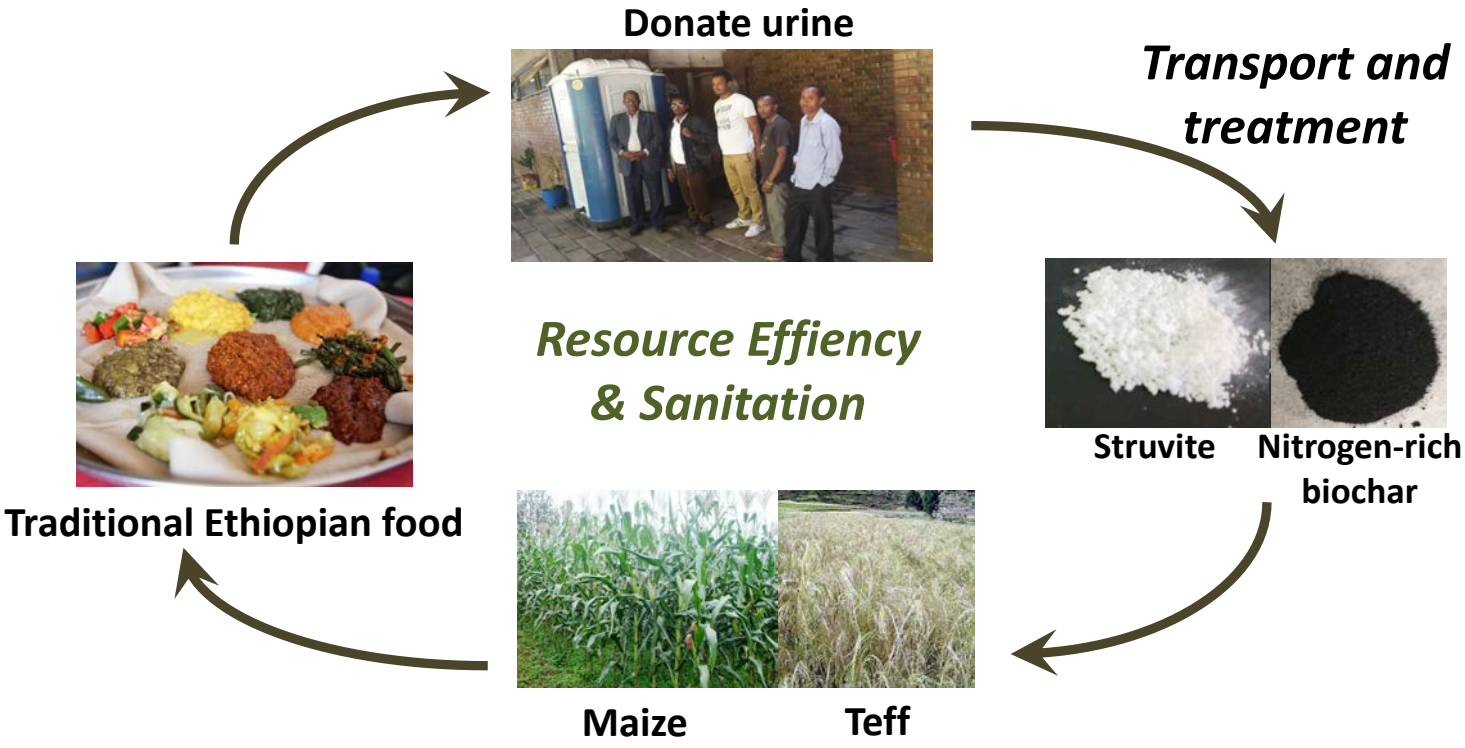
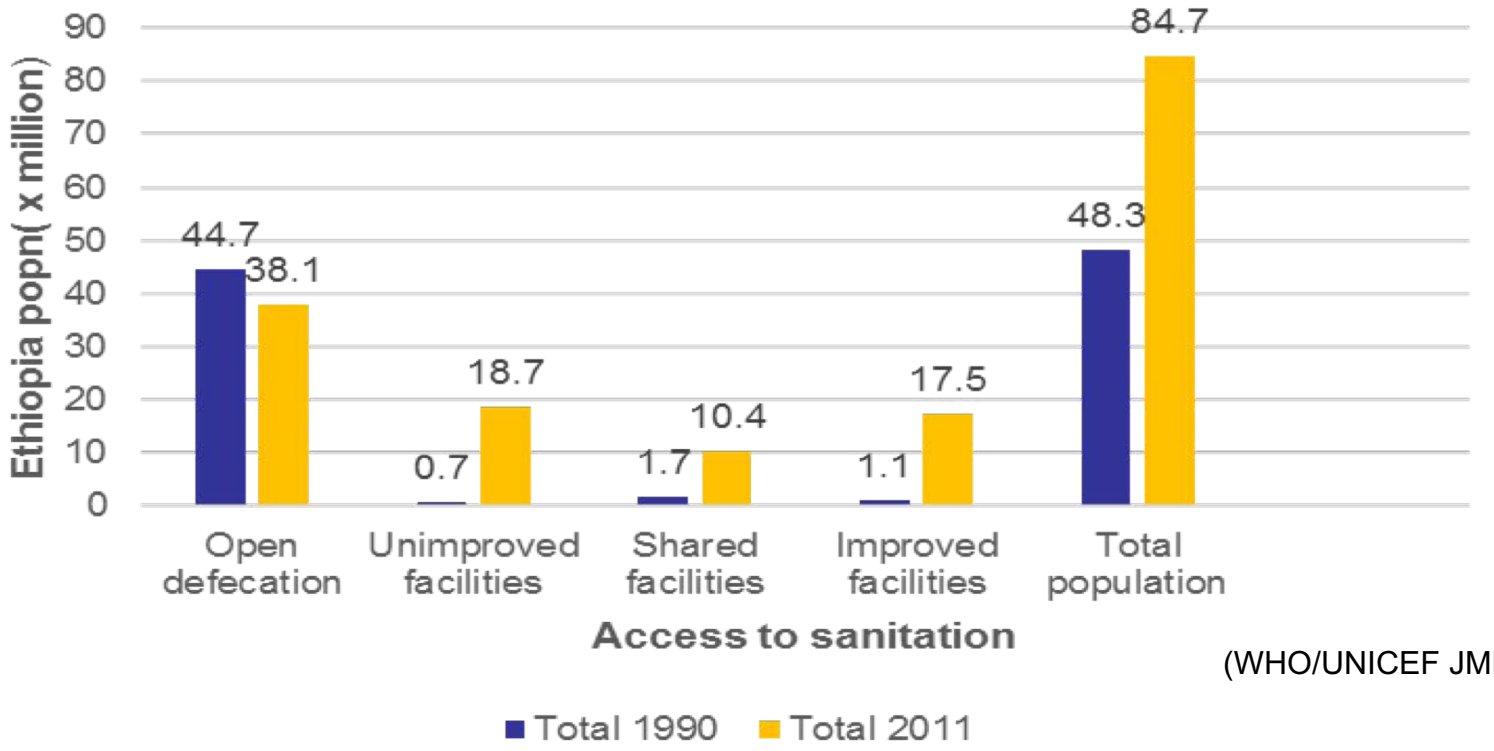
Activated biochar synthesized from Ethiopian Prosopis wood to recycle ammonia off-gassed from source-separated urine



Zerihun Workneh, Mohit Nahata, Xiaoyen Chen, Johannes W. Schwank and Nancy G. Love

Ethiopia has low sanitation coverage; less than 18% of the total population has access to improved sanitation

