# Chemistry and Transport of Metals from Entrenched Biosolids at a Reclaimed Mineral Sands Mining Site in Dinwiddie County, Virginia

Katrina K. Lasley

Thesis submitted to the faculty of

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Crop and Soil Environmental Sciences

Gregory K. Evanylo, Chair
W. Lee Daniels
Matthew J. Eick
Thomas R. Fox

June 30, 2008
Blacksburg, Virginia

Keywords: Biosolids, Entrenchment, Trace Metals, Mobility, Speciation

**Chemistry and Transport of Metals from Entrenched Biosolids at a Reclaimed Mineral Sands Mining Site in Dinwiddie County, Virginia**

Katrina K. Lasley

(ABSTRACT)

Deep row incorporation of biosolids is an alternative land application method that may allow higher than currently permitted mine land reclamation application rates. Biosolids treated by various processes possess characteristics that uniquely affect metal solubility and mobility due to their influence on metal speciation. The objectives of this research were to compare the effects of biosolids stabilization type and rate on heavy metal solubility, mobility, and speciation. Two rates each of Alexandria, (Virginia) anaerobically digested (213 and 426 dry Mg $ha^{-1}$) and Blue Plains (Washington, DC) lime-stabilized (329 and 657 dry Mg $ha^{-1}$) biosolids were placed in trenches at a mineral sands mine reclamation site in Dinwiddie County, Virginia in June and July 2006. Vertical and lateral transport of heavy metals from the biosolids seams were determined by analyzing leachate collected in zero tension lysimeters below the trenches and suction lysimeters adjacent to the trenches. Chloride ($Cl^-$), sulfate ($SO_4^{2-}$), nitrate ($NO_3^-$), phosphate ($PO_4^{3-}$), dissolved organic carbon (DOC), and pH were also determined within the dissolved fractions (< 0.45 µm) collected on September 8, 2006, November 3, 2006, January 5, 2007, June 8, 2007, and September 7, 2007 as input for the speciation program MINTEQA2. Silver, Cd, Pb, and Sn did not move vertically or laterally to any significant extent. Lime-stabilized biosolids produced higher cumulative metal mass transport per sampling period for Cu (967 g $ha^{-1}$), Ni (171 g $ha^{-1}$), and Zn (1027 g $ha^{-1}$) than the anaerobically digested biosolids and control during the 15-month period following entrenching. Barium mass loss was similar for both biosolids. All metals moved primarily with particulates. MINTEQA2 predicted the majority of the metals within the dissolved fraction were present as free ions. As pH decreased and time increased, the amount of association with fulvic acids decreased allowing more free ions and binding with inorganic ligands. Little movement into groundwater demonstrates that anaerobically digested and lime-stabilized biosolids can be land-applied at high rates with little concern of heavy metal contamination of groundwater under these conditions.

## ACKNOWLEDGEMENTS

I would like to thank my family, friends, and colleagues for all of their support over the past few years without them this journey would have been much more difficult. First, I would like to thank my advisor, Dr. Gregory Evanylo, for his guidance and insight to the different accepts of my project. He helped improve my knowledge on many subject matters along with many research techniques. Dr. Evanylo along with the rest of my committee, Dr. W. Lee Daniels, Dr. Matthew Eick, and Dr. Thomas Fox, each provided me with ideas and thoughts that were important to my understanding of the results and the project. Their suggestions helped develop and improve many aspects of the project. Thank you for sharing your knowledge and experience with me.

I would like to extend my gratitude to many people as without their help I would still be working on various aspects of the project. Kirill Kostyanovsky and I worked together to understand and analyze many, many samples from our joint project. Thank you to Beshr Sukkariyah for the insight on metal mobility from biosolids and help in the field and lab. Without W.T. Price helping in the field and Laura Waltham in the lab, we may still be collecting and analyzing samples. Mike Saluta helped develop lysimeters and Carl Clarke helped establish fieldwork by maneuvering large equipment on the site. Julie Berger, thank you for the use of your lab and supplies. Athena Tilley and Julie Jordan I cannot thank you enough for analyzing a countless number of samples. I would also like to thank my fellow graduate students for their ideas, help, and support over the past couple of years.

I would like to thank Iluka Resources, Inc. and the Carraway-Winn family for the site and use of their land for research. The District of Columbia (DC) Water and Sewer Authority provided funding for the research.

My family deserves a huge thank you as they provided a lot of love and support when times were stressful. Without my husband, Adam, I may have quit a long time ago but his faith in me to finish, ability to encourage me, love me, and laugh at me when I was making a molehill out of nothing are most grateful. Thank you. My parents and brother provided me with a solid foundation to continue my life and education in a way that makes me very thankful. I would also like to thank God for providing me with this opportunity and the ability to complete my education.

Thank you to all for providing me with anything from the smallest hello in the hall to company on four hour drives to the field.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# CHAPTER ONE
# INTRODUCTION

The Clean Water Act (PL 92-500, 1972) established regulations to reduce direct pollutant discharges, manage polluted runoff, improve wastewater treatment facilities, and find ways to utilize biosolids. Continued evolution of the act led to research and, later, the development of new technologies for the disposal and utilization of biosolids as they relate to water quality.

Current practices for managing biosolids include disposal (incineration, landfilling) and beneficial use (land application, composting for container media, etc.). Incineration kills pathogens but releases greenhouse gases and other air pollutants and concentrates metals into ash-bound forms. Disposal or use of the trace element-laden ash may increase hazardous landfill leachate or preclude land application. Landfilling biosolids creates greenhouse gases (esp., methane, NOx) and wastes a potentially valuable soil amendment and fertilizer source. Land application, the spreading of biosolids on land for beneficial use, provides a nutrient source and organic matter for the soil-plant system (USEPA, 1999).

Biosolids are valuable soil amendments for agricultural or disturbed soils. Nitrogen (N), phosphorus (P), sometimes lime, and trace elements in biosolids provide essential plant nutrients and soil acidity amelioration. Organic matter in biosolids improves soil productivity by enhancing the soil's physical (aggregation, infiltration, bulk density), chemical (soil pH buffering, increases cation exchange capacity), and biological (provides energy and nutrient source for microorganisms that facilitate important soil processes) properties (Forste, 1996).

Biosolids treatment reduces odor, destroys pathogens, and reduces vector attraction potential in accordance with federal and state regulations (Evanylo, 2003). Commonly employed treatment processes, such as anaerobic digestion and lime stabilization, influence properties of biosolids (Maier et al., 2000). Anaerobic digestion is a microbial process that converts organic matter into more stable forms, which have lower pathogen density and vector attraction. Once stable, metals are more likely to remain immobile (USEPA, 1999).

Lime stabilization destroys pathogens and odor-causing microbes by raising pH to 12 for two hours and to no less than 10.5 upon application. The resulting high pH may reduce the solubility of some metals (Smith, 1996; USEPA, 2007); however, dissolved organic carbon (DOM) will begin to dissociate at this pH and metals complexed with these compounds will become mobile (Richards et al., 2000). The larger presence of phenolic and carboxyl groups within fulvic acids allows these compounds to bind metals at high pH values (Kiekens, 1995).

Biosolids ability to sorb or precipitate metals differs depending on the initial waste inputs. Metals commonly present within biosolids include aluminum (Al), cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn). Iron concentrations may increase, during the addition of ferric chloride and/or ferric sulfate to improve odor control, conditioning, or flocculation. Aluminum increases with the addition of aluminum sulfate to improve conditioning or coagulation (Girovich, 1996b). The presence of organic (i.e. fulvic acid and DOM) and inorganic (i.e. phosphate ($PO_4^{3-}$)) compounds will influence metal mobility by providing a way to increase or decrease mobility.

Odor resulting from anaerobic bacteria decomposing biosolids-borne volatile organic matter can be a nuisance and may trigger fears that biosolids are toxic and harmful (Cheremisinoff, 1994; USEPA, 1999; USEPA, 2007). If treatment plants perform stabilization correctly, then lime-stabilized biosolids will produce a less offensive odor due to increased pH; however, changes in pH may influence odor production. Odor generation from anaerobically digested biosolids is due to microbial decomposition of organic compounds. The addition of chemicals to minimize anaerobic conditions and injection or entrenchment of biosolids will help reduce odor (USEPA, 1999).

The health and environmental consequences of applying biosolids-borne heavy metals to the soil have been addressed in “The Standards for Use and Disposal of Sewage Sludge (Title 40 of the Code of Regulations {CFR} part 503” (USEPA, 1993). Part 503 provides strict regulations when land applying biosolids by establishing pollutant concentration criteria for land-applied biosolids (Table 1.1). Ceiling concentration limits (CCL) are the maximum permissible metal concentration present in biosolids that can be land-applied. The cumulative pollutant-loading rate cannot be exceeded at any site when applying CCL-biosolids. Restrictions do not apply for biosolids containing metal concentrations at or below the pollutant concentrations level (PCL) (USEPA, 2000).

The Clean Water Act (PL 92-500, 1972) requires the USEPA to examine biosolids regulations and potential for new pollutants every two years (CSC, 2007). A review in December 2003 identified nine emerging pollutants of which four were silver (Ag), barium (Ba), beryllium (Be), and tin (Sn). In 2006, researchers analyzed these along with previously regulated metals in approximately 84 sewage sludge samples throughout the United States. From this study, a wide range of Ag, Ba, Be, and Sn concentrations were present within sewage sludge (Table 1.2) resulting in a request for additional data on these elements (CSC, 2007).

Historically, biosolids have been surface applied to the land as a liquid (< 5% solids) or as a dewatered "cake" (20 – 30% solids) and either incorporated via tillage or allowed to remain on the surface to avoid disturbance to permanent vegetation. Deep Biosolids Row Incorporation Technology (DBRIT) (ERCO, Inc., 2000) places biosolids in trenches below the soil surface and covers them with soil or overburden from mining or construction operations. The area can then be vegetated to facilitate soil rehabilitation and/or produce an economic crop.

Entrenching biosolids for disturbed land reclamation instead of routine application and incorporation of biosolids has been proposed to allow higher application rates by creating conditions within the biosolids "seam" that reduce the potential for N loss. Application of higher than permitted mined land rates will supply N, P, and other essential plant nutrients, and organic matter at rates that increase soil reclamation and plant growth. Furthermore, reduced exposure to the atmosphere reduces odors and bioaerosls that may be a source of nuisance and potential health effects (Cheremisinoff, 1994; McFarland, 2001; Lewis et al., 2002). The production of non-food chain energy crops, such as hybrid poplar (*Populus* spp.); decreases risk of food chain transferred biosolids pollutants and produces a renewable source of energy while degraded land is slowly reclaimed by high amounts of nutrients and organic matter.

Despite the agronomic benefits that accrue accompanied by the expected minimal N leaching losses with entrenching biosolids, there exists the potential for solubilization and transport of trace metals when the DBRIT system is employed to reclaim coarse-textured soils with high groundwater tables. Potentially environmentally deleterious biosolids-borne metals, whose mobility may increase due to anaerobic conditions and high concentrations of metal-complexing organic ligands, include Cd, Cu, Pb, Ni, and Zn (Girovich, 1996a). The concentrations of such metals in biosolids have decreased dramatically over the past 20 years due to pretreatment requirements (Basta et al., 2005); however, high biosolids application rates may increase metal leaching under the conditions existing in the trenches (Emmerich et al., 1982).

## OBJECTIVES

Mineral sands surface mining in south central Virginia offers the opportunity to test the potential for metal transport from entrenched biosolids used to reclaim these soils. The coarse textured soils that result from mineral sands mining along with a shallow water table may allow the transport of metals into groundwater. We investigated the potential fate and transport of heavy metals from entrenched biosolids for reclamation of the mined land and production of a hybrid poplar bioenergy crop. Our specific objectives were:

1. To measure the concentrations and mass transport of dissolved and colloidal fractions of key trace metals which leach and move laterally from entrenched biosolids used for the reclamation of mined land and production of hybrid poplars.
2. To employ the chemical speciation model MINTEQA2 to describe trace element species that exist in the dissolved fraction of leachate collected below entrenched biosolids.

## PREVIOUS RESEARCH

Biosolids production increased from 5.4 million Mg in 1989 to 8.0 million Mg per year in 1995 (Girovich, 1996a). Approximately half of the biosolids produced in the United States are land-applied and, as of 1995, the vast majorities were used on agricultural land (USEPA, 2000; USEPA, 2007). The biosolids provide essential plant nutrients and improves soil properties; however, offensive odors, public health, and environmental concerns have resulted in local application restrictions. Therefore, research for alternative methods to surface application began in the 1970's with deep row burial as a way to manage waste, maintain plant and soil productivity, and to prevent human health or environmental damage.

### Biosolids entrenching

Placing biosolids in trenches provides such benefits as the ability to recycle waste, apply at high rates, no surface runoff, and a reduction in odor production. Biosolids utilization also decreases fertilizer application by providing micronutrients and other plant essential nutrients, such as nitrogen (N). Micronutrients include metals such as Cu, Fe, Mn, and Zn, whose transport through some soils may be facilitated or reduced by various biosolids-borne ligands.

Sikora et al. (1979, 1980) investigated the agronomic and environmental effects of entrenched biosolids. They entrenched undigested, lime-stabilized sewage sludge along with digested sewage sludge in sandy soil, sampled the sludge and soil at various depths, and sampled Cd, Cu, and Zn at each depth. Sikora et al. (1979) determined that after 1,508 days, the entrenched undigested lime-stabilized sludge retained 74% of Cd, 33% of Cu, and 5% of Zn originally applied. In soils below the digested sludge, which did not contain any lime, Zn was the only metal with detectable concentrations. These researchers predicted that the lime's ability to increase pH might have influenced metal mobility from the trenches (Sikora et al., 1980); however, the authors did not begin measuring metal content until 18 months after the sewage sludge was entrenched, which may have allowed undetected metal movement.

Taylor et al. (1978) performed a column study simulating entrenched sewage sludge. The researchers placed soil at the bottom of a column followed by variously treated sewage sludge, overburden, and a planting of corn (*Zea mays* L.). Gas samples from untreated sludge indicated that anaerobic conditions occurred within these zones. The soil and sludge samples collected from the columns showed high levels of Zn and Cu present within the sludge and low levels present above and below the trenches (Taylor et al., 1978). Reasons why metal transport was low may have been due to the anaerobic conditions and resulting low redox potentials in the biosolids seam. Pepperman (1995) demonstrated that low oxygen content prevents obligate aerobes from mineralizing organic matter and releasing complexed metals. Under the anaerobic conditions, development of low redox potential causes anaerobes to reduce electron acceptors other than oxygen, resulting in metals precipitation (i.e. sulfides and carbonates) (Maier et al., 2000, Taylor et al., 1978). The metals may also change oxidation states, which would influence its mobility and toxicity (McLean and Bledsoe, 1992).

Researchers at the University of Maryland in conjunction with ERCO, Inc. began investigating biosolids trenching as a tool for reclaiming mined land and producing a bioenergy crop (hybrid poplar) in the early 1990's. Their primary objectives were to learn how degraded land could be reclaimed with high application rates of biosolids-borne organic matter and nutrients for the production of a crop (hybrid poplar) that has high nutrient assimilation rates and to determine whether the practice generates any deleterious environmental effects (Pepperman, 1995; ERCO, Inc., 2000; Felton et al., 2005; Kays, 2006). The researchers analyzed groundwater from monitoring wells installed at various depths around the trenches; however, only one monitoring well was present at the site during the first 5 years after biosolids were entrenched. Over time, additional wells were added, sampled, and analyzed for biosolids constituents, but losses of nutrients and trace elements could have occurred in the interim without being detected. Among the elements analyzed in the groundwater samples, Cd and Pb were at or below detection their limits (Kays, 2006). The soil texture of the Maryland research site was mostly sandy clay loam to loam topsoil underlain by a native clay layer, which acted as a barrier against leachate movement to groundwater directly below the application area

(Pepperman, 1995). Thus, the results from the Maryland site may not be applicable to soils having very coarse-textured subsurface soils, through which dissolved and colloidal-bound constituents may leach.

### Hybrid poplar use for entrenched biosolids

Field studies to investigate the environmental effects of land-applied biosolids have commonly used agronomic crops as the vegetation. Silviculture is increasingly used to revegetate disturbed mine land because trees can provide a bioenergy source, nutrient sink, wildlife habitat, and material for wood products. Biosolids are typically applied to surface soils for agronomic crops in order to provide nutrients within the crop's root zone. Deep row burial can be implemented for production of trees, by placing biosolids (and plant nutrients) at an adequate depth for root uptake (Kays, 2006).

During reclamation of gravel-mined land in Maryland, researchers planted hybrid poplars (*Populus spp.*) over entrenched biosolids as a non-food chain product, a possible wildlife habitat, and a bioenergy source (Pepperman, 1995). At the site, ERCO, Inc. (2000) reported that deep root growth surrounding the trenches provided the opportunity for hybrid poplars to assimilate potential pollutants before they leach into the groundwater. The high assimilation ability of hybrid poplars was demonstrated by an increase in foliar N concentration by 3.5% during the first 6 years (ERCO, Inc., 2000).

There has been recent interest in the use of hybrid poplars for land reclamation due to their potential to assimilate pollutants (Johnson, 1999). Poplar trees have preformed root initials under their bark, which allows for easy establishment within various environments (Licht, 1994). As a hardy perennial, the extensive, deep root system can allow the tree to act as a "pollutant sink" by removing excess nutrients and chemicals from the system (Asare and Madison, 1999; Braatne, 1999). The roots can assimilate water and nutrients up to 1.5 m below the surface allowing the poplars to reduce harmful concentrations below entrenched biosolids (Licht, 1994).

### Metal mobility

Biosolids have raised many concerns within the environmental community as researchers are unsure whether trace elements from land-applied biosolids can be transported to and pollute ground and/or surface water. Many characteristics of soil systems influence the mobility of metal species including chemical properties (i.e. pH) and the presence of binding constituents such as organic matter, hydroxides/oxides, and inorganic ligands. Previous work has shown, depending on the trace metal and the environmental conditions present, one or a combination of these factors may increase or decrease the potential of a metal to be moved into surrounding soil and water systems. Biosolids have several properties that are similar to soils; therefore, biosolids influence metal mobility.

Basic bonding mechanisms influence metal mobility within a soil or biosolids environment. Cation exchange is a reversible reaction where cationic metals within a soil solution will electrostatically form outer sphere complexes with anionic exchange sites on colloids. The amount of adsorbed and relatively immobile metals depends on the number of negatively charged cation exchange sites. Organic matter can also chelate metals and decrease mobility; however, soluble complexes with low-molecular weight organic ligands, such as fulvic acid, can prevent further bonding and increase mobility. The amount of metals complexed depends on the number of hydroxyl, phenoxyl, and carboxyl functional groups present within the organic matter (Alloway, 1995).

Adsorption occurs when ions accumulate on to the surface of the solid phase and is mostly insoluble; however, this mechanism is highly pH-dependent (Alloway, 1995). Through specific adsorption, cationic metals form inner sphere complexes as partly covalent bonds with surface ligands (Alloway, 1995; McLean and Bledsoe, 1992). Clay edges and Fe and/or Mn oxides are common locations for metals to be adsorbed. As compared to specific adsorption, non-specific adsorption is a relatively weaker association. The outer sphere complexes retain the layer of hydration resulting in an electrostatic bond that is easily reversible (McLean and Bledsoe, 1992).

When a metal becomes oversaturated in a soil solution, it will precipitate to form a form three-dimensional solid phase. The highly insoluble bonds make this a strong mechanism for metal retention (McLean and Bledsoe, 1992). As pH increases, the precipitation of trace metals also increases which reduces metal concentrations present in soil solutions (Basta et al., 2005). Each of these mechanisms is reversible to some degree; therefore, they can release metals and metal-ligand complexes into soil solution. Free metal ions have the ability to form bonds with dispersed ligands in the soil solution by similar mechanisms.

**Effects of chemical and physical properties on metal solubility**

Chemical and physical properties of soils and wastes along with binding ligands can influence metal mobility. Changes in pH can influence the sorption of metals to organic matter, oxides, and inorganic ligands. If pH remains constant, then within an inorganic environment metal availability remains constant; however, soils and biosolids are an organically based dynamic system where several factors will influence mobility (Basta et al., 2005). As pH decreases, adsorption sites become positively charged resulting in diminished cation adsorption rates. Metals may compete with $Al^{3+}$ and hydrogen ($H^+$) for the few remaining negative sites, increasing metal concentration in solution (McLean and Bledsoe, 1992). The increased presence of $H^+$ will cause hydroxides to release cationic forms of metals into solution. With the exception of molybdenum (Mo), metals become immobile with an increase in pH (Girovich, 1996a).

Sukkariyah et al. (2007) found greater metal mobility through a coarser -textured soil compared to fine textured, following 14 years of surface application of liquid anaerobically digested biosolids. The soils differed only in silt content with clay content and mineralogy being similar. The coarse-textured Bojac sandy loam (coarse-loamy, mixed, semiactive, thermic Typic Hapludults) had increased Zn and Cu mobility to 0.75 m below the surface, while metals remained concentrated in the zone of incorporation in the fine-textured Acredale silt loam (fine-silty, mixed, active, thermic Typic Endoaqualfs). Water quality of nearby monitoring wells did not show increased metal concentration. Transport appeared to be more associated with physical than chemical soil properties.

Camobreco et al. (1996) constructed disturbed and undisturbed soil columns from Arkport silty loam. The undisturbed columns contained several wormholes and root channels increasing preferential flow. These researchers applied solutions simulating leachate from biosolids and found that metal concentration within the leachate from the undisturbed soil was higher than the disturbed soil. The presence of wormholes and root channels increased metal movement showing the crucial influence preferential flow plays in metal mobility (Camobreco et. al. 1996).

Trace metals can sorb to organic matter found within soil or biosolids causing a decrease in mobility. Copper and Pb form a very strong inner-sphere complex with organic matter. Silver will also adsorb to organic matter becoming highly insoluble (McLean and Bledsoe, 1992). As pH increases, sorption of trace metals to stable organic matter also increases due to the ionization of organic functional groups. Sorption of metals by stable organic matter does not decrease as dramatically with a decrease in pH (Basta et al., 2005) as does sorption to mineral surfaces. At low concentrations, metals sorb to specific sites; however, at high concentrations these sites become saturated. Once filled the nonspecific exchange sites may release metals more readily (O'Conner et al., 1984).

Fulvic and humic acids are broad groups of organic colloids, whose mobility will depend on pH, electrolyte concentration, and ion valency within the electrolyte composition (Tombacz and Meleg, 1990). Stevenson and Ardakani (1972) demonstrated that trace elements will complex with fulvic acids in the following order: Cu > Pb > Fe > Ni > Mn > Co > Zn > Mg. Metals complex with carboxyl, phenol, alcohol, carbonyl, and methoxyl functional groups on fulvic and humic acids. The low molecular weight of fulvic acids allows more mobility than the heavier humic acids (Christensen et al., 1998).

Dissolved organic matter (DOM) can increase Cu, Cd, Ni and Zn mobility (McBride et al., 1997; McBride, 1998). The low molecular weight organic compounds (i.e. polyphenols, amino acids) can either form soluble organo-metallic complexes with free ions or instead of complexing metals it can sorb onto soil surfaces (Antoniadis and Alloway, 2002). As pH increases above neutrality, organic matter releases more of the metals associated with DOM (Japenga et al., 1992).

Oxides found within soils and biosolids will influence the availability of metals that have been land-applied. Common forms of oxides within soils include Fe, Al, and Mn (McBride, 1994; Sposito, 1986). As pH increases, adsorption by oxides will increase; therefore, soil or biosolids containing oxides with a basic pH will more readily adsorb metals than those with acidic conditions (McKenzie, 1980). A decrease in redox potential or pH can cause certain oxides (i.e. Fe and Mn) to be more soluble and release metal ions (Alloway, 1995). Oxides display various affinities to cations that are similar in shape and size to $Mn^{2+}$, $Mn^{3+}$, $Fe^{2+}$, and $Fe^{3+}$ including $Ni^{2+}$, $Cu^{2+}$, $Zn^{2+}$, $Cd^{2+}$, $Pb^{4+}$, and $Ag^{+}$ (Kabata-Pendias and Pendias, 2001).

A recent review by Brown and Parks (2001) indicates that Fe and Mn oxides have a much greater adsorption capacity than Al oxides. Lead, Cu, Mn, Ni, and Zn form inner sphere complexes, which are very strong, with the oxide surfaces (Brown and Parks, 2001; Sparks, 2001). Hettiarachchi et al. (2003) measured adsorption isotherms for Cd before and after reducible Fe and Mn oxides had been removed from lime digested biosolids. The amount of Cd sorbed onto the biosolids' surfaces decreased with the removal of Fe and Mn oxides, as indicated by a decrease in the slope of the isotherms. Hettiarachchi et al. (2003) concluded that other components were responsible for immobilizing Cd within the biosolids because the adsorption slopes for the biosolids and control treatments did not change in similar ways.

Inorganic anions, such as phosphate ($PO_4^{-3}$), sulfate ($SO_4^{-2}$), chloride ($Cl^-$), bicarbonate ($HCO_3^-$), and nitrate ($NO_3^-$), also influence the solubility and mobility of metals (Jensen and Christensen, 1999). These ligands form metal precipitates as pure (i.e. $ZnS_2$) or mixed solids (i.e. $Ba(CrO_4,SO_4)$). Metals such as Cd, Pb, and Ni may have increased mobility due to complexing with inorganic ligands (McLean and Bledsoe, 1992).

Metals can bond with inorganic ligands under diverse conditions. Precipitate formation between the inorganic anions and metallic cations will increase as pH increases (Basta et al., 2005). Hydrated phosphate can precipitate Pb and Zn under neutral to alkaline soil conditions. Sulfates commonly occur under oxidizing conditions. A system must be arid or semiarid for $Cl^-$ to be present and greatly influence metal mobility (Kabata-Pendias and Pendias, 2001). At high salt contents (0.1 to 0.5 M), Donor (1978) concluded Cd mobility increased due to complex formation with $Cl^-$. Nickel and Cu also formed complexes with $Cl^-$ but not as strongly as Cd (Doner, 1978). Elrashidi and O'Connor (1982) found that Zn complexed with $Cl^-$, $SO_4^{2-}$, and $NO_3^-$ under normal salt content for soils. Phosphate directly complexes metals, but may also increase metal mobility by physically blocking specific adsorption sites (McBride, 1985; Cavallaro, 1982).

