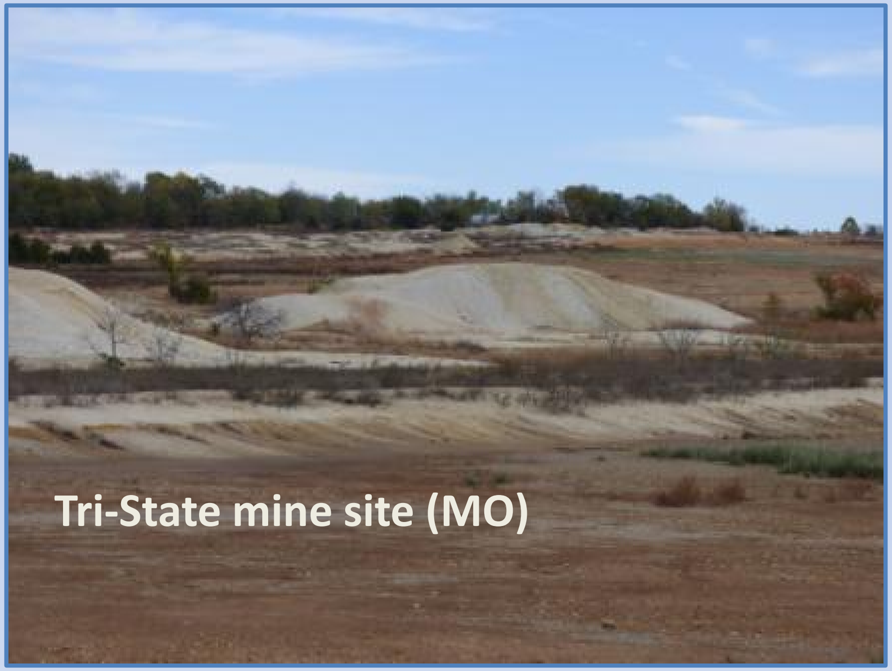
Overview of Designing Biochars to Improve Soil Health Characteristics at Two Superfund Sites



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Introduction:

For almost 10 years, our team has made numerous presentations on feedstocks, pyrolysis process and biochar chemistry…

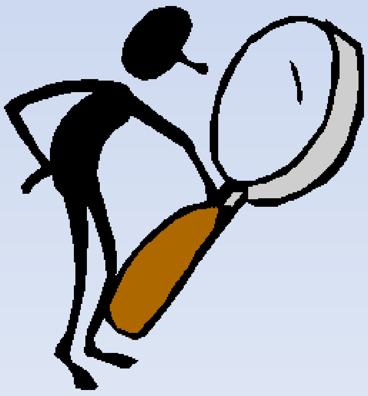
new

Biochar and mine spoils

We have design biochars for soil health improvements

Mine spoil remediation:

Formosa mine site



Tri-State mine site

30
Zn
65.41

29
Cu
63.55

HEAVY METAL

Chemical properties of mine spoils:

Formosa mine site

- Acidic pH < 3
- [Cu] & [Zn] @ 50-60 ppm
- Low P & SOC contents
- High [$SO_4^{=}$] – Gypsum
- Poor water retention
- Poor microbial diversity

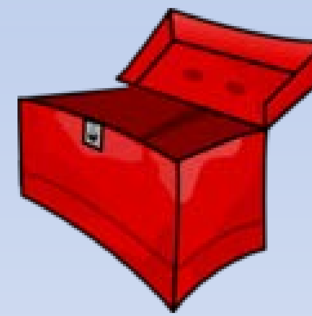
Tri-State mine site

- Total [Zn] ≈ 2500 ppm
- Total [Cd] & [Cu] ≈ 70 ppm
- Variable surface textures (sands to clay)
- Poor K_{sat}
- Coarse fragments

Guidelines for designer biochar selection:

Establish soil/spoil deficiency

Select the appropriate designer biochar from the 'biochar tool box'



Determine biochar application rate, morphology, and application method

Application rate

Pellet vs. dust

Application method

Designing relevant biochars:

