The Regulatory Role of Phenolic Compounds in Peat Decomposition

Alexis E. Slentz[1,2*], Rachel M. Wilson[1], Samantha Bosman[1], Kaley Smith[3], Malak M. Tfaily[4], Christopher W. Schadt[5], Caitlin Petro[6,7], Joel Kostka[6,7], Robert G.M. Spencer[1,2], Jeffrey P. Chanton[1]

[1]Department of Earth, Ocean and Atmospheric Sciences, Florida State University, Tallahassee, FL. [2]National High Magnetic Field Laboratory Geochemistry Group, Tallahassee, FL. [3]Department of Earth, Marine, and Environmental Sciences, The University of North Carolina at Chapel Hill, Chapel Hill, NC. [4]Department of Environmental Science, University of Arizona, Tucson, AZ. [5]Oak Ridge National Laboratory, Oak Ridge, TN. [6]Center for Microbial Dynamics and Infection, School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA. [7]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA.

BACKGROUND

Phenolic compounds have attracted interest as potent regulators of microbial respiration in peatlands due to their apparent disruption of extracellular enzyme activity. Oxygen constraints on phenol oxidase allow phenolics to accumulate in peat.

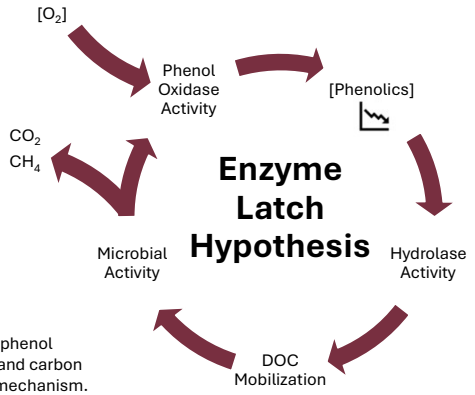

Figure 1. Schematic of the role of phenol oxidase activity in regulating peatland carbon cycling through the enzyme latch mechanism.

Aspects of the enzyme latch hypothesis remain unresolved:

1. The extent to which phenolic compounds inhibit peat decomposition
2. The influence of traditional experimental methods (PVP) on peat DOM composition
3. The controls of biogeochemistry and physicochemical properties on mechanism response

PHENOLIC INHIBITION OF ANAEROBIC RESPIRATION

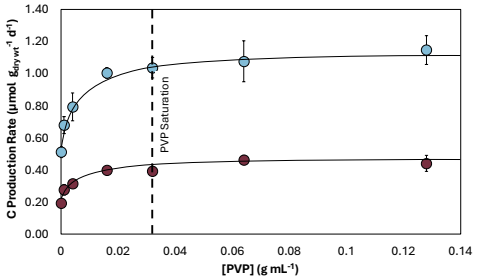

Figure 2. Observed relationship between polyvinylpyrrolidone (PVP) concentration and CO_2 and CH_4 production during anaerobic peat microcosm incubations of bog peat collected from Stordalen Mire, Sweden

Table 1. Site descriptions and biogeochemical properties

Site	Sample ID	Peatland Classification	Dominant Vegetation	Water Table (cm)	pH	[DOC] (mg C L^{-1})	[phenolics] (g mL^{-1})
MN-MEF-BogLakeFen	BLF	Poor Fen	*Sphagnum* spp. and sedges	13-18	3.8	52	16.1
MN-HwyUS2	US2	Fen	variable; *Sphagnum* spp., *Eriophorum vaginatum*, *Carex* spp.	11-18	4.4-5.7	32.6-53.9	5.2-11.8
WI-LostCreek	LC	Shrub Wetland	shrubs and sedges	10-15	5.4-5.7	21.0-28.5	3.0-4.9
NC-Pocosins	POC	Shrub Wetland	shrubs	19-36	3.9	18.1	20.7-22.2
MN-MEF-S3	S3	Bog	variable; *Sphagnum* spp., shrubs, sedges, ferns	0	6.2-6.4	20.9	2.0-3.1
MN-MEF-S1	T1	Bog	*Sphagnum* spp.	23-26	3.5-4.1	66.5-75.3	15.5-17.1
SE-Stordalen-Fen	StorF	Fen	*Eriophorum vaginatum*	4.5	5.8	12.2	1.6
SE-Stordalen-Bog	StorB	Bog	*Sphagnum* spp.	12.5	4.2	89.7	19.5

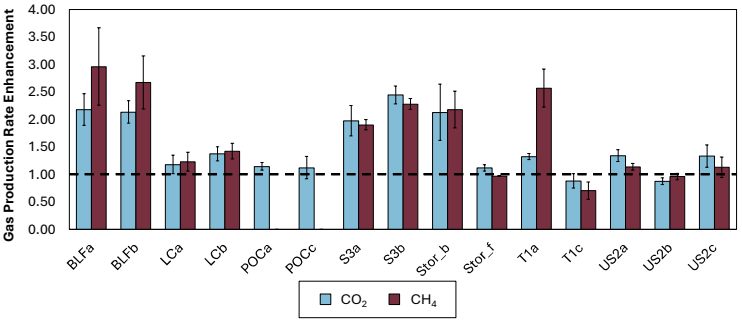

Figure 3. Average enhancement of gas production rates via PVP addition relative to unamended vials in anaerobic peat incubations.