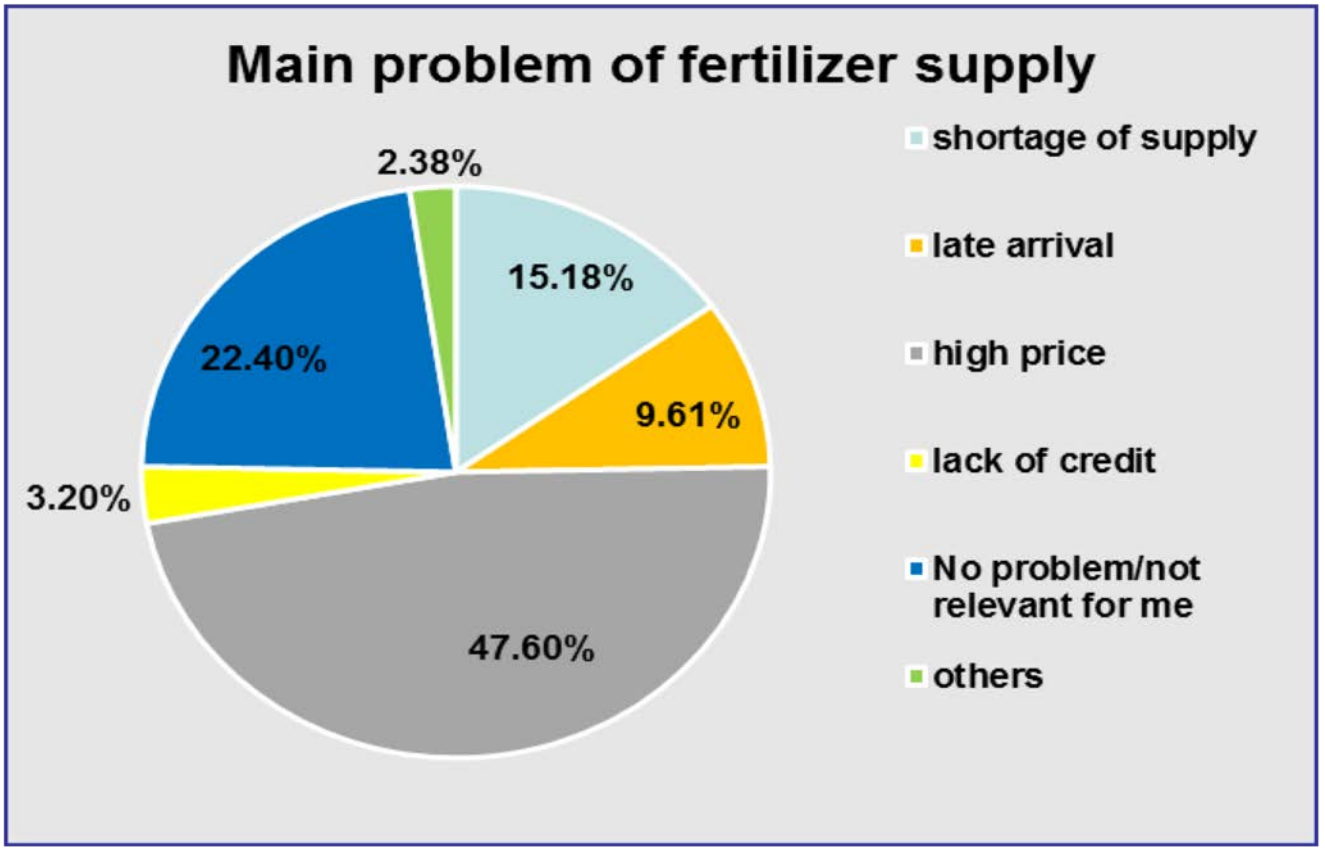


(WHO/UNICEF JMP 2013)

(Photo: Addis Ababa, 2016)

(Photo: Jimma,2013)

The retail price of inorganic fertilizer in Ethiopia is unaffordable for most farmers & increases by up to 20%/yr



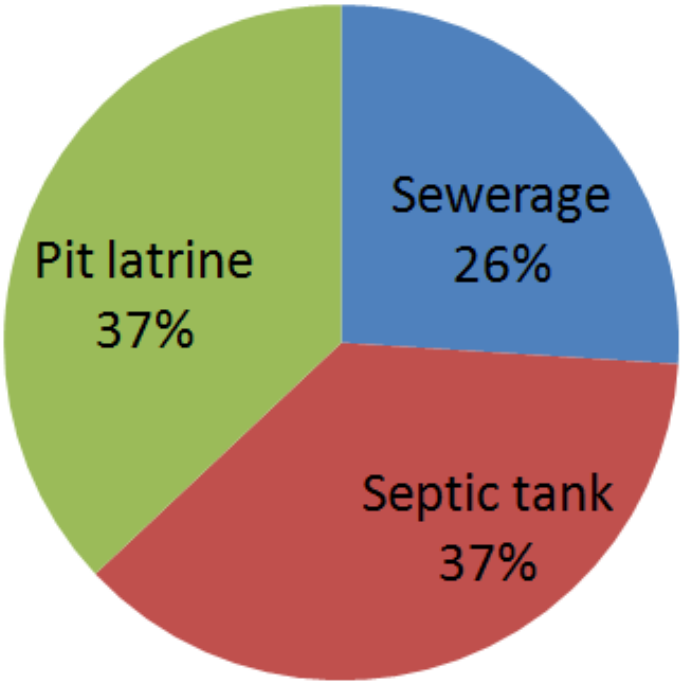
Only 10% of the national fertilizer demand was met from 2010-2015

Source : Based on ERHS, 2004 and Robinson 2006.

Insufficiently treated wastewater from treatment ponds and fecal sludge supplies nutrients for agricultural use

Engineering News Record, 2011

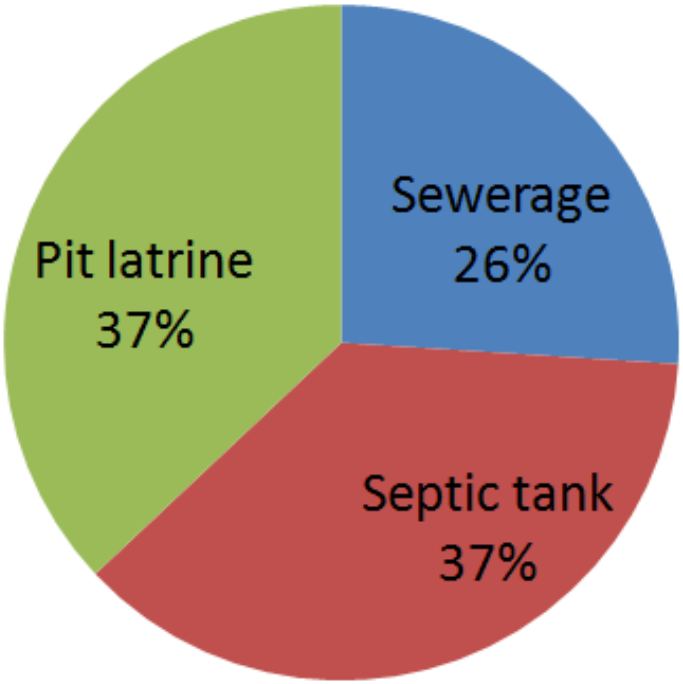
Progress on establishing sanitation services in Addis Ababa



Proposed distribution of sanitation services in Addis Ababa in 2020

(2002 Wastewater Management Master Plan)

Progress on establishing sanitation services in Addis Ababa is slow



Proposed distribution of sanitation services in Addis Ababa in 2020
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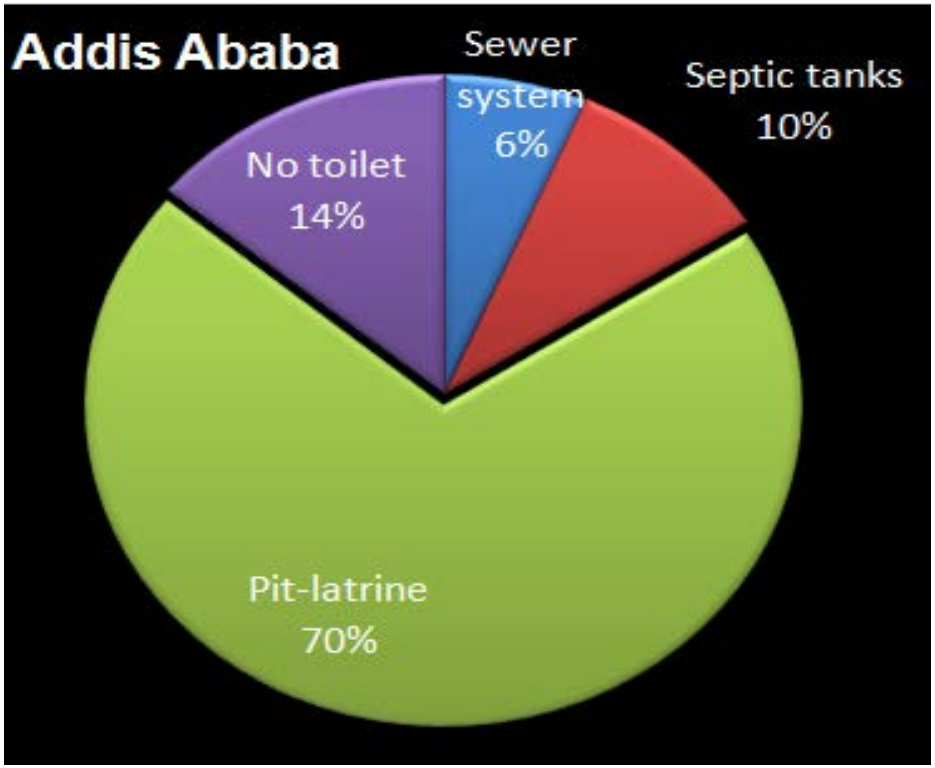

Distribution of sanitation services in Addis Ababa, 2011
(AAWSA, 2011)

Expansion of decentralized sanitation services can enhance food security by:

- Managing enteric pathogens to reduce public health risks
- Capturing resources for reuse

