Phytostabilizing effect of biochars on remediating heavy metals in mine spoil soils

Gilbert C. Sigua[1]*, Jeffrey M. Novak[1], Don Watts[1], Mark G. Johnson[2], James A. Ippolito[3]
Kurt Spokas[4], Thomas Ducey[1] and Kirstin Tripp[5]

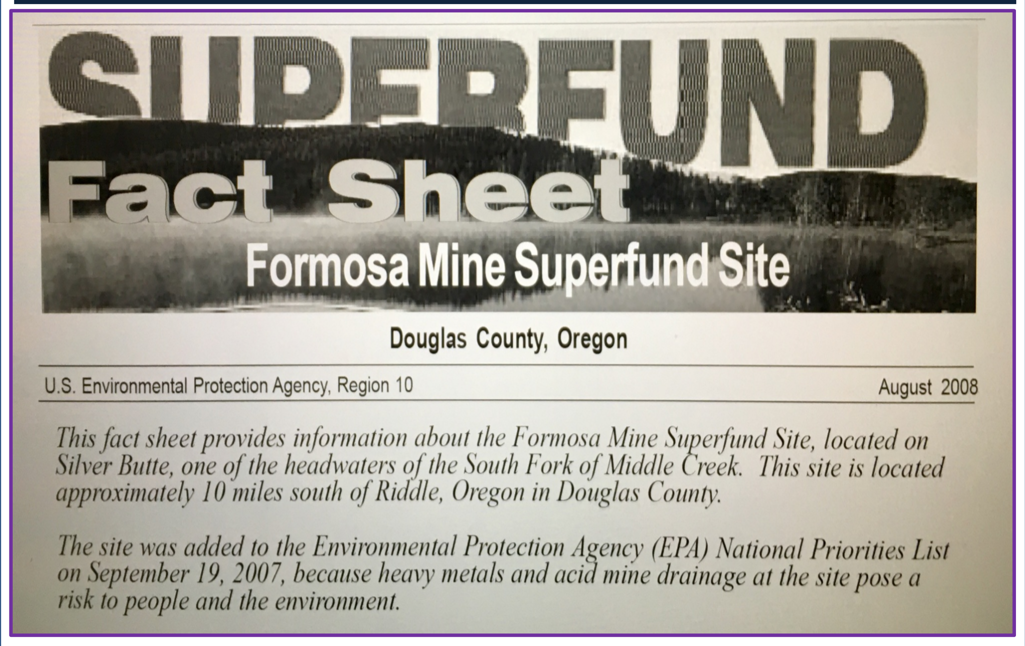
[1]USDA-ARS, Florence, SC; [2]US-EPA, Corvallis, OR; [3]Colorado State University, Fort Collins, CO;
[4]USDA-ARS, St. Paul, MN; and [5]USDA-ARS, Corvallis, OR

*gilbert.sigua@ars.usda.gov

ABSTRACT

- It is proposed that biochar is a suitable amendment to remediate heavy metals in mine spoils, as well as improve chemical conditions for enhanced plant growth.
- Better plant growth will improve phytostabilization, increase containment of metal-laden sediment, while also reducing potential metal uptake by plants. As such, utilization of a biochar with appropriate chemical and physical characteristics is crucial for effective binding of heavy metals while also improving plant growth conditions in the mine spoils.
- Results showed that our designer biochars did increase pH of acid mine spoils, improved the content of critical plant nutrients (e.g., phosphorus and potassium), and reduced plant uptake of heavy metals (e.g. zinc, manganese, etc.).

BACKGROUND AND OBJECTIVE



SUPERFUND
Fact Sheet
Formosa Mine Superfund Site
Douglas County, Oregon
U.S. Environmental Protection Agency, Region 10 — August 2008

This fact sheet provides information about the Formosa Mine Superfund Site, located on Silver Butte, one of the headwaters of the South Fork of Middle Creek. This site is located approximately 10 miles south of Riddle, Oregon in Douglas County.

