Engineering Poultry Litter Biochar

Capturing Phosphorus, Improving Soil Phosphorus Management, and Protecting Water Quality

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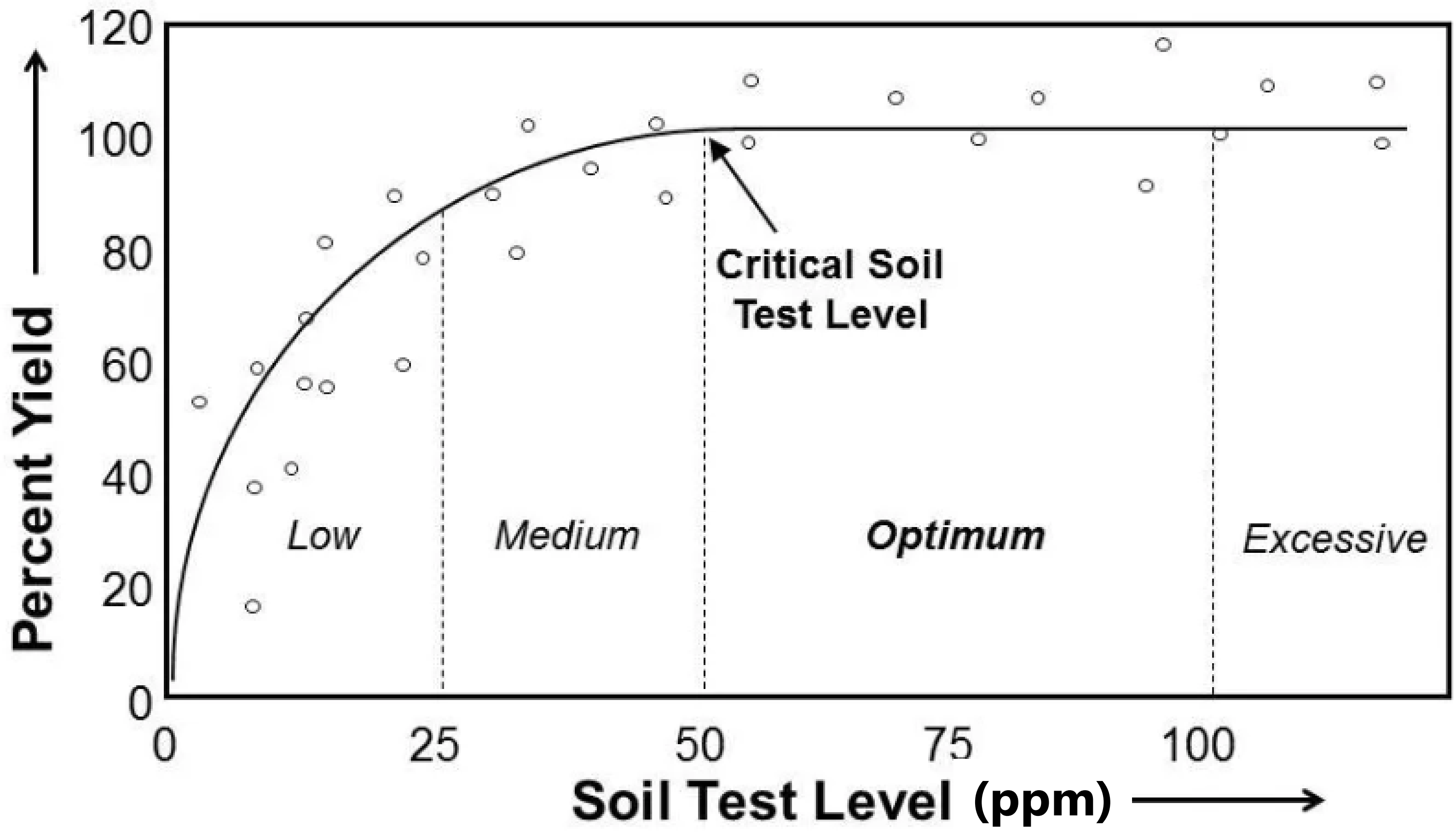
BACKGROUND

