PFAS and Biochar: Some fundamental aspects of biochar

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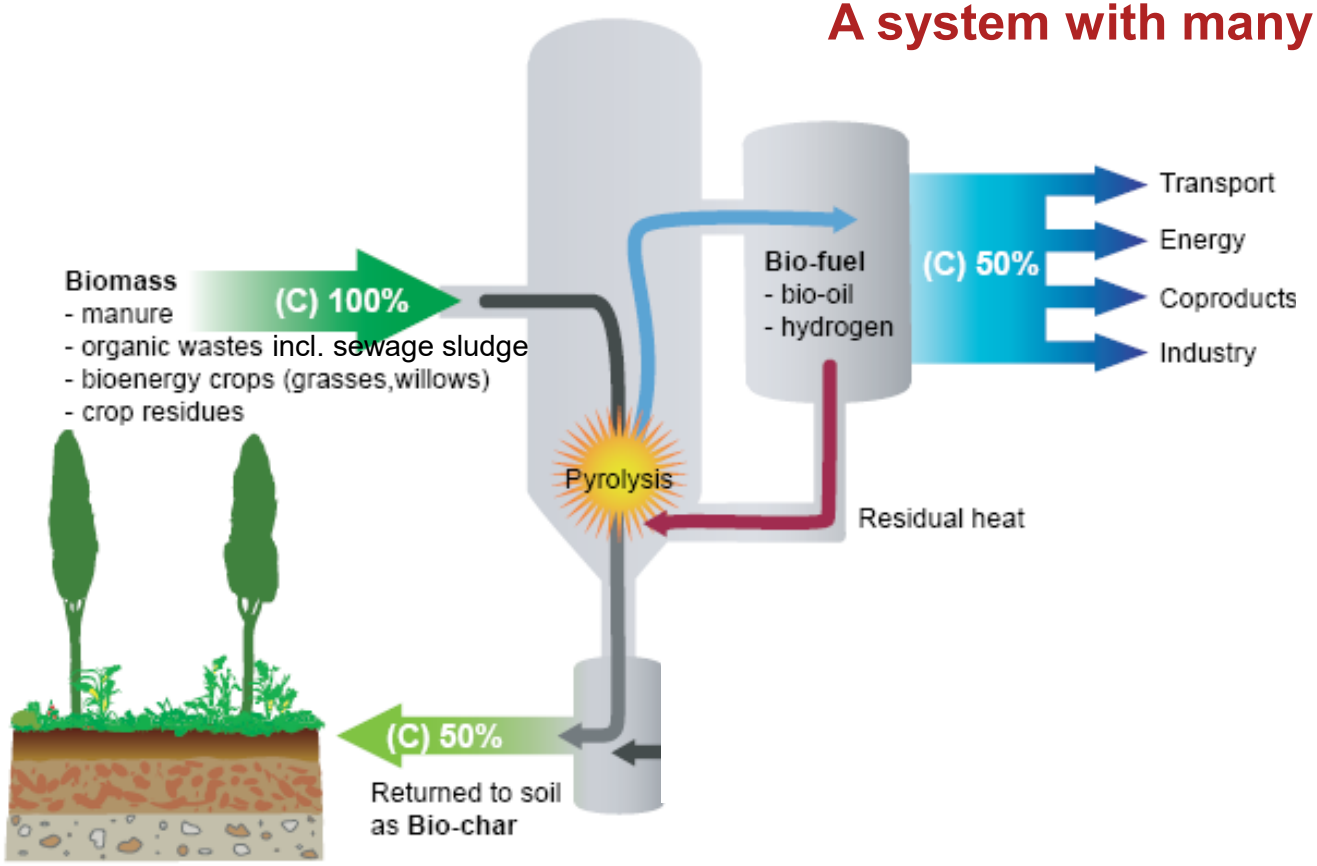
Pyrolysis-Biochar System

