

Formulating biochar and compost amendments to reduce bioavailable Cd and Zn concentrations in mine impacted soil

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Tri-State Mine Site History and Waste Tailings Disposal

- The TSM site encompasses border regions of KS, OK, MO.
 - Lead and Zinc have been mined there since the 1860s (Johnson et al. 2016).
 - Piles of mine spoils called chat are stored on the soil surface.
 - Large tracts of remediated land have little to no vegetation due to heavy metal concentrations.
- ★ Health concerns about exposure to heavy metals from mine tailings.



Physical Remediation Effort at TSM Site



Mine spoils on soil surface before removal.



B/C horizon soil at surface following physical removal of mine spoils.



B/C horizon is a gravely silt loam/clay

TSM surface soil chemical properties



Re-establishment of grass into the B/C horizon is difficult due to poor fertility and heavy metal contents.

Chemical properties of TSM soil (Novak et al. 2019)			
Element	Total (mg/kg) [†]	H ₂ O (mg/kg)	0.01M CaCl ₂ [‡]
Cd	72.2	5.7	50.5
Cu	66.5	0.2	2.2
K	711	26.2	59.5
P	168	3.9	1.4
Pb	23.5	0	0
Zn	2225	141	782

[†]sample digested using 4M HNO₃; [‡] bioavailable metal concentrations (Ippolito et al. 2017)

Bioavailable metals at these concentrations are phytotoxic to most crops and grasses.

Past Mine Spoil Chemical Treatment Methods

- Bolster SOM levels (Norland 1993)
- Add lime to raise pH (Hensley and Carpenter 1984)
- Add municipal biosolids (Brown et al. 2003)
- Add wood pulp/fly ash (Abbot et al. 2001)

These solutions are not long lasting, required high application rates, or had malodor issues.



Formulating Biochars and Compost for Mine Soil Remediation

- Goals:

1. Need to sequester Cd and Zn using biochar and compost to levels that are not phytotoxic.
2. Need to improve soil fertility (pH, SOC, nutrients) for plant growth.
3. Get grass to grow in mine soil.

- Formulations:

1. Choose a biochar that has a calcareous pH.
2. Choose a biochar that has oxyanions to bind with cations.
3. Choose a compost that will rebuild soil fertility.
4. Choose a compost that can also sequester cations.

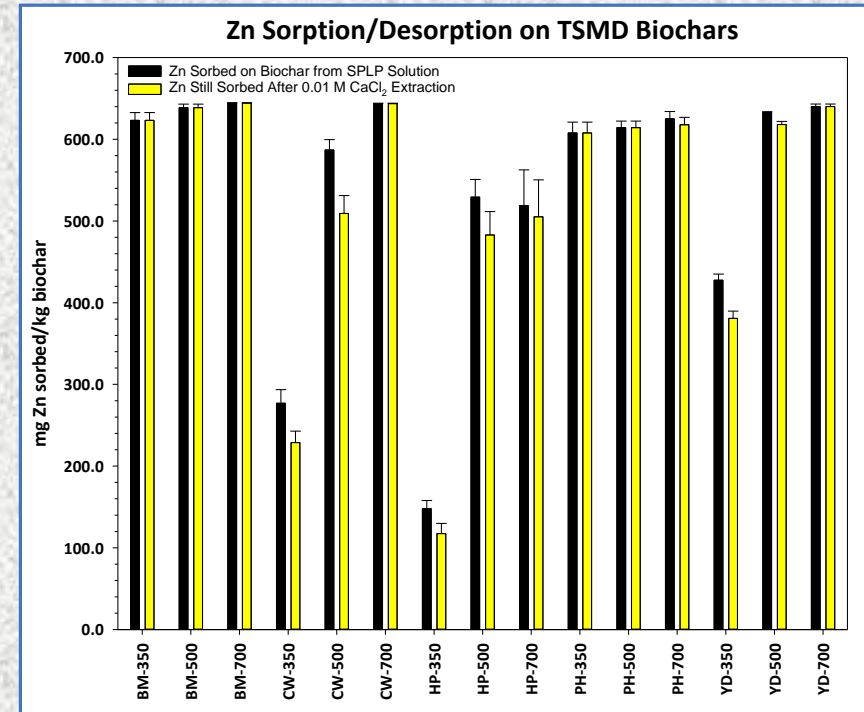
Can biochar bind metals in Tri-state mine soil and improve plant germination/growth?