In the United States, the commercial poultry industry produces an estimated 6.4-18.3 million tons of poultry litter (PL) during broiler production. This nutrient-rich material is commonly used as a fertilizer in agricultural settings; however, it can be a persistent source of nutrient loading into water bodies. Agricultural runoff is creating environmental risks, especially seen where poultry production in the Delmarva (Delaware, Maryland and Virginia) Peninsula has resulted in excess nutrients in Chesapeake Bay.

Our research aimed to see if converting PL into biochar could change the chemistry of P-rich PL and lead to improved soil P dynamics and decrease P mobility and water pollution.

Soil Test P Levels & P-Saturation



Shober et al. 2017. Interpreting Soil Phosphorus and Potassium Tests, University of Delaware

WHAT WE HYPOTHESIZED

- Turning PL into biochar would change the solubility and availability of the resulting P compounds, leading to more stabilized P than that found in raw PL.
- This PL-biochar would also scavenge excess P in P-saturated soils, thereby reducing P mobility and improve runoff quality.
- Activating the PL with metal salts prior to pyrolysis would lead to greater capacities to sorb and retain P.

WHAT THIS MEANS

By converting the poultry litter into biochar and using it as a soil amendment instead of straight PL, the resulting amended soil would not only be improved for plant nutrition, but it would also decrease nutrient pollution to the surrounding Chesapeake Bay.

THE RESEARCH

POULTRY LITTER SOURCE

PLs with different ages were obtained from a poultry production operation in Maryland to see if the PL age makes a difference in the performance of the resulting biochar:

1 year, 3 year, and 7 year old PL

BIOCHAR PRODUCTION

PL converted into biochar via pyrolysis (high heat without oxygen) at 3 different temperatures:

500, 700 and 900 °C

THE RESEARCH (CONTINUED)

ACTIVATION

PL activated with:

- Water treatment residuals (WTR) [e.g., $KAl(SO_4)_2$ (Alum)] from drinking water purification
- Mine drainage residuals (MDR) such as iron oxyhydroxide [e.g., FeOOH (Goethite)] from NE coal mines
- Magnesium chloride ($MgCl_2$)

TESTING

Tested un-activated and activated biochar…

- For capacity of P absorption
- For capacity to supply P to soil
- In P-saturated soils to determine which would best reduce P availability in P-saturated soils
- Potential for sorbing and retaining metals (Cd, Cu, Pb, Ni & Zn) for possible use as means of remediating metal contaminated soils

PRODUCING BIOCHAR FROM POULTRY LITTER

Dry Poultry Litter **Poultry Litter Biochar**

WHAT WE FOUND: P SORPTION/DESORPTION

The age of the PL did not have a significant effect on the P sorption or desorption characteristics of the PL biochars	Activating with $MgCl_2$ significantly increased the P-sorption capacity of the PL biochars	Biochars activated with at least 0.25 M $MgCl_2$ and made at temperatures ≥ 700 °C had negligible extractable P

WHAT WE FOUND: P SORPTION/DESORPTION (CONTINUED)

X-ray diffraction indicated that increased Mg loading favored the formation of stable $Mg_3(PO_4)_2$ phases while increasing temperature favored the formation of both $Mg_3(PO4)_2$ and $Ca_5(PO_4)_3OH$

Maximum P sorption capacities (P_{max}) of the biochars were estimated by fitting Langmuir isotherms to batch sorption data and ranged from 0.66-10.35 mg/g

Biochars produced from 1 M Mg-activated PL did have significantly higher average P_{max} values ($p<0.05$), likely due to a greater abundance of MgO

Overall, our results demonstrate that Mg activation is an effective strategy for producing PL-derived biochars with the ability to reduce P loading into environmentally sensitive ecosystems