A system with many moving parts

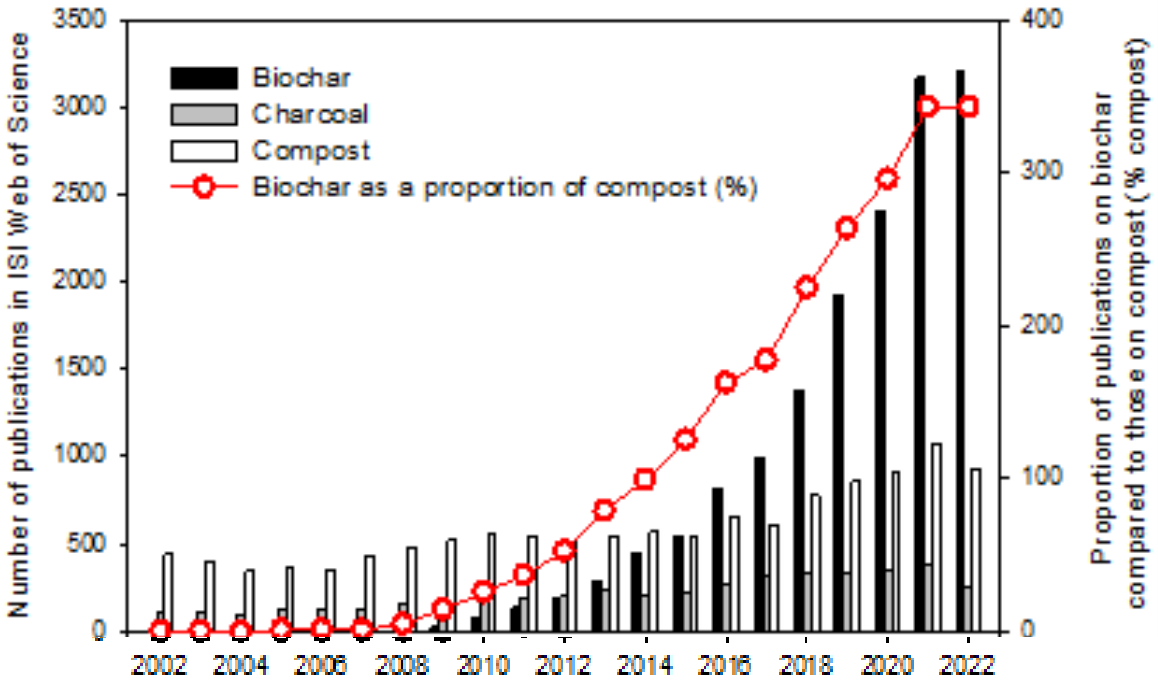


Lehmann, 2007, Frontiers in Ecol Env

Pyrolysis & Wastewater Treatment
An Ithaca Summit
The Soil Factory
October 15 2023