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Carbon →
- Biogas
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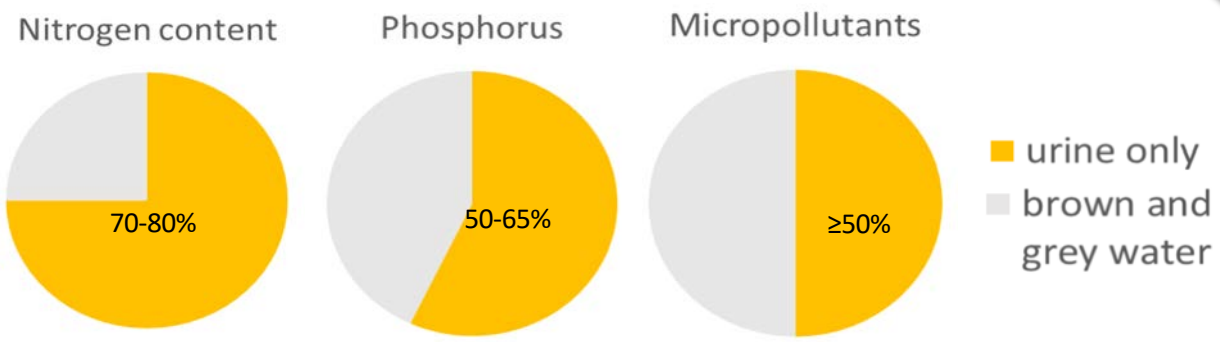
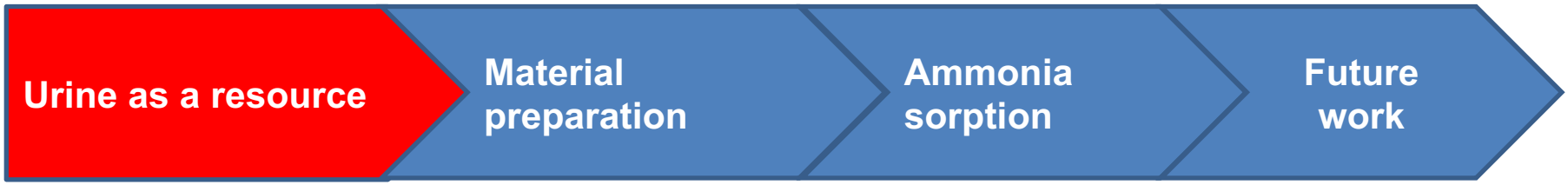
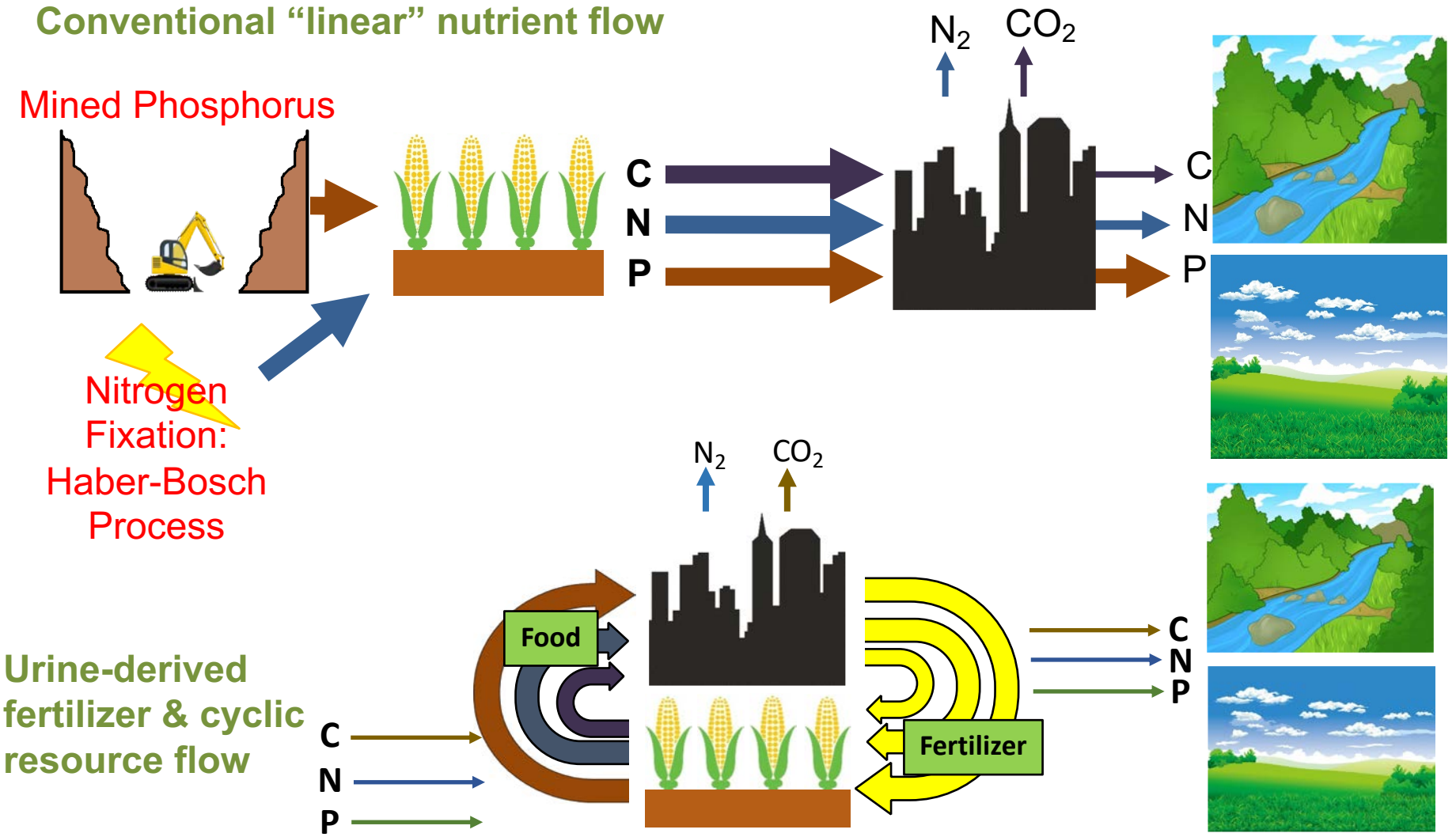
Inorganic Nutrients →

