Trace Metal Species, Mobility, and Transport through Entrenched Biosolids at a Titanium Mining Site in Dinwiddie County, Virginia

Katrina Lasley, Kirill Kostyanovsky, Greg Evanylo, Beshr Sukkariyah, and Chao Shang
Department of Crop and Soil Environmental Sciences, Virginia Tech

INTRODUCTION

- Biosolids are by-products of wastewater treatment plants
- Disposal methods include landfilling, incineration, and land application
- Deep row incorporation prevents odor problems and may allow for higher application rates
- Entrenched biosolids can be used as a nutrient source for vegetation such as hybrid poplars
- Metals may leach from the entrenched biosolids
- Current Metals of Interest – Cd, Cu, Ni, Pb, and Zn
- Emerging Metals of Interest – Ag, Ba, Be, Sn, W
- Metal Movement may be due to microorganisms, pH, or complexation with organic and inorganic ligands

OBJECTIVE

To assess potential environmental consequences of employing the deep row incorporation of biosolids by determining movement, concentration, and speciation of trace metals in lateral and vertical directions.

FIELD METHODS

- Plots were on a mineral sands mine reclamation site near the Coastal Plain-Piedmont fall line in Dinwiddie County, VA
- Trenches were filled at two different rates with lime stabilized and anaerobically-digested biosolids

Figure 1: Entrenched biosolids

	Anaerobically Digested Biosolids		Lime Stabilized Biosolids	
Trench Width (m)	0.45	0.9	0.45	0.9
Application Rate, Mg/ha	213	426	328	656

Table 1: Application rates for the biosolids

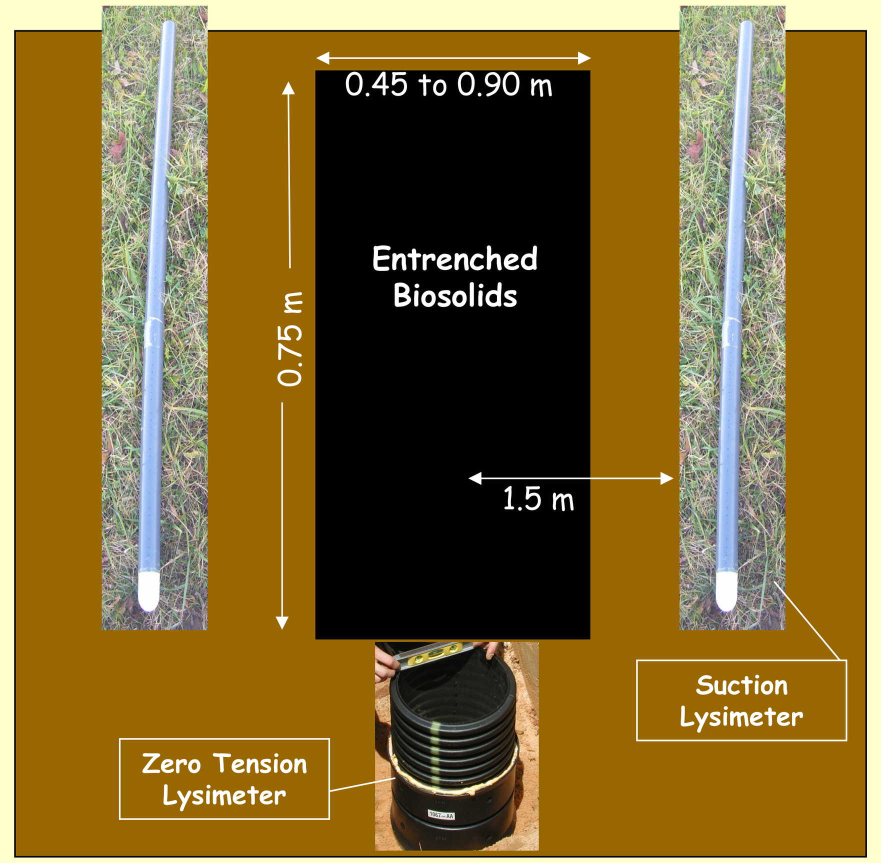


Figure 2: Instrumentation of trenches. Each trench was 15 m long.