Constituents in leachate or soil solution can be present in various size fractions that are operational defined as colloidal or dissolved. The colloidal fraction includes metals bound to clay, organic particles, or precipitates. Dissolved fractions are much smaller than colloids and operationally defined as < 0.45 µm (Jensen and Christensen, 1999). These size fractions influence speciation by providing different ligands via which metals could be complexed.

**Metal leaching column studies**

Past research has presented conflicting results on metal mobility from biosolids treated soils. Emmerich et al. (1982) incorporated anaerobically digested sewage sludge within the top 15 cm of the profile of soil columns. Soils textural classified as sandy loam-fine-loamy, sandy loam-coarse-loamy, and loamy sand-coarse-loamy were collected in 10 cm increments. After leaching the system for 25 months, the columns were sectioned and analyzed for metals. This research group determined that Cd, Cu, Ni, and Zn did not move below the incorporation level and were mostly found within the soil-sludge layer for each soil profile (Emmerich et al., 1982).

Camobreco et al. (1996) measured mobility in the presence of soluble organic molecules in the surrounding soil. They established Arkport silty loam soil columns to which were applied solutions simulating leachate from biosolids. Metal concentrations of leachate Cd, Zn, Cu and Pb increased by 30%, 26%, 28%, and 27%, respectively, when solutions containing soluble organic molecules were added to the columns. The researchers generated the organic solution by passing tap water through a drum filled with sphagnum peat moss (98% organic matter) and then collecting the leachate. The increase was not as dramatic when the solution contained only metals and water (Camobreco et al., 1996). Al-Wabel et al. (2002) showed biosolids increased dissolved organic carbon (DOC), Cd, Zn and Pb mobility within columns established from soils in Colorado, which had received long-term biosolids application. They predicted the difference within the treatments was due to the release of various DOC components (Al-Wabel et al., 2002).

Electrical conductivity (EC) indirectly measures salt content of a soil or soil solution. As dissolved salt content increases, the EC will increase (Brady and Weil, 2002). Al-Wabel et al. (2002) found an increase in Zn concentration when EC increased within their columns established from soils, which had received long term biosolids application. The increased mobility suggests Zn may be binding with the chloride ($Cl^-$) from the dissociated salt compounds or other inorganic ligands (Al-Wabel et al., 2002). At higher concentrations, Zn may also be competing with other metals for various reaction sites on the stable soil material causing it to be present in the soil solution (McLean and Bledsoe, 1992).

**Metal leaching field studies**

Some researchers have determined that column studies do not adequately mimic natural conditions; therefore, actual land application of biosolids has been examined for metal mobility. Williams et al. (1984, 1985) determined that trace metal movement is limited below the layer of incorporation. In 1975, two types of sewage sludge, one of a domestic origin and one containing large amounts of industrial waste, were applied to several plots in California with application rates ranging from 0 to 225 Mg $ha^{-1}$ in increments of 45 Mg $ha^{-1}$. Even though the sewage sludge was produced in 1975, all of the metals concentrations except Pb in the industrial waste met the current USEPA Part 503 regulations (USEPA, 1993). The researchers collected soil samples at various depths and analyzed them for Cd, Cu, Pb, Zn, Ni, Fe, Mn, chromium (Cr), cobalt (Co) and mercury (Hg). With the exception of Zn, which appeared to move an additional 5 cm, trace metals were present in low concentrations below 5 cm of incorporation. Some of these values even became similar to the untreated soil indicating that most of the trace metals remained within the sewage sludge or leached at such a slow rate that they would not cause harm to the surrounding environment (Williams et al., 1984, 1985).

McBride et al. (1999) observed metal movement from surface applied biosolids. In 1978, lime-stabilized biosolids (pH near 7) were rototilled into the top 20 cm of the Hudson silty clay loam soil surface with the nominal loading of Pb, Cd, and Zn being approximately half of the cumulative loading permitted under USEPA Part 503 (USEPA, 1993). Fifteen years later, water samples collected 60 cm below the surface contained arsenic (As), Cd, and Ni concentrations close to the maximum contaminant level (MCL) as defined in the Safe Drinking Water Act (USEPA, 2003). Chromium, Cu, and Pb were below their MCL values. The researchers determined that 70% of the Zn, 82% of the Cd, and 90% of the Cu were not free cations or in forms that were easily dissociated within the dissolved fraction of the leachate; therefore, they conjectured that metals leached with DOM (McBride et al., 1999).

A recent study on long-term land application of sewage sludge in Nigeria demonstrated heavy metal movement into underlying soil horizons. Udom et al. (2004) collected soil samples from the Ap, AB, EB, Bt1, and Bt2 horizons of an Ultisol to which primary sewage sludge had been applied for approximately 40 years. Compared to the control site, the overall Zn, Pb, Cd, and Cu concentration within the soil increased by 611, 230, 39, and 479%, respectively. The greatest accumulation occurred in the AB horizon. It took extreme pH values, 3.2 – 4.9, which normally do not support healthy agronomic crops, to cause metal mobility; however, farmers had been using this area for many years. The researchers concluded that accumulation of heavy metals in the soil due to 40 years of sewage sludge application might have potential health and phototoxic effects which the community did not previously understand (Udom et al., 2004).

As land application of biosolids has been increasingly utilized in land reclamation, interest in deep row burial has increased. Taylor et al. (1978) simulated entrenched sewage sludge by placing variously treated sewage sludge over soil and then covering them with overburden. The soil samples collected below the sludge contained low concentrations of Zn and Cu (less than 1.5 $\mu g\ g^{-1}$) whereas the sludge itself contained the highest concentrations. They suggested decreased mobility was due to metal retention in the sewage sludge via metal-organic matter complexes, precipitation with inorganic ligands, or as sorbed phases. As a beneficial use for biosolids, land application through entrenchment needs more research to understand potential metal mobility into groundwater.

## MINTEQA2

MINTEQA2 predicts metal species by entering concentration of free ions and neutral or charged complexes present within the system. A database containing over 1400 reaction products for the various components along with a thermodynamic database is automatically accessed to determine which species are likely to occur under given conditions. MINTEQA2 calculates equilibrium component activities with the Davies equation to describe the influence of ionic strength on actual concentrations entered by the user. Saturation indices are calculated to determine if solids will precipitate under the given conditions (Allison and Brown, 1995). Dissolved organic carbon can be entered as a component through various models such as the Stockholm Humic Model (SHM). This model uses the Basic Stern Model (BSM) to correct equilibrium constant for electrostatics and assumes that only fulvic acid can be dissolved in soil soil. Unlike the other DOC models present within MINTEQA2, SHM allows DOC to bind as monodentate or bidentate complexes and does not put a restriction on the number of these bond types. Gustafsson and van Schaik (2003) found that bidentate complexes are more common on dissolved fulvic acid.

Bonds formed with organic and inorganic ligands can influence metal mobility. Once within a new environment, other reactions may control metal solubility. Metal speciation is important because it helps predict the potential for metal transport and bioavailability. Understanding metal speciation within leachate could also help explain the mechanism by which metals move from biosolids. Computer programs based on thermodynamic models can predict speciation of metals in leachate collected below biosolids.

One such geochemical program, MINTEQA2, describes metal speciation within dissolved fractions of leachate for given conditions (Allison et al., 1991). The program can thermodynamically predict most stable species; however, kinetics (i.e. rate of reaction) are not considered (Mckinley et al., 2001). This means that metal species predicted by MINTEQA2 could be present in the leachate moving from the biosolids or they may form after the metals were transported to the region of sample collection. MINTEQA2 includes a set of predefined inorganic and organic components that are either free ions or neutral and charged complexes (Allison and Brown, 1995). The user enters these components as empirical data about the sample allowing the program to access various databases to make its prediction (Allison et al., 1991).

Research using the MINTEQA2 as a speciation model describes leachate samples in more detail. Christensen and Christensen (1999) used the program to examine the complexation of Cd, Ni, and Zn by DOC within polluted leachate by sampling from the anaerobic section of a pollution plume found within a Denmark landfill. The researchers analyzed each sample for heavy metals, $Cl^-$, calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), potassium ($K^+$), sodium ($Na^+$), ammonium ($NH_4^+$), and DOC. Empirical data was collected through resin equilibration and aquifer material sorption experiments. The predictions were excellent for Cd when compared to empirical data collected from the same samples. Nickel and Zn produced fair predictions (Christensen and Christensen, 1999). The results show that MINTEQA2 is useful for speciation predictions of heavy metals and DOC.

Jensen and Christensen (1999) performed a similar study by examining the dissolved fraction of leachate collected from a Denmark landfill. According to MINTEQA2, the metals present in the dissolved fraction were most likely to form complexes with DOM. The metals also formed complexes with several inorganic ligands such as $NH_4^+$, $SO_4^{2-}$, $Cl^-$, and $PO_4^{3-}$. These researchers determined that Mg was primarily present in the dissolved fraction, Mn was equally distributed between dissolved and colloidal fractions, and Fe was found predominately in the colloidal fraction (Jensen and Christensen, 1999).

Mckinley et al. (2001) used MINTEQA2 to predict solution components from leachate collected through a column study containing lime-strengthened soil, which was previously amended with sewage sludge. They used dissolved metal and inorganic ligand concentrations along with pH as input date for the program. MINTEQA2 indicated that Cu and Ni would precipitate in the leachate; however, the researchers did not enter any data about DOC. Upon experimental analysis of the leachate samples, the researchers found Cu and Ni present in higher than expected values indicating that they were in mobile forms possibly due to complexation with DOC. MINTEQA2 helped confirm this hypothesis.

## REFERENCES

Alloway, B.J. 1995. Soil processes and the behaviour of heavy metals. *In* B.J. Alloway (ed.) Heavy Metals in Soils. 2nd ed. Blackie Academic & Professional: London.

Al-Wabel, M.A., D.M. Heil, D.G. Westfall, and K.A. Barbarick. 2002. Solution Chemistry Influence on Metal Mobility in Biosolids-Amended Soils. J. Environ. Qual. 31:1157-1165.

Allison, J.D., D.S. Brown, and K.J. Novo-Gradac. 1991. MINTEQA2/PRODEFA2: a Geochemical assessment Model for Environmental Systems: Version 3.0 User's Manual. U.S. Environmental Protection Agency. EPA-600/3-91-021.

Allison, J.D. and D.S. Brown. 1995. MINTEQA2/PRODEFA2 – A Geochemical Speciation Model and Interactive Preprocessor. p. 241-252. *In* R.H. Loeppert, A.P. Schwab, and S. Goldberg (ed.) Chemical Equilibrium and Reaction Models, SSSA Spec. Publ. 42. SSSA, Madison, WI.

Antoniadis, V. and B.J. Alloway. 2002. The role of dissolved organic carbon in the mobility of Cd, Ni and Zn in sewage sludge-amended soils. Environ. Pollut. 117:515-521.

Asare, S. and M. Madison. 1999. Use of Hybrid Poplars for Phytoremediation and Other Environmental Applications. *In* K.A. Blatner, J.D. Johnson, D.M. Baumgartner (ed.) Hybrid Poplars in the Pacific Northwest: Culture, Commerce, and Capability. Symposium Proceedings. April 7-9, 1999. Pasco, WA.

Basta, N.T., J.A. Ryan, and R.L. Chaney. 2005. Trace Element Chemistry in Residual-Treated Soil: Key Concepts and Metal Bioavailability. J. Environ. Qual. 34:49 63.

Braatne, J.H. 1999. Ecological Considerations of Hybrid Poplar Cultivation in Riparian Settings. *In* K.A. Blatner, J.D. Johnson, D.M. Baumgartner (ed.) Hybrid Poplars in the Pacific Northwest: Culture, Commerce, and Capability. Symposium Proceedings. April 7-9, 1999. Pasco, WA.

Brady, N.C. and R.R. Weil. 2002. The Nature and Properties of Soils. 13th ed. Prentice Hall, New Jersey.

Brown, G.E., Jr. and G.A. Parks. 2001. Sorption of trace elements on mineral surfaces: Modern perspectives from spectroscopic studies, and comments on sorption in the marine environment. Int. Geol. Rev. 43:963-1073.

Camobreco, V.J., B.K. Richards, T.S. Steenhuis, J.H. Peverly, M.B. McBride. 1996. Movement of Heavy Metals Through Undisturbed and Homogenized Soil Columns. Soil Sci. 161(11):740-750.

Cavallaro, N. 1982. Sorption and fixation of Cu and Zn, and phosphate by soil clays as influenced by the oxide fraction. Ph.D. diss. Cornell Univ., Ithaca.

Cheremisinoff, P.N. 1994. Sludge Management and Disposal. PTR Prentice Hall, New

Jersey.

Christensen, J.B. and T.H. Christensen. 1999. Complexation of Cd, Ni, and Zn by DOC in Polluted Groundwater: A Comparison of Approaches Using Resin Exchange, Aquifer Material Sorption, and Computer Speciation Models (WHAM and MINTEQA 2). Environ. Sci. Technol. 33:3857-3863.

Christensen, J.B., D.L. Jensen, C.G.Z. Filip, and T.H. Christensen. 1998. Characterization of the dissolved organic carbon in landfill leachate-polluted groundwater. Wat. Res. 32:125-135.

CSC: Environmental Solutions. 2007. CSC's Sampling and Analysis Report for the 2006-2007 Targeted National Sewage Sludge Survey. GSA Task Order GS-10F-0135K.

Doner, H.E. 1978. Chloride as a factor in mobilities of Ni (ii), Cu (ii), and Cd (ii) in soil. Soil Sci. Soc. Am. J. 42:882-885.

Elrashidi, M.A. and G.A. O'Connor. 1982. Influence of solution composition on sorption of zinc by soils. Soil Sci. Soc. Am. J. 46:1153-1158.

Emmerich, W.E., L.J. Lund, A.L. Page, and A.C. Chang. 1982. Movement of Heavy Metals in Sewage Sludge-Treated Soils. J. Envrion. Qual. 11:174-178.

ERCO, Inc. 2000. Beneficial reuse tree farm: Annual Report. Report to MDE pursuant to permit requirements. ERCO, Inc., Glen Burnie, MD 21061.

Evanylo, G.K. 2003. Land Application of Biosolids for Agricultural Purposes in Virginia. Virginia Cooperative Extension, Virginia Tech, Blacksburg, VA.

Felton, G.K., C.U. Buswell, J.S. Kays, and E. Flamino. 2005. Determination of Optimum Tree Density and Biosolid Application Rate and Effect on Water Quality and Tree Growth Using the Deep Row Biosolids Incorporation Method: Third Year Report for Period of January 1, 2002 – December 31, 2004. Maryland Cooperative Extension, Univ. of Maryland, College Park, MD.

Forste, J.B. 1996. Land Application. p. 389-448. *In* M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. M.J. Marcel Dekker, Inc.: New York.

Girovich, M.J. 1996a. Biosolids Characterization, Treatment and Use: An Overview. *In* M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. Marcel Dekker, Inc.: New York.

Girovich, M.J. 1996b. Alkaline Stabilization. *In* M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. Marcel Dekker, Inc.: New York.

Hettiarachchi, G, J.A. Ryan, R.L. Chaney, C.M. La Fleur. 2003. Sorption and Desorption of Cadmium by Different Fractions of Biosolids-Amended Soils. J. Environ. Qual. 32:1684-1693.

Japenga, J., J.W. Dalenberg, D. Wiersma, S.D. Scheltens, D. Hesterberg, and W. Salomons. 1992. Effect of liquid animal manure application on the solubilization of heavy metals from soil. Inter. J. Environ. Anal. Chem., 46:25-39.

Jensen, D.L. and T.H. Christensen. 1999. Colloidal and Dissolved Metals in Leachates from Four Danish Landfills. Wat. Res. 33:2139-2147.

Johnson, J.D. 1999. Hybrid Poplar: An Overview. *In* K.A. Blatner, J.D. Johnson, D.M. Baumgartner (ed.) Hybrid Poplars in the Pacific Northwest: Culture, Commerce, and Capability. Symposium Proceedings. April 7-9, 1999. Pasco, WA.

Kabata-Pendias, A. and H. Pendias. 2001. Trace Elements in Soils and Plants. 3rd ed. CRC Press LLC, Boca Raton, Florida.

Kays, J.S. 2006. Determination of Optimum Tree Density and Biosolid Application Rate and the Effect on Water Quality and Tree Growth Using the Deep Row Biosolids Incorporation Method: Annual Report for Period of July 1, 2005 – June 30, 2006. Maryland Cooperative Extension, Univ. of Maryland, College Park, MD.

Kiekens, L. 1995. Zinc. *In* B.J. Alloway (ed.) Heavy Metals in Soils. B.J. Blackie Academic & Professional: London.

Lewis, D.L., D.K. Gattie, M.E. Novak, S. Sanchez, and C. Pumphrey. 2002. Interactions of pathogens and irritant chemicals in land-applied sewage sludge (biosolids). BMC Public Health. 2:11 Available online: http://www.biomedcentral.com/1471-2458/2/11

Licht, L.A. 1994. Poplar trees treat landfill leachate. Water Environ. And Technology 6:19-20.

Maier, R.M., I.L. Pepper, and C.P. Gerba. 2000. Environmental Microbiology. Academic Press, San Diego.

McBride, M.B. 1985. Sorption of copper (ii) on aluminum hydroxide as affected by phosphate. Soil Sci. Soc. Am. J. 49:843-846.

McBride, M.B. 1994. Environmental chemistry of soils. Oxford Univ. Press, New York.

McBride, M.B., B.K. Richards, T. Steenhuis, J.J. Russo, and S. Sauve′. 1997. Mobility and solubility of toxic metals and nutrients in soil fifteen years after sludge application. Soil Sci. 162:487-500.

McBride, M.B. 1998. Soluble trace metals in alkaline stabilized sludge products. J. Environ. Qual. 27:578-584.

McBride, M.B., B.K. Richards, T. Steenhuis, and G. Spiers. 1999. Long-Term Leaching of Trace Elements in a Heavily Sludge-Amended Silty Clay Loam Soil. Soil Si. 164:613-623.

McFarland, M.J. 2001. Biosolids Engineering. McGraw-Hill, New York.

McKenzie, R.M. 1980. The adsorption of lead and other heavy metals on oxides of manganese and iron. Aust. J. Soil Res. 18:61-73.

Mckinley, J.D., H.R. Thomas, K.P. Williams, and J.M. Reid. Chemical analysis of contaminated soil strengthened by the addition of lime. Engineering Geology. 60:181-192.

McLean, J.E. and B.E. Bledsoe. 1992. EPA Ground Water Issue: Behavior of Metals in Soils. EPA/540/S-92/018.

O'Conner, G.A., C. O'Conner, and G.R. Cline. 1984. Sorption of cadmium by calcareous soils: influence of solution composition. Soil Sci. Soc. Am. J. 48:1244-1247.

Pepperman, R.E. 1995. Report on the ERCO, Inc. Tree Farm Biosolids Beneficial Reuse System. Environmental Group Services, Inc., Baltimore, MD.

Richards, B.K., T.S. Steenhuis, J.H. Peverly, and M.B. McBride. 2000. Effect of sludge processing mode, soil texture and soil pH on metal mobility in undisturbed soil columns under accelerated loading. Environ. Pollut. 109: 327-346.

Sikora, L.J., N.H. Frankos, C.M. Murrary, and J.M. Walker. 1979. Effects of trenching undigested lime-stabilized sludge. J. Water Pollut. Control Federation 51:1841-1849.

Sikora, L.J., N.H. Frankos, C.M. Murray, and J.M. Walker. 1980. Trenching of digested sludge. The Journal of the Environmental Engineering Division. Proceedings of the ASCE. 106:351-361.

Smith, S.R. 1996. Agricultural Recycling of Sewage Sludge and the Environment. CAB International, United Kingdom.

Sparks, D.L. 2001. Elucidating the fundamental chemistry of soils: Past and recent achievements and future frontiers. Geoderma 100:313-319.

Sposito, G. 1986. Sorption of trace metals by humic materials in soils and natural waters. Crit. Rev. Environ. Control 16:193-229.

Stevenson, F.J., and M.S. Ardakani. 1972. Organic matter reactions involving micronutrients in soils. *In* J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (ed.) Micronutrients in agriculture. SSSA, Madison, Wis.

Sukkariyah, B.F., G. Evanylo, and L. Zelazny. 2007. Distribution of Copper, Zinc, and Phosphorus in Coastal Plain Soils Receiving Repeated Liquid Biosolids Applications. J. Environ. Qual. 36;1618-1626.

Taylor, J.M., E. Epstein, W.D. Burge, R.L. Chaney, J.D. Menzies, and L.J. Sikora. 1978. Chemical and Biological Phenomena Observed with Sewage Sludges in Simulated Soil Trenches. J. Environ. Qual. 7:477-482.

The Clean Water Act of 1972. Available online: http://www.epa.gov/waterscience/standards/rules/cwa_sec401.pdf

Tombacz, E. and E. Meleg. 1990. A theoretical explanation of the aggregation of humic substances as a function pH and electrolyte concentration. Org. Geochem. 15: 375.

Udom, B.E., J.S.C. Mbagwu, J.K. Adesodum, N.N. Agbim. 2004. Distributions of zinc, copper, cadmium and lead in a tropical ultisol after long0term disposal of sewage sludge. Environmental International 30:467-470.

USEPA. 1993. Standards for the use and disposal of sewage sludge. 40 CFR, Part 503. Fed. Regist. 58:13-15. U.S. Gov. Print. Office, Washington, DC.

USEPA. 1999. Biosolids Generation, use, and Disposal in the United States. USEPA Rep. 530-R-99-009. U.S. Gov. Print. Office. Washington, DC.

USEPA. 2000. Biosolids Technology Fact Sheet: Land Application of Biosolids. USEPA Rep. 832-F-00-064. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2003. Safe Drinking Water Act. USEPA 816-F-03-016. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2007. Frequently Asked Questions: Biosolids. U.S. Gov. Print. Office, Washington, DC.

Williams, D.E., J. Vlamis, A.H. Pukite, and J.E. Corey. 1984. Metal Movement in Sludge-Treated Soils After Six Years of Sludge Addition: 1. Cadmium, Copper, Lead, and Zinc. Soil Sci. 137:351-359.

Williams, D.E., J. Vlamis, A.H. Pukite, and J.E. Corey. 1985. Metal Movement in Sludge-Treated Soils After Six Years of Sludge Addition: 2. Nickel, Cobalt, Iron, Manganese, Chromium, and Mercury. Soil Sci. 140:120-125.

## TABLES

Table 1.1: Maximum metal concentrations as established by Part 503. Adapted from Table 1 in EPA 832-F-00-064.

| Metal | Ceiling Concentration (mg $kg^{-1}$) | Cumulative Pollutant Loading Rate (kg $ha^{-1}$) | Pollutant Concentrations (mg $kg^{-1}$) |
|---|---|---|---|
| As | 75 | 41 | 41 |
| Cd | 85 | 39 | 39 |
| Cu | 4300 | 1500 | 1500 |
| Pb | 840 | 300 | 300 |
| Hg | 57 | 17 | 17 |
| Mo | 75 | In Progress | In Progress |
| Ni | 420 | 420 | 420 |
| Se | 100 | 100 | 100 |
| Zn | 7500 | 2800 | 2800 |

Table 1.2: Range of metal concentrations found within sewage sludge samples collected across the United States. Adapted from Table 9 in CSC (2007).

| Metal | Concentration (mg $kg^{-1}$) |
|---|---|
| Ag | 1.94 – 856 |
| Ba | 75.1 – 3460 |
| Be | 0.04 – 2.3 |
| Sn | 7.50 - 522 |

# CHAPTER TWO

## Concentration and Mass Transport per Sampling Period of Metals from Entrenched Biosolids at a Reclaimed Mineral Sands Mining Site in Dinwiddie County, Virginia


## ABSTRACT

Deep row incorporation of biosolids is an alternative land application method that may allow higher than currently permitted mine land reclamation application rates of 112 dry Mg $ha^{-1}$. Biosolids treated by various processes have the potential to leach metals into underlying groundwater. The objectives of this research were to compare the effects of biosolids stabilization type and rate on heavy metal solubility and mobility. Two rates each of Alexandria, (Virginia) anaerobically digested (213 and 426 dry Mg $ha^{-1}$) and Blue Plains (Washington, DC) lime-stabilized (329 and 657 dry Mg $ha^{-1}$) biosolids were placed in trenches at a mineral sands mine reclamation site in Dinwiddie County, Virginia in June and July 2006 to provide a slow release nitrogen source for a hybrid poplar bioenergery crop and organic matter for soil reclamation. Vertical and lateral transport of heavy metals from the biosolids seams were determined by analyzing soil water that collected in zero tension lysimeters below the trenches and by suction lysimeters adjacent to the trenches. Leachate metals passing through a 0.45 μm membrane filter were analyzed as a dissolved fraction, and acid digestion was used to determine total metal concentrations. Silver, Cd, Pb, and Sn did not move vertically or laterally to any significant extent. Lime-stabilized biosolids produced higher cumulative metal mass transport per sampling period for Cu (967 g $ha^{-1}$), Ni (171 g $ha^{-1}$), and Zn (1027 g $ha^{-1}$) than did the anaerobically digested biosolids during the 15-month period following entrenching. Barium mass loss was similar for both biosolids types (653 g $ha^{-1}$ from the lime-stabilized biosolids and 659 g $ha^{-1}$ from the anaerobically digested biosolids). The cumulative metal mass transport per sampling period from the control treatment were lower than those from both biosolids types. All metals moved primarily with particulates, as higher concentrations were associated with the colloidal compared to the dissolved fraction. The lack of metal mobility demonstrates that biosolids can have the potential to be applied at high rates with little risk of transport through even coarse sandy soil given this set of circumstances.


## INTRODUCTION

Approximately half of the biosolids produced in the United States are applied to land and, as of 1995, the vast majority were used on agricultural land (USEPA, 2000; USEPA, 2007). Biosolids use decreases fertilizer needs by providing essential plant nutrients and improves soil physical, chemical, and biological properties by the addition of organic matter (Forste, 1996).

An alternative use to agricultural land application being employed in a limited manner is deep row biosolids incorporation (i.e. entrenching) for rehabilitation of drastically disturbed lands (e.g. mine land). This practice involves the placement of biosolids in trenches ranging from 45 to 90 cm wide by 45 to 75 cm deep and covering the biosolids seam with 15 to 30 cm of soil or overburden. By burying the putrescible material, Taylor et al. (1978) and Sikora et al.