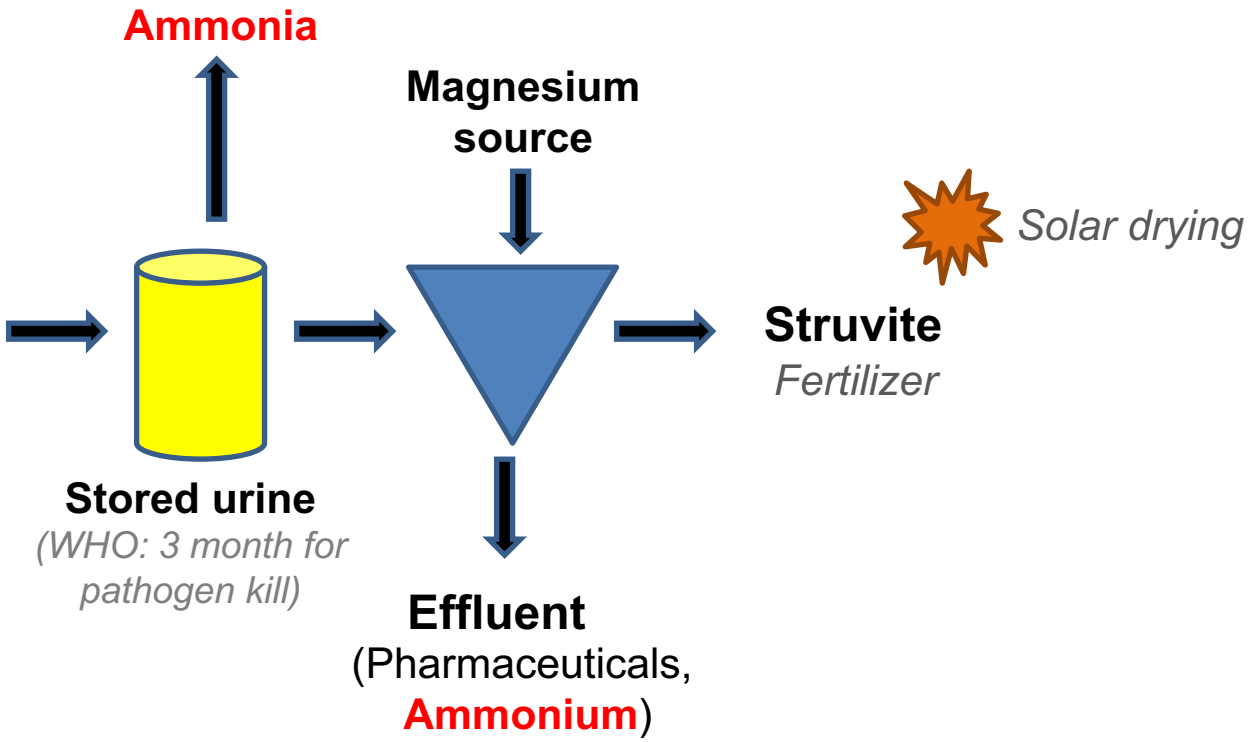



Urine as a resource
Material preparation
Ammonia sorption
Future work

Reconsider nutrient flows and how to achieve *Resource Efficiency* in cities



Ammonia gas can be captured from high pH urine or struvite effluent solutions



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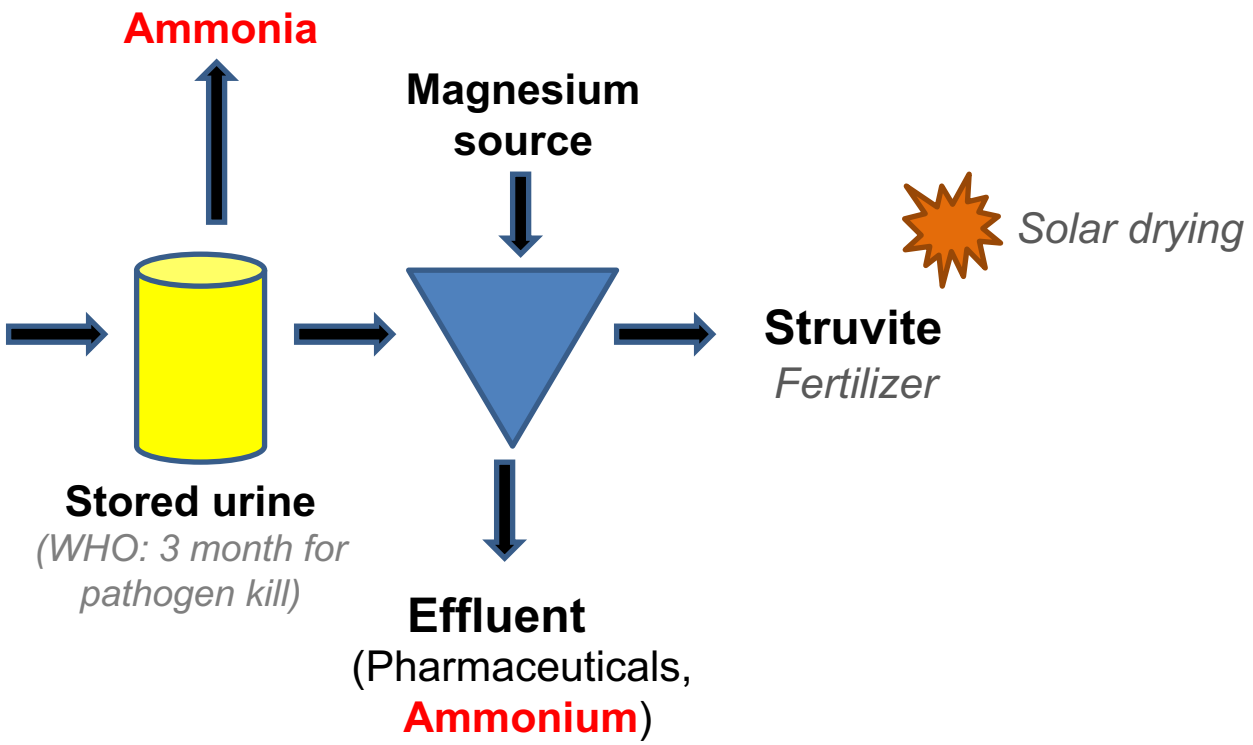
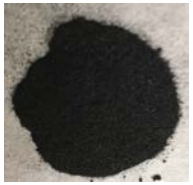
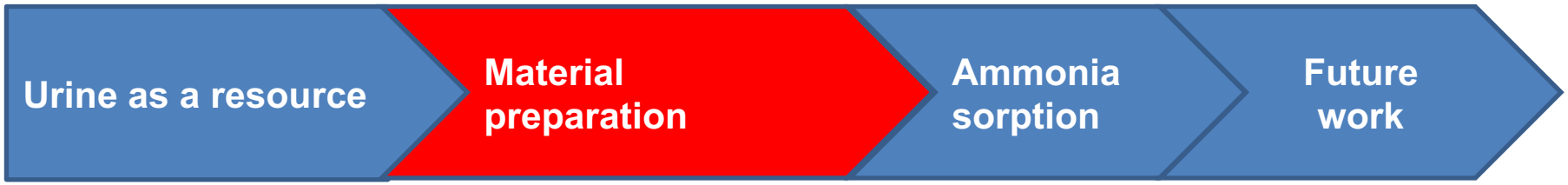


Ammonia gas-selective biochar




Urine as a resource
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Activated biochar was synthesized with methods tailored to resource-constrained settings

Powdered prosopis + DAP

xx = 50, 75 or 100 mg/mL DAP

→ *Room temperature* → *3 hours*

→ *Heat @ 80°C* → *48 hours*

Precursor prosopis (NH_3, H_3PO_4, $NH_4H_2PO_4$)

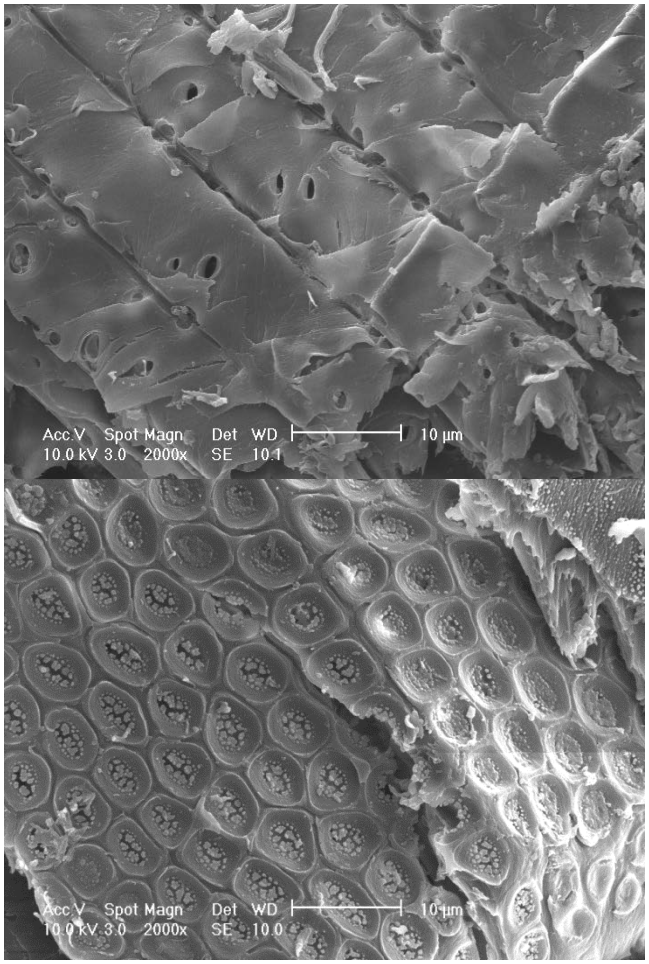
→ *Carbonization with air* → *Heat @ 5°C/min to 450°C* *Hold at 450°C for 1 hr*

→ *Cool to room temperature* → *Wash ~ 20x deionized water* *Dry overnight @ 110°C*

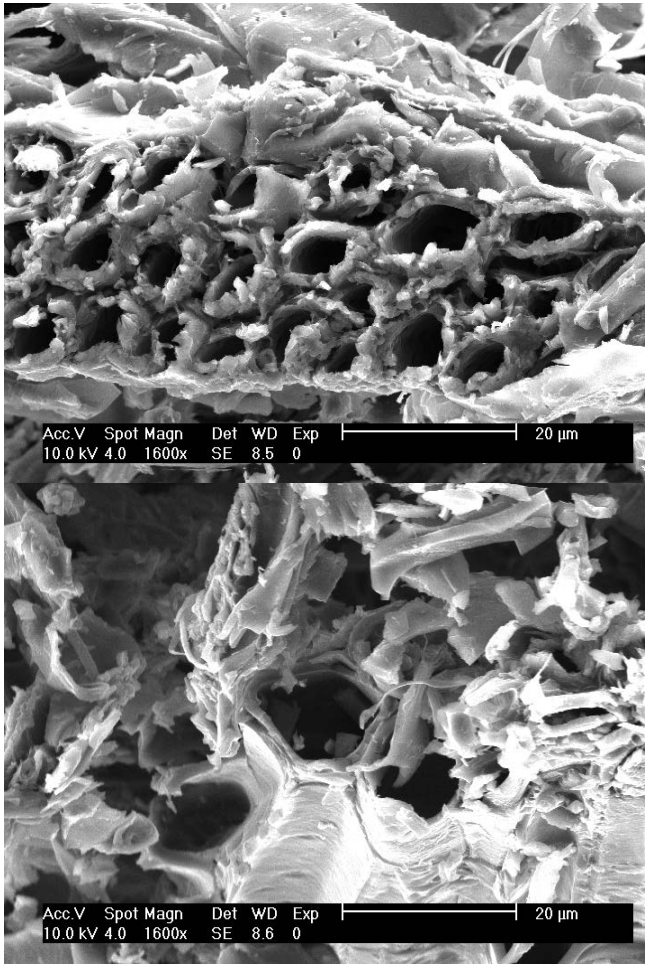
Prosopis activated biochar *(PSP-xx-POX)*

Also created activated biochar from cellulose using same protocol: *AC-xx-POX*

Activated biochar from Ethiopian Prosopis (wood)



Raw material (Prosopis sawdust)