MOLECULAR-LEVEL COMPOSITION

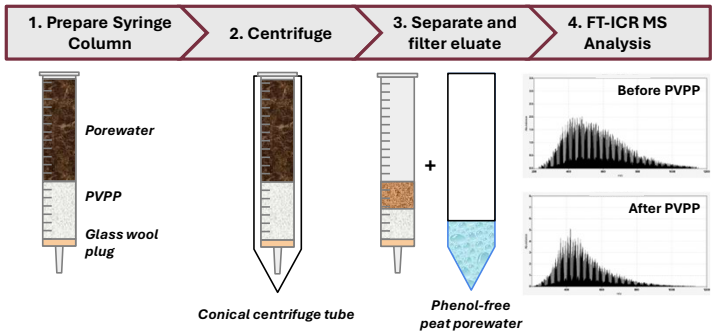

Figure 4. Experimental setup for the theoretical removal of phenolic compounds from the peat porewater DOM using a separation column packed with polyvinylpolypyrrolidone (PVPP; a solid form of PVP) followed by compositional analysis via ESI(-) 9.4T FT-ICR MS.

How does PVP impact peat DOM composition?

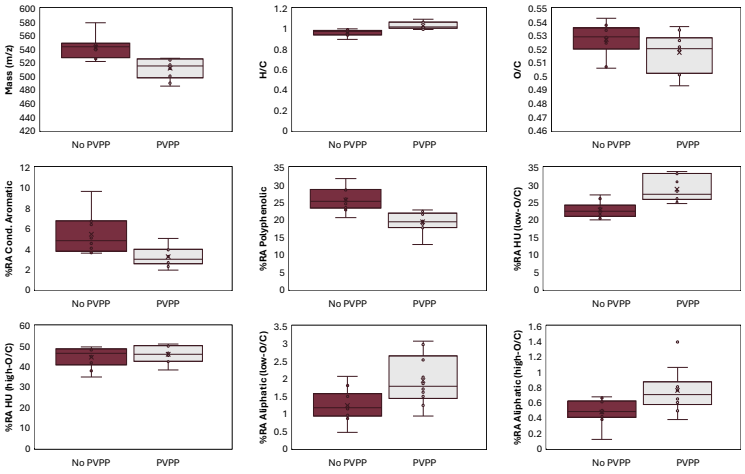

Figure 5. Descriptive box plots demonstrating changes in molecular-level composition of peat porewater across all sites with PVPP treatment.

CONTROLS ON MECHANISM RESPONSE

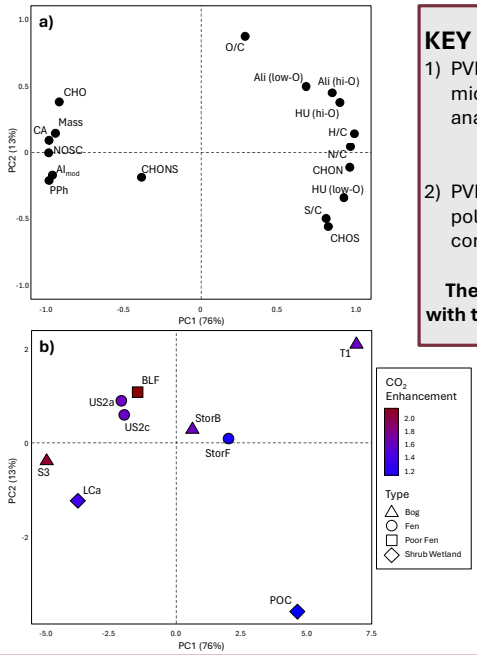

Figure 6. Principal component analysis of changes in molecular compositional parameters of peat porewater as a result of PVPP column extraction showing a) the loadings for each variable and b) the scores of each porewater sample within PCA space. Samples are shaped by wetland type. Colors correspond to CO_2 production enhancement during anaerobic incubations.

KEY FINDINGS

1) PVP significantly stimulates microbial respiration in anaerobic peat incubations
   a) CO_2: >70% of sites
   b) CH_4: 60% of sites
2) PVP selectively removes polyphenolic and aromatic compounds from peat DOM

These findings are consistent with the enzyme latch hypothesis

ACKNOWLEDGEMENTS This work was funded by the U.S. Department of Energy (DE-SC0023297). A portion of this work was performed at the National High Magnetic Field Laboratory ICR User Facility, which is supported by the National Science Foundation Division of Materials Research and Division of Chemistry through DMR 16-44779 and the State of Florida.

REFERENCES (1) Cory, A. B., Chanton, J. P., Spencer, R. G. M., Ogles, O. C., Rich, V. I., McCalley, C. K., et al. (2022). Quantifying the inhibitory impact of soluble phenolics on anaerobic carbon mineralization in a thawing permafrost peatland. *PLoS One 17*(2). (2) Freeman, C., Fenner, N., & Shirsat, A. H. (2012). Peatland geoengineering: an alternative approach to terrestrial carbon sequestration. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *370*(1974), 4404-4421. (3) Freeman, C., Ostle, N. J., Fenner, N., & Kang, H. (2004). A regulatory role for phenol oxidase during decomposition in peatlands. *Soil Biology and Biochemistry*, *36*(10), 1663-1667. (4) Ranatunge, I., Adikary, S., Dasanayake, P., Fernando, C.D., Soysa, P. (2017). Development of a rapid and simple method to remove polyphenols from plant extracts. *International Journal of Analytical Chemistry 2017*(1).