(1979, 1980) first proposed trenching as a means to prevent nuisance odor problems and transport of pollutants and pathogens to surface water. Entrenchment permits higher than agronomic nitrogen rates because the anaerobic environment in the biosolids seam should reduce nitrification and subsequent nitrate N leaching (Taylor et al., 1978). Kays et al. (2006) further refined the practice by using the system for the production of non-food chain crops, such as hybrid poplars, eliminating food chain transfer of potentially harmful trace elements.

Hybrid poplars (*Populus deltoides* L.) possess characteristics that make them ideal for planting in biosolids-entrenched land. Poplar trees have preformed root initials under their bark that permit rapid establishment within various environments. Specifically, the roots can assimilate water and nutrients up to 1.5 m below the surface allowing the poplars to reduce harmful pollutant concentrations below biosolids. The high assimilation rates of hybrid poplars make them efficient nutrient sinks (Licht, 1994).

An issue that must be resolved is the capability of hybrid poplars to establish vigorous root systems rapidly enough so that their assimilation of water, nutrients and other elements eliminates the potential for pollutant leaching. Sikora et al. (1979, 1980) determined that entrenched biosolids became stable after 4 years with little subsequent risk of nutrient mobility; however, they did not monitor leachate during the first 18 months after entrenching biosolids. Likewise, Kays et al. (2006) did not have all monitoring wells beneath their entrenched biosolids study established until 5 years after biosolids entrenchment. More intense and accurate monitoring, especially under coarse-textured soils, is necessary to ensure that groundwater quality will not be impaired.

Pollutants of concern from entrenched biosolids include trace metals, which may pose a health risk when impaired groundwater is used as drinking water. Some metals of concern are cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn), which the USEPA Part 503 "Standards for the use and disposal of sewage sludge" (USEPA, 1993) identifies as pollutants. Additional biosolids-borne metals that have recently received scrutiny include silver (Ag), barium (Ba), beryllium (Be), and tin (Sn) (CSC, 2007). Monitoring the transport of these metals from biosolids seams may be valuable for understanding the chemical mechanisms for controlling metal fate in entrenched biosolids immediately after application and several years later.

There have been few studies on the fate and transport of heavy metals from entrenched biosolids. Sikora et al. (1979, 1980) did not detect metal movement during their delayed monitoring period. Taylor et al. (1978) did not detect metal movement below simulated trenches, which they attributed to retention within the biosolids by organic and inorganic ligands.

Researchers monitoring metal transport through non-entrenched biosolids-amended soil have had conflicting conclusions. Camobreco et al. (1996) and Richards et al. (1997) observed metal movement, which they attributed to soluble organics-facilitated transport through soil via preferential flow. McBride et al. (1999) hypothesized that metals moved below the incorporated biosolids because groundwater metal concentrations were higher than drinking water standards. Most other researchers (e.g. Emmerich et al., 1982; Williams et al. 1984, 1985) report limited metal movement below the incorporation layer.

Metals may bind to organic matter, oxides, and inorganic ligands. Trace metal sorption to stable organic matter can decrease metal mobility (Camobreco et al., 1996). When Cu, Cd, Ni, and Zn bind to dissolved organic matter (DOM), their mobility increases (McBride et al., 1997; McBride, 1998). Oxides can also influence metal availability by complexing the metal with functional groups on its surface. Some common forms of oxides within soils include Al, Fe, and Mn (McBride, 1994; Sposito, 1986). Inorganic ligands, such as phosphate ($PO_4^{-3}$), sulfate ($SO_4^{-2}$), chloride ($Cl^-$), bicarbonate ($HCO_3^-$), and nitrate ($NO_3^-$), will also complex positively charged metal ions at varying strengths depending on the ligands affinity for the specific metal (Jensen and Christensen, 1999).

Conditions surrounding metals can influence their availability. With the exception of molybdenum (Mo), metals become immobile as pH increases when other factors are not influencing its mobility (Girovich, 1996). Dissolved ligands, which can be measured indirectly by electrical conductivity (EC), can bind metals and facilitate their movement through soil (Al-Wabel et al., 2002). Anaerobic conditions that develop in entrenched biosolids may cause a reduction in organic matter mineralization and the release of metals chelated by organic functional groups (Taylor et al, 1978; Pepperman, 1995). Under anaerobic conditions, a low redox potential develops resulting in immobility of metals due to precipitation to other surfaces (i.e. sulfides and carbonates) (Maier et al., 2000, Taylor et al., 1978).

The objectives of this study were to compare the effects of biosolids stabilization type and loading rate on the chemistry, fate, and transport of metals from entrenched biosolids used to reclaim a coarse-textured heavy mineral mine land site.

## MATERIALS AND METHODS

### Site description

The research area was established at the Iluka Resources heavy mineral mine reclamation site in Dinwiddie and Sussex Counties, Virginia in June 2006. Recombined soil material previously pumped into mined pits resulted in segregation of tailings and slime. The soil prior to mining consisted largely of Slagle fine sandy loam (fine-loamy, siliceous, subactive, thermic, Aquic Hapludults) and Roanoke loam (fine, mixed, semiactive, thermic Typic Endoaquults) (Hodges et al., 2002), which was used for the cultivation of peanut, soybean, tobacco, and cotton (Daniels et al., 2003).

Samples (20 cores to 0-15 cm depth and composited) were collected from the segregated sand (96.1% sand) and sandy clay loam (61.2% sand) soil fractions on June 6, 2006 for routine soil test analysis by the Virginia Tech Soil Testing Laboratory (Donohue, 1992). Analyses are presented in Table 2.1.

Over the 15-month sampling period, precipitation and temperature data (Table 2.2) were gathered from the closest weather station in Petersburg, Virginia, which is approximately 32 km from the site. The temperature values were the averages of the high and low temperatures for each month.

### Experimental design

The experimental design was a randomized complete block with eight treatments and four replications (Figure 2.1). The eight treatments included two biosolids products each applied on a one-time basis at two rates determined by trench volumes and four rates of fertilizer N, ranging from 0 to 450 kg ha$^{-1}$ in 150 kg ha$^{-1}$ increments (Table 2.3). The biosolids used were from Alexandria, Virginia (anaerobically digested) and Washington, D.C. (Blue Plains lime-stabilized).

The highest fertilizer N rate treatment was designed to supply the highest annual estimated assimilation capacity for hybrid poplar. The fertilizer N treatments were used to develop a hybrid poplar biomass calibration curve that could be used to estimate the plant available N provided by the biosolids. Ammonium nitrate was used as the fertilizer N source.

For the purpose of this study, only the four biosolids and single control fertilizer treatments were compared for trace metal chemistry and transport. Annual additions of phosphorus (as triple superphosphate) and potassium (as muriate of potash) were applied as basal fertilizer treatments to prevent P and K limitation to hybrid poplar growth.

The treatment plots were arranged as illustrated in Figure 2.1. Each plot contained two 15-m long trenches, which were excavated with a backhoe. The volume of soil corresponding to the smaller trench size was disturbed with a backhoe in the fertilizer N treatment plots at the same time that the biosolids trenches were constructed. Trenches were all 75 cm deep and either 45 cm (low rate) or 90 cm (high rate) wide. A 3- m alleyway between tiers of plots was established to allow vehicle access and provide buffers between entrenched areas.

Biosolids were delivered to the site in June 2006 (anaerobically digested) and July 2006 (lime-stabilized) for trench incorporation. We used skid steer loaders to place biosolids in the trenches and to cover the seams with fill from the trenches. The entire site was graded to provide a 30-cm soil cover over the entrenched biosolids.

**Vegetation establishment**

We planted German millet (*Setaria italica* (L.) P. Beauv.) at a rate of 22.5 kg $ha^{-1}$ in August 2006 as a ground cover to prevent excess weed growth and erosion at the site. The millet above the trenches was killed by roto-tilling the top 15 cm in late February 2007.

In March 2007, we planted hybrid poplar cuttings (*Populus deltoids* L., Clone OP-367) in a 3x3 m pattern over the trenches, i.e., 3 m between row centers with 3 m seedling spacing. We placed the 30-cm long cuttings about 20-25 cm into the soil and protected them with 30-cm tall, 5-cm diameter staked plastic tree shelters. The cuttings were irrigated immediately after planting and continuing throughout the summer to reduce water stress (Table 2.3).

**Instrumentation and monitoring**

We instrumented treatment plots with zero tension lysimeters below trenches to collect vertical leachate from the biosolids and unamended control. Suction lysimeters placed adjacent to trenches helped monitor lateral flow of water-transported constituents. Installation of the zero tension lysimeters was performed between trench excavation and biosolids application. The suction lysimeters were installed after the biosolids were entrenched and site was graded.

We installed one zero tension lysimeter 15 cm below each trench within the biosolids plots (total 2 per plot) and one 15 cm below a single trench within the fertilizer plots (total 1 per plot) (Figure 2.2). Locations were randomized within the trench. The zero tension lysimeters were constructed by attaching a culvert cap to the end of culvert piping measuring 25 cm in diameter and 51 cm in length. A silicone sealant and polyurethane foam sealant (Flexible Products Company, Joliet, IL) were applied at the contact point between the culvert tubing and cap to prevent leakage. We placed 7.5-10 cm of clean "Quikrete" Play Sand in the bottom of the lysimeters and topped them off with coarse sand from the trench. We ran Kynar tubing from the lysimeter sand reservoir to the surface to evacuate (with an electric pump) water for analysis. A mesh filter placed on the end of the Kynar tubing prevented large soil particles from clogging the tubes.

We installed 16 suction lysimeters between the two trenches in each of the biosolids plots. For trenches with a 45 cm and 90 cm width, we placed the lysimeters 0.53 cm and 0.30 cm, respectively, from the biosolids trench with the ceramic cup aligned with the bottom of the biosolids trench (Figure 2.2). The suction lysimeters were constructed by attaching a porous ceramic cup (Round Bottom Neck Top Ceramic Cup 2" 1 Bar High Flow, Soilmoisture Equipment Corp., Santa Barbara, CA) with 2-part epoxy to the end of 5 cm diameter “H-P VACUFCD” PVC piping. Silica flour placed in the bottom of each augered hole provided a good contact surface between the ceramic cup and the soil. We filled the rest of the hole surrounding the lysimeter with a 50/50 mixture of clean "Quikrete" Play Sand and bentonite reducing the likelihood of preferential flow along the lysimeter. We pumped water samples from the lysimeter bottom to the surface for analysis by means of Kynar tubing. A rubber stopper placed over the PVC pipe prevented foreign objects and surface water from entering the lysimeter.

**Biosolids sampling and analysis**

We collected three composited samples of approximately 3000 g from the anaerobically digested biosolids and 5000 g from the lime-stabilized biosolids at the time of application. The samples were analyzed by A&L Eastern Laboratories, Inc (Richmond, VA) for total and volatile (organic matter) solids by SM2540G (APHA, 1998); total Kjeldahl N (TKN-N) by USEPA 351.3 (USEPA, 1983b); $NH_4$-N by USEPA 350.2 (USEPA, 1983a); $NO_3$-N by SM4500-NO3F (APHA, 1998); phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), aluminum (Al), manganese (Mn), cadmium (Cd), copper (Cu), lead (Pb), molybdenum (Mo), nickel (Ni), and zinc (Zn) by SW846-6010B (USEPA, 2002); arsenic (As) by SW846-7061A (USEPA, 2002); mercury (Hg) by SW846-7471A (USEPA, 2002); selenium (Se) by SW846-7741A (USEPA, 2002); silver (Ag), barium (Ba), beryllium (Be), and tin (Sn) by SW846-3051/6010B; pH by SW846-9045C (USEPA, 2002); calcium carbonate equivalent (CCE) by AOAC 955.01 (AOAC, 2000); and total organic carbon (TOC) by EPA 415.1 (USEPA, 2002).

We calculated bulk density by determining the mass (dry weight after 72 hrs of oven-drying at 105°C) of known biosolids volume. The characteristics and loading rates for the anaerobically digested and lime-stabilized biosolids used in the study are presented in Tables 2.4 and 2.5.

**Biosolids sequential extraction**

We used subsamples from the biosolids collected for bulk density (June, July 2006) to perform our initial biosolids sequential extraction. On October 12, 2007, we exposed the top portion of entrenched biosolids by excavating the soil above each biosolids seam and sampled the seam to a depth of 10-13 cm. Samples were collected from both trenches within the high application rate treatments of the anaerobically digested and lime-stabilized biosolids. All samples were immediately frozen with dry ice until further preparation for analysis and thawed 2-3 hours before we began sequential extraction. We analyzed four subsamples for each of the initial biosolids types. For the 2007 analysis, we subsampled and combined biosolids from each of the two trenches as a composite sample for that treatment plot, resulting in four replications for each high application of biosolids type.

We employed the European Community Bureau of Reference (BCR) sequential extraction procedure for biosolids (Sahuquillo et al., 1998). We placed 1.0 g of biosolids in a 100 mL polypropylene centrifuge tube, added 40 mL of 0.11 mol $L^{-1}$ acetic acid, and extracted the exchangeable metal fraction by shaking for 16 hours at room temperature. After centrifuging to separate the sample from the extract, we decanted the liquid into a dilution vial for analysis of Ba, Cd, Cu, Ni, Pb, and Zn by an ICP-AES. We weighed the tube plus remaining sample to account for any remaining extract. Forty mL of 0.1 mol $L^{-1}$ $NH_2OH{\cdot}HCl$ (adjusted pH to 2 with $HNO_3$) was added to the residue in order to remove the reducible metal fraction. After shaking for 16 hours, we separated and weighed the sample as in the exchangeable metal fraction step. In the initial step for determining the oxidizable metal fraction, we added 10 mL of 300 mg $g^{-1}$ $H_2O_2$ to the remaining residue and covered the tube with a watch glass for 1 hour. The test tube was incubated in a water bath at 85°C for 1 hour before we removed the watch glass to allow the sample to evaporate to 1-2 mL. We repeated this step starting with another 10 mL of $H_2O_2$. We allowed the sample to cool after the second step, and then added 50 mL 1 mol $L^{-1}$ ammonium acetate (adjusted pH to 2 with $HNO_3$) before shaking for 16 hours. The separation and weighing procedure was the same as in previous steps. An acid digestion for total metal concentrations removed the residual metal fraction by adding 11 mL of HCl along with 4 mL of $HNO_3$ to the samples and allowing them to digest in a 90°C water bath for 2 hours (Backman and Gustavsson, 1996). After cooling, we separated the sample as in previous steps and then diluted with 15 mL of distilled water.

**Sample collection and monitoring**

Beginning August 10, 2006, we collected samples from the zero tension and suction lysimeters at least once a month. A tropical depression during the first of September 2006 produced several inches of rain, which prevented us from completely evacuating the zero tension lysimeters; therefore, we collected a subsample in September and pumped the lysimeters dry in October. We calculated the leachate volume for this period by assuming that all precipitation was collected by the lysimeters. Rainfall was estimated from a weather station in Petersburg, Virginia located approximately 32 km from our study site (Table 2.2). During the winter, (December 2006, January and March 2007) samples were collected twice a month due to the increased precipitation. For the zero tension lysimeters, we used a vacuum pump to evacuate leachate from the lysimeter into a collection container. Pumping continued until continuous bubbles were present within the tubing signaling that the lysimeter was dry. Sample collection for suction lysimeters was performed after applying a vacuum for 3-4 hours.

We used a graduated cylinder to determine the volume removed from the zero tension and suction lysimeters. Dissolved oxygen (DO) and EC were measured in the field with an YSI 85 Oxygen Conductivity, Salinity, and Temperature meter and a Hanna Instrument HI 9023 pH meter measured pH. We split composite samples into two subsamples and placed on dry ice in 250 Nalgene bottles until further analysis. We removed samples from the freezer and placed them in the refrigerator for thawing 24 hours before beginning analysis.

We measured redox potential within trenches at a depth of 45 cm during the entire sampling period for both biosolids types and control. Specifically, we used a platinum electrode assembly with Ag/AgCl reference electrodes along with a DM 383B digital multimeter to measure the potential between the electrodes. The measurements provided us with a better understanding of the environment within the biosolids trenches.

**Soluble metal analysis within leachate**

Once the sample thawed, we used a vacuum filtration system to filter 50 mL through a polycarbonate membrane filter with a pore size of 0.45 µm. The sample that passed through the filter contained the operationally defined dissolved metal species (Jensen and Christensen, 1999). We placed 25 mL from the filtered sample in a dilution vial for analysis and acidified it with one drop of concentrated nitric acid. Barium, Cd, Cu, Ni, Pb, and Zn were analyzed by inductively coupled plasma atomic emission spectrometer (Spectro CirOS VISION ICP Model FVS12 with CETAC Autosampler Type: ASX-520HS, ICP-AES). We did not analyze certain metals every sampling period if their concentrations were below the detection limit for the first several sampling periods. Silver and Sn were analyzed from August 10 to October 6, 2006 and from March 2 to April 13, 2007. Cadmium and Pb were analyzed from August 10 to January 5, 2007, March 2 to April 13, 2007, and August 9 to September 7, 2007. Additional sample were frozen for analysis of $NO_3^-$, $PO_4^{3-}$, $SO_4^{2-}$, $Cl^-$, inorganic carbon, and DOC as possible metal-coupling ligands.

**Total metal analysis within leachate**

We determined total recoverable metals by digesting according to the EPA-200.7 process (USEPA, 1994) and analyzing with an ICP-AES. Processing and analysis of leachate performed according to methods for wastewater, with a few modifications due to original sample volumes. We placed 50 mL of sample, instead of the 100 mL indicated in the method, in 50 mL beakers that had previously been acid washed. The volumes for the digestion solution were reduced by half resulting in 1 mL of (1+1) nitric acid along with 0.5 mL of (1+1) hydrochloric acid being added to the 50 mL sample. We heated the beakers on a hot plate to approximately 85°C, which reduced sample volume to 25 mL after 1.5 to 2 h. We then placed a watch glass on the beakers and allowed the samples to reflux for 30 minutes. After cooling the beakers, we transferred the samples to graduated cylinders and added distilled water to bring the volume to 25 mL. Analysis was then performed by ICP-AES. We used the same analytical schedule for both the total recoverable metals and the soluble metals.

### Statistical analysis

For the determination of statistical differences among biosolids fractions, we used the "Proc GLM" procedure within Statistical Analysis System (SAS Institute, 1999) with multiple comparisons (Least Significant Difference, LSD) done between each fraction for a specific metal and between each biosolids type for each fraction. The procedure allows the comparison of fixed effects. Alpha was set to 0.05 due to the ability to have more control over the laboratory procedures.

We calculated standard errors for the total metal mass transport per sampling period to describe the variation within each treatment. We used p-values calculated by the "Proc MIXED" procedure to determine significance among cumulative metal mass transport per sampling period because this method accounts for research models with random effects (random placement of replicates for each treatment), non-constant variance, and repeated measures. The alpha was set to 0.1, as experimental error is common within a field project.

## RESULTS AND DISCUSSION

### Biosolids composition

The initial biosolids composition influences a given metals' potential to become mobile. Among the Part 503 metals (Cd, Cu, Ni, Pb, and Zn) and the emerging metals (Ag, Ba, Be, Sn), Zn had the highest initial concentrations within both biosolids types (Table 2.4). As an emerging metal of interest, Ba was found within the anaerobically digested and lime-stabilized biosolids at 442 and 195 mg $kg^{-1}$, respectively. Beryllium had the lowest value (<5 mg $kg^{-1}$) as it was not above the detection limit provided by the A&L Laboratories. With the exception of Cu, the rest of the Part 503 and emerging metals of interest were present within both biosolids types at concentrations below 70 mg $kg^{-1}$ (Table 2.4).

### Biosolids sequential extraction

The sequential extraction of metals in the biosolids at time of application and after 15 months showed that differences in metal binding were due to metal and biosolids type (Tables 2.6 and 2.7). Within the anaerobically digested biosolids Ba and Pb were mostly associated with the residual fraction (Figure 2.3). Between 83 and 86 percent of Cu was associated with organic complexes while Zn was distributed among all of the fractions. There was relatively less ($P \leq 0.05$) Zn bound to the exchangeable and oxide fractions than to the organic and residual fractions

(Table 2.6). The distribution of metal among the exchangeable, oxide, organic, and residual fractions did not change significantly 15 months after biosolids entrenching.

Like the anaerobically digested biosolids, the Ba and Pb in the lime-stabilized biosolids were mostly associated with the residual fraction (Figure 2.4). Eighty-eight percent of the Cu and 69% of the Zn were complexed with organics. A much higher fraction of Zn was associated with organics in the lime-stabilized than in the anaerobically digested biosolids.

The chemical species and sites to which metals are bound or complexed within biosolids will influence their solubility and mobility. Sequential extraction permitted the determination of various fractions in which metals were found in the biosolids at application and with time. Metals may occur as exchangeable, oxide-bound, organically-complexed, or residual fractions. The exchangeable fraction is the most soluble and mobile whereas the metals associated with residuals such as clay and oxides are the least mobile and most difficult to solubilize under "normal" conditions. The residual-bound Ba comprised a higher ($P \leq 0.05$) fraction (0.74 vs 0.51) of the anaerobically digested than of the lime-stabilized biosolids (Figures 2.3 and 2.4). The relative exchangeable and organic fractions to which Zn was bound varied significantly ($P \leq 0.05$) between the anaerobically digested and lime-stabilized biosolids (Figures 2.3 and 2.4). During the analysis, incomplete dissolution of the various bonds formed within the fractions may have allowed some metals to be associated with the following extracted fraction. The metals may also readsorb to another fraction before sample collection (McLaren and Clucas, 2001).

**Redox potential within trenches**

Redox potentials within both biosolids types and control trenches indicated a difference in the surrounding conditions (Figure 2.5). The controls had more positive potentials (483 mV) than both the biosolids types. These conditions result in an aerobic environment. The -112 mV for the anaerobically digested biosolids and the -89 mV for the lime-stabilized biosolids indicate that an anaerobic environment exists within the trenches. The anaerobic conditions and low redox potentials may reduce metal mobility by preventing obligate aerobes from mineralizing organic matter or increasing metal precipitation as sulfides or carbonates (Pepperman, 1995; Maier et al., 2000; Taylor et al., 1978).

### Leachate characteristics

The pH of the leachate collected below the lime-stabilized biosolids was initially higher than that from the anaerobically digested biosolids due to the treatment process (Figure 2.6). Over time, the pH decreased and followed a similar trend as the anaerobically digested biosolids. Biosolids contain a large amount of organic matter, which may be mineralizing and decreasing pH through the production of organic acids (Forste, 1996). Production of hydrogen ions during nitrification of ammonium ($NH_4^+$) to nitrate ($NO_3^-$) is likely to have contributed to pH reduction as well. The high concentrations of ammonium that leached from both biosolids treatments provided the reduced N source for generation of acidity (Evanylo et al., 2008).

Electrical conductivity (EC) is an indirect measurement of soluble salt concentration, which may affect metal chemistry. The EC of the leachate was initially lower from the lime-stabilized than from the anaerobically digested biosolids; however, the EC increased by about 4000 $\mu$S $cm^{-1}$ by October 6, 2006, indicating an increase in dissolved salts concentration (Figure 2.7). The change may have occurred due to increased moisture from a large rainfall in early September 2006, which would have flushed large concentrations of dissociated salts from the biosolids and into the zero tension lysimeters. The leachate EC dropped dramatically from both biosolids types by December 15, 2006 and remained similar throughout the collection period. The leachate from the lime-stabilized biosolids was slightly higher than that of the anaerobically digested biosolids during spring 2007. The larger Ca concentration in the lime-stabilized biosolids may have caused its leachate to have a higher EC value than the leachate from the anaerobically digested biosolids (Table 2.4 and Figure 2.7).

Dissolved oxygen (DO) concentrations, which fluctuated between 3 and 7 mg $L^{-1}$, were not different between biosolids sources (Figure 2.8). Monitoring of DO was not begun until five months after entrenching, during which period DO may have been most subject to reduction by microbial respiration. Microbes would likely have more readily decomposed organic matter in the biosolids during warmer months (June 8, - September 7, 2007) (Murphy, 2007). Cooler temperatures beginning around October 12, 2007 may have caused a decrease in microbial activity and an increase in DO (Figure 2.8).

### Vertical transport

We determined vertical transport from the entrenched biosolids by analyzing leachate collected within zero tension lysimeters. Silver and Sn were rarely detected (Table 2.8) as they do not become mobile unless very acidic environments are present (Kabata-Pendias and Pendias, 2001), which never occurred within the leachate (Figure 2.6). Within both types of biosolids, Pb was mostly associated with the residual fraction (Figures 2.3 and 2.4), which caused the element to remain immobile. Cadmium was detected in 12% of the leachate samples (Table 2.8). Greater transport during the first few months occurred from the anaerobically digested than from the lime-stabilized biosolids (See Appendix Tables 5.51 and 5.52). The low occurrence of these metals detected in the leachate supports results of previous studies (Sikora et al., 1979, 1980; Emmerich et al., 1982; Sukkariyah et al., 2005; Kays, 2006) that showed exceptional metal binding in high quality (i.e. low heavy metal concentrations) biosolids.

Total Ba metal mass transport per sampling period varied with sampling time but was only different between biosolids sources during two sampling periods (Figure 2.9). Leaching masses spiked on September 8,2006 and January 19 and June 8, 2007. The spike on September 8, 2006 was due to the high rainfall amount that occurred in early September 2006. The Ba leaching mass was greater for anaerobically digested than for lime-stabilized biosolids on January 19, 2007 and lower for anaerobically digested than lime-stabilized on June 8, 2007. Higher amounts of Ba were associated with the colloidal than the dissolved fraction, indicating that Ba transport was largely as a bound particulate, as previously shown by Gounaris et al. (1993) (Figure 2.9). Although we operationally defined the fractions that passed through the 0.45 µm membrane filter as dissolved, small (0.001-0.01 µm) colloidally-bound Ba may pass through the filter (Jensen and Christensen, 1999). Our results, therefore, may have termed a larger proportion of Ba as "dissolved" than actually occurred.

The relative amounts of Ba that leached compared to that applied were very low (Table 2.5). The anaerobically digested biosolids applied 188,000 g Ba $ha^{-1}$ and the lime-stabilized biosolids applied 127,000 g Ba $ha^{-1}$. On September 8, 2006, the metal mass transport per sampling period from the lime-stabilized biosolids, 187 g Ba $ha^{-1}$, shows the largest spike (Figure 2.9); however, it still does not exceed the initial Ba loading rate (Table 2.5). Over 90% of Ba was associated with the organic, oxide, and residual fractions, which may account for the low metal mass transport per sampling period (Figures 2.3 and 2.4).