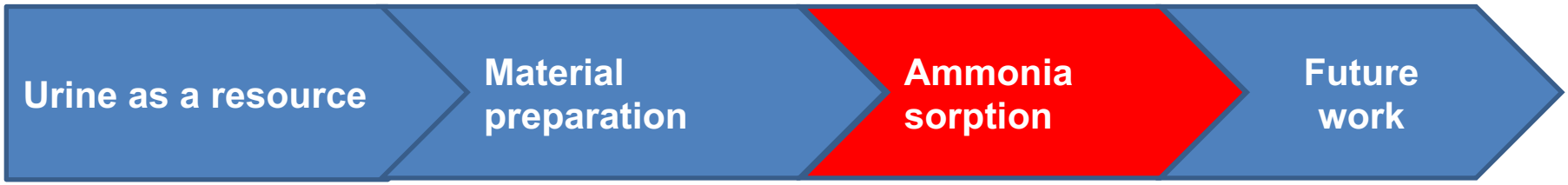


Activated biochar from Prosopis

Botanic structure of the plant material is preserved post carbonization

Prosopis activated biochar is structurally similar to cellulosic activated biochar

	Micropore volume (cm^3/g)	BET surface area (m^2/g)	Total pore volume (cm^3/g)	Median pore size (nm)
AC-50-POX	0.312 ± 0.004	666 ± 9	0.319 ± 0.006	0.564
PSP-50-POX	0.265 ± 0.011	567 ± 19	0.278 ± 0.011	0.560
Char (no activation)	0.187	388	0.191	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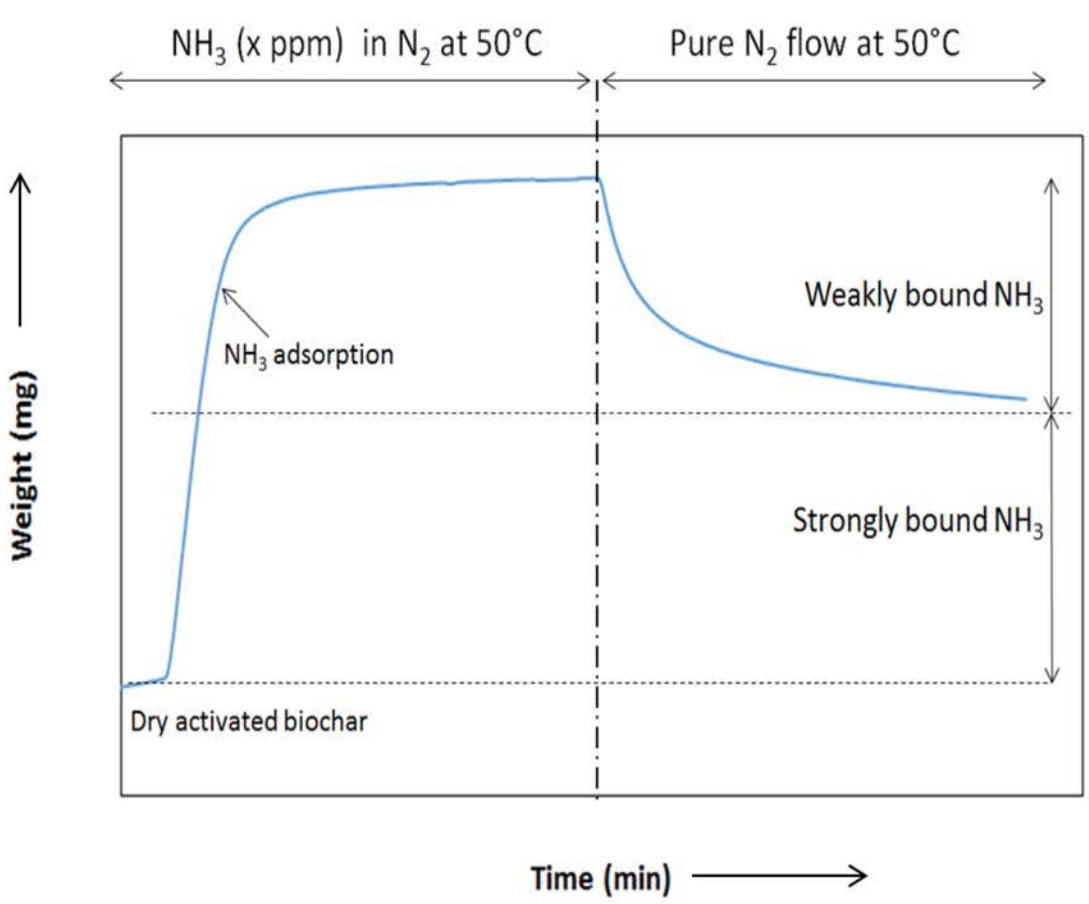
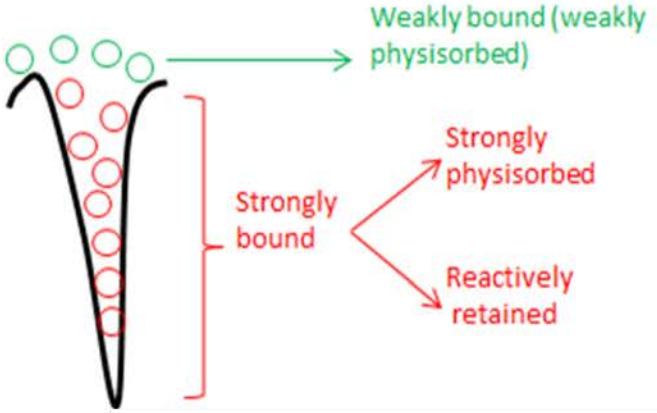
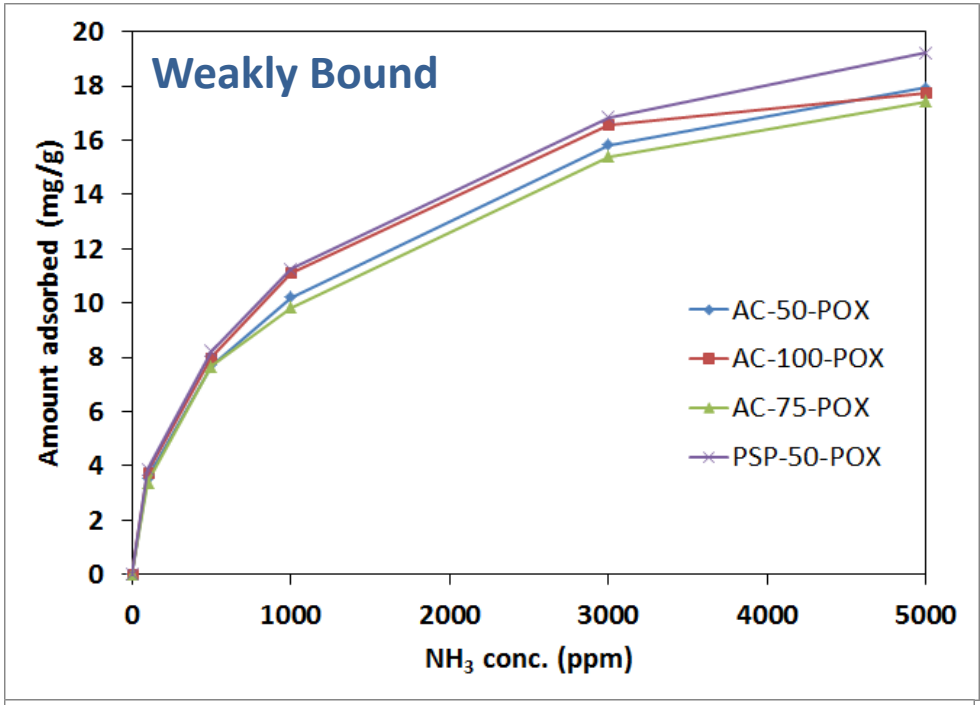
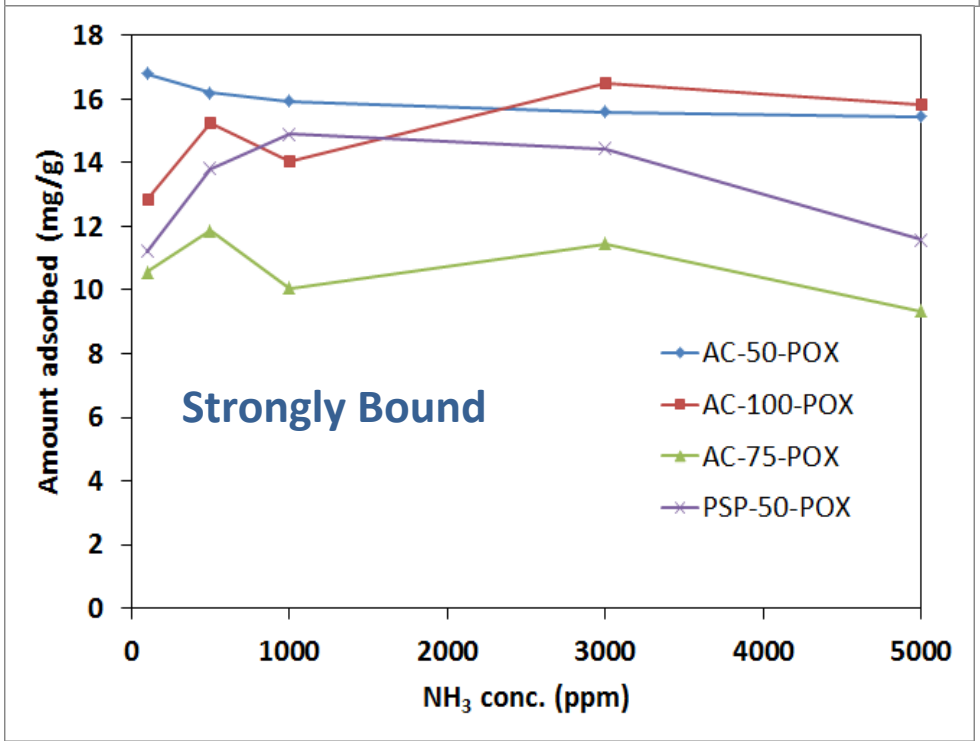
Thermogravimetric analysis is used to characterize NH_3 adsorption and desorption.