- Leachate samples were analyzed for trace metal analysis along with pH, DO, and EC
- Hybrid poplars were planted Spring 2007

	Anaerobically Digested Biosolids	Lime Stabilized Biosolids
	concentration (mg/kg)	concentration (mg/kg)
Fe	43000	34333
Al	24700	3893
Mn	1021	216
Cu	328	197
Zn	1473	490
Cd	2	2
Ni	27	16
Pb	66	53
pH	8.5	12

Table 2: Biosolids composition

LABORATORY METHODS

- Samples filtered through 0.45 μm membrane filter for soluble metal forms
- Samples digested with a modified version of EPA 200.7 for total metal forms
- Samples analyzed by ICP-AES for Ag, Al, Ba, Be, Cd, Cu, Fe, Mn, Ni, Pb, Sn, W, Zn

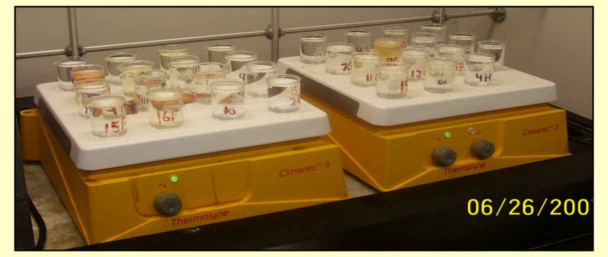
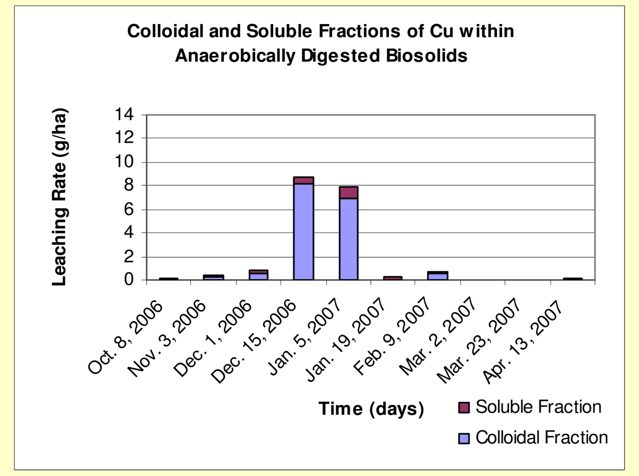
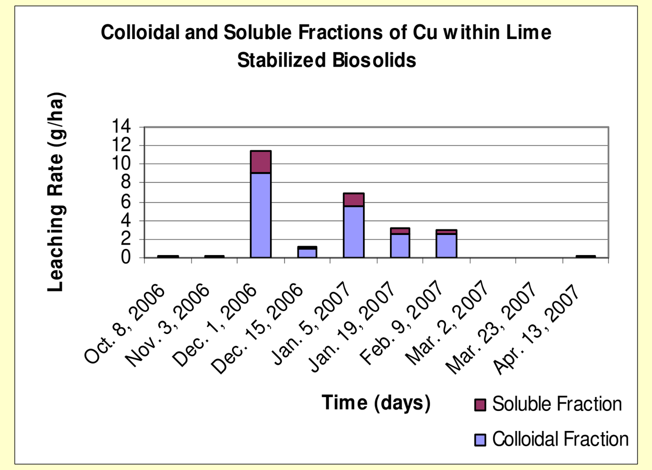