Cornell University

Development of Biochar Science

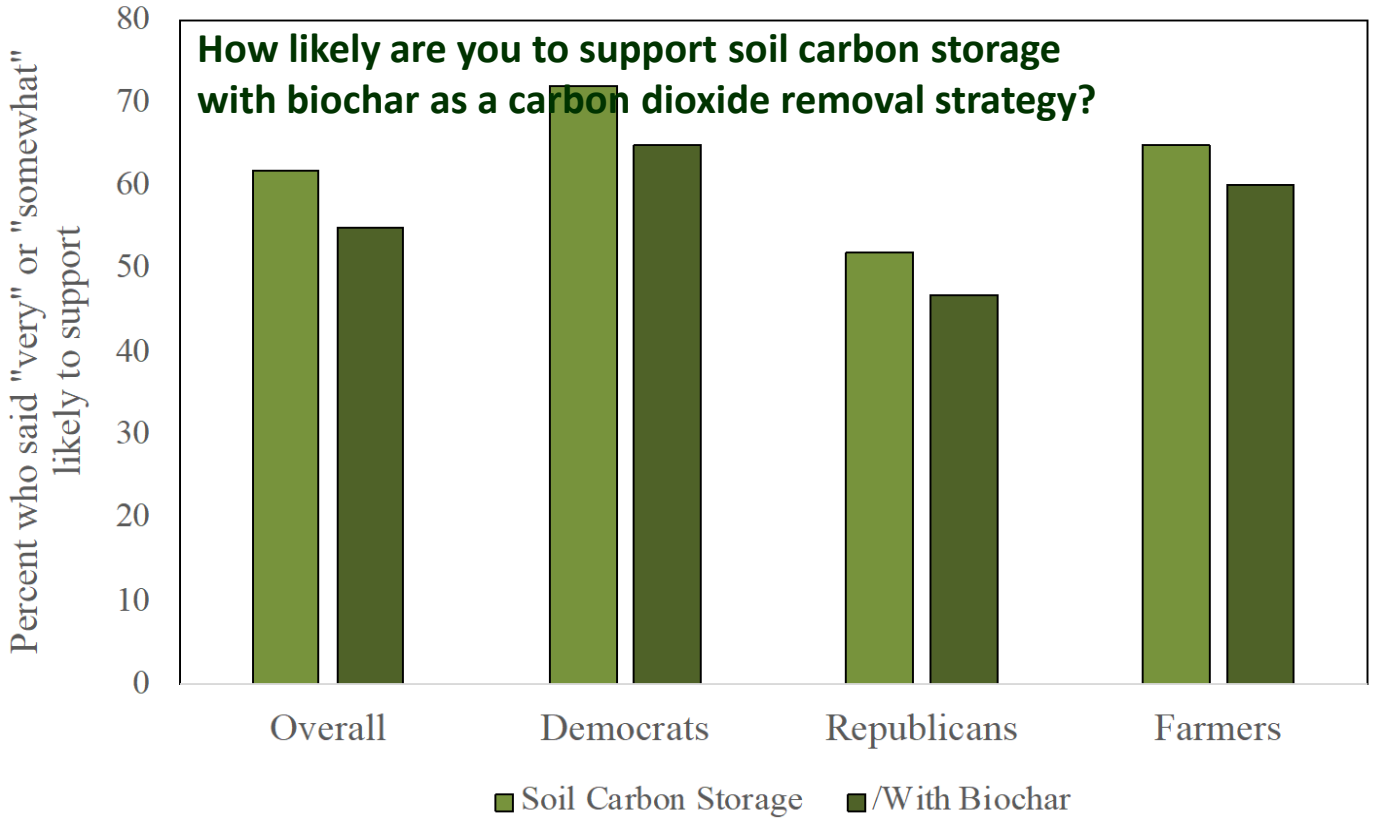


Since 2015, more publications on biochar than on compost

Expectation: science on PFAS&biochar will grow quickly

Climate Change Mitigation as a Policy Driver?

Public support for biochar across political lines



62% for soil carbon

55% for biochar

How to navigate public acceptance?

1222 U.S. adults, AmeriSpeak® Panel, 97% of the US American population, of 92% that believed climate change is “definitely” or “somewhat” happening

Sweet et al 2021 *Climatic Change* 166, 22
Schuldt et al., 2021 *The Hill*

PFAS and Pyrolysis

Treatment of PFAS in solids: destruction through heating (above 600C)
(solids: separated solids from screw press of wet sludge)

Treatment of PFAS in liquids: adsorption and subsequent pyrolysis
(liquids: separated liquids from screw press of wet sludge; leachate from landfill; etc)