WHAT WE FOUND – SOIL INCUBATIONS

Two $MgCl_2$ activated PL biochars reduced extractable P in one of two P-saturated soils:	**1)** One year old PL activated with 1 M $MgCl_2$, made at 700 °C and applied at a rate of 1% by weight (PL1-700)	**2)** Three year old PL activated with 0.5 M $MgCl_2$, made at 900 °C and applied at a rate of 1% by weight (PL3-900)

The final step in our research is a greenhouse study to see how using the PL3-900 $MgCl_2$ activated biochar affects corn growth and porewater P concentrations in P-saturated soils from Delaware

WHAT WE FOUND – SOIL INCUBATIONS

We are also testing four other biochars in incubation studies for inclusion in a greenhouse study

Biochar made from un-activated and 0.5 M $MgCl_2$ activated pine chips made at 900 °C	Biochar made from un-activated and 0.5 <u>M</u> $MgCl_2$ activated mixture of 80% pine chips and 20% PL made at 900 °C

The thought is that these biochars may be better P sorbers in P-saturated soils than biochars made from pure PL

P SORPTION SUMMARY

CONCLUSIONS

PL biochars work best at reducing soil P availability when activated with $MgCl_2$.

REMAINING RESEARCH

Complete incubation studies to determine the efficacy of un-activated and activated pine chip biochar and 80:20 (pine chip:PL) biochar on P sorption. Conduct greenhouse study on corn growth in amended P-saturated soils.

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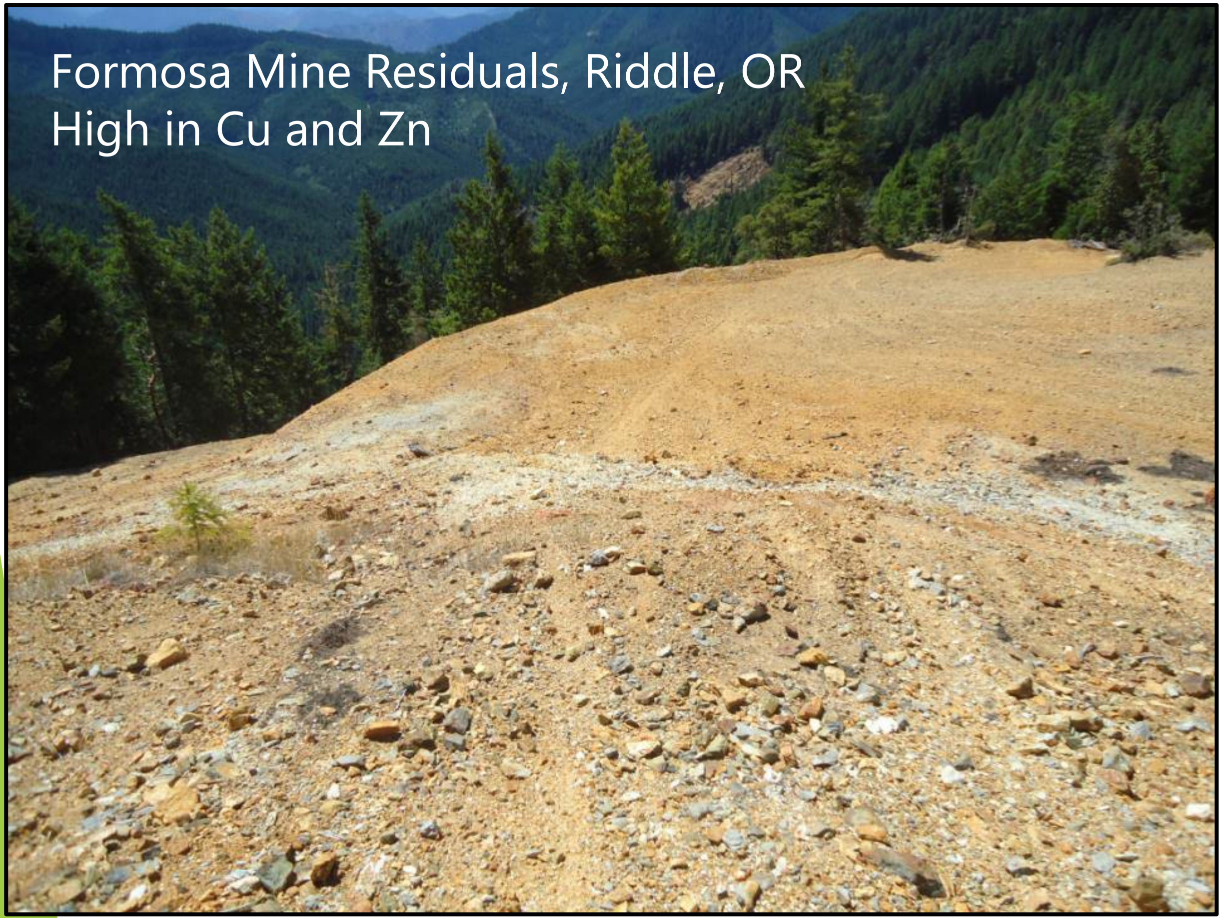
METAL-CONTAMINATED SOILS ARE WIDESPREAD