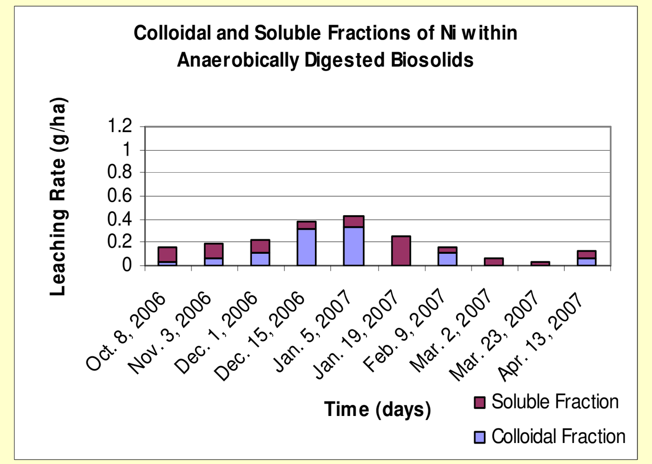
Figure 3: Digestion Process

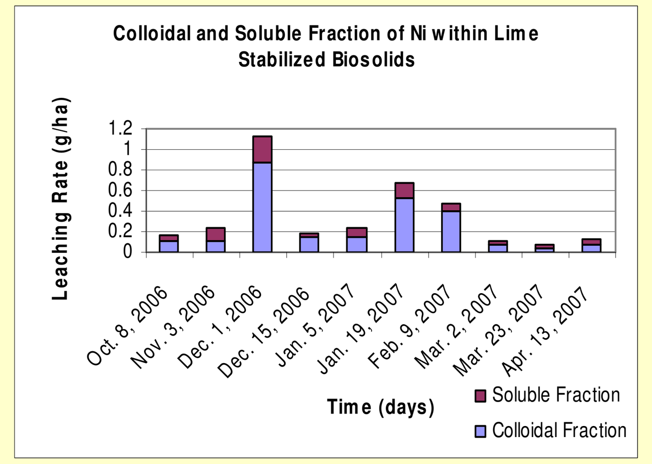
RESULTS



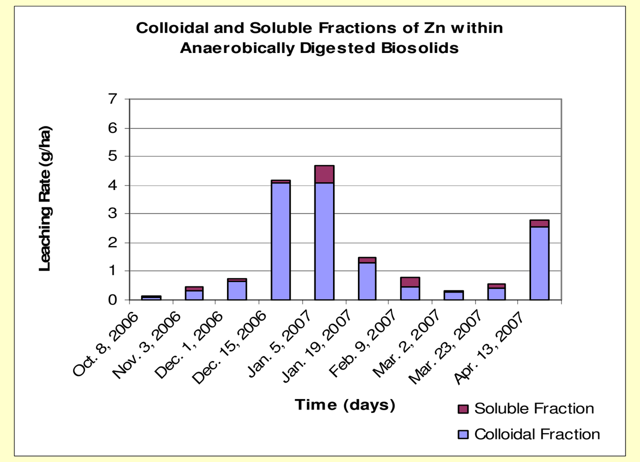


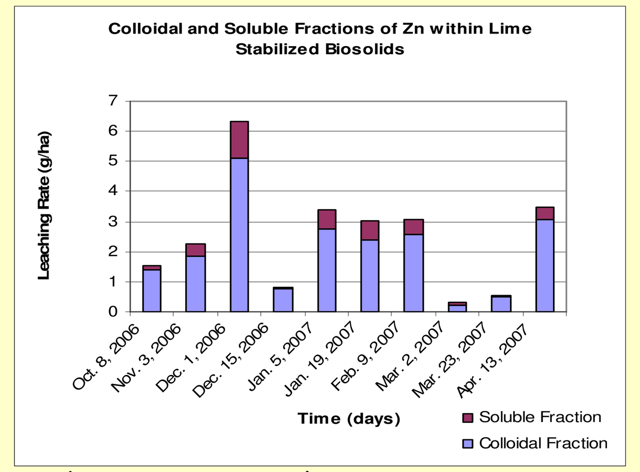
Figures 4 and 5: Cu movement over time within zero tension lysimeters.