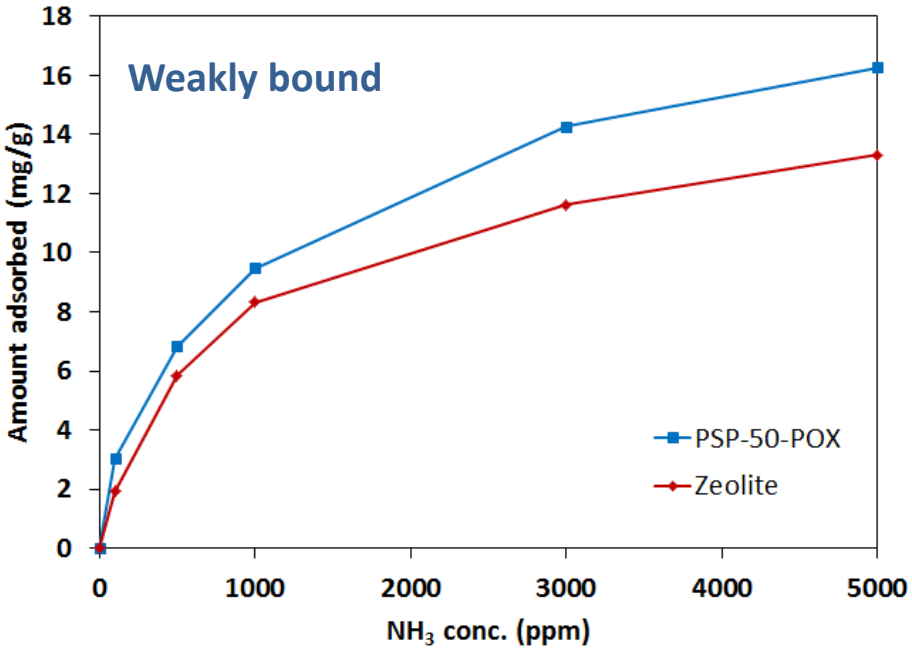


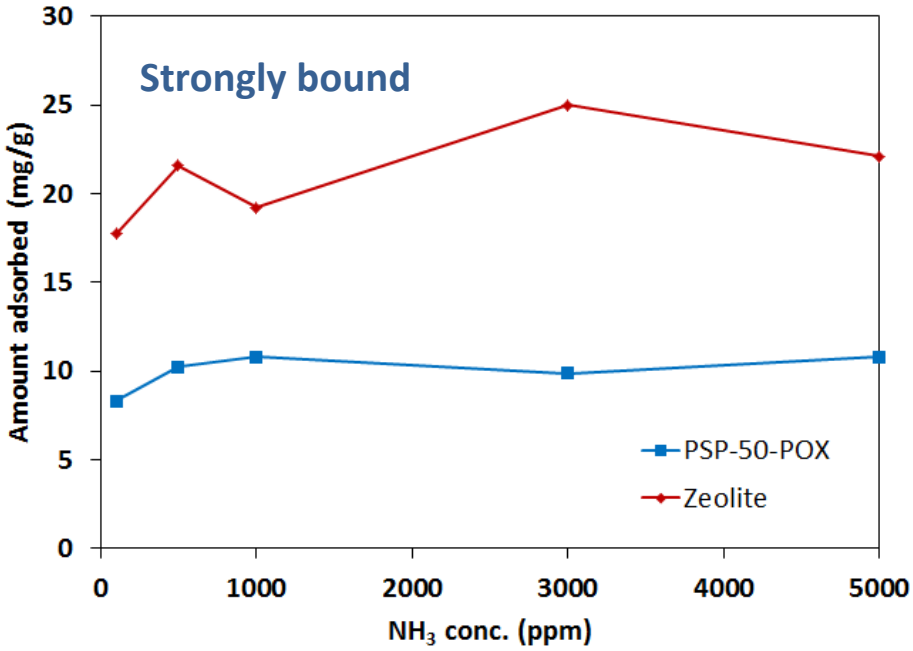
PSP-50-POX activated biochar has ammonia sorption characteristics comparable to cellulosic activated biochar



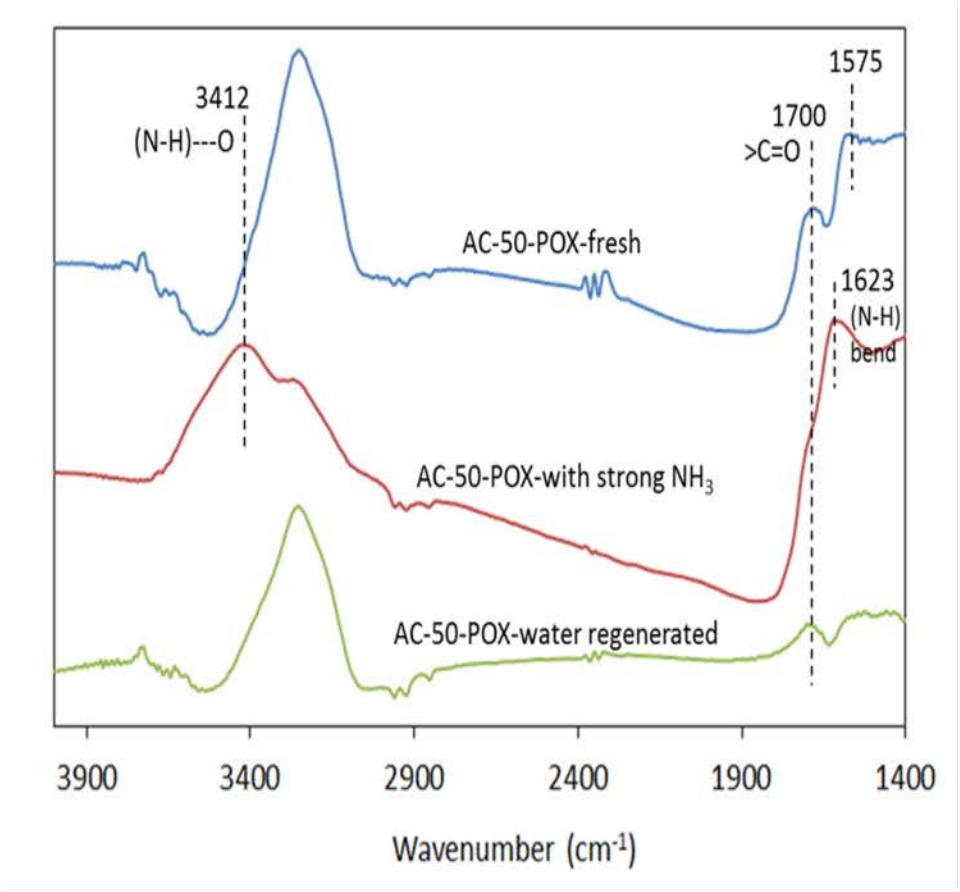


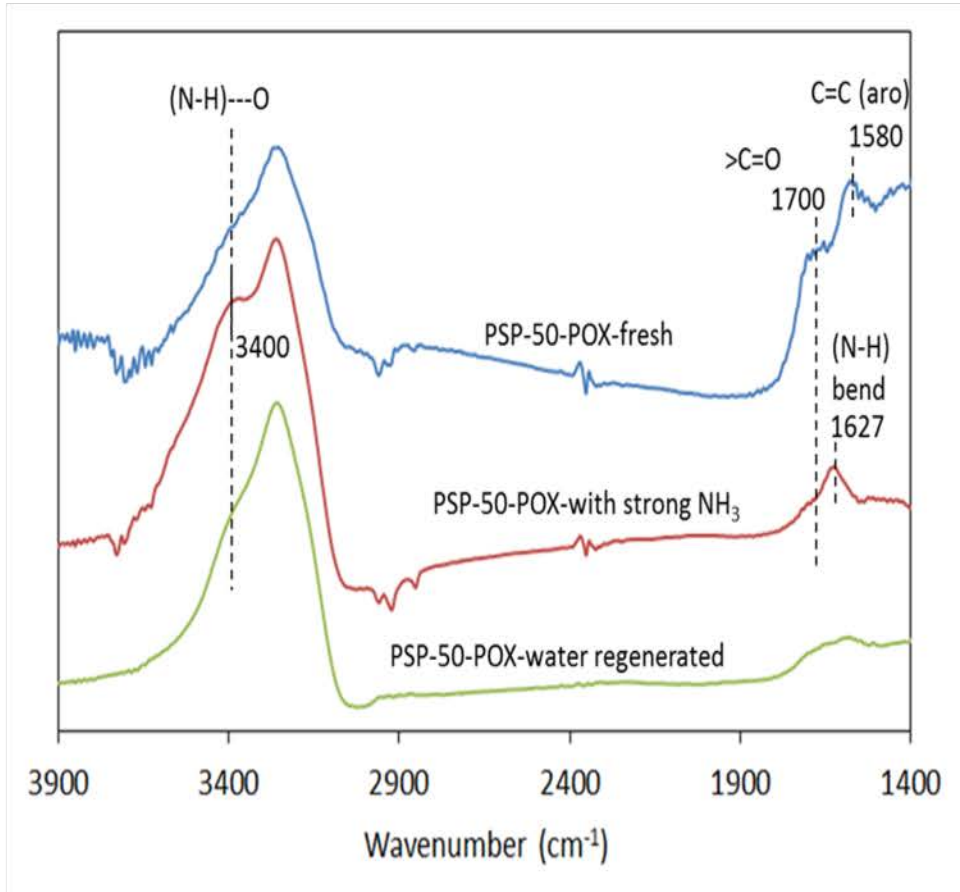
PSP-50-POX activated biochar has ammonia sorption characteristics superior to **Zeolite**