Nearly all of the Cu that leached from the biosolids was detected during the first 8 months after application and then essentially ceased (Figure 2.10). The largest spike for both biosolids occurred after the rainfall events shortly before the sampling event of September 8,

2006. More Cu leached from the lime-stabilized (696 g $ha^{-1}$) than from the anaerobically digested (179 g $ha^{-1}$) in September 2006, which were largely in the colloidal leachate fractions.

Initial biosolids loading rates (Table 2.5) were much higher than the metal mass transport per sampling period for Cu. The lime-stabilized biosolids supplied 129,000 g $ha^{-1}$ of Cu, and the anaerobically digested biosolids supplied 139,000 g $ha^{-1}$. Between 80% and 90% of applied Cu was associated with organic-complexes (Figures 2.3 and 2.4). Jensen et al. (1999) found that the colloidal leachate fraction consists largely of organic compounds. Copper mobility has been shown to be increased by complexation with soluble organics (Camobreco et al., 1996; Antoniadis and Alloway, 2002). Since most of the leachate Cu was associated with colloids and the largest fraction of Cu in the biosolids was organically-complexed, it is likely that the soluble organic matter were releasing Cu as soluble organo-metallic complexes.

The metal mass transport per sampling period for Ni were generally low (Figure 2.11) compared to Ba, Cu, and Zn. The leachate Ni from the lime-stabilized biosolids showed a large spike on September 8, 2006 with smaller spikes between December 1, 2006 and February 9, 2007. The lime-stabilized biosolids produced greater metal mass transport per sampling period than the anaerobically digested biosolids. Nickel was found largely in the colloidal fraction, but the soluble fraction was larger than for Ba and Cu. This was especially true within the spikes from the anaerobically digested biosolids on January 19, when the entire 2.4 g $ha^{-1}$ metal mass transport per sampling period was in the dissolved fraction.

Like Ba and Cu, the metal mass transport per sampling period for Ni were very small compared to the initial loading rates (Table 2.5) of 10,500 g Ni $ha^{-1}$ for lime-stabilized biosolids and 11,500 g Ni $ha^{-1}$ for anaerobically digested biosolids. Nickel was found mostly associated with the organic fraction in the biosolids, but there was also a significant amount of the element associated with the residual fraction of the lime-stabilized biosolids (Figures 2.3 and 2.4). The strong insoluble organic-complexes and bonds with residuals will result in the lower metal mass transport per sampling period for Ni. Jensen and Christensen (1999) found Ni associated mostly with the smallest colloidal fraction (0.001-0.01 μm), which we measured as "dissolved."

The greatest loss of Zn occurred immediately following the rainfall event in early September 2006 (Figure 2.12) and was higher below the lime-stabilized than the anaerobically digested biosolids. In general, more Zn leached from the lime-stabilized than from the anaerobically digested biosolids throughout the year. For both biosolids treatments, the majority of the Zn leached in the colloidal fraction, but more dissolved Zn leached from the lime-stabilized than from the anaerobically digested biosolids.

The metal mass transport per sampling period were very low compared to the original loading rates for the lime-stabilized (322,000 g Zn $ha^{-1}$) and anaerobically digested (627,000 g Zn $ha^{-1}$) biosolids (Table 2.5). The low metal mass transport per sampling period may be attributed to the strong organic-complexes present within the biosolids. Sixty-nine percent of Zn in the lime-stabilized biosolids and 38% of Zn in the anaerobically digested biosolids were associated with the organically-complexed fractions (Figures 2.3 and 2.4). Twenty percent of the Zn, which was higher than for any other metal, was associated with the exchangeable fraction of the anaerobically digested biosolids. The Zn present on the exchange sites could easily be removed into the soil solution causing metal mass transport per sampling period to increase.

We calculated the cumulative metal mass transport per sampling period for the metals that moved in the largest quantities – Ba, Cu, Ni, and Zn -- from the biosolids (Figure 2.13). The Ba and Zn leaching masses were greater ($p \leq 0.1$) from either biosolids than from the control treatment. Masses of Cu and Ni that leached from the anaerobically digested biosolids were not different ($p > 0.1$) from the control. Leachate metals (with the exception of Ba) concentrations and masses from the lime-stabilized biosolids were higher than from the anaerobically digested biosolids. The more basic initial pH within the lime-stabilized biosolids may have resulted in a release of organically bound metals as it began to dissociate over time (McBride and Blasiak, 1979; Mckinley et al., 2001). Statistically, the metal mass transport per sampling period from the biosolids types were not significantly different ($p > 0.1$) from each other for Ba, Ni, and Zn. Metal mass transport per sampling period for Cu were different between the different biosolids treatments ($p \leq 0.1$). For all biosolids types and metal analyzed, the largest concentrations were found within the colloidal portion.

Compared to initial loading rates (Table 2.5), the metal mass transport per sampling period were very low. For Ba, Cu, and Zn the metal mass transport per sampling period period represents less than 0.8% of the initial loading rate for each metal within both biosolids types. From the anaerobically digested biosolids less than 0.8% of nickel's initial loading rate actually leached; however, 1.6% leached from the lime-stabilized biosolids. Over 50% of the biosolids were associated with the two least soluble fractions, organically-bound and residual, which likely retained the metals within the biosolids (Figures 2.3 and 2.4). Overall, the low cumulative metal mass transport per sampling period were encouraging since the biosolids were applied at such high rates (Table 2.5).

### Lateral transport

We used suction lysimeters to collect leachates that moved laterally from the entrenched biosolids in order to further assess metal mobility. As with the zero tension lysimeters, metal concentration within the suction lysimeters varied greatly (Table 2.9). Silver, Cd, Pb, and Sn were not present above the detection limit in any of the samples collected. Copper was present in 55% of the samples and ranged from 0.006 to 5.813 mg $L^{-1}$. Nickel was detected about the same frequency as Cu, but its highest concentration was a magnitude of order less than Cu. Barium and Zn were both detected in nearly every sample.

The lack of lateral movement for Ag, Cd, Pb, and Sn offers more evidence of the insolubility and immobility of the heavy metals in biosolids (Table 2.9). Barium and Zn showed the most movement, which could be due to their large occurrence as exchangeable cations in the biosolids (Figures 2.3 and 2.4). This fraction is the most soluble and may allow a large amount of movement.

The lack of detection of metals in the suction lysimeters may have been partially caused by sorption of metals to the ceramic cup or silica flour (McGuire et al., 1992; James and Healy, 1971). McGuire et al. (1992) found Cd and Zn adsorption to ceramic cups, of the same type that we used, to be generally one magnitude greater than on stainless steel, fritted glass, and polytetrafluoroethylene (PTFE) samplers. Silica flour may adsorb metals at pH 6 to 8, which was the pH range in the leachate samples collected in this experiment (Figure 2.6). The lack of detectable Ag, Cd, Pb, and Sn (Table 2.9) may have been due to such adsorption; however, these metals were also present in low concentrations in the zero tension lysimeters indicating that our results were accurate.

### Comparison with the Drinking Water Standards

Metal concentrations in the leachate collected below the entrenched anaerobically digested and lime-stabilized biosolids were compared to the Drinking Water Standards established by the USEPA (2003) (Table 2.10). Nickel and tin do not currently have USEPA Drinking Water Standards established for them (USEPA, 2003). The fraction of samples whose concentration was above the standards was low with the highest value due to Cd (0.11) transport from the biosolids (Table 2.10). High concentrations that leached from the biosolids would become diluted as the metal entered a larger body of water; therefore, reducing its potential to pose a threat to the surrounding environment (McBride et al., 1999).

## CONCLUSION

There was little or no vertical or horizontal transport of metals in leachate. Silver, Cd, Pb, and Sn showed almost no movement in a vertical direction, which is encouraging as Cd and Pb can pose potential environmental and health concerns. Barium, Cu, Ni, and Zn were the most mobile metals, but the absolute mass leached posed no health or environmental concerns when compared to the USEPA Drinking Water Standards. Especially important is that metals of emerging interest were not present in detectable concentrations in biosolids (i.e. Be) or showed virtually no solubility or mobility (i.e. Ag, Sn). Barium was the only one of these metals whose transport may merit further investigation.

After 15 months, the lime-stabilized biosolids produced higher cumulative metal mass transport per sampling period for Cu, Ni, and Zn than the anaerobically digested biosolids. Barium mass loss was similar from both biosolids treatments. The metals species, which did leach from the biosolids, were found primarily associated with particulates, as higher concentrations were present within the colloidal fraction compared to the dissolved fraction. Overall heavy metal movement from entrenched biosolids is of little concern; however, research to identify the species of metals being leached may elucidate the mechanisms responsible for metal transport.

## REFERENCES

Al-Wabel, M.A., D.M. Heil, D.G. Westfall, and K.A. Barbarick. 2002. Solution Chemistry Influence on Metal Mobility in Biosolids-Amended Soils. J. Environ. Qual. 31:1157-1165.

Antoniadis, V. and B.J. Alloway. 2002. The role of dissolved organic carbon in the mobility of Cd, Ni and Zn in sewage sludge-amended soils. Environ. Pollut. 117:515-521.

AOAC (Association of Official Analytical Chemists). 2000. Agricultural liming materials. In P.F. Kane (ed.) AOAC Methods. Association of Official Analytical Chemists. Washington, DC.

APHA. 1998. Standard methods for the examination of water and wastewater. 20th edition, Am. Public Health Assoc., Am. Water Works Assoc., and Water Environment Federation. Washington, DC.

Backman, C. and N. Gustavsson. 1996. Ruggedness test of an aqua regia extraction method made with the geochemical reference material GXR-2. CEM. 10:371-378.

Camobreco, V.J., B.K. Richards, T.S. Steenhuis, J.H. Peverly, M.B. McBride. 1996. Movement of Heavy Metals Through Undisturbed and Homogenized Soil Columns. Soil Sci. 161(11):740-750.

CSC: Environmental Solutions. 2007. CSC's Sampling and Analysis Report for the 2006-2007 Targeted National Sewage Sludge Survey. GSA Task Order GS-10F-0135K.

Daniels W.L., P.D. Schroedoer, S.M. Nagle, L.W. Zelazny, and M.M. Alley. 2003. Reclamation of Prime Farmland and Following Mineral Sands Mining in Virginia. Min Eng-Littleton p. 42-48.

Donohue, S.J. 1992. Reference soil and media diagnostic procedures for the southern region of the United States. Southern Coop. Serv. Bull. 374. Virginia Tech, Blacksburg, VA.

Forste, J.B. 1996. Land Application. *In* M.J. Girovich (ed.) Biosolids Treatment and Management. Marcel Dekker, Inc., New York.

Emmerich, W.E., L.J. Lund, A.L. Page, and A.C. Chang. 1982. Movement of Heavy Metals in Sewage Sludge-Treated Soils. J. Envrion. Qual. 11:174-178.

Evanylo, G., K. Kostyanovsky, K. Lasley, B. Sukkariyah, and C. Shang. 2008. Environmental effects of biosolids trenching for reclaiming mined land for hybrid poplar production. p. 255-276. Proceedings of the 2008 Biosolids and Residual Specialty Conference. Philadelphia, PA. March 30-April 2.

Forste, J.B. 1996. Land Application. p. 389-448. In M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. M.J. Marcel Dekker, Inc.: New York.

Girovich, M.J. 1996. Biosolids Characterization, Treatment and Use: An Overview. *In* M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. Marcel Dekker, Inc.: New York.

Gounaris, V., P.R. Anderson, and T.M. Holsen. 1993. Characteristics and Environmental Significance of Colloids in Landfill Leachate. Environ. Sci. Technol. 27:381-1387.

Hodges, R.L., P.J. Thomas, W.L. Daniels, M.H. Genthner, Z.W. Orndorff, and P. Donovan. 2002. Soil Survey of the Old Hickory Area, Virginia. United States Dept. of Agri., NRCS. Virginia Polytechnic Institute and State University. Blacksburg, VA.

James, R.O. and T.W. Healy. 1971. Adsorption of hydrolysable metal ions at the oxide water interface: Co(II) adsorption on $SiO_2$ and $TiO_2$ as model systems. J. Colloid Interface Sci. 40:42-52.

Jensen, D.L. and T.H. Christensen. 1999. Colloidal and Dissolved Metals in Leachates from Four Danish Landfills. Wat. Res. 33:2139-2147.

Jensen, D.L., A. Ledin, and T.H. Christensen. 1999. Speciation of Heavy Metals in Landfill-Leachate Polluted Groundwater. Wat. Res. 33:2642-2650.

Kabata-Pendias, A. and H. Pendias. 2001. Trace Elements in Soils and Plants. 3rd ed. CRC Press LLC, Boca Raton, Florida.

Kays, J.S., G.K. Felton, and E. Flamino. 2006. Determination of Optimum Tree Density and Biosolid Aplication Rate and the Effect on Water Quality and Tree Growth Using the Deep Row Biosolids Incorporation Method. Maryland Cooperative Extension, Univ. of Maryland, College Park, MD.

Licht, L.A. 1994. Poplar trees treat landfill leachate. Water Environ. And Technology 6:19-20.

Maier, R.M., I.L. Pepper, and C.P. Gerba. 2000. Environmental Microbiology. Academic Press, San Diego.

McBride, M.B and J.J. Blasiak. 1979. Zinc and copper solubility as a function of pH in an acid soil. Soil Science Society of America Journal 43: 866-870.

McBride, M.B. 1994. Environmental chemistry of soils. Oxford Univ. Press, New York.

McBride, M.B., B.K. Richards, T. Steenhuis, J.J. Russo, and S. Sauve′. 1997. Mobility and solubility of toxic metals and nutrients in soil fifteen years after sludge application. Soil Sci. 162:487-500.

McBride, M.B. 1998. Soluble trace metals in alkaline stabilized sludge products. J. Environ. Qual. 27:578-584.

McBride, M.B., B.K. Richards, T. Steenhuis, and G. Spiers. 1999. Long-Term Leaching of Trace Elements in a Heavily Sludge-Amended Silty Clay Loam Soil. Soil Si. 164:613-623.

McGuire, P.E., B. Lowery, and P.A. Helmke. 1992. Potential Sampling Error: Trace Metal Adsorption on Vacuum Porous Cup Samplers. Soil Sci. Am. J. 56:74-82.

Mckinley, J.D., H.R. Thomas, K.P. Williams, and J.M. Reid. 2001. Chemical analysis of contaminated soil strengthened by the addition of lime. Engineering Geology. 60: 181-192.

McLaren R.G. and L.M. Clucas. 2001. Fractionation of Copper, Nickel, and Zinc in Metal-Spiked Sewage Sludge. J. Environ. Qual. 30: 1968-1975.

Murphy, S. 2007. General Information on Dissolved Oxygen. Available at bcn.boulder.co.us/basin/data/BACT/info/DO.html. Accessed March 12, 2008. City of Boulder/USGS Water Quality Monitoring.

Pepperman, R.E. 1995. Report on the ERCO, Inc. Tree Farm Biosolids Beneficial Reuse System. Environmental Group Services, Inc., Baltimore, MD.

Richards, B.K., T.S. Steenhuis, J.H. Peverly, M.B. McBride. 1997. Metal mobility at an old, heavily loaded sludge application site. Environmental Pollution. 99:365-377.

Sahuquillo, A., J.F. Lopez-Sanchez, R. Rubio, G. Rauret, R.P. Thomas, C.M. Davidson, and A.M. Ure. 1999. Use of a certified reference material for extractable trace metals to assess sources of uncertainty in the BCR three-stage sequential extraction procedure. Anal. Chim. Acta.. 382:317-327.

SAS Institute. 1999. The SAS system for Windows. Released 8.0 SAS Inst., Cary, NC.

Sikora, L.J., N.H. Frankos, C.M. Murrary, and J.M. Walker. 1979. Effects of trenching undigested lime-stabilized sludge. J. Water Pollut. Control Federation 51:1841-1849.

Sikora, L.J., N.H. Frankos, C.M. Murray, and J.M. Walker. 1980. Trenching of digested sludge. The Journal of the Environmental Engineering Division. Proceedings of the ASCE. 106:351-361.

Sposito, G. 1986. Sorption of trace metals by humic materials in soils and natural waters. Crit. Rev. Environ. Control 16:193-229.

Sukkariyah, B.F., G. Evanylo, L. Zelazny, and R.L. Chaney. 2005. Recovery and Distribution of Biosolids-Derived Trace Metals in a Clay Loam Soil. J. Environ. Qual. 34:1843-1850.

Taylor, J.M., E. Epstein, W.D. Burge, R.L. Chaney, J.D. Menzies, and L.J. Sikora. 1978. Chemical and Biological Phenomena Observed with Sewage Sludges in Simulated Soil Trenches. J. Environ. Qual. 7:477-482.

USEPA. 1983a. Test method 350.2 Nitrogen, ammonia (colorimetric; titrimetric; potentiometric- distillation procedure). In Methods for the chemical analysis of water and wastes (MCAWW). EPA/600/4-79/020. NTIS Item PB84-128677. Environ. Monitoring and Support Lab., Office of Res. And Dev., USEPA, Cincinnati, OH.

USEPA. 1983b. EPA Test method 351.3 Nitrogen, Kjeldahl total (colorimetric; titrimetric; potentiometric). In Methods for the chemical analysis of water and wastes (MCAWW).

EPA/600/4-79/020. NTIS Item PB84-128677. Environ. Monitoring and Support Lab., Office of Res. and Dev., USEPA, Cincinnati, OH.

USEPA. 1993. Standards for the use and disposal of sewage sludge. 40 CFR, Part 503. Fed. Regist. 58:13-15. U.S. Gov. Print. Office, Washington, DC.

USEPA. 1994. Determination of Metals and Trace Elements in Water and Wastes By Inductively Coupled Plasma-Atomic Emission Spectrometry. USEPA 200.7. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2000. Biosolids Technology Fact Sheet: Land Application of Biosolids. USEPA Rep. 832-F-00-064. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2002. Test methods for evaluating solid waste, physical/chemical methods SW-846 manual. U.S. Gov. Print. Office, Washington, DC. Available at www.epa.gov/epaoswer/hazwaste/test/sw846.htm.

USEPA. 2003. Safe Drinking Water Act. USEPA 816-F-03-016. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2007. Frequently Asked Questions: Biosolids. U.S. Gov. Print. Office, Washington, DC.

Williams, D.E., J. Vlamis, A.H. Pukite, and J.E. Corey. 1984. Metal Movement in Sludge-Treated Soils After Six Years of Sludge Addition: 1. Cadmium, Copper, Lead, and Zinc. Soil Sci. 137:351-359.

Williams, D.E., J. Vlamis, A.H. Pukite, and J.E. Corey. 1985. Metal Movement in Sludge-Treated Soils After Six Years of Sludge Addition: 2. Nickel, Cobalt, Iron, Manganese, Chromium, and Mercury. Soil Sci. 140:120-125.

## TABLES

Table 2.1: Values of pH, Mehlich I-extractable elements, and particle size analysis for the soil textural fractions at the research site

| Soil Property | Sandy Clay Loam | Sand |
|---|---|---|
| pH | 6.8 | 6.1 |
| P (mg $kg^{-1}$) | 63 | 11 |
| K (mg $kg^{-1}$) | 101 | 15 |
| Ca (mg $kg^{-1}$) | 752 | 149 |
| Mg (mg $kg^{-1}$) | 152 | 31 |
| Zn (mg $kg^{-1}$) | 3.9 | 0.6 |
| Mn (mg $kg^{-1}$) | 9.1 | 1.2 |
| Cu (mg $kg^{-1}$) | 0.5 | 0.1 |
| Fe (mg $kg^{-1}$) | 15.6 | 9.9 |
| Total Sand (%) | 61.2 | 96.1 |
| Total Silt (%) | 8.6 | 2.0 |
| Total Clay (%) | 30.2 | 1.9 |

Table 2.2: Actual and mean monthly temperature and precipitation over the 15-month sampling period. Total precipitation for each month is also included.

| | Months | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weather Property | Aug 2006 | Sept 2006 | Oct 2006 | Nov 2006 | Dec 2006 | Jan 2007 | Feb 2007 | Mar 2007 | April 2007 | May 2007 | June 2007 | July 2007 | Aug 2007 | Sept 2007 | Oct 2007 |
| Monthly Mean Temperature (°C) | 26 | 20 | 14 | 10 | 7 | 6 | 2 | 10 | 13 | 19 | 23 | 25 | 26 | 21 | 18 |
| Historical Monthly Mean Temperature (°C) | 24 | 20 | 13 | 8 | 3 | 2 | 5 | 9 | 14 | 18 | 23 | 25 | 24 | 20 | 13 |
| Monthly Precipitation (mm) | 73 | 219 | 214 | 219 | 29 | 43 | 54 | 92 | 121 | 62 | 88 | 38 | 61 | 2 | 69 |
| Historical Monthly Mean Precipitation (mm) | 105 | 102 | 89 | 75 | 81 | 91 | 77 | 102 | 78 | 99 | 91 | 121 | 105 | 102 | 89 |
| Monthly Irrigation (mm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 165 | 0 | 51 | 76 | 102 | 89 | 38 | 0 |

Table 2.3: Treatment descriptions and trench volumes of the study.

| Treatment | Trench Volume ($m^3$ $ha^{-1}$) |
|---|---|
| 0 kg fertilizer N $ha^{-1}$ $yr^{-1}$ | 1125 |
| 150 kg fertilizer N $ha^{-1}$ $yr^{-1}$ | 1125 |
| 300 kg fertilizer N $ha^{-1}$ $yr^{-1}$ | 1125 |
| 450 kg fertilizer N $ha^{-1}$ $yr^{-1}$ | 1125 |
| Anaerobically digested biosolids | 1125 |
| Anaerobically digested biosolids | 2250 |
| Lime-stabilized biosolids | 1125 |
| Lime-stabilized biosolids | 2250 |

Table 2.4: Chemical and physical analysis of anaerobically digested and lime-stabilized biosolids entrenched in 2006.

| Biosolids property | Anaerobically Digested Biosolids<br>Concentration, mg $kg^{-1}$ (except moisture content) | Lime-stabilized Biosolids<br>Concentration, mg $kg^{-1}$ (except moisture content) |
|---|---|---|
| Moisture content, mg $g^{-1}$ | 727 | 685 |
| Total Ag | 23 | 10 |
| Total Al | 24,700 | 3,893 |
| Total As | 3.1 | 1.7 |
| Total Ba | 442 | 195 |
| Total Be | <5 | <5 |
| Total Cd | 2.3 | 2.0 |
| Total Cu | 328 | 197 |
| Total Fe | 43,000 | 34,333 |
| Total Hg | 1.9 | 0.7 |
| Total Mn | 1,021 | 216 |
| Total Mo | 9 | 11 |
| Total Ni | 27 | 16 |
| Total Pb | 66 | 53 |
| Total Se | 5.3 | 2.1 |
| Total Sn | 27 | 17 |
| Total Zn | 1,473 | 490 |
| N, total Kjeldahl | 53,133 | 44,533 |
| N, $NH_3 + NH_4^+$ | 12,900 | 1,967 |
| N, organic | 40,233 | 42,567 |
| N, $NO_2^- + NO_3^-$ | 8 | 15 |
| Total P | 26,533 | 8,667 |
| Total K | 933 | 1,367 |
| Total S | 7,033 | 6,367 |
| Total Ca | 23,467 | 114,533 |
| Total Mg | 2,900 | 2,233 |
| Total Na | 367 | 200 |
| pH | 8.5 | 12.3 |
| Calcium carbonate equivalent, CCE | 5,700 | 176,200 |
| Organic matter | 604,366 | 601,600 |

Table 2.5: Total loading rates on a dry weight basis (kg $ha^{-1}$) for anaerobically digested and lime-stabilized biosolids at low and high application rates.

| Biosolids Property | Anaerobically Digested Biosolids | | Lime-stabilized Biosolids | |
|---|---|---|---|---|
| Trench width (m) | 0.45 | 0.90 | 0.45 | 0.90 |
| Application Rate | 213,000 | 426,000 | 328,000 | 656,000 |
| Total Ag | 4.9 | 9.8 | 3.3 | 6.6 |
| Total Al | 5,253 | 10,507 | 1,278 | 2,556 |
| Total As | 0.7 | 1.3 | 0.6 | 1.1 |
| Total Ba | 94 | 188 | 64 | 128 |
| Total Cd | 0.5 | 1.0 | 0.4 | 0.9 |
| Total Cu | 69.7 | 139 | 65 | 129 |
| Total Fe | 9,145 | 18,290 | 11,261 | 22,521 |
| Total Hg | 0.4 | 0.8 | 0.2 | 0.5 |
| Total Mn | 217 | 434 | 71 | 142 |
| Total Mo | 2.7 | 5.4 | 3.7 | 7.4 |
| Total Ni | 5.7 | 11.5 | 5.2 | 10.5 |
| Total Pb | 14 | 28 | 17 | 35 |
| Total Se | 1.1 | 2.2 | 0.7 | 1.4 |
| Total Sn | 5.6 | 11 | 5.7 | 11 |
| Total Zn | 313 | 627 | 161 | 322 |
| N, total Kjeldahl | 11,301 | 22,601 | 14,606 | 29,212 |
| N, $NH_3 + NH_4^+$ | 2,744 | 5,487 | 645 | 1,290 |
| N, organic | 8,557 | 17,114 | 13,961 | 27,922 |
| N, $NO_2^- + NO_3^-$ | 2.0 | 3.0 | 5.0 | 10 |
| Total P | 5,643 | 11,286 | 2,842 | 5,685 |
| Total K | 199 | 397 | 448 | 896 |
| Organic Matter | 128,539 | 257,078 | 197,310 | 394,621 |

Table 2.6: Actual metal concentrations within each fraction for anaerobically digested biosolids. The 2006 samples were collected during installation of the project and the 2007 samples were collected 15 months later.

| | 2006 fractions (mg kg$^{-1}$ biosolids) | | | | 2007 fractions (mg kg$^{-1}$ biosolids) | | | |
|---|---|---|---|---|---|---|---|---|
| | Exchangeable | Oxides | Organic | Residual | Exchangeable | Oxides | Organic | Residual |
| Ba | 8.43 a | 22.7 b | 100 c | 379 d | 12.0 a | 23.3 a | 105.2 b | 362 c |
| Cd | <0.10 * | <0.20 * | <0.60 * | <0.20 * | <0.10 * | <0.30 * | <0.80 * | <0.30 * |
| Cu | <1.00 * | <1.00 * | 353 | 68.3 | <1.00 * | <2.00 * | 338 | 53.0 |
| Ni | <3.00 * | <2.00 * | <6.00 * | <3.00 * | <3.00 * | <1.00 * | <5.00 * | <4.00 * |
| Pb | <1.00 * | <1.00 * | <2.00 * | 55.7 | <1.00 * | <1.00 * | <3.00 * | 58.9 |
| Zn | 321 a | 404 b | 578 c | 205 d | 297 ac | 420 a | 636 b | 117 c |

* Denotes those concentrations at or below the ICP-AES detection limit.
Row means for each metal within years followed by the same letter are not significantly (P = 0.05) different.