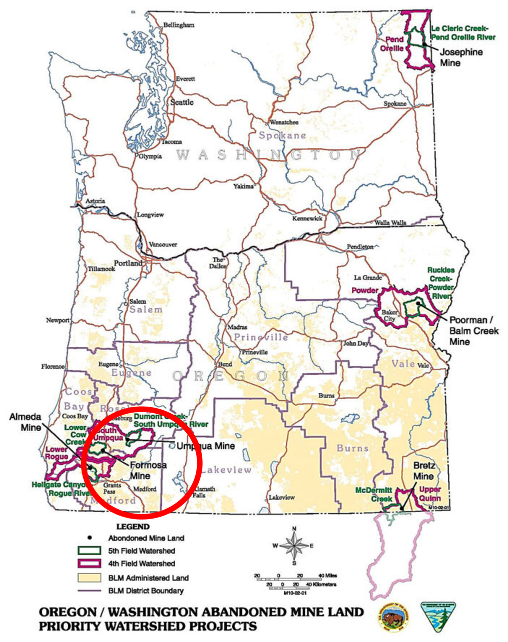
The site was added to the Environmental Protection Agency (EPA) National Priorities List on September 19, 2007, because heavy metals and acid mine drainage at the site pose a risk to people and the environment.

- The 76-acre Formosa Mine Superfund Site was originally mined for copper and zinc from approximately 1910 to 1937.
- The mine was reopened in 1989 by Formosa Exploration, Inc. and its parent company Formosa Resources Corporation.

- Using Formosa mine spoils, we conducted laboratory and greenhouse experiments to determine the ability of biochar specifically designed to improve their pH, nutrient content, and sequestration of heavy metals.
- Moreover, we examined the capacity of designer biochars to limit heavy metal uptake by a grass (e.g., wild blue rye) grown in mine spoils.

MATERIALS AND METHODS

Formosa Mine Superfund Site Riddle, Oregon



The acid rock drainage flowing from the mine and mine materials have severely degraded 13 miles of Middle Creek and the South Fork of Middle Creek, affecting macro-invertebrates, resident fish, coastal steelhead trout, and Oregon coastal Coho salmon.

Greenhouse Study

- Used Miscanthus biochar (18.5% *ash, pH = 10)*
- Added 0.8% lime (CaO)
- Added 200 kg N/ha (~0.2205 g/pot)
- Planted Wild Blue Rye (Native species for OR)
- Had lime vs. no lime trt.
- Had biochar vs. no biochar trt.

Soils (Formosa Mine): 2,150 g/pot; Amount of water: 15% by weight

Experimental Design and Treatments

Experimental Design: Randomized Complete Design; Greenhouse; 4 Reps

Experimental Treatments:
- T1 – Control
- T2 – + Lime
- T3 – + Lime + N
- T4 – 1.0% Biochar + N + 0 Lime
- T5 – 2.5% Biochar + N + 0 Lime
- T6 – 5.0% Biochar + N + 0 Lime
- T7 – 1.0% Biochar + N + Lime
- T8 – 2.5% Biochar + N + Lime
- T9 – 5.0% Biochar + N + Lime