	Single feedstock/blend	Pyrolysis (°C)	Particle size	Soil impact
SE USA sandy soils	Switchgrass	250 to 500	Dust (< 0.42-mm)	+ water storage
SE USA sandy soils	Hardwoods	350 to 700	Dust (<0.42-mm)	+ water storage
SE USA sandy soils	Pecan shells	700	Dust (< 0.42-mm)	+nutrients/lime
SE USA sandy soils	Loblolly pine chips	350 to 700	Dust, pellets (> 2-mm)	C sequestration
SE USA sandy soils	Pine chips/poultry litter	350 to 700	Dust, pellets (> 2-mm)	C sequestration & balance soil [P]
Mine spoils/soils	*Gasified dairy manure	> 700	Flakes (2-6 mm)	Metal binding & adds [P]
Mine spoils/soils	*Lodge pole pine	500	Flakes (2-6 mm)	Metal binding
Mine spoils/soils	*Miscanthus	500	Flakes (> 2-mm)	Metal binding

Novak et al., 2009; Novak and Busscher, 2012; Novak et al., 2014, Sigua et al., 2016, * *unpublished*

Formosa mine site (Riddle, OR):

- **spoil issue (solution):**
  - Acidic (calcareous biochar or lime)
  - Low [P] & [K] (manure biochar or fertilizer)
  - [Cu] & [Zn] binding (high temp > 500^{o}C biochar)
  - Low OC content (biochar or composts)
  - Poor water retention (grass biochar)

- **2015 (1^{st} GH study)**
  - Used gasified dairy manure biochar (52% ash, pH = 10.7)
  - Lime (Cao) & poultry litter

We were able to improve soil fertility resulting in rye and wheat growth, but couldn't separate impact of lime vs. biochar

Formosa mine site (Riddle, OR):

- 2016 Greenhouse study
  - Used Miscanthus biochar (18.5% ash, pH = 10)
  - Added 0.8% lime (CaO)
  - Added N-P-K
  - Planted Wild Blue rye (Native species for OR)
  - Had lime vs. no lime trt.
  - Had biochar vs. no biochar trt.

5% Miscanthus biochar + N + 0 CaO

5% Miscanthus biochar + N + CaO

Mean rye seed germination in Formosa:

All pots (n = 4) treated with lime

Biochar (%)	Day 15	Day 18
0	14 (11)	18 (9)
1	15 (4)	18 (4)
2.5	11 (8)	16 (6)
5.0	13 (4)	19 (5)