Pyrolysis – A Few Facts relevant to PFAS

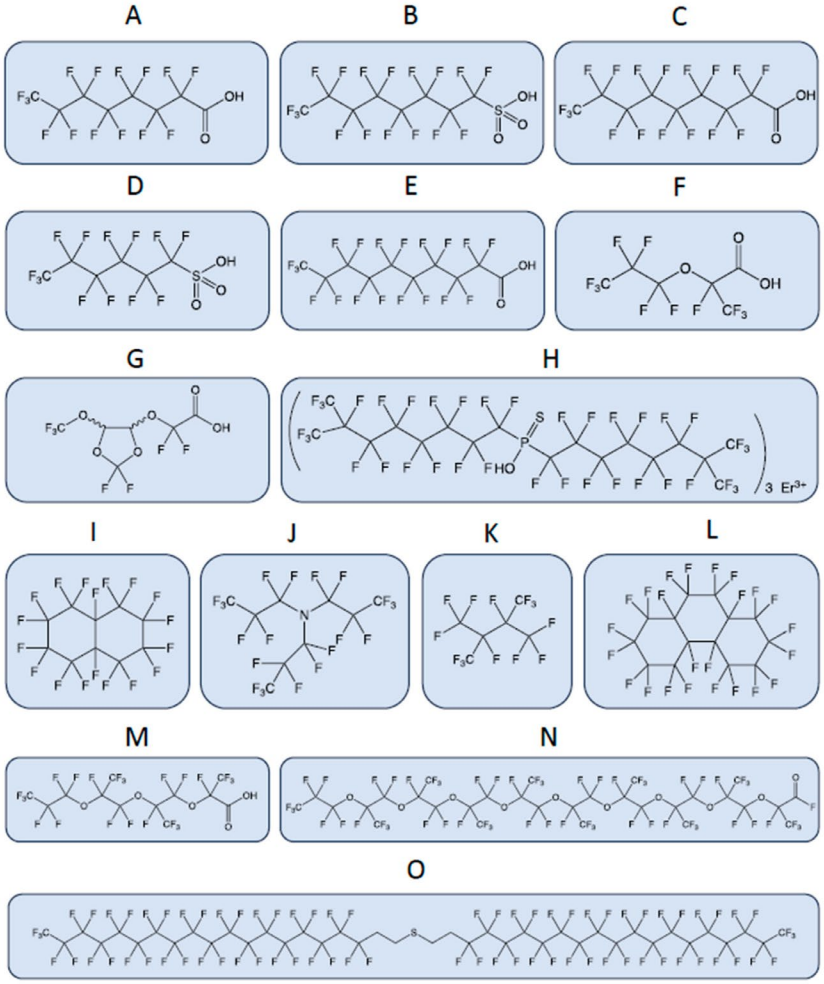
Destruction:
Pyrolysis is exothermic – no energy required
If feedstock is very wet, additional energy needed
Residence time rather unexplored
Heat needed for PFAS destruction fairly well known
Weight+volume reduction of separated solids by >90%

Adsorption:
Less well known
First publications show good retention of PFAS

Valid for October 16, 2023 – see earlier remark on development of biochar science