Miscanthus Biochar

Soil Sampling and Soil Analyses

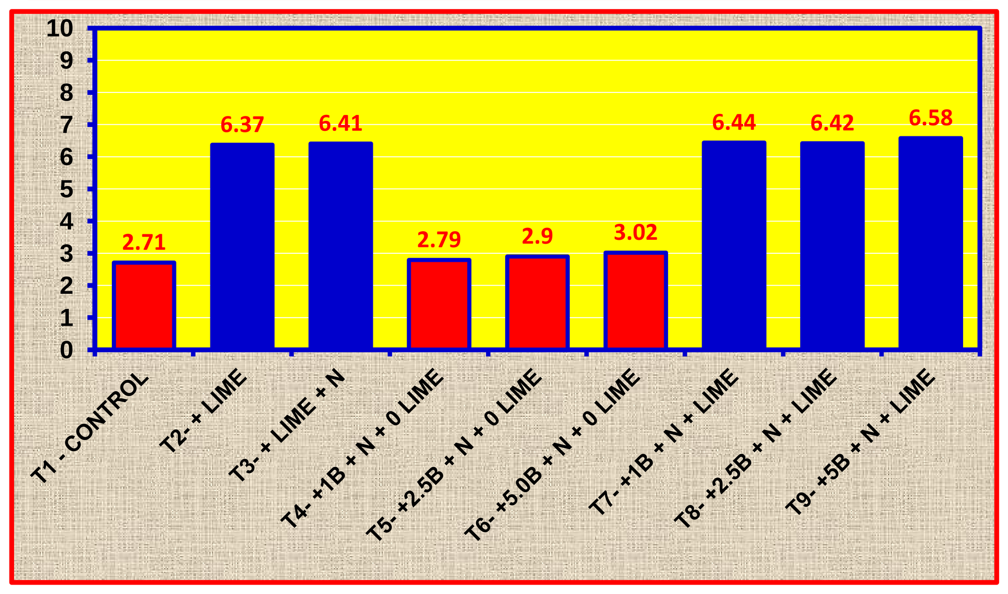
- Soil Samples were air-dried and sieved.
- Extracted with double acid (0.025 N H_2SO_4 + 0.05 N HCl). Analyzed for extractable nutrients using an ICP.
- Soil Samples were also analyzed for total Carbon and total N using LECO; pH and EC (1:2 soil:water) using pH meter.

LECO: CN

(ICP)

RESULTS

Biochar + Lime Effects on soil pH



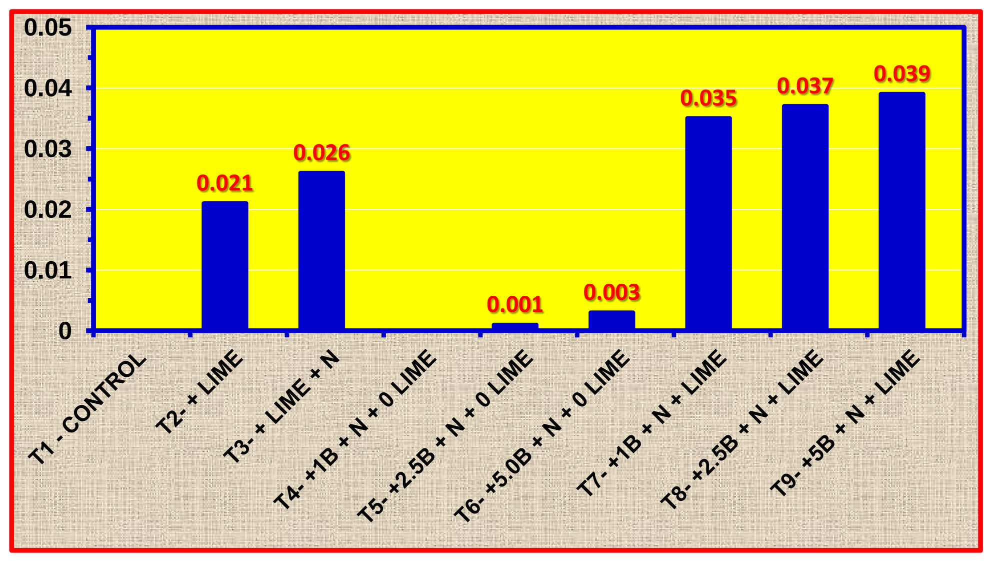
Biochar + Lime Effects on Al, Cr, Zn & Ni (Soils)

Expt'l Treatments	Al	Cr	Zn	Ni
	--------------(mg/kg)--------------			
T1 - Control	435ab	0.542a	45.4abc	0.694bc
T2 - + Lime (L)	297d	0.510d	39.9bcd	0.658bc
T3 - + Lime + N	274de	0.51cd	36.4cde	0.636c
T4 – 1.0%B + N + 0 L	464a	0.536a	54.1a	0.725b
T5 – 2.5%B + N + 0 L	396bc	0.524b	46.8ab	0.690bc
T6 – 5.0%B + N + 0 L	374c	0.523b	46.9ab	0.841a
T7 – 1.0%B + N + L	264de	0.514cd	27.2e	0.622c
T8 – 2.5%B + N + L	295d	0.519bc	38.6bcd	0.654bc
T9 – 5.0%B + N + L	226.4e	0.507d	35.6de	0.645c
LSD (p<0.05)	49.5	0.007	9.8	0.08