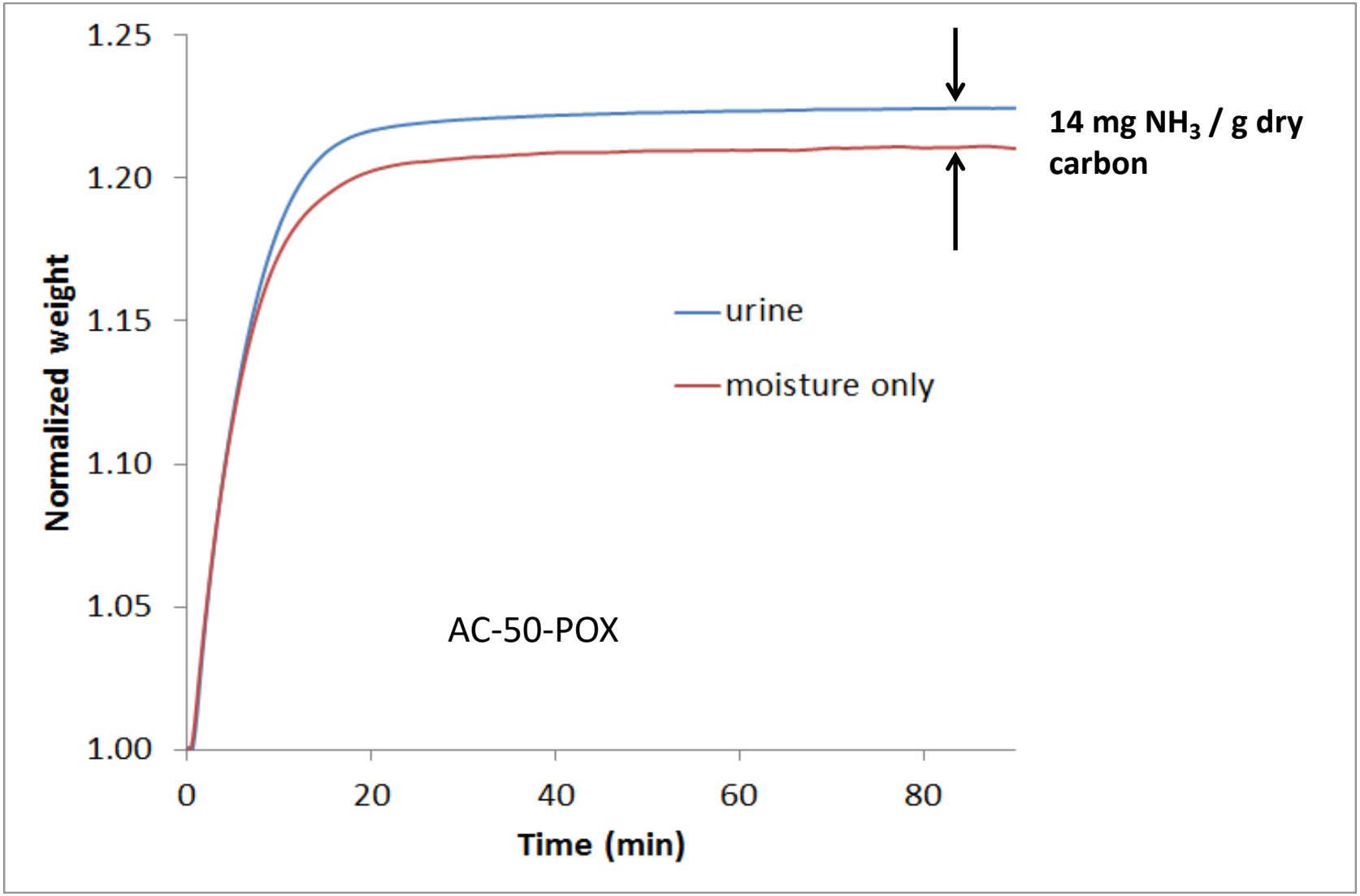


Diffuse Reflectance Infra-Red Fourier Transform Spectroscopy (DRIFTS) spectra for activated biochar and activated prosopis biochar showing evidence for ammonia binding.