Table 2.7: Actual metal concentrations within each fraction for lime-stabilized biosolids. The 2006 samples were collected during installation of the project and the 2007 samples were collected 15 months later.

| | 2006 fractions (mg kg$^{-1}$ biosolids) | | | | 2007 fractions (mg kg$^{-1}$ biosolids) | | | |
|---|---|---|---|---|---|---|---|---|
| | Exchangeable | Oxides | Organic | Residual | Exchangeable | Oxides | Organic | Residual |
| Ba | 22.5 a | 21.3 a | 62.0 b | 111 c | 15.6 a | 10.1 a | 55.9 b | 110 c |
| Cd | <0.10 * | <0.20 * | <0.60 * | <0.20 * | <0.10 * | <0.20 * | <0.60 * | <0.30 * |
| Cu | <2.00 * | <1.00 * | 200 | 24.6 | 3.70 | <2.00 * | 203 | 25.5 |
| Ni | <1.00 * | <1.00 * | <3.00 * | <3.00 * | <2.00 * | <0.40 * | <3.00 * | <3.00 * |
| Pb | <1.00 * | <1.00 * | <2.00 * | 39.8 | <2.00 * | <1.00 * | <2.00 * | 41.3 |
| Zn | 18.6 a | 87.4 a | 348 b | 53.7 a | 26.8 a | 65.2 a | 383 b | 56.5 a |

* Denotes those concentrations at or below the ICP-AES detection limit.
Row means for each metal within years followed by the same letter are not significantly (P = 0.05) different.

Table 2.8: Summary data for Ag, Cd, Pb, and Sn collected in zero tension lysimeters below entrenched anaerobically digested and lime-stabilized biosolids during the sampling period from August 10, 2006 to October 12, 2007.

| | Metal | | | |
|---|---|---|---|---|
| | Ag | Cd | Pb | Sn |
| Method Detection Limit, MDL (mg $L^{-1}$) | 0.006 | 0.004 | 0.016 | 0.027 |
| Total Concentration Range (mg $L^{-1}$) [a] | <0.006 - 0.046 | <0.004 - 0.042 | <0.016 - 0.061 | <0.027 |
| Number of Samples Collected | 125 | 277 | 277 | 125 |
| Fraction of samples whose concentration>DL | 0.03 | 0.12 | 0.004 | 0 |

[a] Total concentration includes colloidal and dissolved fractions.

Table 2.9: Summary of data for metals collected in the suction lysimeters adjacent to entrenched anaerobically digested and lime-stabilized biosolids during the sampling period from August 10, 2006 to October 12, 2007.

| | Metal | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ag | Ba | Cd | Cu | Ni | Pb | Sn | Zn |
| Method Detection Limit, MDL (mg $L^{-1}$) | 0.006 | 0.001 | 0.004 | 0.006 | 0.008 | 0.016 | 0.027 | 0.004 |
| Total Concentration Range (mg $L^{-1}$) [a] | <0.006 | <0.001 - 1.800 | <0.004 | <0.006 - 5.813 | <0.008 - 0.522 | <0.0160 | <0.0270 | <0.018 - 2.676 |
| Number of Samples Collected | 18 | 102 | 70 | 102 | 102 | 70 | 18 | 102 |
| Fraction of samples whose concentration >DL | 0 | 0.995 | 0 | 0.55 | 0.59 | 0 | 0 | 1 |

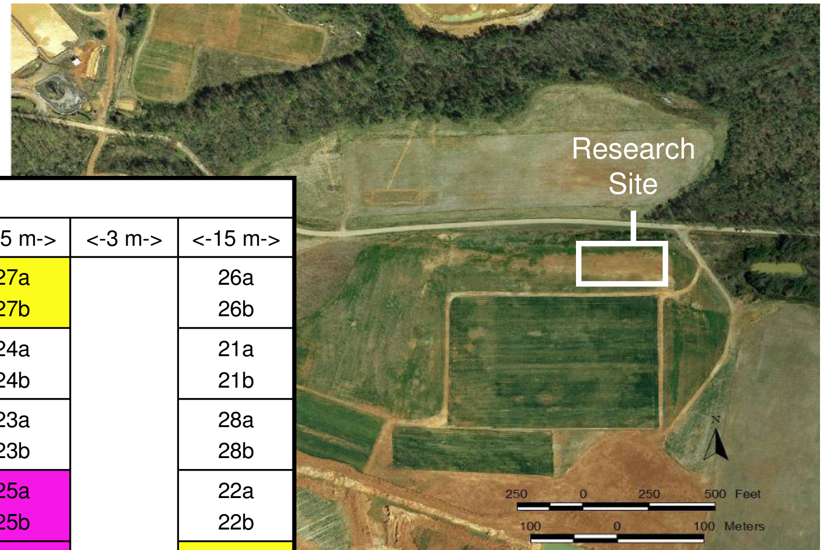
[a] Total concentration includes colloidal and dissolved fractions.

Table 2.10: Summary of data for metals collected in zero tension lysimeters below entrenched anaerobically digested and lime-stabilized biosolids during the 15-month sampling period as compared to the US EPA Drinking Water Standards (2003).

| | Metal | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ag | Ba | Cd | Cu | Ni | Pb | Sn | Zn |
| Drinking Water Standard (mg $L^{-1}$), DWS | 0.1† | 2‡ | 0.005‡ | 1.3‡ | *** | 0.015‡ | *** | 5† |
| Number of Samples Collected | 125 | 497 | 277 | 497 | *** | 277 | *** | 497 |
| Fraction of samples whose concentration>DWS | 0 | 0.03 | 0.11 | 0.05 | *** | 0.004 | *** | 0.02 |

† From EPA National Secondary Drinking Water Standards, 2003.
‡ From EPA National Primary Drinking Water Standards, 2003.
*** Drinking Water Standards not established.

# FIGURES




| Marshy Culvert | | | | | | |
|---|---|---|---|---|---|---|
| <-15 m-> | <-3 m-> | <-15 m-> | <-3 m-> | <-15 m-> | <-3 m-> | <-15 m-> |
| 12a 12b | | 11a 11b | | 27a 27b | | 26a 26b |
| 13a 13b | | 17a 17b | | 24a 24b | | 21a 21b |
| 15a 15b | | 16a 16b | | 23a 23b | | 28a 28b |
| 18a 18b | | 14a 14b | | 25a 25b | | 22a 22b |
| 38a 38b | | 34a 34b | | 46a 46b | | 47a 47b |
| 32a 32b | | 37a 37b | | 44a 44b | | 45a 45b |
| 36a 36b | | 31a 31b | | 42a 42b | | 43a 43b |
| 33a 33b | | 35a 35b | | 41a 41b | | 48a 48b |
| Field Road | | | | | | |

| Treatment Number | Treatment Description |
|---|---|
| 1 | Fertilizer at 0x Agronomic N Rate |
| 2 | Fertilizer at 0.5x Agronomic N Rate |
| 3 | Fertilizer at 1.0x Agronomic N Rate |
| 4 | Fertilizer at 1.5x Agronomic N Rate |
| 5 | Anaerobically Digested Biosolids in 45 cm Wide Trench |
| 6 | Anaerobically Digested Biosolids in 90 cm Wide Trench |
| 7 | Lime-Stabilized Biosolids in 45 cm Wide Trench |
| 8 | Lime-Stabilized Biosolids in 90 cm Wide Trench |

Figure 2.1: Plot lay out at the research site in Dinwiddie County, VA. The solid black boxes represent one plot. The first digit in the plot number indicates the rep number, second digit indicates treatment, and the letter represents the trench.

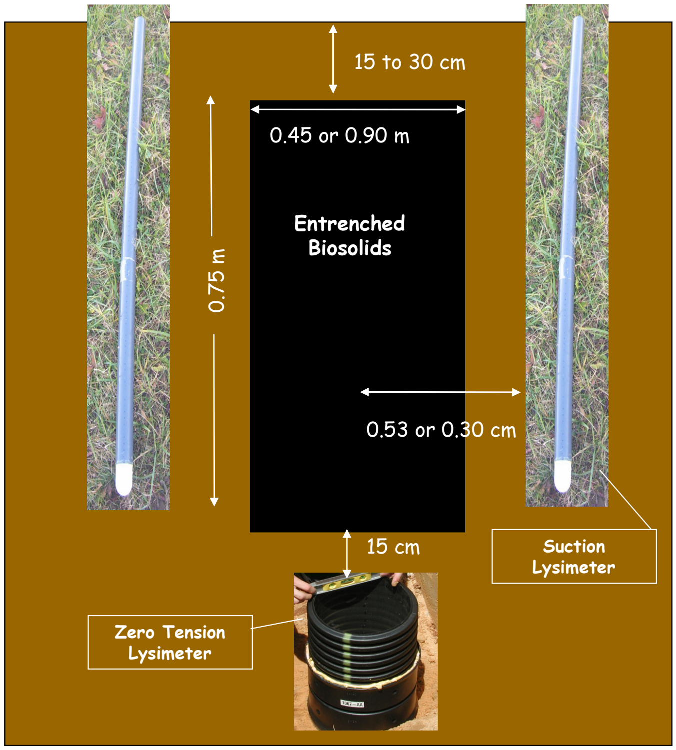



Figure 2.2: Location of zero tension and suction lysimeters within biosolids plots on reclaimed mine land. Each trench was 15 m long.

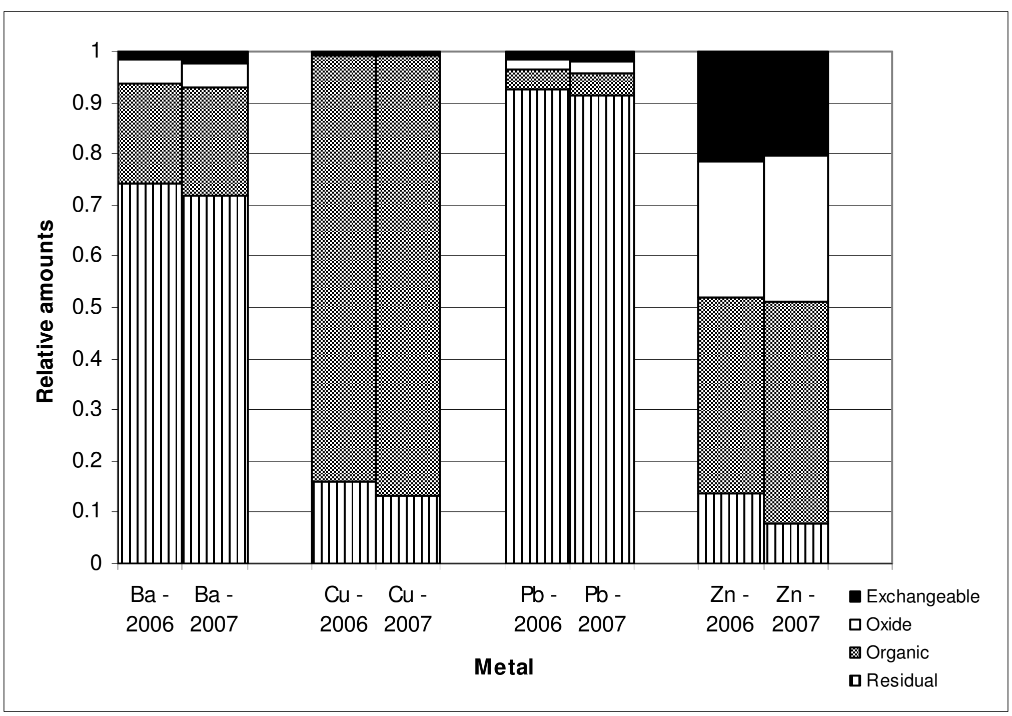



Figure 2.3: Chemical fractions of anaerobically digested biosolids to which Ba, Cu, Pb, and Zn were bound. The 2006 samples were collected during installation of the project and the 2007 samples were collected 15 months later.

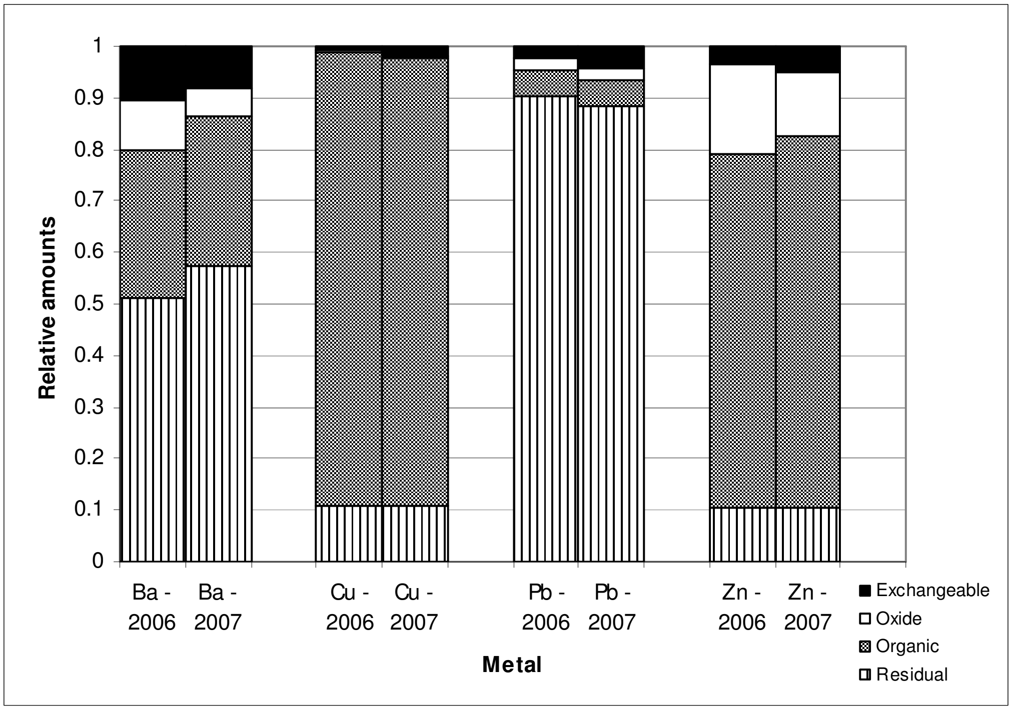



Figure 2.4: Chemical fractions of lime-stabilized biosolids to which Ba, Cu, Pb, and Zn were bound. The 2006 samples were collected during installation of the project and the 2007 samples were collected 15 months later.

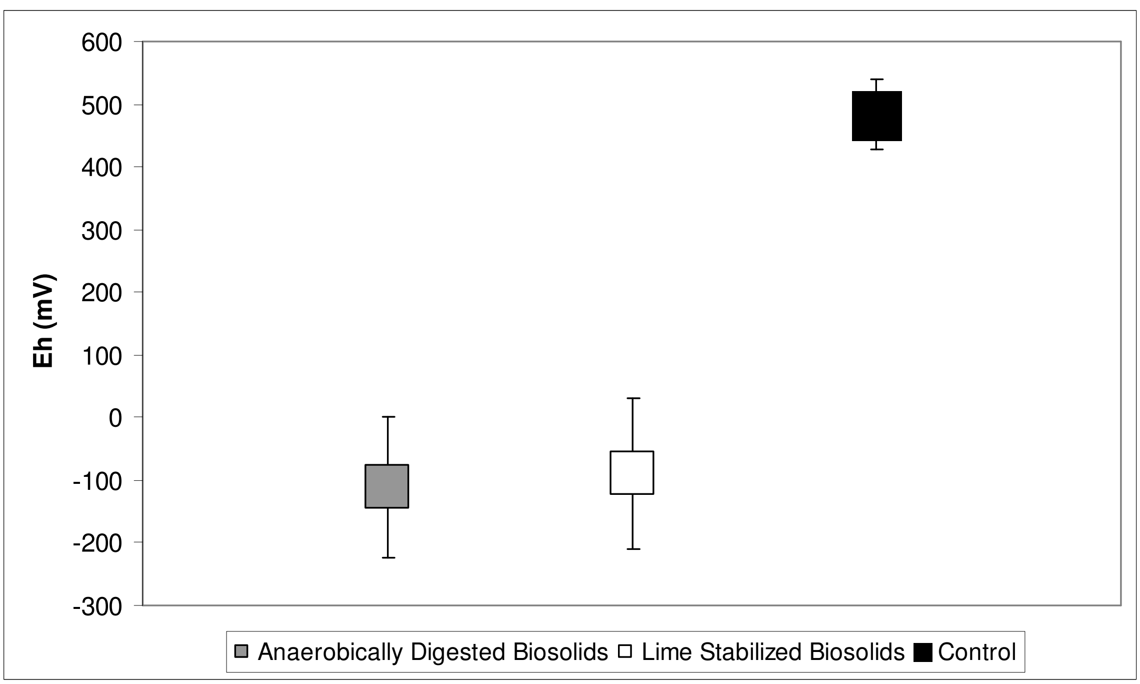



Figure 2.5: Mean redox potential within both types of biosolids and control trenches. Mean is average of monthly measurements taken from August 2006 to August 2007. Error bars represent standard deviations.

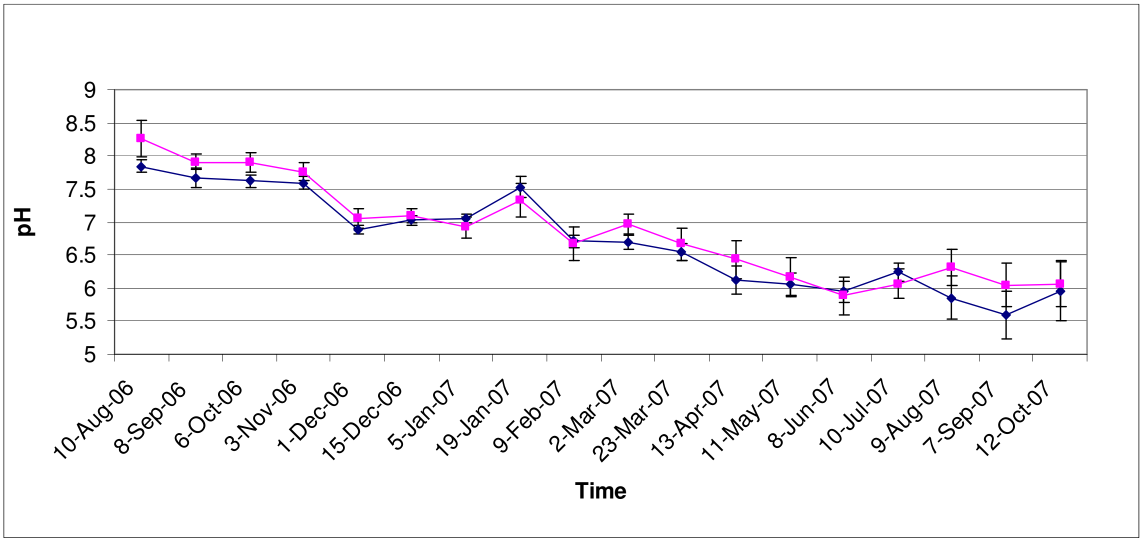



Figure 2.6: Changes in leachate pH with sampling time below entrenched anaerobically digested (diamonds) and lime-stabilized biosolids (squares). Standard error bars for each sampling period.

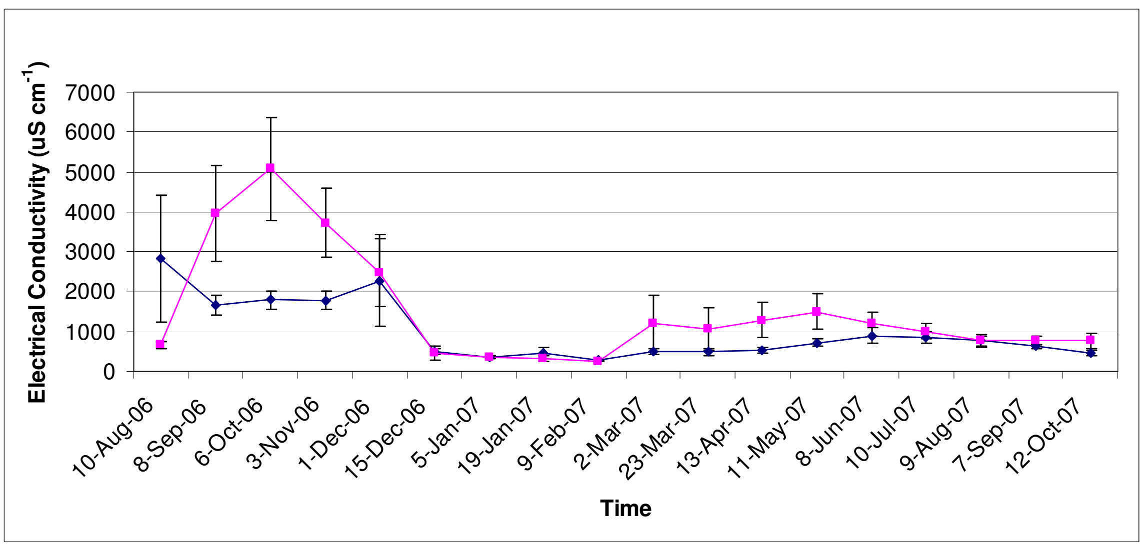



Figure 2.7: Changes in leachate electrical conductivity with sampling time below entrenched anaerobically digested (diamonds) and lime-stabilized biosolids (squares). Standard error bars for each sampling period.

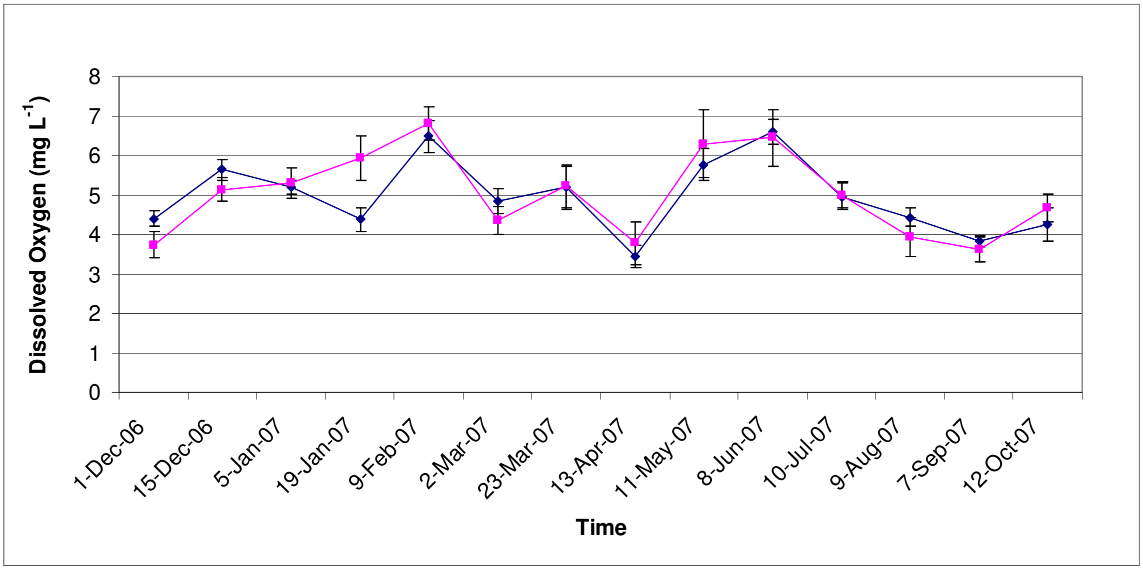



Figure 2.8: Changes in leachate dissolved oxygen with sampling time below entrenched anaerobically digested (diamonds) and lime-stabilized biosolids (squares). Standard error bars for each sampling period.

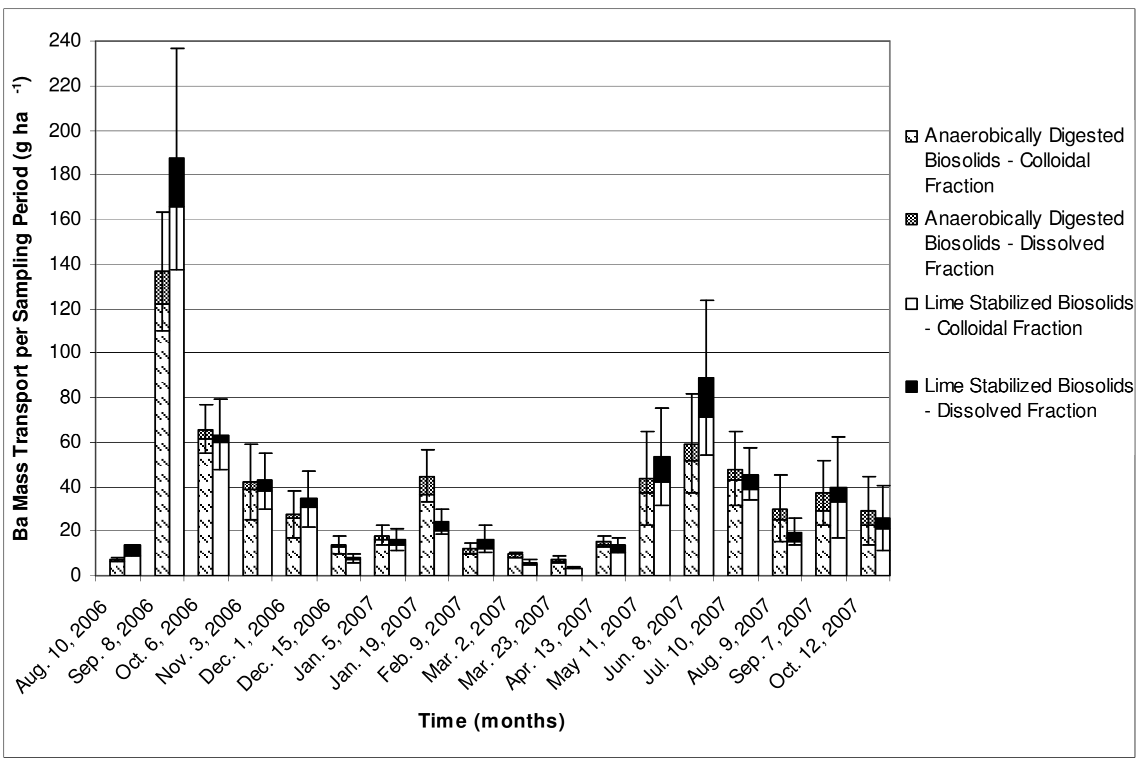



Figure 2.9: Temporal effect of sampling and biosolids source on colloidal and dissolved fractions of leachate Ba mass collected by the zero tension lysimeters over a 15-month sampling period. Standard error bars are for total Ba mean.