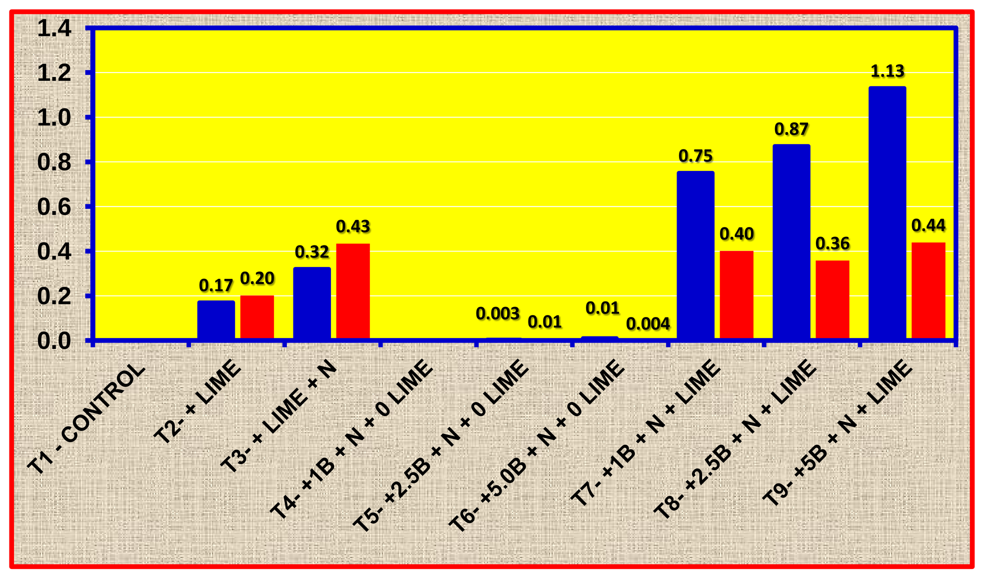
Biochar + Lime Effects on K, Ca, Mg & Fe (Soils)

Expt'l Treatments	K	Ca	Mg	Fe
	--------------(mg/kg)--------------			
T1 - Control	16.1e*	82d	93cd	506a
T2 - + Lime (L)	29.4e	2189bc	121a	308c
T3 - + Lime + N	29.3e	2174c	112ab	296c
T4 – 1.0%B + N + 0 L	28.2e	128d	105bc	494a
T5 – 2.5%B + N + 0 L	84.2d	113d	89d	449b
T6 – 5.0%B + N + 0 L	202.5b	151d	96cd	430b
T7 – 1.0%B + N + L	94.4d	2299bc	111ab	243d
T8 – 2.5%B + N + L	131.8c	2500ab	116ab	283c
T9 – 5.0%B + N + L	236.9a	2555a	112ab	256d
LSD (p<0.05)	17.3	226	15	26.7