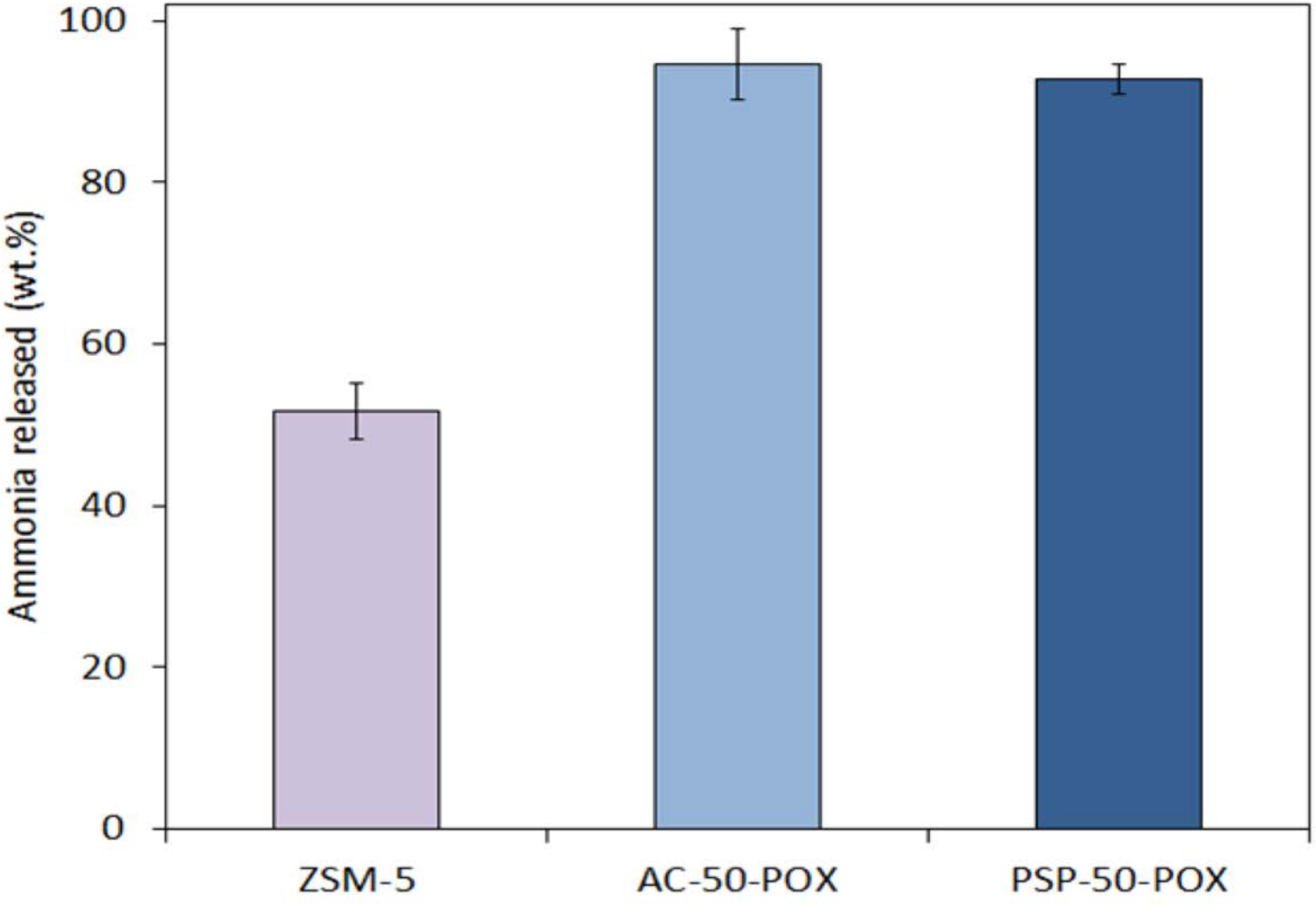




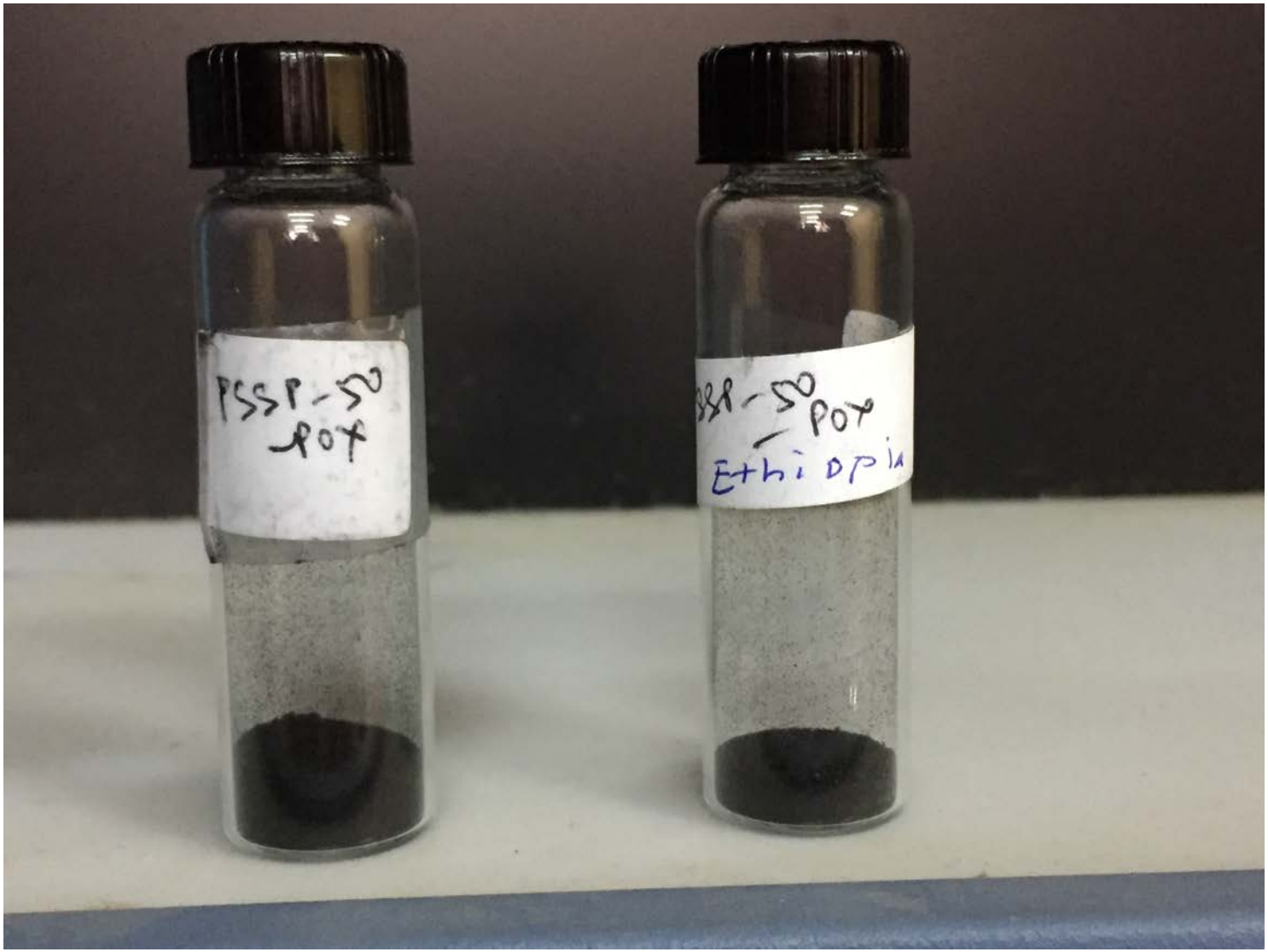
Ammonia off-gas from high pH urine was captured on activated biochar.

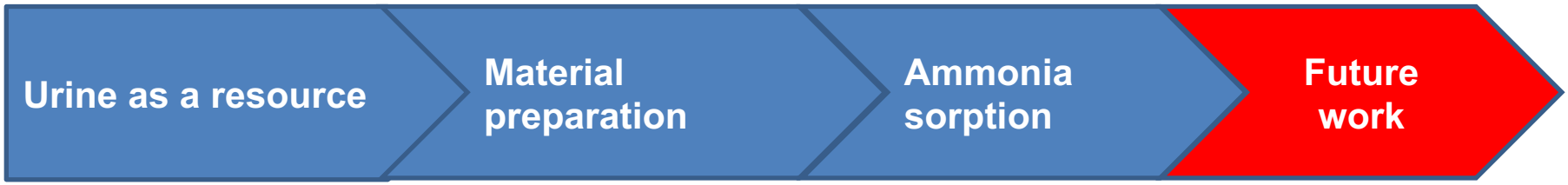


Strongly physisorbed NH_3 can be released when biochar is submerged in water, suggesting bioavailability for plants.



Work has continued in Ethiopia





- **Scale up volume of biochar synthesized**
- **Evaluate alternative activating chemistry**
- **Plant studies with indigenous crops**

To date, we've shown:

- Activated biochar can be synthesized in modest semi-batch reactors in presence of air, without the use of solvents, leading to the possibility of its small scale production in low resource settings

- Activated biochar made from the Ethiopian prosopis tree has characteristics comparable to cellulosic sources available in the U.S.

- Acidic surface functionalities make DAP-activated biochar suitable for adsorbing NH_3

- Adsorbed NH_3 can be easily recovered, implying bioavailability for plants.

Acknowledgements

Zerihun Getaneh Workneh

Dr. Mohit Nahata

University of Michigan African Presidential Scholars Program

NSF Innovation at the Nexus of Food-Energy-Water Systems

University of Michigan 3rd Century REFRESCH program

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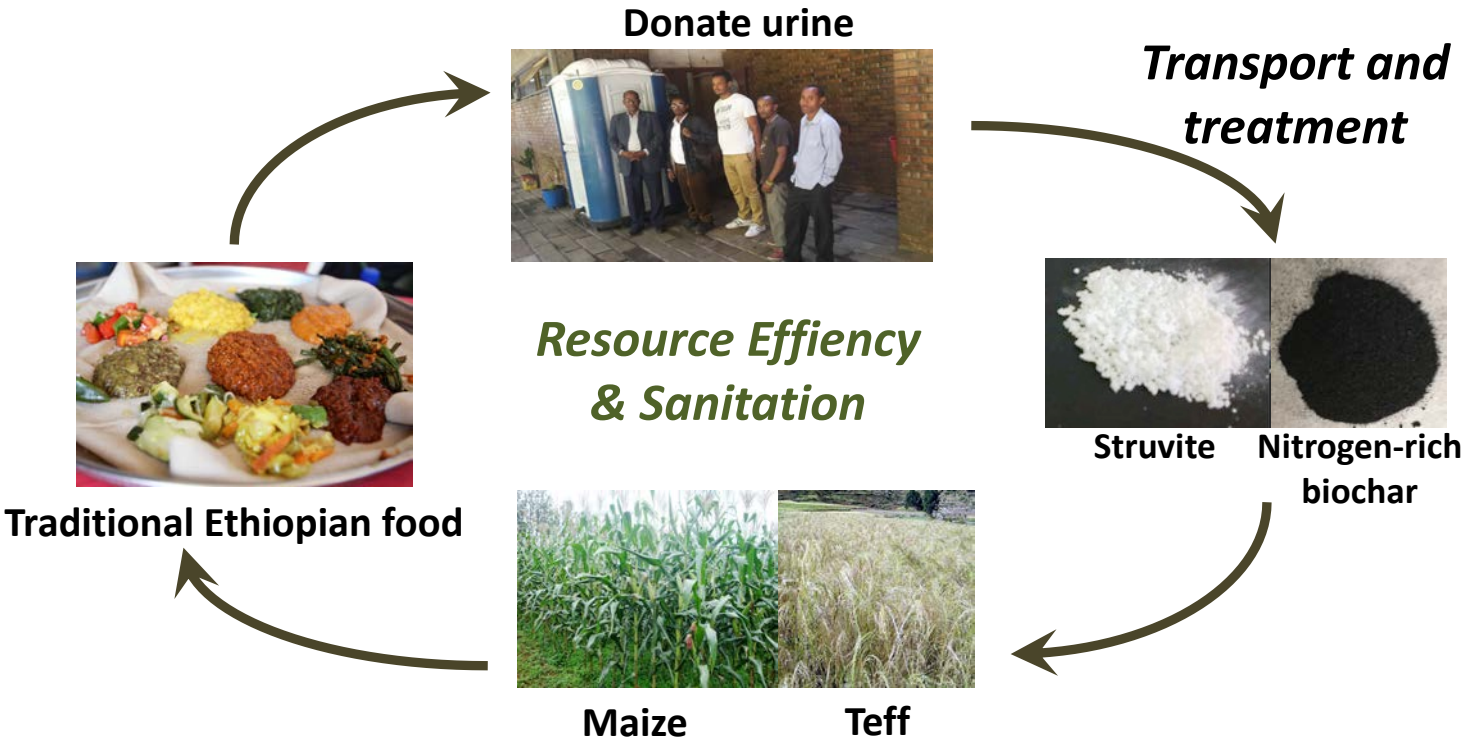

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Urine separation is a growing practice around the world