“Of the biochars interrogated ... the Beef Manure (BM) biochars at 500 and 700 °C appeared to be the best performers.

They sorb the most metal and virtually lose none of it upon extraction with 0.01 M CaCl₂”

Drs. Mark G Johnson (EPA) and Jim Ippolito (CSU) conducted trial biochar and heavy metal binding studies.



Biochar and compost formulations (cont).

- Previous work (Ippolito & Johnson) showed that beef cattle manure biochar was affective at sequestering Zn.
- Other amendments include:
 - Poultry litter biochar has an alkaline pH and is available commercially.
 - Lodgepole pine biochar is available commercially.
 - Beef cattle manure compost is available from local feedlots for soil fertility improvements.

Dr. Gilbert Sigua and Mr. Don Watts



Coordinate biochar types for use in a Switchgrass growth experiment with Tri-State Mine soil (2018)



% Application rate (w/w)	
<u>Biochar</u>	<u>Manure compost</u>
0	0
0	2.5
0	5
2.5	0
2.5	2.5
2.5	5
5	0
5	2.5
5	5



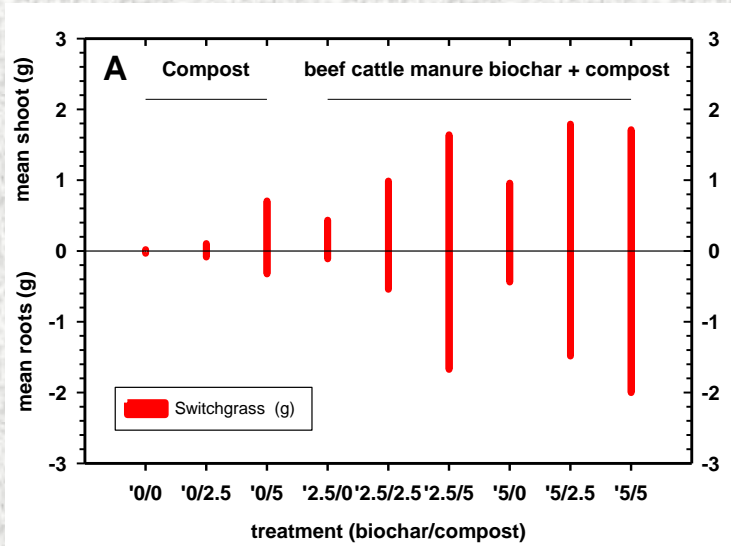
What did we find?



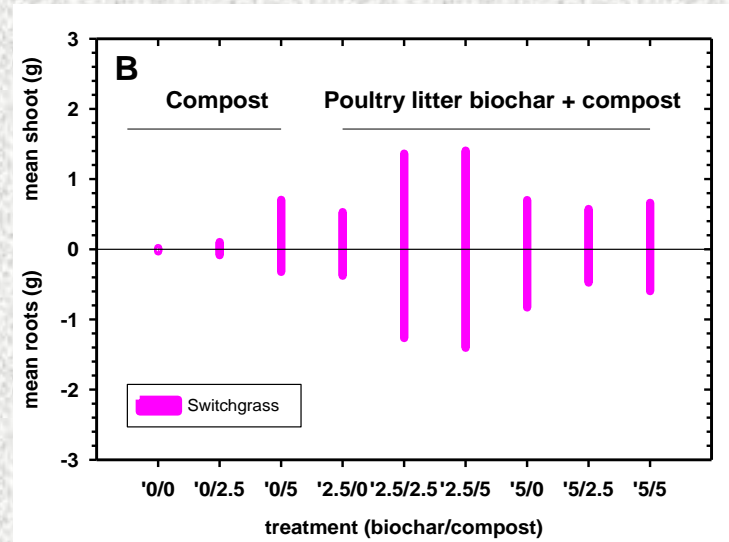
Pot 112 is TSM treated with 2.5% lodgepole pine biochar & 2.5% manure compost.
AGB = 0.084 g; pH = 4.8
Salt-Cd = 135 mg/kg; Salt-Zn = 270 mg/kg
Shoot-Cd = 135 mg/kg; shoot-Zn = 2,961 mg/kg

Pot 86 is TSM treated with 5% beef manure biochar & 2.5% manure compost.
AGB = 2.017g; pH = 5.76
Salt-Cd = 8.4 mg/kg; Salt-Zn = 150 mg/kg
Shoot-Cd = 44.5 mg/kg; shoot-Zn = 761 mg/kg