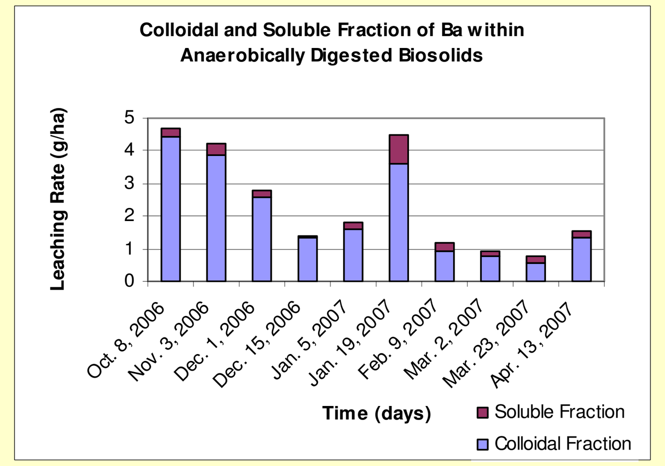


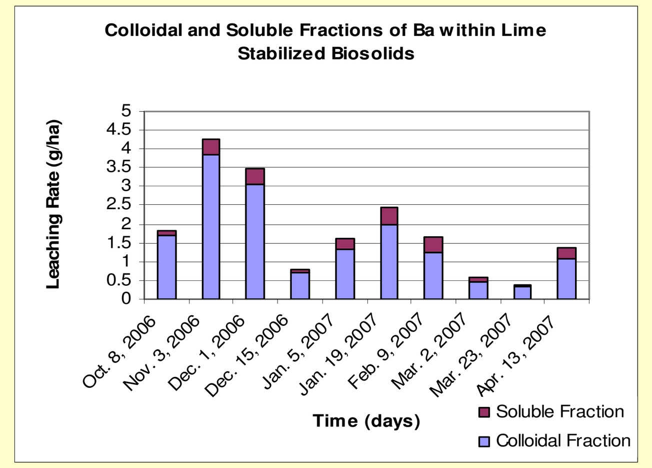
Figures 6 and 7: Ni movement over time within zero tension lysimeters.





Figures 8 and 9: Zn movement over time within zero tension lysimeters.





Figures 10 and 11: Ba movement over time within zero tension lysimeters.

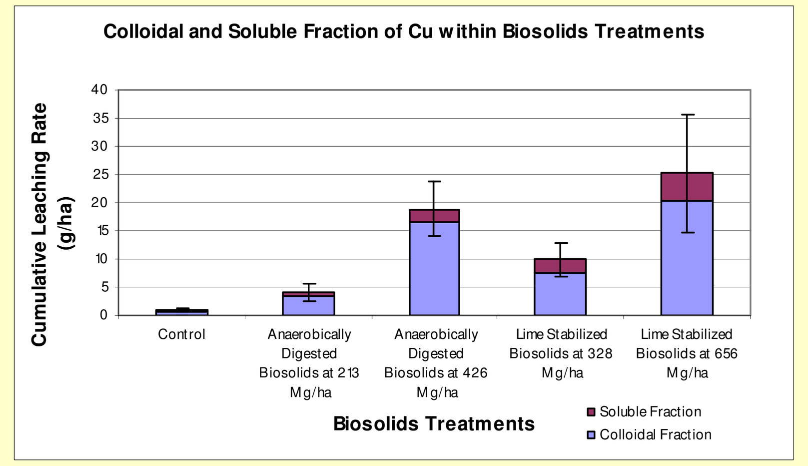


Figure 12: Cumulative leaching rate for Cu within zero tension lysimeters. Error bars are for total Cu.

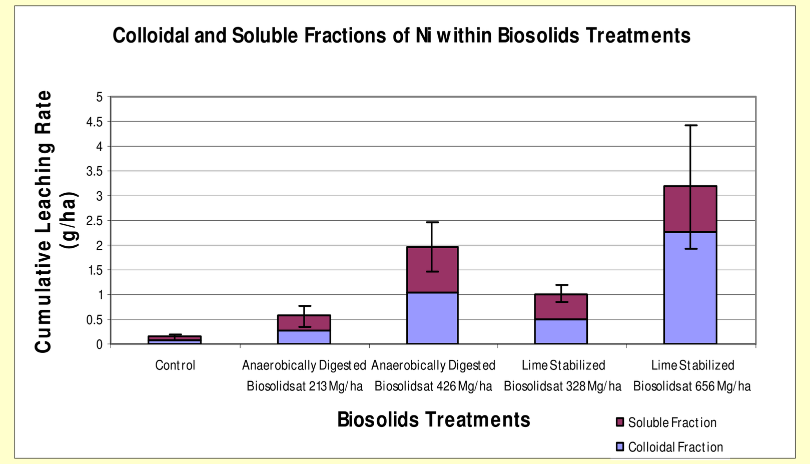


Figure 13: Cumulative leaching rate for Ni within zero tension lysimeters. Error bars are for total Ni.

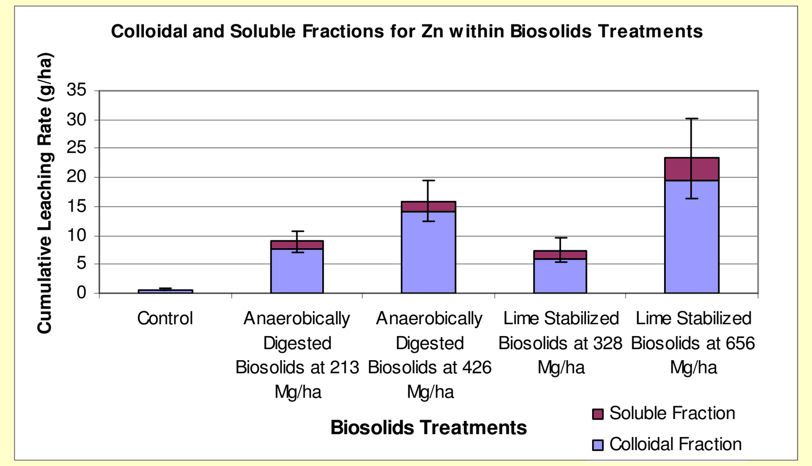


Figure 14: Cumulative leaching rate for Zn within zero tension lysimeters. Error bars are for total Zn.

