Heavy Metal Uptake from Abandoned Mine Waste Materials Amended with Biosolids.

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Introduction:

- Lead (Pb) and zinc (Zn) mines in the Tri-State Mining District of waste materials around the mines are highly polluted with Pb, Zn, and cadmium (Cd), which often co-occurs geologically with Zn.
- Baker et al. (2011) found that only high levels of compost increased microbial activity on Galena's mine wastes.
- Biosolids have never been applied to these mine waste materials.
- The objective of this project was to complete a greenhouse study to see the effect of biosolids on the remediation of the mine waste materials. In particular, the research was done to determine if the biosolids will immobilize heavy metals.

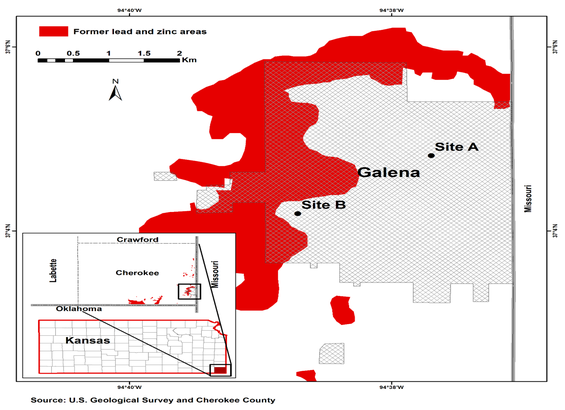

Fig 1. Site A and B map

Fig 2. Measuring out biosolids to add to pots

Materials and Methods:

- Two field sites were established in 2006 (Figs. 1 and 2) with 7 treatments consisting of combinations of low and high compost, lime, and/or bentonite. In November, 2014, 8.5 years after the addition of the amendments, the mine waste materials from the plots were sampled and brought to Manhattan, KS.
- Liquid, aerobically digested sewage sludge came from the Manhattan (KS) Wastewater Treatment Plant (Fig. 2). Before planting, half of the pots (each 22 cm diam; 22 cm height) each received 1000 mL sludge.
- On 28 Jan. 2015, seeds of the forage crop sudex [*Sorghum bicolor* (L.) Moench x *S. sudanese* (P.) Staph.] were planted into the pots. After germination and thinning, each pot had 10 plants (Fig. 3). Pots were kept at pot capacity during the experiment.
- Plants were harvested on 18-19 May 2015 by cutting the culms just above the soil surface. Grain was removed, if a plant had produced grain. Leaves and culms were combined and labelled "shoots." Roots were washed free of the waste material.
- Mine waste materials were analyzed for heavy metals, organic matter, total C, total organic C, total phosphorus, and extractable phosphorus. Roots, shoots, and grain were analyzed for heavy metals using ICP-AES.
- The experiment was a split plot design with 84 pots (2 sites; 7 original treatments; 3 replications, and 2 biosolids treatment, i.e., with and without biosolids).
- The original experimental design of Baker et al. (2011) was a randomized complete block and the greenhouse experimental design was a split- plot with 7 treatments X 3 replicates X 2 sites X 2 biosolids treatments = 84 pots. Because differences in the seven original treatments established by Baker et al. (2011) generally were not significant at 0.05, the seven treatments were averaged together. Statistical analyses were performed using PROC GLIMMIX of SAS Version 9.4 (Statistical Analysis System 2013). Least Square Means of biosolids' methods (with or without biosolids) were compared at the 0.05 level of significance within each site.

Fig 3. Sudex 44 days after planting. Plants in back row grown with biosolids

Fig 4. Plants grown with biosolids are on right, and they were the only ones to produce heads.

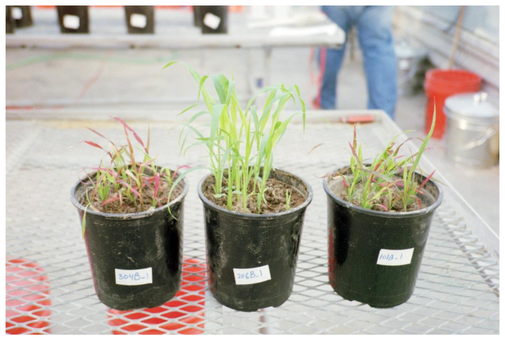

Fig 5. Plants grown without sludge showed severe heavy-metal toxicity.