For example:



CAN PL BIOCHARS BE USED TO REMEDIATE METAL-CONTAMINATED SOILS?

Final Condition

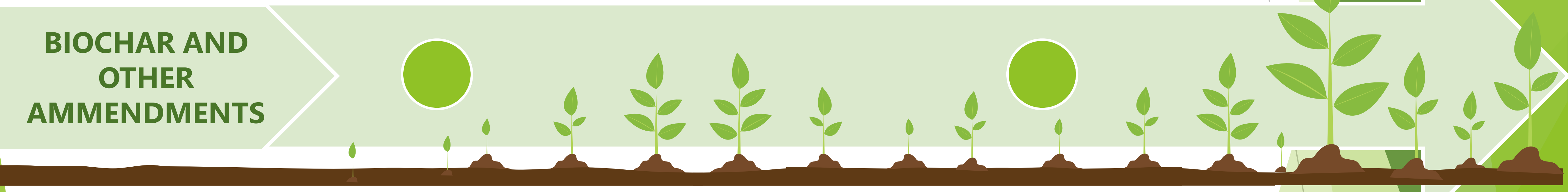
Near neutral pH

Low Mobility/Low bioavailable Metal Content

High Soil Moisture Retention

High Soil Carbon Content

Vegetative Cover/Stable Surface Soil



Initial Condition

Acidic pH

Highly Mobile and Bioavailable Metal Content

Low Soil Moisture Infiltration and Retention

Low Organic Mater Content

No Vegetation/High Potential for Soil Erosion

HYPOTHESIS

PL based biochars would be effective at sorbing metals in metal contaminated soils thereby becoming an effective *in situ* amendment for conditioning and remediating these soils to support vegetation.

WHAT THIS MEANS

Using PL biochars may be an excellent tool to aid the recovery of metal-contaminated soils.

If true, this creates a very large market for PL-based biochars!

WHAT WE INVESTIGATED

PL biochar's capacity to sorb and retain the following metals

Cd	Cu	Pb	Ni	Zn
Cadmium	Copper	Lead	Nickel	Zinc

for possible use as a tool for remediating metal contaminated soils

METAL SORPTION SUMMARY

- Very stable metal-biochar associations were formed
- PL biochars are effective sorbers of Cu, Cd, Ni and Zn when soil pHs are ≥ 5.5
- PL biochars are effective Pb sorbers at any pH

CONCLUSION

PL biochar appears to be a useful tool for reducing heavy metal bioaccessibility in metal contaminated soils.

Questions?

SPECIAL THANKS TO EPA REGION 3

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