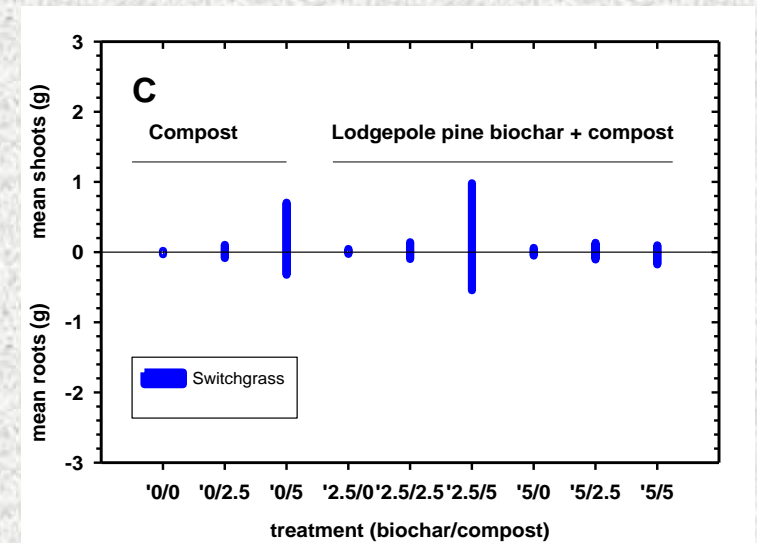
Switchgrass shoot and root mass results



Beef cattle manure biochar

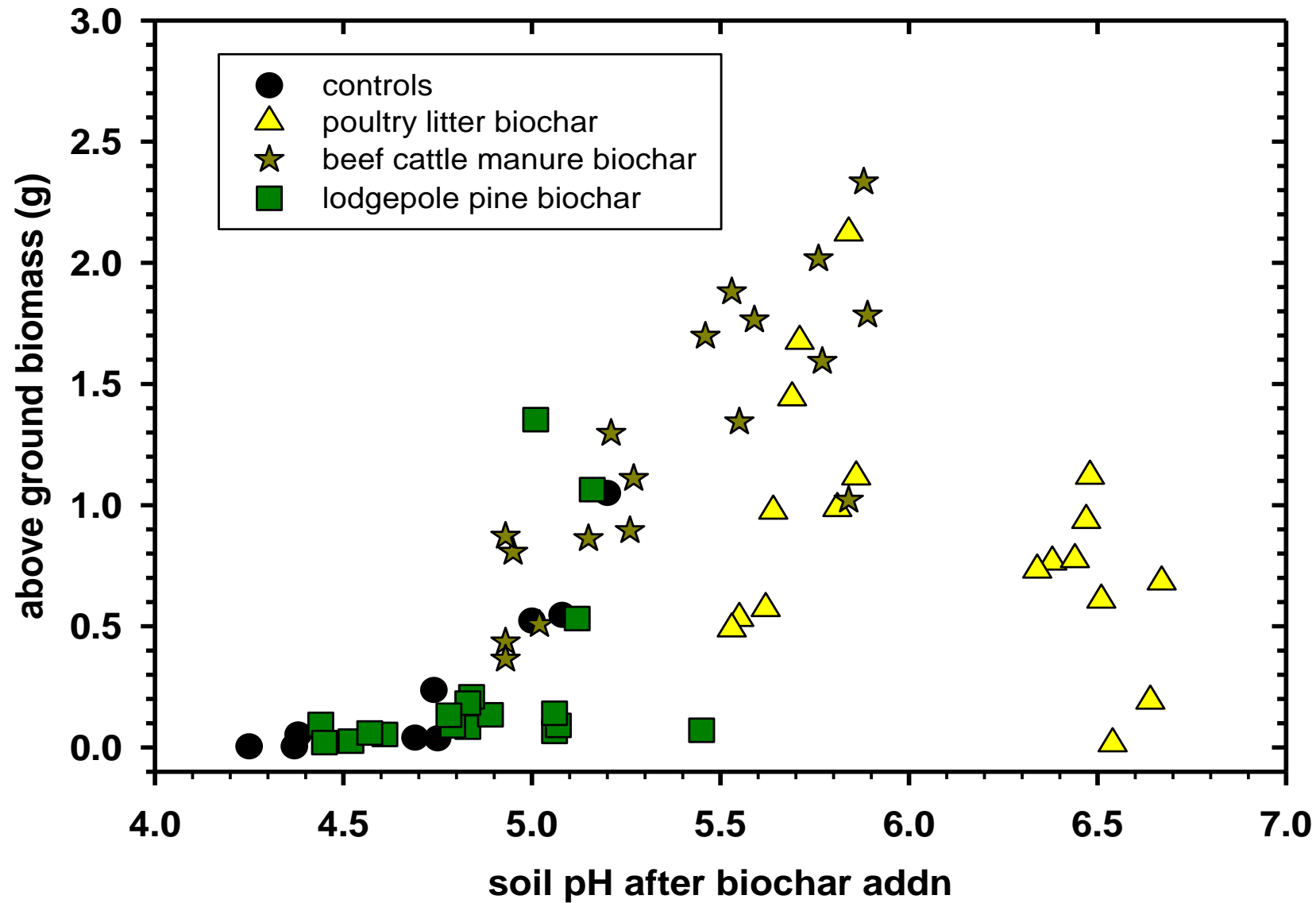


Poultry litter biochar