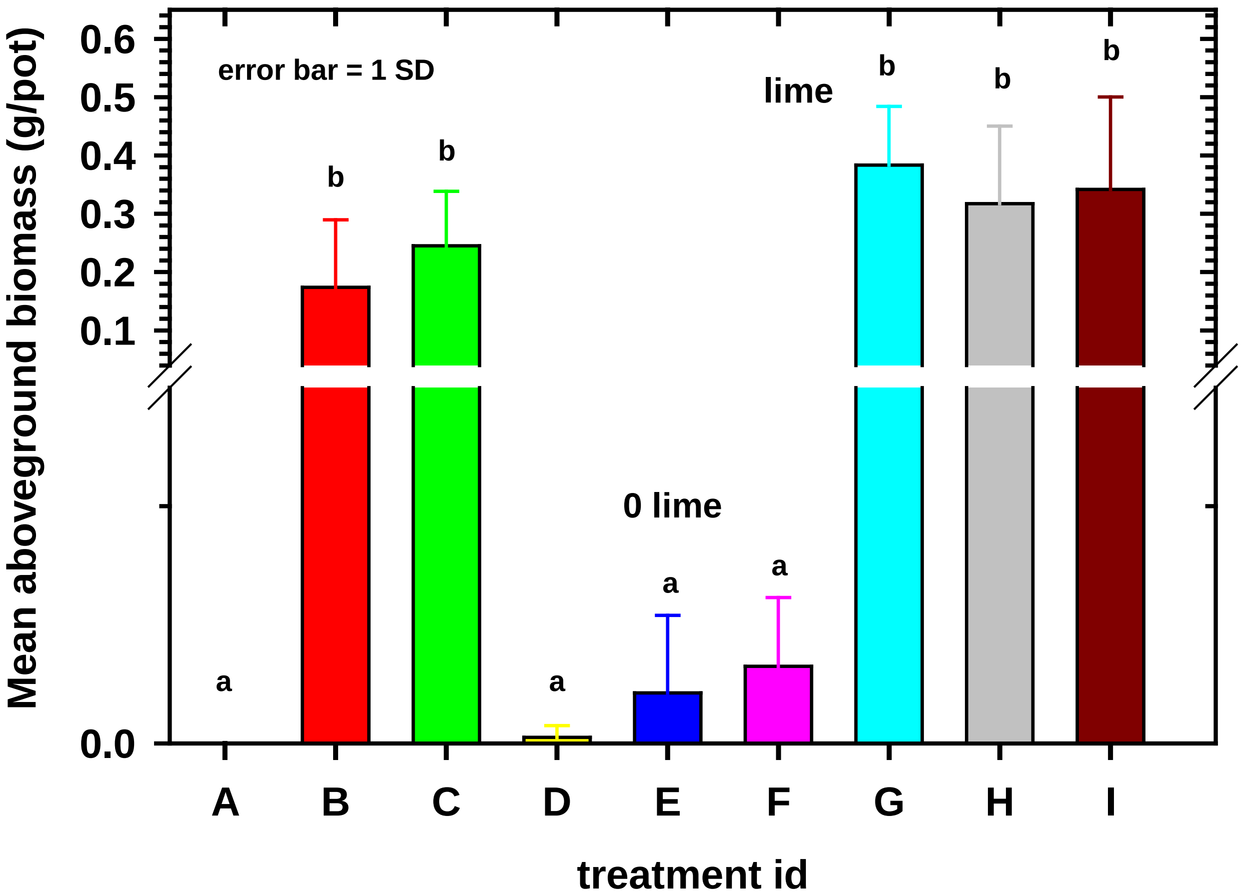
All pots (n = 4) treated with 0 lime

Biochar (%)	Day 35	Day 49
0	0	0
1	0	1
2.5	1	1.3 (1)
5.0	1	2.8 (2.1)

Formosa + 5% biochar + N + lime

Formosa + 5% biochar + N + 0 lime

Above ground rye biomass grown in Formosa mine spoil



Rye in trt I (5% Miscanthus biochar + N + lime)

Mehlich 3 extractable Cu concentrations measured in Formosa spoil after treatment with lime and Miscanthus biochar (2-way ANOVA, $p < 0.05$)		
Biochar (%)	**Lime**	**0 lime**
0	**18.4 a,z**	**30.3 b,a**
1	**13.2 a,a**	**36.6 b,a**
2.5	**17.6 a,a**	**30.0 b,a**
5	**13.5 a,a**	**28.7 b,a**
average	**15.7a**	**30.8 b**
First letter shows significance differences between columns (lime vs. 0 lime) Second letter shows significant differences within a column (%biochar vs. lime, and 0 lime).		

Mehlich 3 extractable Zn is more impacted by lime than by the amount of Miscanthus biochar.

Mehlich 3 extractable Zn concentrations measured in Formosa spoil after treatment with lime and Miscanthus biochar (2-way ANOVA, $p < 0.05$)		
Biochar (%)	**Lime**	**0 lime**
0	**37.3 a,a**	**35.3 a,a**
1	**21.0 a,a**	**54.1 b,a**
2.5	**40.0 a,a**	**42.8 a,a**
5	**34.4 a,a**	**42.0 a,a**
average	**33.2 a**	**43.6 b**
First letter shows significance differences between columns (lime vs. 0 lime) Second letter shows significant differences within a column (%biochar vs. lime, and 0 lime).		

Mehlich 3 extractable Zn is more impacted by lime than by the amount of Miscanthus biochar.

What did we learn:

- Rye plant growth was improved with lime addition.
- Miscanthus biochar had minimal impact on binding Cu & Zn in the presence of lime (Ca0 at 0.8 g/kg).
- Was Miscanthus biochar the appropriate selection with respect to metal binding or was it a benefit to solve other issues (water holding, microbial populations, etc.)?
- Compost could be used to improve OC content, as a food source for microorganisms, and begin aggregate formation.
- Alternative soil amendments (wood-based, fresh manure, compost blend) to add long-term OC material, plant nutrients, and easily degraded OC compounds.

Tri-State mine site (KS-OK-MO):