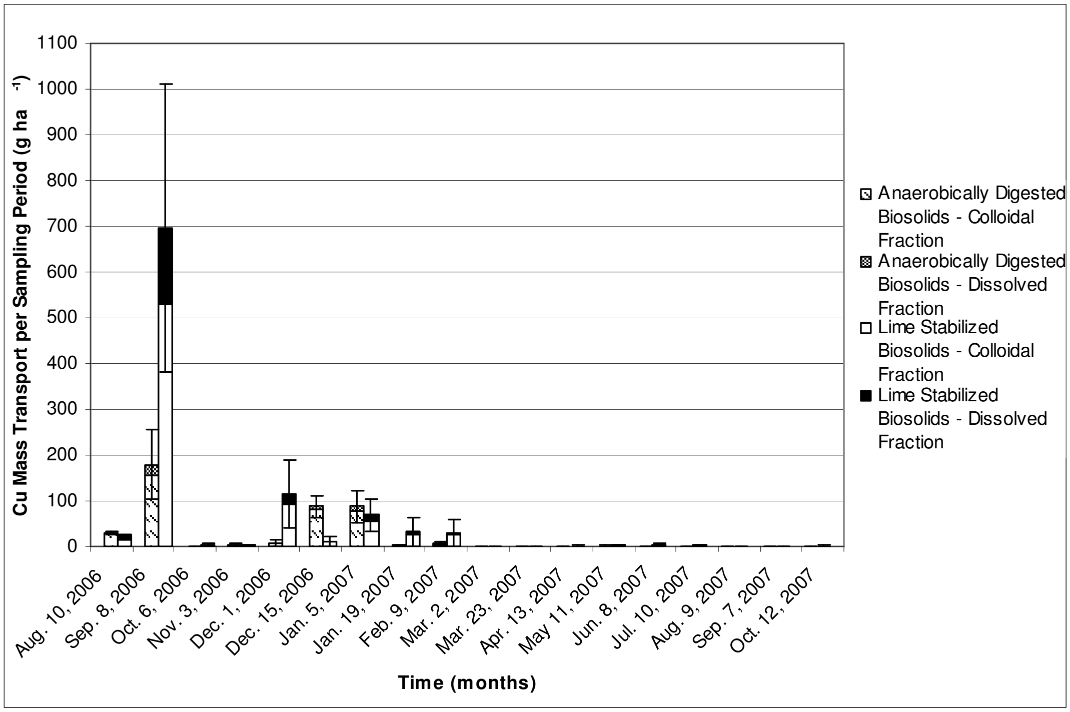



Figure 2.10: Temporal effect of sampling and biosolids source on colloidal and dissolved fractions of leachate Cu mass collected by the zero tension lysimeters over a 15-month sampling period. Standard error bars are for total Cu mean.

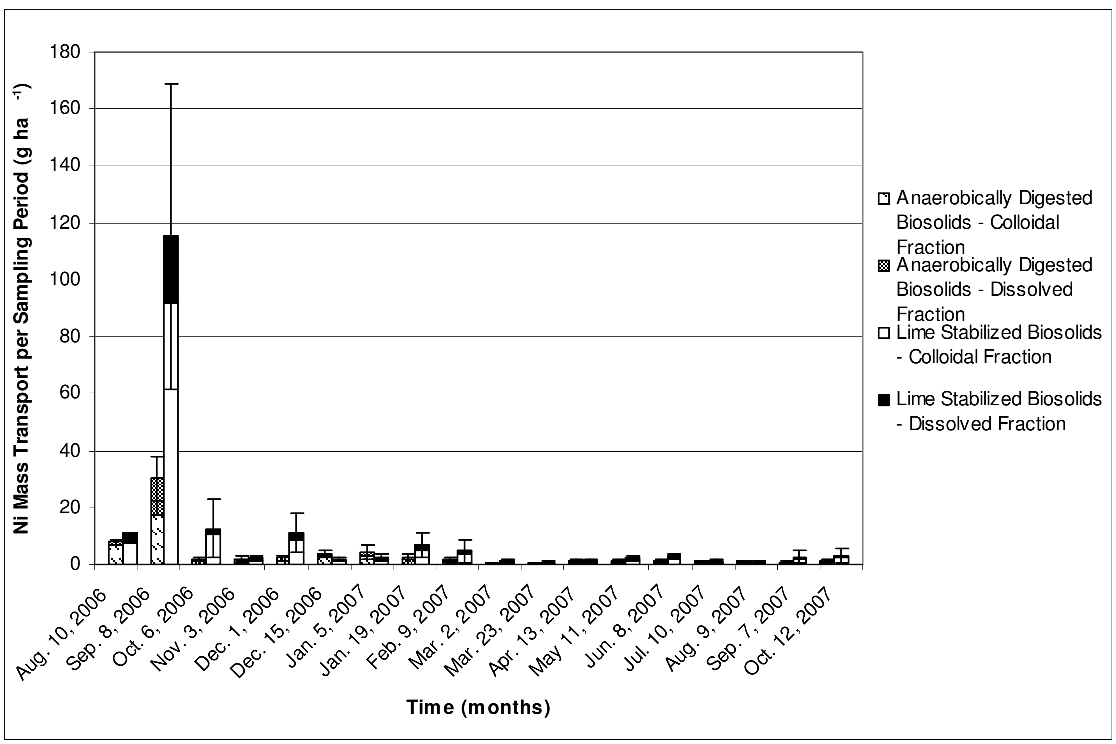



Figure 2.11: Temporal effect of sampling and biosolids source on colloidal and dissolved fractions of leachate Ni mass collected by the zero tension lysimeters over a 15-month sampling period. Standard error bars are for total Ni mean.

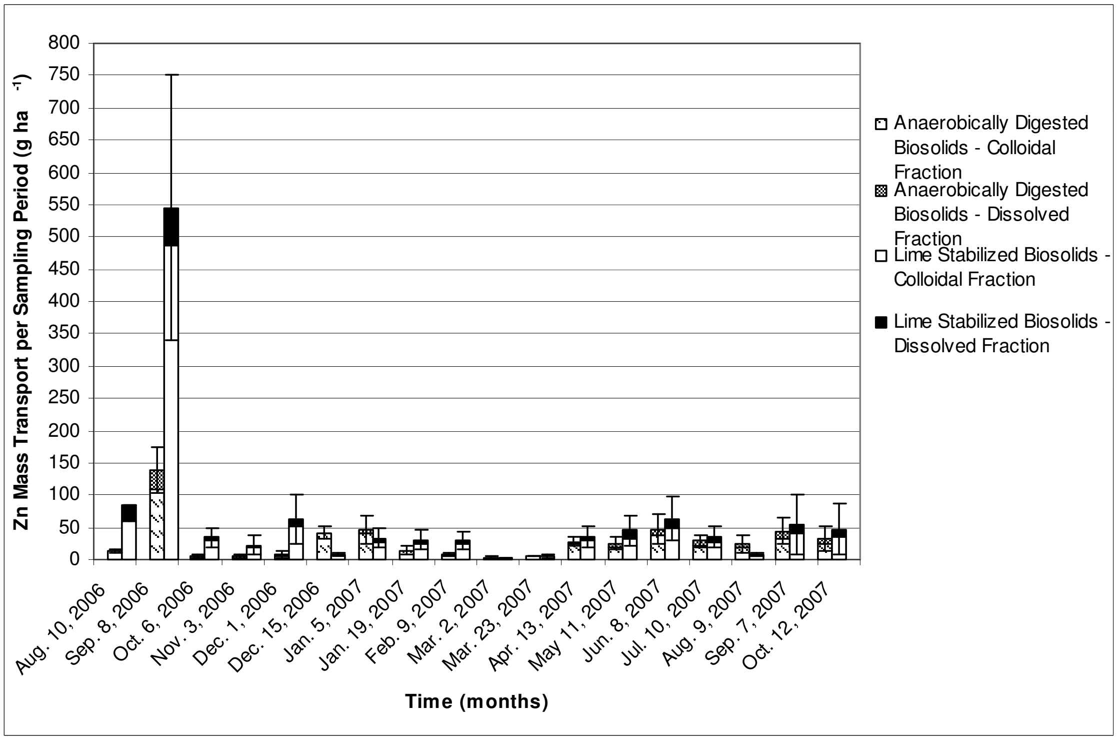



Figure 2.12: Temporal effect of sampling and biosolids source on colloidal and dissolved fractions of leachate Zn mass collected by the zero tension lysimeters over a 15-month sampling period. Standard error bars are for total Zn mean.

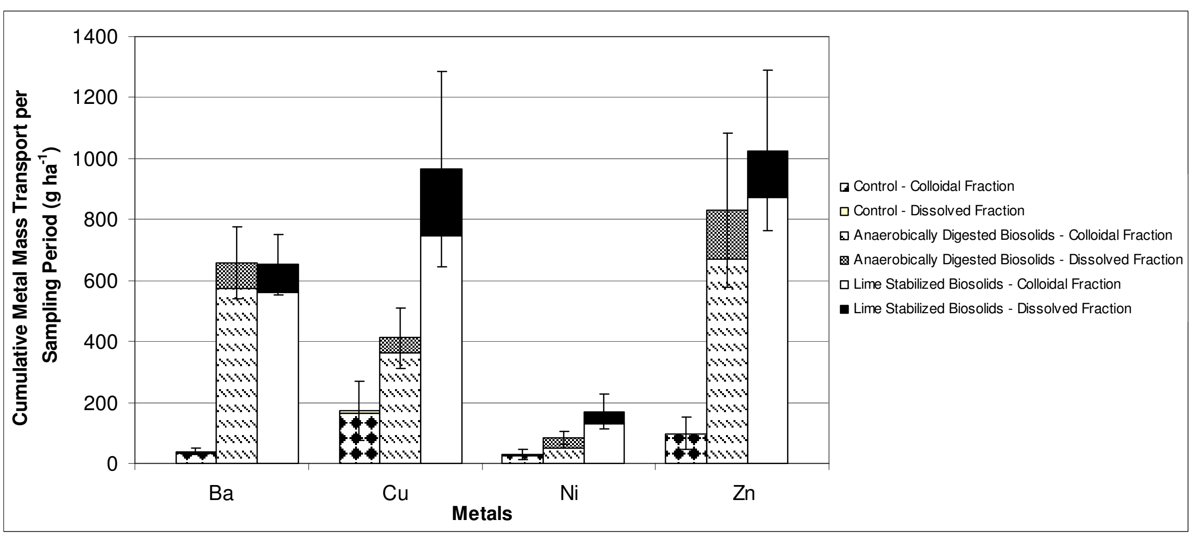



Figure 2.13: Cumulative metal mass transport per sampling period of colloidal and dissolved fractions of Ba, Cu, Ni, and Zn collected by zero tension lysimeters below anaerobically digested and lime-stabilized biosolids seams for a 15-month period. Standard error bars are for total metal means.

## CHAPTER THREE

## Predicted Speciation of Metals from Entrenched Biosolids at a Reclaimed Mineral Sands Mining Site in Dinwiddie County, Virginia


## ABSTRACT

Deep row incorporation of biosolids is an alternative land application method that may allow higher than currently permitted mine land reclamation application rates. Biosolids treated by various processes possess characteristics that uniquely affect metal solubility and mobility due to their influence on metal speciation. The objective was to determine trace metal species within the dissolved fraction of leachate collected beneath entrenched biosolids to aid in the understanding of the mechanisms that facilitate their transport to groundwater. On a mineral sands mine reclamation site in Dinwiddie County, Virginia, anaerobically digested (426 dry Mg $ha^{-1}$) and lime-stabilized (657 dry Mg $ha^{-1}$) biosolids were shallowly entrenched below the soil surface. Zero tension lysimeters placed below the trenches collected leachate for Ba, Cd, Cu, Ni, Pb, Zn, chloride ($Cl^-$), sulfate ($SO_4^{2-}$), nitrate ($NO_3^-$), phosphate ($PO_4^{3-}$), dissolved organic carbon (DOC), inorganic carbon, Al, Fe, Mn, Ca, Mg, and pH analysis within its dissolved fraction. To assess temporal changes, we analyzed samples via the speciation model MINTEQA2 on September 8, 2006, November 3, 2006, January 5, 2007, June 8, 2007, and September 7, 2007. For Ba, Cd, Ni, Zn the majority of their concentrations were predicted to form free ions within the leachate. Copper and lead were predicted to have over 70% of their concentration to form FA-metal complexes. As pH decreased and time from initial application increased, the amount of metals associated with fulvic acids decreased allowing more metals to become free ions or bound to inorganic ions (i.e. $Cl^-$, $SO_4^{2-}$, $NO_3^-$, $PO_4^{3-}$, $HCO_3^-$). With increased presence of free ions, a concern about metal bioavailability and toxicity within underlying groundwater may develop.


## INTRODUCTION

Approximately half of the biosolids produced in the United States are applied to land with the majority placed on agricultural land (USEPA, 2000; USEPA, 2007). Using biosolids to reclaim and revegetate soils disturbed by surface mining is becoming an increasingly adopted practice because of the need to replace organic matter and essential plant nutrients in such soils. Entrenchment of biosolids enables higher rates of organic matter and nutrients to be applied than routine mine land reclamation rates while reducing odor nuisance (ERCO, Inc, 2000).

The high rates of biosolids applied via entrenching (ERCO, Inc., 2000) of 383 Mg $ha^{-1}$ may increase the risk of loss of pollutants such as nutrients and heavy metals. Sikora et al. (1979, 1980) and ERCO, Inc. (2000) did not detect heavy metal movement through soil; however, the study sites did not consist of high groundwater tables in very coarse-textured material. Furthermore, previous researchers did not begin monitoring metal transport until 655 days following biosolids incorporation. A mineral sands surface mine site provided us with the opportunity to test the leaching potential of heavy metals from biosolids entrenched in a coarse-textured medium underlain by a high groundwater table.

Cadmium, Cu, Ni, Pb, and Zn are metals of interest because they can be toxic to plants, animals, or humans (USEPA, 1993; Woodbury, 2005). A recent review of Part 503 has identified silver (Ag), barium (Ba), beryllium (Be), and tin (Sn) as emerging metals of interest (CSC, 2007). Soil and biosolids chemical properties, such as pH, redox potential, and the presence of binding constituents such as organic matter, hydroxides/oxides, and inorganic ligands affect metal mobility. The properties of biosolids applied to coarse-textured media possessing little chemical charge will largely control metal speciation and mobility (Emmerich et al., 1982). Metals found as free, uncomplexed metal ions (i.e. $Cd^{2+}$, $Zn^{2+}$) are more bioavailable and toxic to the environment (McLean and Bledsoe, 1992).

Sorption sites on organic matter, oxides, and inorganic ligands are dependent on pH, whose value will increase or decrease metal mobility. Metal mobility, except for that of molybdenum (Girovich, 1996), will increase with acidity. Taylor et al. (1978) showed that anaerobic conditions or low redox potentials within untreated sewage sludge prevent the decomposition of organic matter allowing chelated metals to remain within biosolids. Solution electrical conductivity (EC) can affect metal solubility as shown by an increase in Zn concentrations with higher EC (Al-Wabel et al., 2002).

The sorption of trace metals to organic compounds can influence mobility of several metals within soils. Specifically, metals bind to organic functional groups such as carboxyls, phenols, alcohols, carbonyls, and methoxyls (Camobreco et al., 1996). The strength of metal binding to the fulvic acid fraction of organic matter is in the following order: Cu > Pb > Fe > Ni > Mn > Co > Zn > Mg (Stevenson and Ardakani, 1972). Trace metals complexed with fulvic acid and/or dissolved organic matter (DOM) can become mobile. As pH increases above neutral, metals previously associated with DOM are released (Japenga et al., 1992). Copper, Cd, Ni, and Zn have increased mobility when bound with DOM (McBride et al., 1997; McBride, 1998).

Common forms of oxides within soils include iron (Fe), aluminum (Al), and manganese (Mn) (McBride, 1994; Sposito, 1986). Oxides display various affinities for cations that are similar in shape and size to $Mn^{2+}$, $Mn^{3+}$, $Fe^{2+}$, and $Fe^{3+}$, including $Ni^{2+}$, $Cu^{2+}$, $Zn^{2+}$, $Cd^{2+}$, $Pb^{4+}$, and $Ag^{+}$ (Kabata-Pendias and Pendias, 2001). Lead, Cu, Ni, and Zn form very strong inner sphere complexes with oxide surfaces allowing for insignificant removal of these metals from the system (Brown and Parks, 2001; Sparks, 2001).

Metal mobility may increase due to bonding with inorganic anions such as $Cl^-$, phosphate ($PO_4^{-3}$), sulfate ($SO_4^{-2}$), bicarbonate ($HCO_3^-$) and nitrate ($NO_3^-$) (McLean and Bledsoe, 1992; Jensen and Christensen, 1999). Hydrated $PO_4^{-3}$ can precipitate Pb and Zn under neutral to alkaline soil conditions. Sulfate complexes remove dissolved metals from the soil solution (Kabata-Pendias and Pendias, 2001). Chloride is a common fertilizer ion, which pairs with and increases the mobility of Cd (Doner, 1978; Weggler et al. 2004).

Metal leaching data obtained from a biosolids trenching study can be used to understand the mechanisms by which metals are transported if their forms can be elucidated using a geochemical speciation model (Allison et al., 1991). One such program, MINTEQA2, can thermodynamically, but not kinetically, predict metal speciation (Allison and Brown, 1995; Mckinley et al., 2001). The objective of this study was to employ the chemical speciation model MINTEQA2 to describe trace element species that exist in the dissolved fraction of leachate collected below two types of entrenched biosolids in order to aid in understanding the mechanism that facilitated transport.

## **MATERIALS AND METHODS**Error! Bookmark not defined.

### Site description

We obtained chemical data for the speciation model MINTEQA2 from a field study in which leachate was collected from below entrenched biosolids. The research area was established at the Iluka Resources heavy mineral mine reclamation site in Dinwiddie and Sussex Counties, Virginia in June 2006 (Daniels et al., 2003; Chapter 2). Segregation of the mixture of tailings and slimes pumped onto the mined site resulted in a study medium that was predominantly coarse-textured (96.1% sand) below the biosolids. This very coarse sand-dominated material had a pH of 6.1 and the following Mehlich I-extractable element concentrations (Donohue, 1992): P = 11 mg $kg^{-1}$, K = 15 mg $kg^{-1}$, Ca = 149 mg $kg^{-1}$, Mg = 31 mg $kg^{-1}$, Cu = 0.1 mg $kg^{-1}$, Fe = 9.9 mg $kg^{-1}$, Mn = 1.2 mg $kg^{-1}$, and Zn = 0.6 mg $kg^{-1}$**.**

### Experimental design

The data for the model was obtained from the following three treatments described in the field study (Chapter 2): control (no biosolids) and high rates (i.e. trench volume = 2250 $m^3$ $ha^{-1}$) of anaerobically digested (Source: Alexandria Sanitation Authority, Virginia) and lime-stabilized

(Source: District of Columbia Water and Sewer Authority, Washington, DC) biosolids. Excavated trenches were filled with anaerobically digested biosolids on June 26-28, 2006 and with lime-stabilized biosolids on July 10-12, 2006 with skid steer loaders. Each treatment was replicated four times and arranged in a randomized complete block design.

**Instrumentation and monitoring**

Leachate was collected in and sampled from zero tension lysimeters installed below the entrenched biosolids and the unamended control treatments in order to monitor leaching of biosolids-borne constituents. We installed the zero tension lysimeters after excavating the trenches and prior to applying biosolids.

The zero tension lysimeters were installed randomly along the length of the trench at a depth of 15 cm below each of two trenches in the biosolids treatment plots and one of the two trenches in the control treatment plots. Lysimeters were constructed by attaching and sealing, to prevent leakage, a culvert cap to the end of culvert piping measuring 25 cm in diameter and 51 cm in length. The lysimeter was filled with a 10 cm bottom layer of clean "Quikrete" play sand and topped with coarse sand from the trench. We ran Kynar tubing from the lysimeter sand reservoir to the surface to evacuate water.

**Biosolids analysis**

Three composited samples of each the anaerobically digested and the lime-stabilized biosolids were collected at the time of application and analyzed by A&L Eastern Laboratories, Inc (Richmond, VA) for total and volatile (organic matter) solids by SM2540G (APHA, 1998); total Kjeldahl N (TKN-N) by USEPA 351.3 (USEPA, 1983b); $NH_4$-N by USEPA 350.2 (USEPA, 1983a); $NO_3$-N by SM4500-NO3F (APHA, 1998); phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), aluminum (Al), manganese (Mn), cadmium (Cd), copper (Cu), lead (Pb), molybdenum (Mo), nickel (Ni), and zinc (Zn) by SW846-6010B (USEPA, 2002); arsenic (As) by SW846-7061A (USEPA, 2002); mercury (Hg) by SW846-7471A (USEPA, 2002); selenium (Se) by SW846-7741A (USEPA, 2002); silver (Ag), barium (Ba), beryllium (Be), and tin (Sn) by SW846-3051/6010B; pH by SW846-9045C (USEPA, 2002); calcium carbonate equivalent (CCE) by AOAC 955.01 (AOAC, 2000); and total organic carbon (TOC) by EPA 415.1 (USEPA, 2002). We calculated bulk density by determining the mass (dry weight at 105 °C for 72 hours) of known biosolids volume. The characteristics and loading rates for the anaerobically digested and lime-stabilized biosolids used in the study are presented in Tables 3.1 and 3.2.

**Leachate sample collection**

Samples collected once or twice a month (depending on precipitation frequency and amount), beginning August 10, 2006, were used to determine concentrations of biosolids constituents of interest. We used a vacuum pump to evacuate the entire liquid contents of the lysimeters at each sampling period. Leachate volume was determined by measuring evacuated liquid with a graduated cylinder. We measured pH of the leachate in the field using a Hanna Instrument HI 9023 pH meter. Bottled (Nalgene) samples were frozen with dry ice in the field and stored until they were thawed in the laboratory for analysis.

**Soluble metal analysis of the leachate**

We used a vacuum filtration system to filter 50 mL through a polycarbonate membrane filter with a pore size of 0.45 µm. The sample that passed through the filter contained the operationally defined dissolved metal species (Jensen and Christensen, 1999). We placed 25 mL from the filtered sample in a dilution vial for analysis and acidified it with one drop of concentrated nitric acid. The Virginia Tech Soil Testing Laboratory analyzed for Ba, Cd, Cu, Ni, Pb, and Zn by inductively coupled plasma atomic emission spectrometer (Spectro CirOS VISION ICP Model FVS12 with CETAC Autosampler Type: ASX-520HS, ICP-AES).

Spikes in metal concentrations for one or more of the metals were detected on September 8 and November 3, 2006 and on January 5, June 8, and September 7, 2007. We used the sample data from these dates to evaluate the leachate chemical composition for input into MINTEQA2 for the first 15 months after application.

**Ligand analysis**

Nitrate ($NO_3^-$)

After filtration, analysis of $NO_3^-$ was performed by a flow injection analyzer (QuickChem 8500 Lachat A85100) using the QuickChem Method 10-107-04-1-A, in which $NO_3^-$ reduced to nitrite and then coupled with N-(1-naphthyl) ethylenediamine dihydrochloride to form a magenta color. The absorbance values produced at 520 nm were proportional to $NO_3^-$ present within the leachate samples (Wendt, 1995).

Phosphate ($PO_4^{3-}$)

We determined $PO_4^{3-}$ by a flow injection analyzer (QuickChem 8500 Lachat A85100) according to QuickChem Method 10-115-01-1-A (Lachat Instruments, 1995). Under acidic conditions, $PO_4^{3-}$ reacted with ammonium molybdate and antimony potassium tartrate to form a complex that produced a blue color when reduced by ascorbic acid. The absorbance values produced at 880 nm were proportional to $PO_4^{3-}$ present within the leachate samples (Lachat Instruments, 1995).

Dissolved organic carbon (DOC) and inorganic carbon

Upon thawing of the filtered leachate, we placed 40 mL of samples within amber vials for DOC analysis. They were run in batches on a Sievers 900 Laboratory Total Organic Carbon Analyzer. The inorganic compounds ($CO_2$, $HCO_3^-$, $CO_3^{2-}$) within the sample were initially analyzed. The organic compounds were oxidized with ammonium persulfate to produce $CO_2$ giving total carbon present within the sample. The difference between the total carbon and inorganic carbon produces the DOC for each sample (GE Infrastructure, 2006). Calibration verification occurred by making samples with known amounts of carbon (2, 5, 10, 25, 50, 100 mg $L^{-1}$) from potassium hydrogen phthalate (KHP).

Chloride ($Cl^-$)

Chloride concentrations were determined by the Virginia Tech Water Quality Lab using method SM 4500 $Cl^-$ B (Clesceri et al., 1998). Samples were titrated with silver nitrate, which reacted with the $Cl^-$ to form insoluble white silver chloride. Once conversion of $Cl^-$ to silver chloride was complete, the indicator, potassium chromate, formed a red-orange precipitate, marking the end of the titration (Clesceri et al., 1998).

Sulfate ($SO_4^{2-}$)

The Virginia Tech Water Quality Lab using the SM 4500 SO42- E method (Clesceri et al., 1998) determined sulfate concentrations. When placed in an acetic acid medium, $SO_4^{2-}$ precipitated with barium chloride to form barium sulfate crystals. The turbidity created by the barium sulfate suspension was measured by spectrophotometry (Hach Company, DR/2500 Odyssey). The amount of turbidity was proportional to $SO_4^{2-}$ concentration (Clesceri et al., 1998).