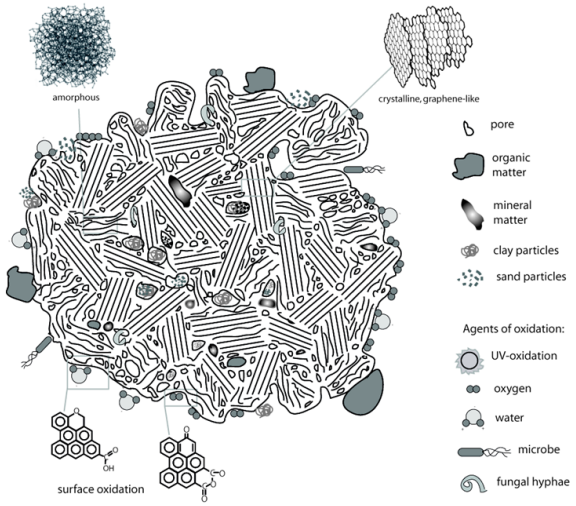
Pyrolysis – State of Engineering

The PFAS World… is vast



Retention therefore has to cater for many different forms and properties

Diversity of surfaces and functional groups…

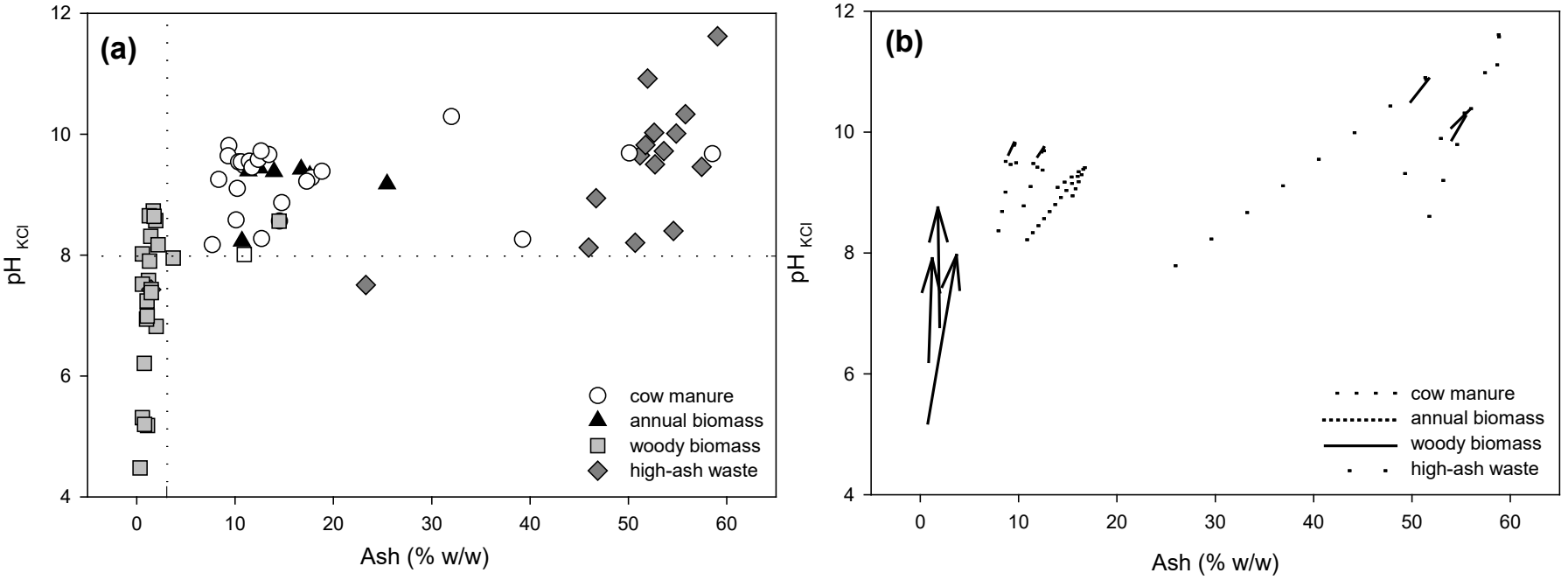


