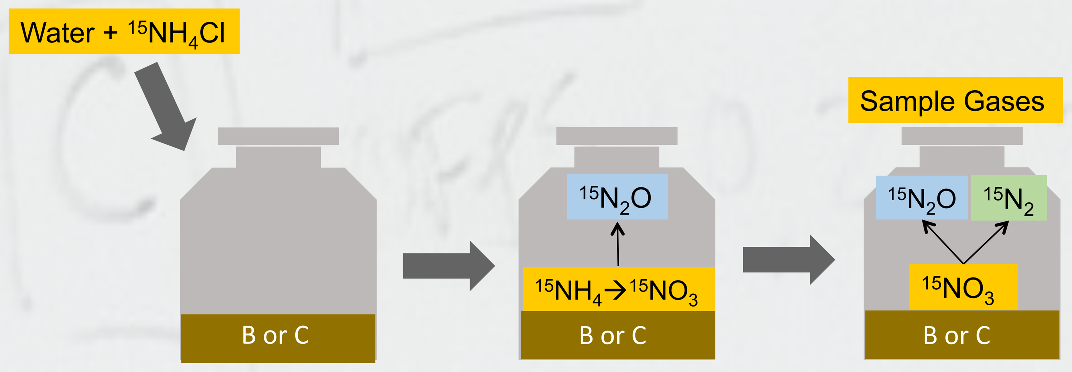
We examined how WFPS affects N_2 & N_2O production in drainfield soils

How did we go about it?

- Used mesocosms to determine the short-term (1-h) response of N_2O and N_2 production to WFPS in B (silt loam) and C (very gravelly coarse sand) horizon soil.
- Used deionized water (DW), sand filter effluent (SFE) or septic tank effluent (STE) amended with $^{15}NH_4$ to adjust WFPS and measured $^{15}N_2$ and $^{15}N_2O$.
- Provide a range of concentrations of organic C, nutrients, dissolved O_2 and microorganisms.

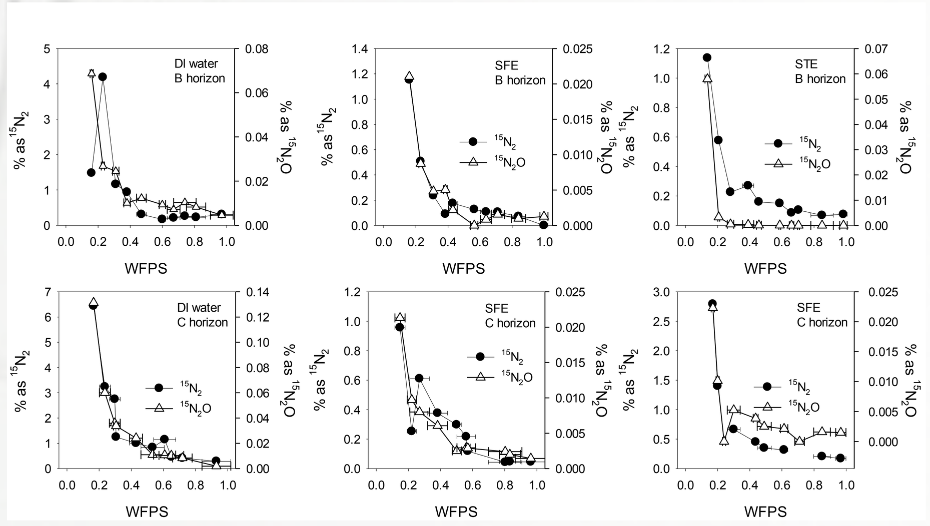


Water type	DO	BOD	Total N	NH_4	NO_3
	(mg/L)				
Septic tank effluent	0	200	84	47	0
Sand-filter effluent	2	2	53	6	51
Deionized water	8	0	0	0	0