Lodgepole pine biochar

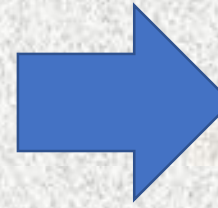
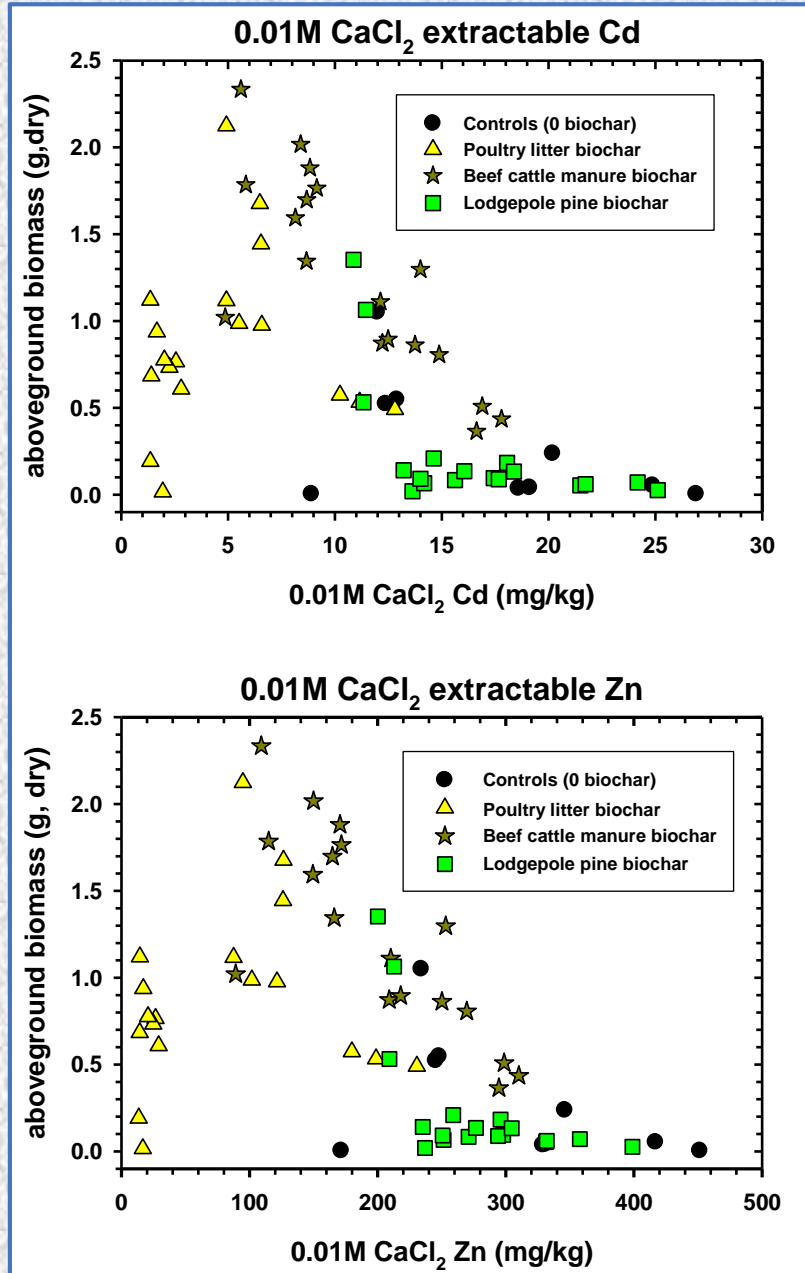
Switchgrass above ground biomass (g) vs. soil pH after biochar addition