Spyrakis and Dragani 2023 Toxics 11, 721

Hammes et al 2009 in: Earthscan

PFAS Adsorption – Biochar Properties

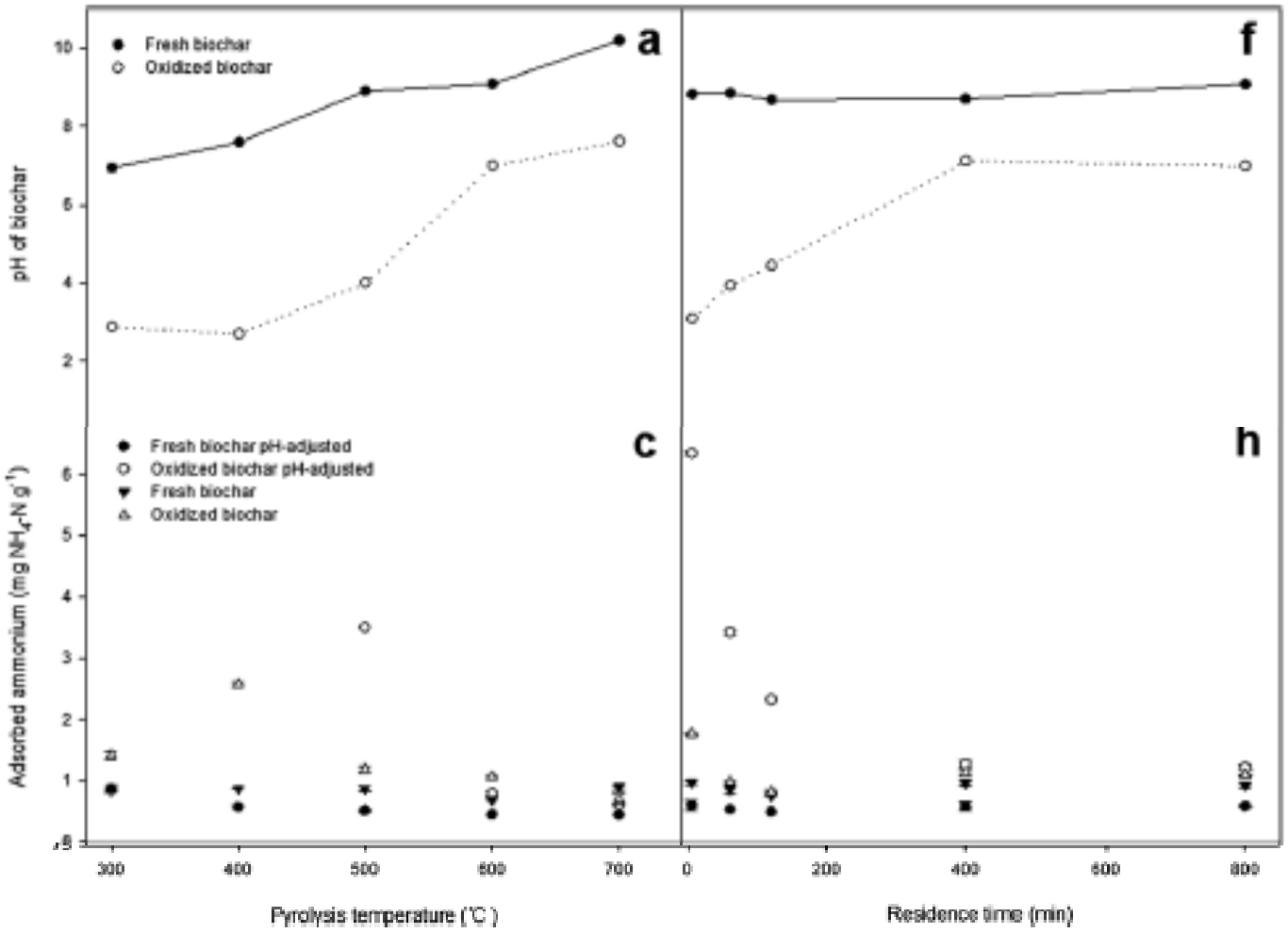
Arrows from lowest to highest temperature within a given feedstock