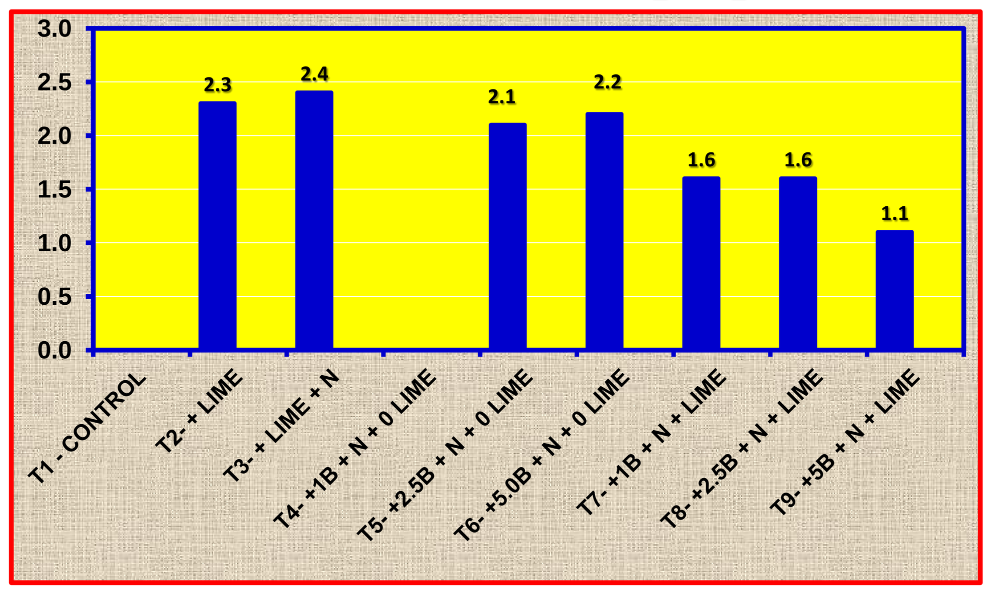
Biochar + Lime Effects on P in Plant Tissue (g/kg)



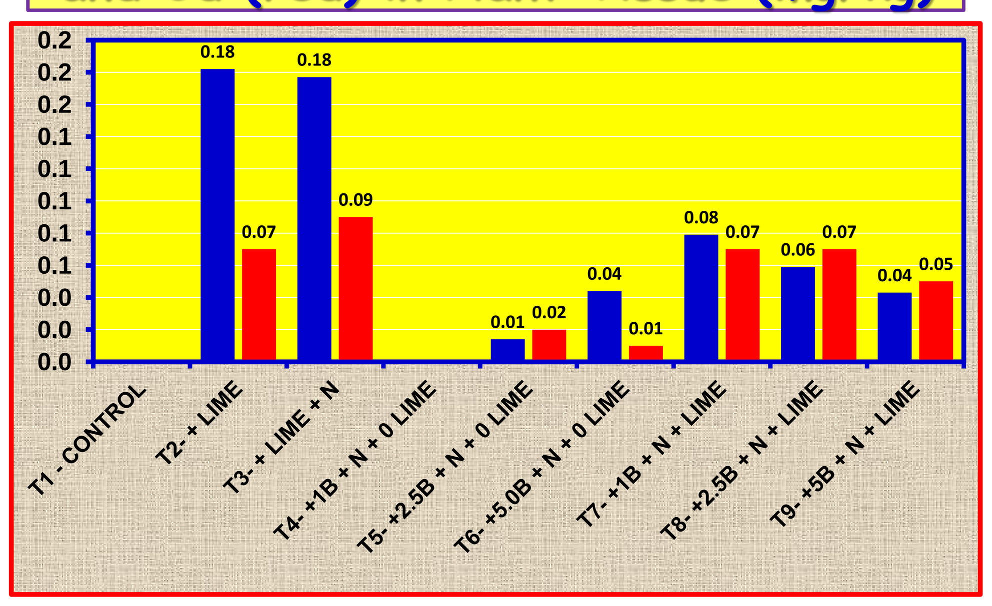
Biochar + Lime Effects on K (blue) and Ca (red) in Plant Tissue (mg/kg)



Biochar + Lime Effects on Cu in Plant Tissue (mg/kg)



Biochar + Lime Effects on Pb (blue) and Cd (red) in Plant Tissue (mg/kg)



TAKE HOME MESSAGE

Miscanthus biochar + Lime Treatments:

- Increased/improved pH of acid mine spoils;
- Improved the uptake of critical plant nutrients (e.g. P, K, Ca) while reducing potential metal uptake of plants; and
- Reduced concentrations of heavy metals (e.g., Al, Cr, Zn, Ni, Mn, Pb, Cu and Cd) in the soils.