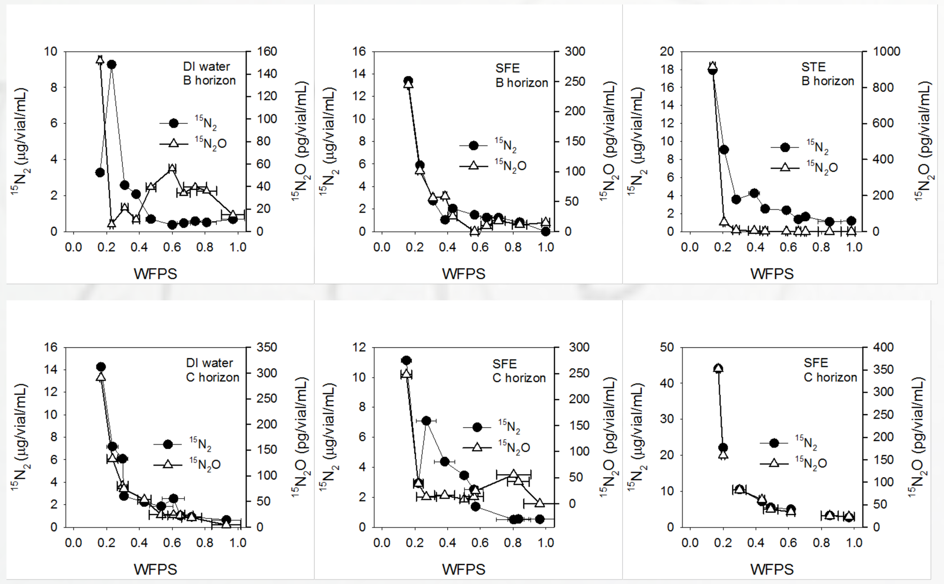


What did we find?

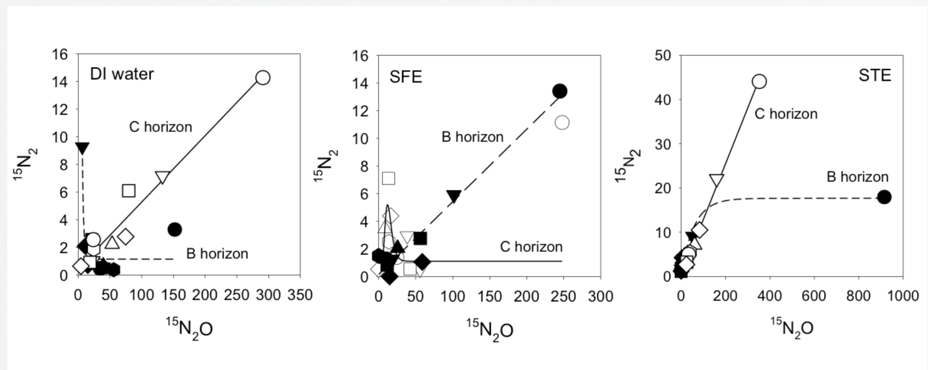
- Conversion of $^{15}NH_4$ to N gases was generally highest at the lowest WFPS value for all water and soil types
- Production of N gases accounted for 4–6 % for DW and 1–2% for STE and SFE.

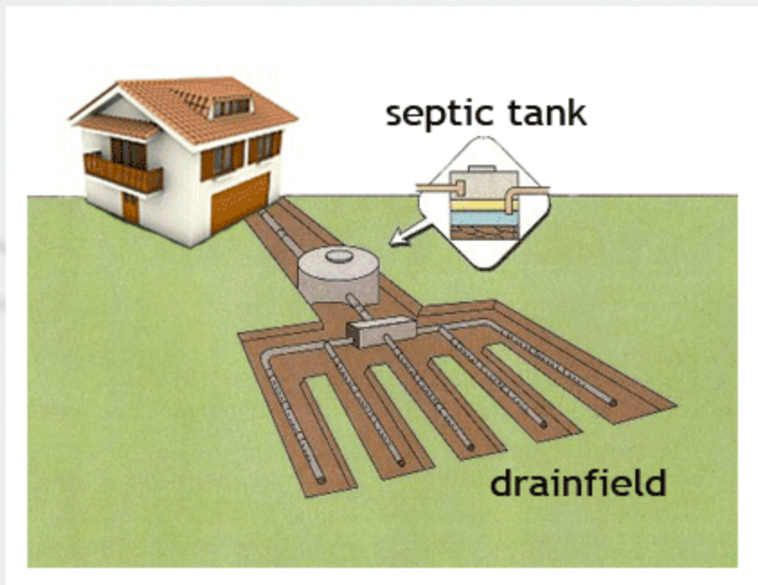


- Production of $^{15}N_2$ was 50 to 100x that of $^{15}N_2O$ at nearly all values of WFPS in B and C horizon soil for all water types.
- When normalized by the amount of substrate added, the effect of WFPS on $^{15}N_2$ and $^{15}N_2O$ was greater at the lowest WFPS for all water types and soils tested.



- Production of $^{15}N_2$ varied linearly with $^{15}N_2O$ for most water and soil types, suggesting strong coupling of processes.





Why do we care?

- Numerical models of the fate of N in OWTS drainfields should reconsider moisture-dependence of N removal.
- Contrary to current design guidelines, applying a lower volume of wastewater to soil – which results in a lower WFPS – may improve N removal efficiency.
- Sea level rise and increased precipitation due to climate change will affect WFPS and the ability to remove N in the soil.

So, do we need to rethink this?

- **Yes.** The response of N gas production in surface agricultural soil to WFPS does not represent what takes place in soil-based wastewater treatment.
- Microbial production of N_2 and N_2O in subsurface horizons happens quickly over a broad range of WFPS values, but especially at low WFPS.

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