Slow pyrolysis

Enders et al.,2012, Bioresource Technology 114, 644-653

PFAS Adsorption – Pyrolysis temp+time

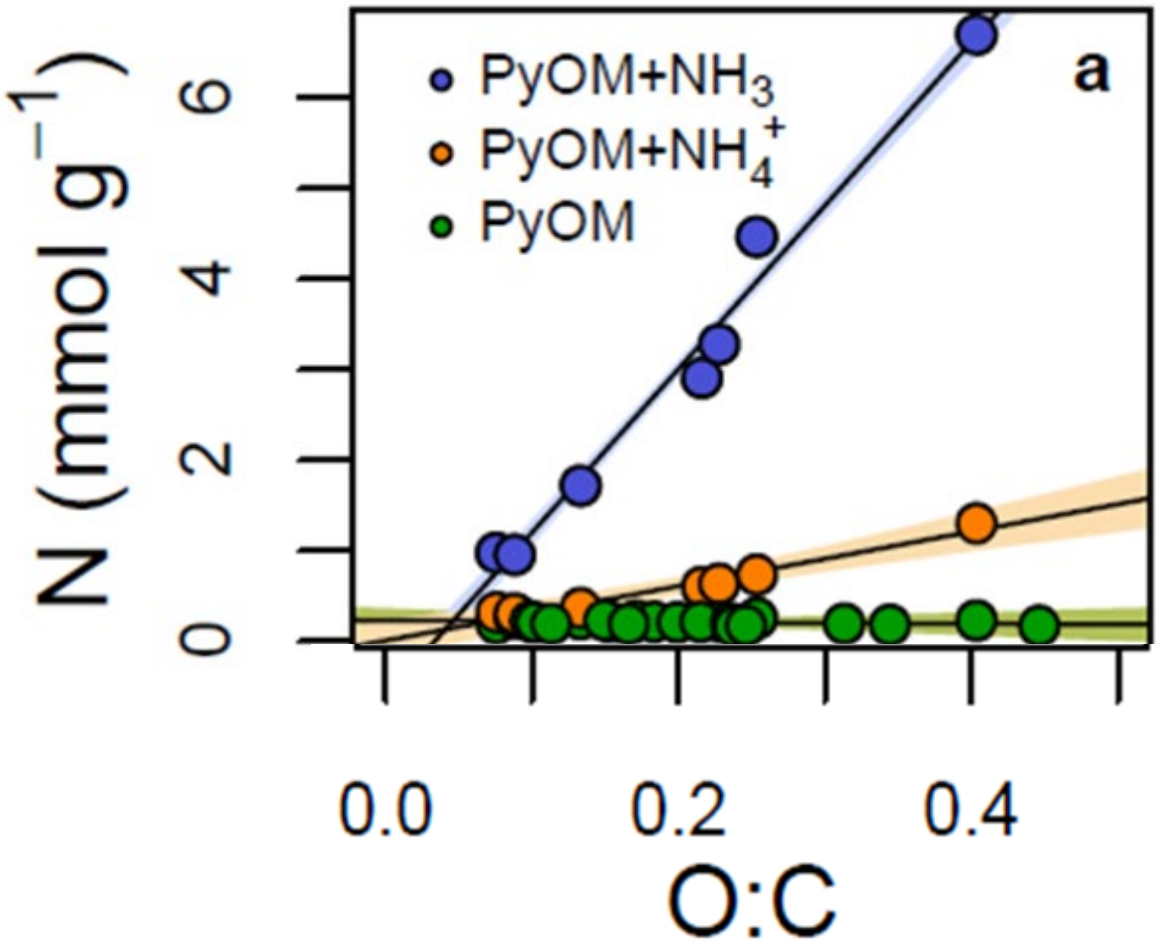


Intermediate temperature and low residence times promote oxidation

(and therefore optimization of interaction with charged solutes)