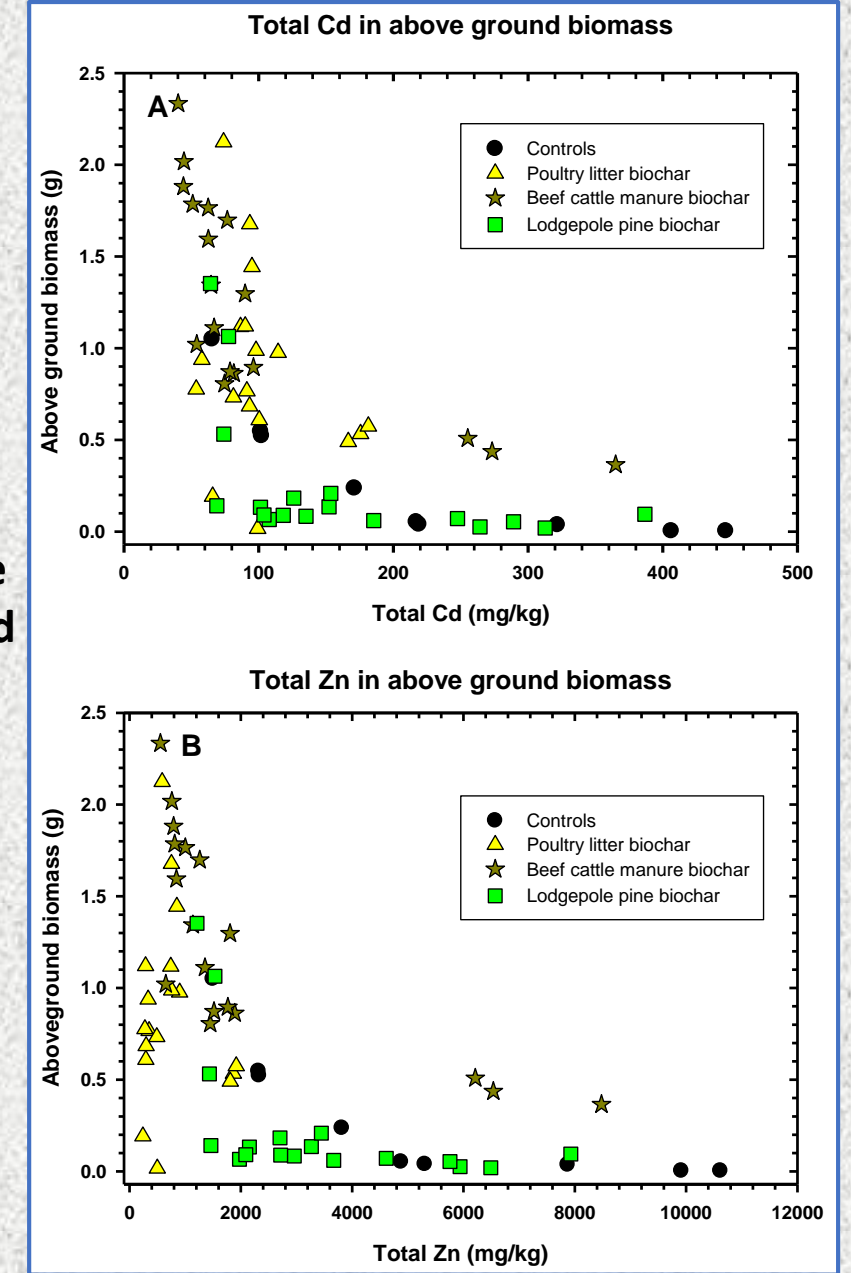
Raising mine soil pH was a key factor with improving switchgrass above ground biomass (Novak et al. 2019).

Results

Certain biochars reduced bioavailable Cd and Zn concentrations, while other amendments had minimal impacts.



Reducing Total Cd and Zn uptake caused more aboveground biomass production (Novak et al. 2019).



Conclusions

- Biochars can be formulated to target a specific soil/spoil deficiency.
- The background soil/spoil deficiency must be well established prior to formulating biochar production conditions.
- All biochars are not the same!