## MINTEQA2

MINTEQA2 predicts metal species by entering concentration of free ions and neutral or charged complexes present within the system. A database containing over 1400 reaction products for the various components along with a thermodynamic database is automatically accessed to determine which species are likely to occur under given conditions. MINTEQA2 calculates equilibrium component activities with the Davies equation to describe the influence of ionic strength on actual concentrations entered by the user. Saturation indices are calculated to determine if solids will precipitate under the given conditions (Allison and Brown, 1995). Dissolved organic carbon can be entered as a component through various models such as the Stockholm Humic Model (SHM). This model uses the Basic Stern Model (BSM) to correct equilibrium constant for electrostatics and assumes that only fulvic acid can be dissolved in soil soil. Unlike the other DOC models present within MINTEQA2, SHM allows DOC to bind as monodentate or bidentate complexes and does not put a restriction on the number of these bond types. Gustafsson and van Schaik (2003) found that bidentate complexes are more common on dissolved fulvic acid.

For this experiment, the inputs were $Ba^{2+}$, $Cd^{2+}$, $Cu^{2+}$, $Ni^{2+}$, $Pb^{2+}$, $Zn^{2+}$, pH, $NO_3^-$, $PO_4^{3-}$, $HCO_3^-$, DOC, $Cl^-$, $SO_4^{2-}$, $Al^{3+}$, $Fe^{3+}$, $Mn^{3+}$, $Ca^{2+}$, and $Mg^{2+}$ (Tables 3.3a and 3.3b). During the first 6 months, Cd and Pb concentrations were consistently below the ICP-AES detection limit; thus, we analyzed leachate every 4-5 months for the rest of the sampling period resulting in no analyzed data for Cd and Pb on June 8, 2007. Iron and manganese were assumed to be present as oxidizes due to the constantly high levels of dissolved oxygen present within the system (Appendix Tables 5.4 and 5.5) (Stumm and Morgan, 1970; Vance, 1994). We entered the measurements for inorganic carbon as $HCO_3^-$ due to a $pK_a$ value for the conversion of $HCO_3^-$ to $CO_3^{2-}$ being around 10.3; therefore, when pH is below this value $HCO_3^{2-}$ is the dominant inorganic species for this reaction (Stumm and Morgan, 1970). Our pH values were routinely below 10.3 (Tables 3.3a and 3.3b).

The leachate was not analyzed for the specific components (i.e. humic and fulvic acids) of DOC; therefore, DOC was assumed to be 100% fulvic acid. The carboxyl and phenolic groups present within fulvic acids will readily complex with metals (Kiekens, 1995). Fulvic acids are soluble over the entire pH range, whereas humic acids are insoluble in acids and will gradually begin to dissolve as pH increases, especially at pH above 10 (Yates and von

Wandruszka, 1999). The pH values of the leachate in our study were initially mildly basic and became neutral to slightly acidic with time (Table 3.3a). Esteves da Silva and Oliveira (2002) found fulvic acids from composted sewage sludge forming stable complexes with Cu (II), Pb (II), and Cd (II) at pH values similar to the range in our research.

## RESULTS AND DISCUSSION

The metals for which MINTEQA2 was used included the current Part 503 priority pollutants Cd, Cu, Ni, Pb, and Zn and the non-Part 503 Rule metal, Ba. Cadmium and Pb were rarely above the detection level, but Cu, Ni and Zn were found routinely. The relatively high concentrations and frequency of Ba detection during the first year of sampling (Table 3.3b) recommended its inclusion in the model. The other emerging metals of interest (CSC, 2007) were not included in the model because either they were not found at detectable concentrations in the biosolids (i.e. Be) or they were never or rarely detected in the lysimeter leachate (i.e. Ag, Sn).

### Properties affecting metal speciation

Changes in pH influence charges on reaction sites of various ligands, which bind metals and facilitate transport. The pH values became more acidic (Tables 3.3a) over the 15-month sampling period. On September 7, 2007, pH values were similar, 5.84 for leachate from the anaerobically digested biosolids and 5.85 from the lime-stabilized biosolids. During the first two months, September and November 2006, leachate from the lime-stabilized biosolids had higher values whereas during the next two months, January and June 2007, leachate from the anaerobically digested biosolids had higher values. For all sampling periods, the control had higher pH values than the biosolids treatments. The difference may be due to production of organic acids or nitrification within the biosolids seams (Forste, 1996; Evanylo et al., 2008)

Several ligands ($Cl^-$, $SO_4^{2-}$, $NO_3^-$, $HCO_3^-$, and $PO_4^{3-}$) can bind metals and facilitate transport from entrenched biosolids. Higher inorganic ligand concentrations will provide more reaction sites for metals to bind. For every sampling date, $Cl^-$ concentrations were highest in the leachate from the control plots (Table 3.3a). On September 8, 2006 $Cl^-$ concentrations were highest for all treatments. In general, $SO_4^{2-}$ concentrations decreased with time and except for September 8, 2006, the leachate from the controls contained the highest concentrations (Table 3.3a). Between the biosolids treatments, the leachate from the anaerobically digested biosolids contained elevated $SO_4^{2-}$ concentrations from September 2006 to January 2007 whereas the leachate from the lime-stabilized biosolids contained higher concentrations from June to September 2007. Nitrate concentrations were largest within the leachate from the lime-stabilized biosolids with no particular trend occurring over time for all treatments (Table 3.3a). Concentrations from the anaerobically digested biosolids were low until June 2007. Bicarbonate was present within all of the leachate samples to varying degrees; however, on January 5, 2007 the lime-stabilized biosolids leached the highest concentration (2791.110 mg $L^{-1}$) (Table 3.3a). For all treatments and over time, $PO_4^{3-}$ concentrations were low (Table 3.3a).

**Cadmium**

Predicted Cd speciation changed with time as leachate chemistry changed (Table3.4). Initially, Cd in the control was predicted to be associated 45% with fulvic acid (FA), 45% as the free ion, 7% with $SO_4^{2-}$, and < 2% with the inorganic ligands while leachate from the anaerobically digested biosolids produced similar results as the control. The leachate from the lime-stabilized biosolids was predicted to contain Cd that was mostly associated with FA followed by its presence as free ions. Eventually, a majority of the Cd became free ions with reduced association with FA in all treatments. By the final sampling date, the ionic species comprised a greater proportion in both biosolids treatment. During this final sampling period, pH values were similar (Table 3.3a); however, the DOC within the leachate from the lime-stabilized biosolids was double, 14.6 mg $L^{-1}$ compared to 7.4 mg $L^{-1}$, that from the anaerobically digested biosolids. The higher concentrations within the leachate of the lime-stabilized biosolids may have contributed to the higher association Cd had with fulvic acids.

**Copper**

Predicted Cu showed little variation in species distribution over time and among treatments (Table 3.5). Leachate collected from the control and each of the biosolids types contained Cu that was over 98% associated with FA. Copper has a strong association with soluble organic matter over a wide pH range (Kabata-Pendias and Pendias, 2001).

**Nickel**

Nickel was predicted to be mostly free ions in leachate collected from control and biosolids treatments (Table 3.6). Nickel in the control treatment leachate was initially 66% as $Ni^{2+}$, 21% associated with FA, 9% with $SO_4^{2-}$, and < 2% associated with other inorganic ions. Ions such as $Al^{3+}$, $Fe^{3+}$, $Mn^{3+}$, $Ca^{2+}$ and $Mg^{2+}$ (Table 3.3a) may outcompete Ni for sorption sites resulting in the majority of Ni to be predicted as free ions. On September 8, 2006, the DOC within the leachate from the lime-stabilized biosolids was present in the largest concentration (47.511 mg $L^{-1}$) (Table 3.3a) and may have increased the formation of Ni-FA species. The increased $HCO_3^-$ concentration (2791.110 mg $L^{-1}$) (Table 3.3a) from the lime-stabilized biosolids' leachate may have caused the decrease in $Ni^{2+}$ and Ni-FA complexes and increase in $NiHCO_3^+$ (Table 3.6).

**Lead**

Similar to Cu, Pb was predicted to be largely (>75%) associated with the FA fraction of the DOC for all treatments (Table 3.7). By the last sampling period, a portion of the Pb in the anaerobically digested (~21%) and lime-stabilized (~15%) biosolids had existed as $Pb^{2+}$. The leachate pH values at this sampling period were lower than during previous sampling periods (Table 3.3a), which may account for the lower fractions associated with FA. The differences between the leachate from the anaerobically digested (76%) and lime-stabilized (83%) biosolids may be due to variations in DOC concentrations. Jensen and Christensen (1999) used MINTEQA2 to speciate landfill leachate and found Pb was predicted to be mostly associated with the organic fraction. On January 5, 2007, only 33% of the Pb within the leachate from the lime-stabilized biosolids was predicted to form Pb-FA complexes. The high $HCO_3^-$ concentration (2791.110 mg $L^{-1}$) (Table 3.3a) on this date caused an increase in the fractions of Pb associated with $CO_3^{2-}$ and $HCO_3^-$ (Table 3.7).

**Zinc**

Zinc exhibited the most diverse predicted association with ligands of the metals studied (Table 3.8). Initially, 50% of the Zn was associated with FA, 32% as $Zn^{2+}$, 5% as $ZnSO_4$ (aq), 9% as $Zn(OH)_2$ (aq), 4% as $ZnOH^+$, and < 2% associating with other inorganic ligands in the control treatment. Over time, much of the FA-Zn converted to other species involving inorganic ligands such as $SO_4^{2-}$, $HCO_3^-$, $NO_3^+$, and $Cl^-$ or were predicted as free ions. Twelve to fifteen months after biosolids incorporation, the free ions comprised 91-93% of the Zn from the anaerobically digested and 87-90% of the Zn from the lime-stabilized biosolids. The $Al^{3+}$, $Fe^{3+}$, and $Mn^{3+}$ possibly present on the organic functional groups and $Ca^{2+}$ and $Mg^{2+}$ on inorganic ligands (Table 3.3a) may be preventing the sorption of Zn and causing more free ions to be present within the leachate (Table 3.8).

The least amount of Zn association with FA (5%) for the leachate from the anaerobically digested biosolids occurred on September 7, 2007. The leachate sampled on this date had the overall lowest pH (Table 3.3a), which may have resulted in decreased complexation between functional groups on fulvic acid and positively charged free ions (Table 3.8). On September 7, 2007, the differences between the leachate from the anaerobically digested and lime-stabilized biosolids may be attributed to variations in DOC concentrations, as the pH values were very similar (Table 3.3a). Due to the high $HCO_3^-$ concentration within the lime-stabilized biosolids' leachate on January 5, 2007, MINTEQA2 predicts zinc's association with $CO_3^{2-}$ and $HCO_3^-$ would increase (Table 3.8). These associations were the highest among all of the inorganic-Zn species.

### Barium

Barium exhibited similarities to Zn in the distribution of chemical species with time (Table 3.9). Barium in the control treatment leachate was initially 91% as $Ba^{2+}$, 0.3% FA-complexed, 8% as $BaSO_4$ (aq), and < 0.1% as complexes with inorganic anions. By the second sampling period and through the final sampling period, over 90% of the Ba was predicted to be present as free ions with the exception of the leachate from the lime-stabilized biosolids on January 5, 2007. On this date, free ions decreased to 81% with MINTEQA2 predicting the Ba was now associated with $HCO_3^-$ (Table 3.9).

The FA-complexed Ba in the leachate from the anaerobically digested and lime-stabilized biosolids decreased to 0.20-0.24% and 0.23-0.26%, respectively by the June and September 2007 sampling periods. The predominant forms of non FA-complexed Ba during these periods were as free ions or bound with inorganic anions. Like the previous metals, the portions of Ba complexed with FA were largely a function of the amount of DOC and pH during these periods (Table 3.3a and 3.9).

## CONCLUSION

Depending on the environment within the anaerobically digested and lime-stabilized biosolids seams (i.e. pH and DOC), the metal speciation within the leachate could also change causing a concern about bioavailability (Tables 3.4-3.9). Free ions, the predicted dominant fraction for Ba, Cd, Ni, and Zn, increased over time as pH decreased, and/or as fulvic acid species decreased. Copper's high affinity for organic matter and lack of affinity for inorganic ligands allowed most of the metal to be predicted as Cu-FA species. Like Cu, Pb has a high affinity for organic matter (i.e. FA). After biosolids entrenchment persisted, monitoring of leachate characteristics would help determine if free ion concentrations would become a concern for the groundwater.

The MINTEQA2 model speciation calculations for Cd, Cu, Ni, Pb, Zn, and Ba (Tables 3.4-3.9) predicted that, for all metals other than Cu, Ni, and Pb, the amount of metal associated with the fulvic acid decreased with a decrease in pH. For the cases when leachate pH values were similar between biosolids treatments, a higher proportion of metal was associated with FA in the biosolids treatment (viz. lime-stabilized) containing the highest concentration of DOC. Fulvic acids within the DOC would help facilitate metal movement, as metals will complex with the various numbers of carboxyl and phenolic functional groups.

Metal movement can increase when associated with increased $SO_4^{2-}$, $Cl^-$, $NO_3^-$, $HCO_3^-$, and $PO_4^{3-}$ solution levels. As the association with free ions increased the amount of inorganic ligands, binding metals also increased. A neutral or positive charge was present on the various species indicating they may have been repelled by the positively charged sites on the biosolids. Every metal was predicted to complex with $SO_4^{2-}$ to some extent. Over time, Cd had the most association with $Cl^-$ (Table 3.4). With the exception of Cu, metal species involving $NO_3^-$ increased as pH decreased and free ions increased. Copper, Pb, and Zn (Tables 3.5, 3.7, and 3.8) were the only metals bound with $OH^-$ found in the biosolids' leachate. When $HCO_3^-$ concentrations were highest (i.e. from the lime-stabilized biosolids' leachate on January 5, 2007), the fraction of predicted species involving $HCO_3^-$ and $CO_3^-$ also increased.

Metal speciation within leachate is very important as it can give some indication about how a metal may influence its surrounding environment. Some species such as the free ions are bioavailable and taken up by plants. Scientists are still unsure about the long-term impact of organically complexed species on the food chain. Little research has been conducted on speciation within leachate from biosolids and more information is needed to reach a better understanding of the metal species that are transported in soil solution. Continued research on actual speciation instead of using a predication model would be beneficial.

## REFERENCES

AOAC (Association of Official Analytical Chemists). 2000. Agricultural liming materials. In P.F. Kane (ed.) AOAC Methods. Association of Official Analytical Chemists. Washington, DC.

APHA. 1998. Standard methods for the examination of water and wastewater. 20th edition, Am. Public Health Assoc., Am. Water Works Assoc., and Water Environment Federation. Washington, DC.

Al-Wabel, M.A., D.M. Heil, D.G. Westfall, and K.A. Barbarick. 2002. Solution Chemistry Influence on Metal Mobility in Biosolids-Amended Soils. J. Environ. Qual. 31:1157-1165.

Allison, J.D. and D.S. Brown. 1995. MINTEQA2/PRODEFA2 – A Geochemical Speciation Model and Interactive Preprocessor. p. 241-252. *In* R.H. Loeppert, A.P. Schwab, and S. Goldberg (ed.) Chemical Equilibrium and Reaction Models, SSSA Spec. Publ. 42. SSSA, Madison, WI.

Allison, J.D., D.S. Brown, and K.J. Novo-Gradac. 1991. MINTEQA2/PRODEFA2: a Geochemical assessment Model for Environmental Systems: Version 3.0 User's Manual. U.S. Environmental Protection Agency. EPA-600/3-91-021.

Brown, G.E., Jr. and G.A. Parks. 2001. Sorption of trace elements on mineral surfaces: Modern perspectives from spectroscopic studies, and comments on sorption in the marine environment. Int. Geol. Rev. 43:963-1073.

Camobreco, V.J., B.K. Richards, T.S. Steenhuis, J.H. Peverly, M.B. McBride. 1996. Movement of Heavy Metals Through Undisturbed and Homogenized Soil Columns. Soil Sci. 161(11):740-750.

Clesceri, L.S., A.E. Greenberg, and A.D. Eaton (Eds.). 1998. Standard Methods for the Examination of Water and Wastewater, 20$^{th}$ Ed. APHA, Washington D.C.

CSC: Environmental Solutions. 2007. CSC's Sampling and Analysis Report for the 2006-2007 Targeted National Sewage Sludge Survey. GSA Task Order GS-10F-0135K.

Daniels W.L., P.D. Schroedoer, S.M. Nagle, L.W. Zelazny, and M.M. Alley. 2003. Reclamation of Prime Farmland and Following Mineral Sands Mining in Virginia. Min Eng-Littleton. 42-48.

Donohue, S.J. 1992. Reference soil and media diagnostic procedures for the southern region of the United States. Southern Coop. Serv. Bull. 374. Virginia Tech, Blacksburg, VA.

Doner, H.E. 1978. Chloride as a factor in mobilities of Ni (ii), Cu (ii), and Cd (ii) in soil. Soil Sci. Soc. Am. J. 42:882-885.

Emmerich, W.E., L.J. Lund, A.L. Page, and A.C. Chang. 1982. Solid Phase Forms of Heavy Metals in Sewage Sludge-Treated Soils. J. Environ. Qual. 11:178-181.

ERCO, Inc. 2000. Beneficial reuse tree farm: Annual Report. Report to MDE pursuant

To permit requirements. ERCO, Inc., Glen Burnie, MD 21061.

Esteves da Silva, J.C.G. and C.J.A. Oliveira. 2002. Metal ion complexation properties of fulvic acids extracted from composted sewage sludge as compared to a soil fulvic acid. Wat. Res. 36: 3404-3409.

Evanylo, G., K. Kostyanovsky, K. Lasley, B. Sukkariyah, and C. Shang. 2008. Environmental effects of biosolids trenching for reclaiming mined land for hybrid poplar production. p. 255-276. Proceedings of the 2008 Biosolids and Residual Specialty Conference. Philadelphia, PA. March 30-April 2.

Forste, J.B. 1996. Land Application. p. 389-448. In M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. M.J. Marcel Dekker, Inc.: New York.

GE Infrastructure Water and Process Technologies Analytical Instruments. 2006. Sievers 900 Laboratory Total Carbon Analyzer: Operation and Maintenance Manual: Firmware Version 1.22 or later. DLM 902111 Rev. A. United States.

Girovich, M.J. 1996. Biosolids Characterization, Treatment and Use: An Overview. *In* M.J. Girovich (ed.) Biosolids Treatment and Management: Processes for Beneficial Use. Marcel Dekker, Inc.: New York.

Gustafsson, J.P. and J.W.J. van Schaik. 2003. Cation binding in a mor layer: batch experiments and modeling. Eur J Soil Sci. 54: 295-310.

Japenga, J., J.W. Dalenberg, D. Wiersma, S.D. Scheltens, D. Hesterberg, and W. Salomons. 1992. Effect of liquid animal manure application on the solubilization of heavy metals from soil. Inter. J. Environ. Anal. Chem., 46:25-39.

Jensen, D.L. and T.H. Christensen. 1999. Colloidal and Dissolved Metals in Leachates from Four Danish Landfills. Wat. Res. 33:2139-2147.

Kabata-Pendias, A. and H. Pendias. 2001. Trace Elements in Soils and Plants. 3rd ed. CRC Press LLC, Boca Raton, Florida.

Kiekens, L. 1995. Zinc. *In* B.J. Alloway (ed.) Heavy Metals in Soils. B.J. Blackie Academic & Professional: London.

Lachat Instruments. 1995. QuickChem Method 10-115-01-1-A. Lachat Instruments, 6645 West Mill Road, Milwaukee, WI 53218.

McBride, M.B. 1994. Environmental chemistry of soils. Oxford Univ. Press, New York.

McBride, M.B., B.K. Richards, T. Steenhuis, J.J. Russo, and S. Sauve′. 1997. Mobility and solubility of toxic metals and nutrients in soil fifteen years after sludge application. Soil Sci. 162:487-500.

McBride, M.B. 1998. Soluble trace metals in alkaline stabilized sludge products. J. Environ. Qual. 27:578-584.

Mckinley, J.D., H.R. Thomas, K.P. Williams, and J.M. Reid. Chemical analysis of contaminated soil strengthened by the addition of lime. Eng. Geol. 60:181-192.

McLean, J.E. and B.E. Bledsoe. 1992. EPA Ground Water Issue: Behavior of Metals in Soils. EPA/540/S-92/018.

Sikora, L.J., N.H. Frankos, C.M. Murrary, and J.M. Walker. 1979. Effects of trenching undigested lime-stabilized sludge. J. Water Pollut. Control Federation 51:1841-1849.

Sikora, L.J., N.H. Frankos, C.M. Murray, and J.M. Walker. 1980. Trenching of digested sludge. The Journal of the Environmental Engineering Division. Proceedings of the ASCE. 106:351-361.

Sparks, D.L. 2001. Elucidating the fundamental chemistry of soils: Past and recent achievements and future frontiers. Geoderma 100:313-319.

Sposito, G. 1986. Sorption of trace metals by humic materials in soils and natural waters. Crit. Rev. Environ. Control 16:193-229.

Stevenson, F.J., and M.S. Ardakani. 1972. Organic matter reactions involving micronutrients in soils. *In* J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (ed.) Micronutrients in agriculture. SSSA, Madison, Wis.

Stumm, W. and J. Morgan. 1970. Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters. Wiley-Interscience, New York.

Taylor, J.M., E. Epstein, W.D. Burge, R.L. Chaney, J.D. Menzies, and L.J. Sikora. 1978. Chemical and Biological Phenomena Observed with Sewage Sludges in Simulated Soil Trenches. J. Environ. Qual. 7:477-482.

USEPA. 1983a. Test method 350.2 Nitrogen, ammonia (colorimetric; titrimetric; potentiometric- distillation procedure). In Methods for the chemical analysis of water and wastes (MCAWW). EPA/600/4-79/020. NTIS Item PB84-128677. Environ. Monitoring and Support Lab., Office of Res. And Dev., USEPA, Cincinnati, OH.

USEPA. 1983b. EPA Test method 351.3 Nitrogen, Kjeldahl total (colorimetric; titrimetric; potentiometric). In Methods for the chemical analysis of water and wastes (MCAWW). EPA/600/4-79/020. NTIS Item PB84-128677. Environ. Monitoring and Support Lab., Office of Res. and Dev., USEPA, Cincinnati, OH.

USEPA. 1993. Standards for the use and disposal of sewage sludge. 40 CFR, Part 503. Fed. Regist. 58:13-15. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2000. Biosolids Technology Fact Sheet: Land Application of Biosolids. USEPA Rep. 832-F-00-064. U.S. Gov. Print. Office, Washington, DC.

USEPA. 2002. Test methods for evaluating solid waste, physical/chemical methods SW-846 manual. U.S. Gov. Print. Office, Washington, DC. Available at www.epa.gov/epaoswer/hazwaste/test/sw846.htm.

USEPA. 2007. Frequently Asked Questions: Biosolids. U.S. Gov. Print. Office, Washington, DC.

Vance, D. 1994. Iron - The Environmental Impact Of A Universal Element. National Environmental Technology. 4:24-25. Available at http://2the4.net/iron.htm.

Weggler, K., M.J. McLaughlin, and R.D. Graham. 2004. Effect of chloride in soil solution on the plant availability of biosolids-borne cadmium. J. Environ. Qual.33:406-504.

Wendt, K. 1995. QuickChem Method 10-107-04-1-A. Lachat Instruments, 6645 West Mill Road, Milwaukee, WI 53218.

Woodbury, P.B. 2005. Municipal solid waste composting: potential effects of heavy metals in municipal solid waste composts on plants, Munic. Solid Waste Composting Fact Sheet 4. Boyce Thompson Institute for Plant Research at Cornell Univ.

Yates, L.M. and R. von Wandruszka. 1999. Effects of pH and Metals on the Surface Tension of Aqueous Humic Materials. Soil Sci. Soc. Am. J. 63:1645-1649.