Results and Discussion

Because differences in concentrations of Pb, Zn, and Cd in the mine waste materials, roots, shoots, and grain were not evident among the original seven treatments, they were averaged together and results are shown in Tables 1 and 2

Table 1. Organic matter, total nitrogen, total carbon, total organic carbon, total phosphorus, and extractable phosphorus in mine waste materials with and without biosolids. Within each row, values with the same case letter do not differ significantly at 0.05. Each value is the average of 21 measurements.

Measurement	Site A		Site B	
	With biosolids	Without biosolids	With biosolids	Without biosolids
Organic matter, %	2.73a	2.26b	2.24A	2.00B
Total N, %	0.15a	0.13b	0.11A	0.10A
Total C, %	1.71a	1.36b	1.11A	1.01B
Total organic C, %	1.44a	1.24b	1.08A	0.96B
Total P, ppm	1106a	777b	887A	705B
Extractable P, ppm	551a	349b	311A	208B

Table 2. Concentration (mg kg^{-1}) of heavy metals in roots, shoots, and heads of sudex grown with and without biosolids in mine waste materials from two different sites in Galena, Kansas.

Sudex	Pb		Zn		Cd	
	Site A	Site B	Site A	Site B	Site A	Site B
	With biosolids					
Roots	1196.8	585.0	7771.7	3054.0	42.6	18.7
Shoots	59.7	22.2	2307.3	711.5	12.1	6.6
Heads	3.8	1.8	116.4	57.0	2.2	0.7
	Without biosolids					
Roots	1504.7	715.1	6174.8	5045.6	56.4	42.0
Shoots	163.0	121.0	1791.9	1117.9	22.1	10.5
Heads	…†	…	…	…	…	…
	Maximum Normal					
	5.0		150.0		0.2	

† Plants grown without biosolids did not produce heads

Only the plants grown with biosolids produced grain (Fig. 4). The plants grown without biosolids showed severe heavy-metal toxicity (Fig. 5). In general, the biosolids reduced the uptake of heavy metals into the shoots. However, they were still contaminated with Pb, Zn, and Cd. Maximum levels of Pb, Zn, and Cd in plants grown on non-contaminated soils are 5.0, 150, and 0.2 mg kg^{-1}, respectively. In the grain, only Cd was above-normal levels.

Plants grew better with biosolids than without biosolids. Plants grew better in mine waste materials from Site B than Site A (Fig 6).

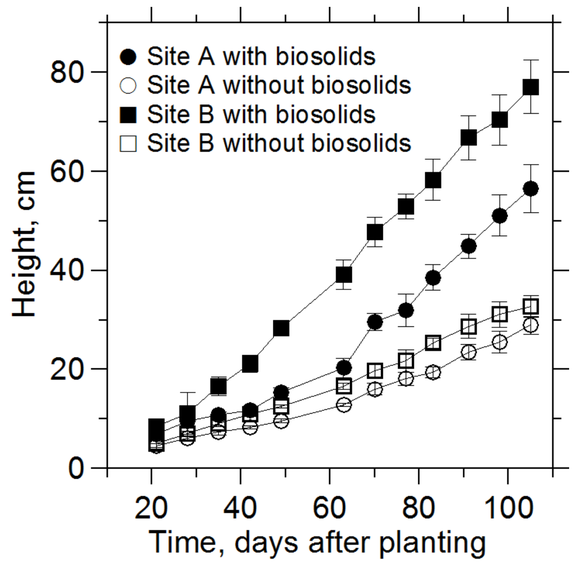

Fig 6. Height of sudex grown with and without biosolids

CONCLUSION

- The increased growth of the plants grown with biosolids appeared to be due to the total C, total organic C, and P from the biosolids.
- The OC apparently immobilized the Pb and Zn. The P not only was an essential nutrient, but it also may have bound the heavy metals and made them less available for uptake.
- The results suggest that biosolids, which are readily available from any town and continually produced, could be added to mine waste materials to revegetate land.

REFERENCE
Baker, L.R., P.M. White, and G.M. Pierzynski. 2011. Changes in microbial properties after manure, lime, and bentonite application to a heavy-metal contaminated mine waste. Applied Soil Ecology 48:1-10.

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