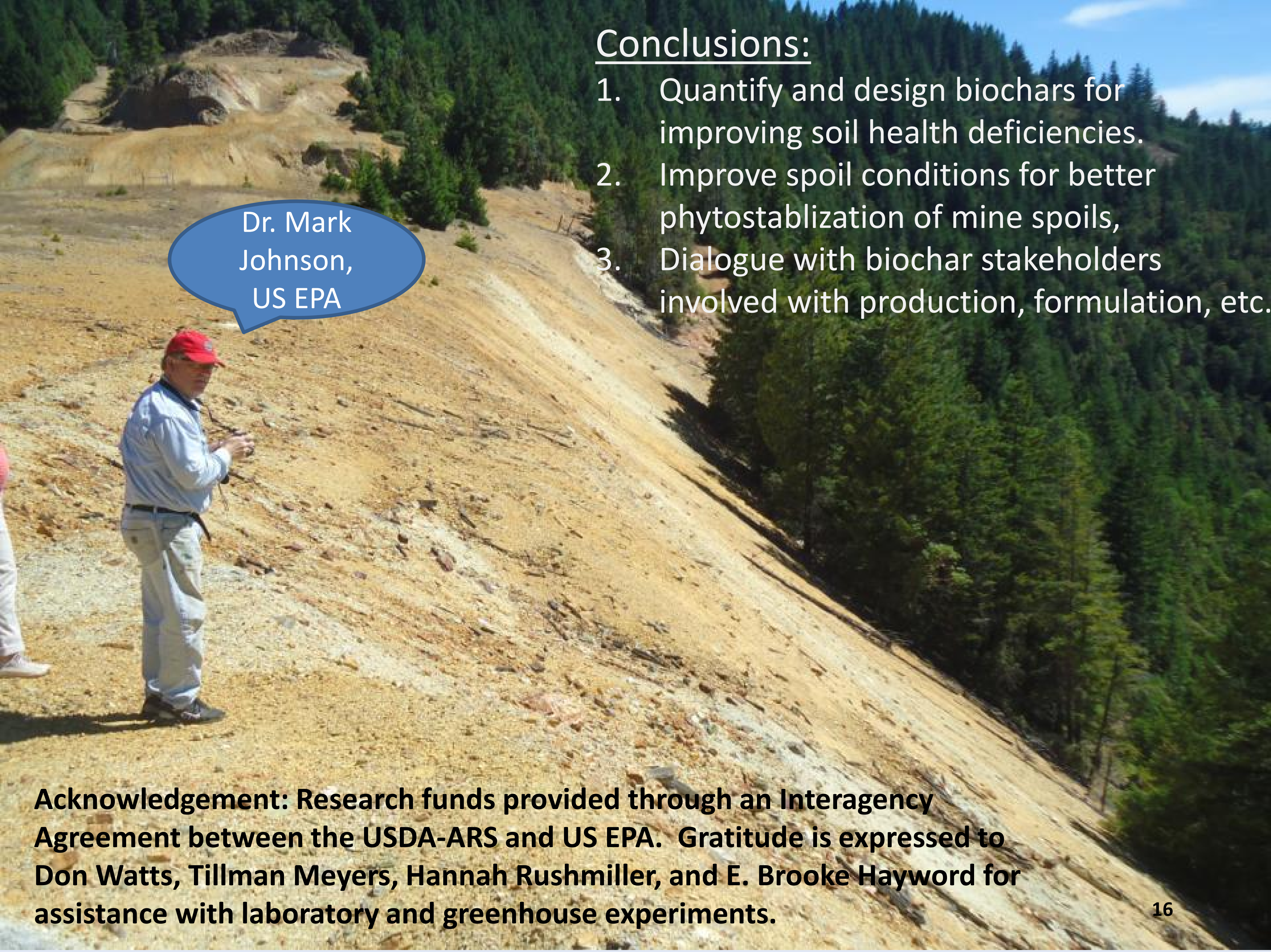
item	Range in value
CEC (meq/100 g)	6.6 – 53.6
pH	4.5 – 5.70
M3 P (ppm)	1 -- 18
M3 K (ppm)	60 -- 168
M3 Cu (ppm)	0.8 – 27.3
M3 Zn	12.9 -- 2688

Plant trials in Tri-State mine spoils:

Corn, soybean, and wild blue rye plant growth on day 28. Corn showing metal toxicity symptoms (yellowing of leaves and eventual necrosis).

Tissue Zn concentrations of 20 -70 mg/kg indicates corn uptake sufficiency level (www.soilfertility.info/zincdeficiencycorn.pdf)

Mean metal concentrations in Tri-state mine spoil and elements taken up by corn stems and roots (using 4M HNO3 as digest solution)				
	Mine spoil (mg/kg)		Plant uptake (mg/kg)	
element	Total	Mehlich 3	Stems	roots
Cd	72	67	na	na
Cu	67	30	30	195
Zn	2,225	1,049	1,848	2,715



Conclusions:

1. Quantify and design biochars for improving soil health deficiencies.
2. Improve spoil conditions for better phytostablization of mine spoils,
3. Dialogue with biochar stakeholders involved with production, formulation, etc.

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