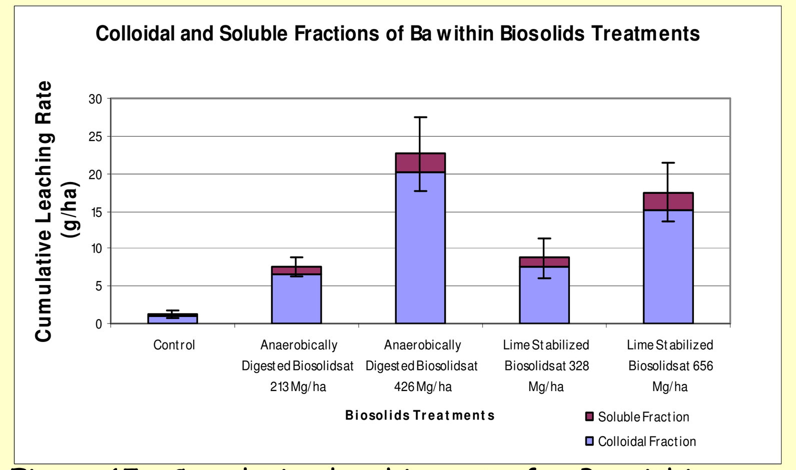


Figure 15: Cumulative leaching rate for Ba within zero tension lysimeters. Error bars are for total Ba.

	Metal					
	Ag	Be	Cd	Pb	Sn	W
Detection Limit (mg/L)	*0.006*	*0.0002*	*0.004*	*0.016*	*0.027*	*0.022*
Total Concentration Range (mg/L) [a]	0.006 - 0.014	0.0002 - 0.0013	0.004 - 0.022	0.0160	0.0270	0.022
% above Detection Limit	14	23	10	0	0	0

[a] Includes colloidal and soluble fractions.

Table 3: Summary of metals which are commonly below the ICP-AES detection limit.

Figure 16: Hybrid poplars at site 6 months after initial planting in March 2007.

	Average Concentration (mg/L)											
	Cd		Cu		Ni		Pb		Zn		Ba	
Detection Limit	*0.004*		*0.006*		*0.008*		*0.016*		*0.004*		*0.001*	
	Soluble	Colloidal	Soluble	Colloidal	Soluble	Colloidal	Soluble	Colloidal	Soluble	Colloidal	Soluble	Colloidal
Control	0.004	0	0.006	0	0.008	0	0.016	0	0.002	0.002	0.011	0.082
Anaerobically Digested Biosolids at 426 Mg/ha	0.004	0	0.007	0	0.009	0	0.016	0	0.033	0.177	0.061	0.225
Lime Stabilized Biosolids at 656 Mg/ha	0.004	0	0.006	0	0.015	0.046	0.016	0	0.067	0.276	0.11	0.667

Table 4: Example metal concentrations obtained from suction lysimeters for October 10 – November 3, 2006.

CONCLUSIONS

- Metal movement may be due to changes in pH or metals complexing with organic matter. Further analysis of pH and DOC will help determine this.
- Ni's large soluble fraction may be due to Ni's ability to be stable as Ni^{2+} in soil solution.
- Ag, Be, Cd, Pb, Sn, and W are of little concern as concentration within leachate are very seldom above the detection limit on the ICP-AES.
- Lateral movement into suction lysimeters is lower than vertical movement into the zero tension lysimeters. Any metal movement is within the soluble fraction.

CONTINUED WORK

- Analysis of binding ligands such as NO_3^-, NH_4^+, SO_4^{2-}, Cl^-, and DOC will continue
- Trace metal concentrations, pH, EC, DOC, and binding ligand concentration will be used in MINTEAQ2 for metal speciation
- Collected data will be employed to evaluate the environmental viability of the deep row biosolids incorporation technology.