Wang et al, 2015, *Chemosphere* 138, 120-126

Biochar Oxidation

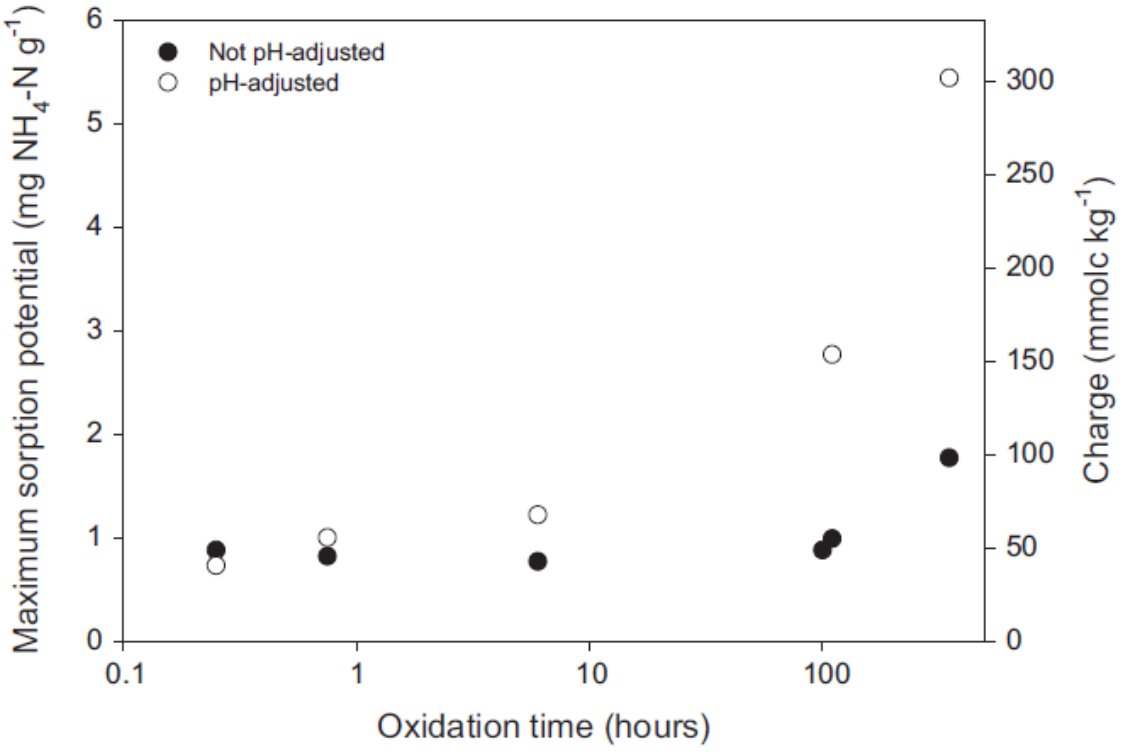


Chemisorption of NH_3

Electrostatic adsorption of NH_4^+

Hestrin et al, 2019, *Nature Communications* 10, 664

Biochar Oxidation - Time



Electrostatic adsorption increases with oxidation time

Wang et al, 2015, *Chemosphere* 138, 120-126

Biochar vs Activated Carbon

Activated Carbon: Higher surface area

Usually does not justify 10-100x price

Table 1. Elemental Composition, Elemental Ratio, pH, CEC and Measured and Predicted Micropore Surface Area of the Unaged As Well As BIO (Biologically Aged), CHEM 60 (Chemical Aging at 60 °C), CHEM 110 (Chemical Aging at 110 °C) and PHYS (Physical Aging) Aged AC, Biochar, AC + Soil and Biochar + Soil

										micropore surface area [d] $m^2 g^{-1}$	
material	aging regime	C %[a]	O %[a]	H %	N %[a,b]	O/C[c]	C/N[c]	pH	CEC $mmol_c kg^{-1}$	measured	predicted [e]
AC	UNAGED	81.2 ± 1.0	8.4 ± 1.8	0.03	0.2 ± 0.03	0.15	117.7	9.6	8	838	
	BIO	75.3 ± 3.8	8.0 ± 0.1	0.14	0.5 ± 0.04	0.17	86.2	6.9	nd[h]	792	
	CHEM 60	78.2 ± 3.5	9.5 ± 1.6	0.13	0.2 ± 0.04	0.17	118.3	7.9	18	838	
	CHEM 110	77.4 ± 2.5	12.2 ± 1.8	0.30	0.2 ± 0.02	0.18	120.3	6.6	54	795	
	PHYS	79.3 ± 4.0	9.3 ± 1.3	0.14	0.2 ± 0.03	0.16	112.8	8.3	100	859	
biochar	UNAGED	41.6 ± 7.5	8.1 ± 3.5	1.5	0.4 ± 0.03	1.43	94.8	9.9	278	178	
	BIO	41.5 ± 4.5	9.1 ± 0.6	1.9	0.9 ± 0.8	0.91	51.6	7.6	272	167	
	CHEM 60	28.0 ± 16.5[f]	7.3 ± 0.4	1.3	0.3 ± 0.2	1.83	92.6	9.2	299	190	
	CHEM 110	40.6 ± 4.5	8.3 ± 1.4	1.3	0.4 ± 0.03	1.53	96.4	7.0	518	179	
	PHYS	46.0 ± 7.7	7.7 ± 2.1	1.5	0.5 ± 0.1	1.22	96.1	9.9	311	181	

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Hale et al, 2011, EST

Following Ithaca Summit – Next Steps:

White Paper on “What is Pyrolysis”

Fact sheet on “PFAS and Pyrolysis: what do we know and what do we want to know”

Live and regularly updated bibliography on PFAS & biochar on cornell.edu

Next meeting in early December at The Soil Factory