## TABLES

Table 3.1: Chemical and physical analysis of anaerobically digested and lime-stabilized biosolids entrenched in 2006.

| Biosolids property | Anaerobically Digested Biosolids | Lime-stabilized Biosolids |
|---|---|---|
| | Concentration, mg $kg^{-1}$ (except moisture content) | Concentration, mg $kg^{-1}$ (except moisture content) |
| Moisture content, mg $g^{-1}$ | 727 | 685 |
| Total Ag | 23 | 10 |
| Total Al | 24,700 | 3,893 |
| Total As | 3.1 | 1.7 |
| Total Ba | 442 | 195 |
| Total Be | <5 | <5 |
| Total Cd | 2.3 | 2.0 |
| Total Cu | 328 | 197 |
| Total Fe | 43,000 | 34,333 |
| Total Hg | 1.9 | 0.7 |
| Total Mn | 1,021 | 216 |
| Total Mo | 9 | 11 |
| Total Ni | 27 | 16 |
| Total Pb | 66 | 53 |
| Total Se | 5.3 | 2.1 |
| Total Sn | 27 | 17 |
| Total Zn | 1,473 | 490 |
| N, total Kjeldahl | 53,133 | 44,533 |
| N, $NH_3^+$ $NH_4^+$ | 12,900 | 1,967 |
| N, organic | 40,233 | 42,567 |
| N, $NO_2^-$ + $NO_3^-$ | 8 | 15 |
| Total P | 26,533 | 8,667 |
| Total K | 933 | 1,367 |
| Total S | 7,033 | 6,367 |
| Total Ca | 23,467 | 114,533 |
| Total Mg | 2,900 | 2,233 |
| Total Na | 367 | 200 |
| pH | 8.5 | 12.3 |
| Calcium carbonate equivalent, CCE | 5,700 | 176,200 |
| Organic matter | 604,366 | 601,600 |

Table 3.2: Total loading rates on a dry weight basis (kg $ha^{-1}$) for anaerobically digested and lime-stabilized biosolids with trench width of 0.90 m.

| Biosolids Property | Anaerobically Digested Biosolids | Lime-stabilized Biosolids |
|---|---|---|
| Application Rate | 426,000 | 656,000 |
| Total Ag | 9.8 | 6.6 |
| Total Al | 10,507 | 2,556 |
| Total As | 1.3 | 1.1 |
| Total Ba | 188 | 128 |
| Total Cd | 1.0 | 0.9 |
| Total Cu | 139 | 129 |
| Total Fe | 18,290 | 22,521 |
| Total Hg | 0.8 | 0.5 |
| Total Mn | 434 | 142 |
| Total Mo | 5.4 | 7.4 |
| Total Ni | 11.5 | 10.5 |
| Total Pb | 28 | 35 |
| Total Se | 2.2 | 1.4 |
| Total Sn | 11 | 11 |
| Total Zn | 627 | 322 |
| N, total Kjeldahl | 22,601 | 29,212 |
| N, $NH_3 + NH_4^+$ | 5,487 | 1,290 |
| N, organic | 17,114 | 27,922 |
| N, $NO_2^- + NO_3^-$ | 3.0 | 10 |
| Total P | 11,286 | 5,685 |
| Total K | 397 | 896 |
| Organic Matter | 257,078 | 394,621 |

Table 3.3a: MINTEQA2 inputs for speciation analysis of leachate collected below entrenched anaerobically digested and lime-stabilized biosolids.

| Sampling Date | Treatment | pH | DOC | $Cl^-$ | $SO_4^{2-}$ | $NO_3^-$ | $PO_4^{3-}$ | $HCO_3^-$ | Al | Fe | Mn | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 8.26 | 8.428 | 22.000 | 182.500 | 11.740 | 0.040 | 9.620 | 0.002 | 0.004 | 0.008 | 84.294 | 22.966 |
| | Anaerobically Digested Biosolids | 7.69 | 15.867 | 21.286 | 243.571 | 0.276 | 0.015 | 48.469 | 0.002 | 0.080 | 0.565 | 80.383 | 32.923 |
| | Lime Stabilized Biosolids | 7.80 | 47.511 | 27.125 | 220.500 | 129.447 | 0.041 | 24.026 | 0.003 | 0.247 | 0.198 | 50.525 | 23.955 |
| 3-Nov-06 | Control | 7.680 | 6.659 | 19.550 | 235.780 | 46.000 | 0.003 | 10.924 | 0.002 | 0.004 | 0.004 | 121.103 | 29.926 |
| | Anaerobically Digested Biosolids | 7.60 | 14.673 | 14.050 | 186.780 | 5.510 | 0.141 | 58.699 | 0.002 | 0.014 | 0.308 | 60.424 | 29.985 |
| | Lime Stabilized Biosolids | 7.79 | 5.324 | 14.657 | 131.637 | 58.526 | 0.152 | 54.039 | 0.002 | 0.303 | 0.091 | 27.159 | 19.189 |
| 5-Jan-07 | Control | 7.39 | 6.705 | 16.000 | 192.665 | 4.752 | 0.005 | 9.099 | 0.002 | 0.014 | 0.004 | 95.198 | 24.737 |
| | Anaerobically Digested Biosolids | 7.04 | 6.851 | 13.875 | 109.915 | 2.582 | 0.001 | 33.053 | 0.002 | 0.004 | 0.128 | 31.238 | 17.204 |
| | Lime Stabilized Biosolids | 6.82 | 13.047 | 12.714 | 74.629 | 37.662 | 0.086 | 2791.110 | 0.002 | 0.230 | 0.150 | 24.060 | 14.275 |
| 8-Jun-07 | Control | 6.82 | 10.836 | 14.000 | 128.680 | 7.943 | 0.011 | 7.908 | 0.003 | 0.004 | 0.003 | 110.925 | 23.817 |
| | Anaerobically Digested Biosolids | 6.00 | 6.644 | 11.125 | 32.430 | 87.543 | 0.003 | 12.651 | 0.085 | 0.004 | 0.496 | 75.420 | 23.511 |
| | Lime Stabilized Biosolids | 5.69 | 8.914 | 11.714 | 65.501 | 136.612 | 0.003 | 6.017 | 3.252 | 0.020 | 0.474 | 101.423 | 23.570 |
| 7-Sep-07 | Control | 6.86 | 9.115 | 22.000 | 227.940 | 42.011 | 0.011 | 14.021 | 0.002 | 0.001 | 0.013 | 125.110 | 20.639 |
| | Anaerobically Digested Biosolids | 5.84 | 7.379 | 12.250 | 27.565 | 59.384 | 0.011 | 25.465 | 1.493 | 0.011 | 1.102 | 99.722 | 30.725 |
| | Lime Stabilized Biosolids | 5.85 | 14.645 | 13.400 | 88.940 | 163.642 | 0.069 | 12.737 | 1.013 | 0.034 | 1.936 | 200.499 | 32.237 |

*** Samples not analyzed for these metals during this sampling period.

† Units = mg $L^{-1}$

Table 3.3b: MINTEQA2 inputs for speciation analysis of leachate collected below entrenched anaerobically digested and lime-stabilized biosolids.

| Sampling Date | Treatment | Ba | Cd | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0.009 | 0.004 | 0.032 | 0.027 | 0.016 | 0.015 |
| | Anaerobically Digested Biosolids | 0.024 | 0.004 | 0.037 | 0.022 | 0.016 | 0.050 |
| | Lime Stabilized Biosolids | 0.037 | 0.004 | 0.279 | 0.040 | 0.016 | 0.097 |
| 3-Nov-06 | Control | 0.011 | 0.004 | 0.006 | 0.008 | 0.016 | 0.002 |
| | Anaerobically Digested Biosolids | 0.021 | 0.004 | 0.010 | 0.011 | 0.016 | 0.008 |
| | Lime Stabilized Biosolids | 0.021 | 0.004 | 0.010 | 0.016 | 0.016 | 0.016 |
| 5-Jan-07 | Control | 0.009 | 0.004 | 0.036 | 0.008 | 0.016 | 0.021 |
| | Anaerobically Digested Biosolids | 0.014 | 0.004 | 0.077 | 0.008 | 0.016 | 0.044 |
| | Lime Stabilized Biosolids | 0.031 | 0.004 | 0.344 | 0.016 | 0.016 | 0.059 |
| 8-Jun-07 | Control | 0.018 | *** | 0.006 | 0.008 | *** | 0.007 |
| | Anaerobically Digested Biosolids | 0.096 | *** | 0.006 | 0.007 | *** | 0.114 |
| | Lime Stabilized Biosolids | 0.176 | *** | 0.014 | 0.011 | *** | 0.266 |
| 7-Sep-07 | Control | 0.048 | 0.004 | 0.006 | 0.008 | 0.016 | 0.002 |
| | Anaerobically Digested Biosolids | 0.323 | 0.004 | 0.008 | 0.010 | 0.016 | 0.452 |
| | Lime Stabilized Biosolids | 0.199 | 0.003 | 0.013 | 0.024 | 0.016 | 0.423 |

*** Samples not analyzed for these metals during this sampling period.

† Units = mg $L^{-1}$

Table 3.4: Comparisons of the fractions of Cd species in leachate collected below the control and biosolids treatments.

| Sampling Date | Treatment | $Cd^{+2}$ | Fulvic Acid-Cd | $CdSO_4$ (aq) | $Cd(SO_4)_2^{-2}$ | $CdCO_3$ (aq) | $Cd(CO_3)_2^{-2}$ | $CdHCO_3^+$ | $CdNO_3^+$ | $CdCl^+$ | $CdOH^+$ | $CdHPO_4$ (aq) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0.4467 | 0.4469 | 0.0724 | 0.0015 | 0.0081 | 0 | 0.0014 | 0.0002 | 0.0178 | 0.0049 | 0 |
| | Anaerobically Digested Biosolids | 0.4313 | 0.4436 | 0.0884 | 0.0024 | 0.0102 | 0 | 0.0067 | 0 | 0.0162 | 0.0012 | 0 |
| | Lime Stabilized Biosolids | 0.2664 | 0.6551 | 0.0554 | 0.0015 | 0.0042 | 0 | 0.0021 | 0.0012 | 0.0130 | 0.0010 | 0 |
| 3-Nov-06 | Control | 0.5024 | 0.3820 | 0.0901 | 0.0023 | 0.0025 | 0 | 0.0017 | 0.0008 | 0.0169 | 0.0014 | 0 |
| | Anaerobically Digested Biosolids | 0.2534 | 0.6839 | 0.0436 | 0.0009 | 0.0061 | 0 | 0.0049 | 0 | 0.0065 | 0.0006 | 0 |
| | Lime Stabilized Biosolids | 0.5032 | 0.3762 | 0.0733 | 0.0012 | 0.0190 | 0 | 0.0097 | 0.0011 | 0.0142 | 0.0019 | 0.0001 |
| 5-Jan-07 | Control | 0.7315 | 0.1199 | 0.1201 | 0.0025 | 0.0016 | 0 | 0.0021 | 0.0001 | 0.0210 | 0.0011 | 0 |
| | Anaerobically Digested Biosolids | 0.7616 | 0.1083 | 0.0965 | 0.0013 | 0.0028 | 0 | 0.0080 | 0 | 0.0209 | 0.0005 | 0 |
| | Lime Stabilized Biosolids | 0.4811 | 0.1185 | 0.0263 | 0.0003 | 0.0599 | 0.0007 | 0.3030 | 0.0005 | 0.0093 | 0.0002 | 0.0003 |
| 8-Jun-07 | Control | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| | Anaerobically Digested Biosolids | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| | Lime Stabilized Biosolids | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 7-Sep-07 | Control | 0.6281 | 0.2292 | 0.1120 | 0.0027 | 0.0005 | 0 | 0.0023 | 0.0009 | 0.0240 | 0.0003 | 0 |
| | Anaerobically Digested Biosolids | 0.8895 | 0.0664 | 0.0203 | 0 | 0 | 0 | 0.0020 | 0.0018 | 0.0199 | 0 | 0 |
| | Lime Stabilized Biosolids | 0.8409 | 0.0890 | 0.0459 | 0.0004 | 0 | 0 | 0.0009 | 0.0043 | 0.0184 | 0 | 0 |

*** denotes date when leachate was not analyzed for Cd.

Table 3.5: Comparisons of the fractions of Cu species in leachate collected below the control and biosolids treatments.

| Sampling Date | Treatment | $Cu^{+2}$ | Fulvic Acid-Cu | $CuSO_4$ (aq) | $CuCO_3$ (aq) | $Cu(CO_3)_2^{-2}$ | $CuHCO_3^+$ | $CuOH^+$ |
|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0 | 0.9994 | 0 | 0.0002 | 0 | 0 | 0.0002 |
| | Anaerobically Digested Biosolids | 0 | 0.9992 | 0 | 0.0006 | 0 | 0 | 0.0001 |
| | Lime Stabilized Biosolids | 0 | 0.9997 | 0 | 0.0002 | 0 | 0 | 0 |
| 3-Nov-06 | Control | 0 | 0.9997 | 0 | 0.0001 | 0 | 0 | 0.0001 |
| | Anaerobically Digested Biosolids | 0 | 0.9998 | 0 | 0.0002 | 0 | 0 | 0 |
| | Lime Stabilized Biosolids | 0.0001 | 0.9985 | 0 | 0.0011 | 0 | 0 | 0.0002 |
| 5-Jan-07 | Control | 0.0012 | 0.9972 | 0.0002 | 0.0007 | 0 | 0 | 0.0007 |
| | Anaerobically Digested Biosolids | 0.0064 | 0.9849 | 0.0008 | 0.0060 | 0 | 0.0001 | 0.0018 |
| | Lime Stabilized Biosolids | 0.0082 | 0.7118 | 0.0004 | 0.2566 | 0.0116 | 0.0103 | 0.0011 |
| 8-Jun-07 | Control | 0.0002 | 0.9997 | 0 | 0 | 0 | 0 | 0 |
| | Anaerobically Digested Biosolids | 0.0050 | 0.9946 | 0.0002 | 0 | 0 | 0 | 0.0001 |
| | Lime Stabilized Biosolids | 0.0145 | 0.9844 | 0.0008 | 0 | 0 | 0 | 0.0002 |
| 7-Sep-07 | Control | 0.0004 | 0.9994 | 0 | 0 | 0 | 0 | 0 |
| | Anaerobically Digested Biosolids | 0.0114 | 0.9879 | 0.0003 | 0.0001 | 0 | 0 | 0.0002 |
| | Lime Stabilized Biosolids | 0.0061 | 0.9934 | 0.0003 | 0 | 0 | 0 | 0 |

Table 3.6: Comparisons of the fractions of Ni species in leachate collected below the control and biosolids treatments.

| Sampling Date | Treatment | $Ni^{+2}$ | Fulvic Acid-Ni | $NiSO_4$ (aq) | $NiCO_3$ (aq) | $NiHCO_3^+$ | $NiNO_3^+$ | $NiCl^+$ | $Ni(OH)_2$ (aq) | $NiOH^+$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0.6581 | 0.2109 | 0.0908 | 0.0190 | 0.0082 | 0.0002 | 0.0001 | 0.0015 | 0.0113 |
| | Anaerobically Digested Biosolids | 0.5319 | 0.3208 | 0.0928 | 0.0199 | 0.0320 | 0 | 0 | 0 | 0.0024 |
| | Lime Stabilized Biosolids | 0.2718 | 0.6622 | 0.0481 | 0.0068 | 0.0084 | 0.0010 | 0 | 0 | 0.0016 |
| 3-Nov-06 | Control | 0.7191 | 0.1518 | 0.1097 | 0.0057 | 0.0095 | 0.0009 | 0 | 0.0001 | 0.0031 |
| | Anaerobically Digested Biosolids | 0.5081 | 0.3579 | 0.0744 | 0.0194 | 0.0381 | 0 | 0 | 0 | 0.0019 |
| | Lime Stabilized Biosolids | 0.6030 | 0.2363 | 0.0748 | 0.0360 | 0.0450 | 0.0010 | 0 | 0.0002 | 0.0037 |
| 5-Jan-07 | Control | 0.7215 | 0.1653 | 0.1008 | 0.0025 | 0.0080 | 0 | 0 | 0 | 0.0017 |
| | Anaerobically Digested Biosolids | 0.6562 | 0.2415 | 0.0708 | 0.0039 | 0.0269 | 0 | 0 | 0 | 0.0007 |
| | Lime Stabilized Biosolids | 0.2272 | 0.1602 | 0.0106 | 0.0035 | 0.5568 | 0.0002 | 0 | 0 | 0.0001 |
| 8-Jun-07 | Control | 0.6755 | 0.2567 | 0.0613 | 0.0005 | 0.0054 | 0.0002 | 0 | 0 | 0.0004 |
| | Anaerobically Digested Biosolids | 0.7789 | 0.1943 | 0.0201 | 0 | 0.0046 | 0.0019 | 0 | 0 | 0 |
| | Lime Stabilized Biosolids | 0.7686 | 0.1914 | 0.0359 | 0 | 0.0012 | 0.0029 | 0 | 0 | 0 |
| 7-Sep-07 | Control | 0.6771 | 0.2085 | 0.1027 | 0.0009 | 0.0095 | 0.0007 | 0.0001 | 0 | 0.0005 |
| | Anaerobically Digested Biosolids | 0.8133 | 0.1622 | 0.0158 | 0 | 0.0072 | 0.0013 | 0 | 0 | 0 |
| | Lime Stabilized Biosolids | 0.7549 | 0.2037 | 0.0351 | 0 | 0.0031 | 0.0030 | 0 | 0 | 0 |

Table 3.7: Comparisons of the fractions of Pb species in leachate collected below the control and biosolids treatments.

| Sampling Date | Treatment | $Pb^{+2}$ | Fulvic Acid-Pb | $PbSO_4$ (aq) | $PbCO_3$ (aq) | $Pb(CO_3)_2^{-2}$ | $PbHCO_3^+$ | $PbNO_3^+$ | $PbCl^+$ | $Pb(OH)_2$ (aq) | $PbOH^+$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0.0028 | 0.9784 | 0.0010 | 0.0074 | 0 | 0.0002 | 0 | 0 | 0.0005 | 0.0096 |
| | Anaerobically Digested Biosolids | 0.0035 | 0.9782 | 0.0015 | 0.0120 | 0 | 0.0014 | 0 | 0 | 0 | 0.0032 |
| | Lime Stabilized Biosolids | 0.0013 | 0.9933 | 0.0006 | 0.0029 | 0 | 0.0003 | 0 | 0 | 0 | 0.0015 |
| 3-Nov-06 | Control | 0.0064 | 0.9803 | 0.0024 | 0.0046 | 0 | 0.0005 | 0 | 0 | 0 | 0.0055 |
| | Anaerobically Digested Biosolids | 0.0021 | 0.9874 | 0.0007 | 0.0072 | 0 | 0.0010 | 0 | 0 | 0 | 0.0016 |
| | Lime Stabilized Biosolids | 0.0048 | 0.9592 | 0.0015 | 0.0261 | 0.0002 | 0.0023 | 0 | 0 | 0.0001 | 0.0058 |
| 5-Jan-07 | Control | 0.0243 | 0.9462 | 0.0084 | 0.0077 | 0 | 0.0017 | 0 | 0.0003 | 0 | 0.0112 |
| | Anaerobically Digested Biosolids | 0.0516 | 0.8814 | 0.0137 | 0.0276 | 0 | 0.0136 | 0 | 0.0005 | 0 | 0.0114 |
| | Lime Stabilized Biosolids | 0.0186 | 0.3324 | 0.0021 | 0.3353 | 0.0145 | 0.2948 | 0 | 0.0001 | 0 | 0.0020 |
| 8-Jun-07 | Control | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| | Anaerobically Digested Biosolids | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| | Lime Stabilized Biosolids | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 7-Sep-07 | Control | 0.0197 | 0.9657 | 0.0073 | 0.0023 | 0 | 0.0018 | 0.0001 | 0.0003 | 0 | 0.0026 |
| | Anaerobically Digested Biosolids | 0.2093 | 0.7608 | 0.0100 | 0.0015 | 0 | 0.0015 | 0.0020 | 0.0018 | 0 | 0.0028 |
| | Lime Stabilized Biosolids | 0.1467 | 0.8256 | 0.0167 | 0.0005 | 0 | 0.0005 | 0.0035 | 0.0012 | 0 | 0.0018 |

*** denotes date when leachate was not analyzed for Pb.

Table 3.8: Comparisons of the fractions of Zn species in leachate collected below the control and biosolids treatments.

| Sampling Date | Treatment | $Zn^{+2}$ | Fulvic Acid-Zn | $ZnSO_4$ (aq) | $Zn(SO_4)_2^{-2}$ | $ZnCO_3$ (aq) | $Zn(CO_3)_2^{-2}$ | $ZnHCO_3^+$ | $ZnNO_3^+$ | $ZnCl^+$ | $Zn(OH)_2$ (aq) | $ZnOH^+$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0.3091 | 0.4978 | 0.0467 | 0.0006 | 0.0138 | 0 | 0.0010 | 0 | 0.0004 | 0.0882 | 0.0423 |
| | Anaerobically Digested Biosolids | 0.3747 | 0.5034 | 0.0717 | 0.0013 | 0.0217 | 0 | 0.0058 | 0 | 0.0004 | 0.0075 | 0.0135 |
| | Lime Stabilized Biosolids | 0.1927 | 0.7436 | 0.0066 | 0.0006 | 0.0074 | 0 | 0.0015 | 0 | 0.0003 | 0.0066 | 0.0091 |
| 3-Nov-06 | Control | 0.5093 | 0.3678 | 0.0852 | 0.0014 | 0.0063 | 0 | 0.0017 | 0.0006 | 0.0005 | 0.0095 | 0.0176 |
| | Anaerobically Digested Biosolids | 0.2826 | 0.6365 | 0.0454 | 0.0006 | 0.0167 | 0 | 0.0054 | 0 | 0.0002 | 0.0039 | 0.0085 |
| | Lime Stabilized Biosolids | 0.4354 | 0.4188 | 0.0592 | 0.0006 | 0.0403 | 0 | 0.0083 | 0.0007 | 0.0004 | 0.0151 | 0.0211 |
| 5-Jan-07 | Control | 0.7140 | 0.1518 | 0.1094 | 0.0015 | 0.0038 | 0 | 0.0020 | 0 | 0.0006 | 0.0037 | 0.0131 |
| | Anaerobically Digested Biosolids | 0.7708 | 0.1138 | 0.0911 | 0.0008 | 0.0070 | 0 | 0.0081 | 0 | 0.0006 | 0.0009 | 0.0068 |
| | Lime Stabilized Biosolids | 0.4499 | 0.1031 | 0.0229 | 0.0002 | 0.1375 | 0.0008 | 0.2828 | 0.0004 | 0.0003 | 0.0001 | 0.0020 |
| 8-Jun-07 | Control | 0.6660 | 0.2609 | 0.0662 | 0.0006 | 0.0007 | 0 | 0.0014 | 0.0001 | 0.0005 | 0.0003 | 0.0033 |
| | Anaerobically Digested Biosolids | 0.9067 | 0.0626 | 0.0257 | 0 | 0.0001 | 0 | 0.0014 | 0.0023 | 0.0006 | 0 | 0.0007 |
| | Lime Stabilized Biosolids | 0.8965 | 0.0528 | 0.0459 | 0.0002 | 0 | 0 | 0.0004 | 0.0033 | 0.0006 | 0 | 0.0003 |
| 7-Sep-07 | Control | 0.6889 | 0.1853 | 0.1146 | 0.0018 | 0.0014 | 0 | 0.0025 | 0.0008 | 0.0008 | 0.0003 | 0.0036 |
| | Anaerobically Digested Biosolids | 0.9286 | 0.0468 | 0.0198 | 0 | 0.0001 | 0 | 0.0021 | 0.0015 | 0.0006 | 0 | 0.0005 |
| | Lime Stabilized Biosolids | 0.8866 | 0.0623 | 0.0452 | 0.0003 | 0 | 0 | 0.0009 | 0.0036 | 0.0006 | 0 | 0.0004 |

Table 3.9: Comparisons of the fractions of Ba species in leachate collected below the control and biosolids treatments.

| Sampling Date | Treatment | $Ba^{2+}$ | Fulvic Acid-Ba | $BaSO_4$ (aq) | $BaCO_3$ (aq) | $BaHCO_3^+$ | $BaNO_3^+$ | $BaCl^+$ |
|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | 0.9096 | 0.0033 | 0.0848 | 0.0004 | 0.0009 | 0.0006 | 0.0004 |
| | Anaerobically Digested Biosolids | 0.8852 | 0.0055 | 0.1044 | 0.0005 | 0.0041 | 0 | 0.0003 |
| | Lime Stabilized Biosolids | 0.8620 | 0.0260 | 0.1032 | 0.0003 | 0.0021 | 0.0061 | 0.0004 |
| 3-Nov-06 | Control | 0.9018 | 0.0018 | 0.0930 | 0 | 0.0009 | 0.0021 | 0.0003 |
| | Anaerobically Digested Biosolids | 0.8986 | 0.0062 | 0.0890 | 0.0005 | 0.0052 | 0.0003 | 0.0002 |
| | Lime Stabilized Biosolids | 0.9100 | 0.0043 | 0.0763 | 0.0008 | 0.0053 | 0.0031 | 0.0003 |
| 5-Jan-07 | Control | 0.9105 | 0.0022 | 0.0860 | 0 | 0.0008 | 0.0002 | 0.0003 |
| | Anaerobically Digested Biosolids | 0.9240 | 0.0052 | 0.0674 | 0 | 0.0029 | 0.0001 | 0.0003 |
| | Lime Stabilized Biosolids | 0.8057 | 0.0123 | 0.0253 | 0.0022 | 0.1529 | 0.0014 | 0.0002 |
| 8-Jun-07 | Control | 0.9381 | 0.0031 | 0.0575 | 0 | 0.0006 | 0.0004 | 0.0002 |
| | Anaerobically Digested Biosolids | 0.9751 | 0.0024 | 0.0170 | 0 | 0.0004 | 0.0048 | 0.0002 |
| | Lime Stabilized Biosolids | 0.9597 | 0.0026 | 0.0303 | 0 | 0.0001 | 0.0071 | 0.0002 |
| 7-Sep-07 | Control | 0.9017 | 0.0025 | 0.0925 | 0 | 0.0010 | 0.0020 | 0.0003 |
| | Anaerobically Digested Biosolids | 0.9811 | 0.0020 | 0.0129 | 0 | 0.0007 | 0.0032 | 0.0002 |
| | Lime Stabilized Biosolids | 0.9593 | 0.0023 | 0.0302 | 0 | 0.0003 | 0.0077 | 0.0002 |

# CHAPTER FOUR

# CONCLUSIONS

As a component of reclamation, we applied biosolids to mineral sands mine land in Dinwiddie County, Virginia in June and July of 2006. Alexandria, (Virginia) anaerobically digested (213 and 426 dry Mg $ha^{-1}$) and Blue Plains (Washington, DC) lime-stabilized (329 and 657 dry Mg $ha^{-1}$) biosolids were placed in trenches. Leachate samples collected below and adjacent to the trenches helped provide information about metal transport from large applications of biosolids. The majority of Ag, Cd, Pb, Sn was at or below the method detection limit in both a horizontal and a vertical direction. The initial loading rates for the metals analyzed (Ba, Cu, Zn) were very high; however, less than 0.8% of those amounts actually leached during the 15-month sampling period. Nickel from the lime-stabilized biosolids showed the most movement with 1.6% of the initial loading rates actually leaching. The fraction of metal concentrations above the USEPA Drinking Water Standards was low with any leachate with high concentrations being further diluted by larger bodies of water. The lack of metal presence in the leachate demonstrates that high application rates for entrenched biosolids will pose little risk of metal transport into groundwater under these conditions. MINTEQA2 predicted that the majority of Ba, Cd, Ni, and Zn were present as free ions and over 70% of Cu and Pb would be complexed with fulvic acids. With increased presence of free ions, a concern about the potential for metal bioavailability and toxicity within underlying groundwater may develop.

1-Residual and organically-bound fractions comprised the greatest sources of metal species in both biosolids types. Within the lime-stabilized biosolids, Ba and Zn had more association with the exchangeable and oxide fractions than the other metals, whereas only Zn had high associations in the anaerobically digested biosolids.

2-The pH values for leachate collected from both biosolids types decreased over the 15-month sampling period. Electrical conductivity became steady after December 15, 2006 and DO fluctuated between 3 and 7 mg $L^{-1}$ once analysis began on December 1, 2006.

3-Silver, Cd, Pb, and Sn were not transported in a horizontal or a vertical direction to any significant extent.

4- Copper and Ni decreased to less than 10 g $ha^{-1}$ during the 15-month sampling period.

5-The lime-stabilized biosolids cumulatively leached more Cu, Ni, and Zn; however, the cumulative metal mass transport per sampling period from the anaerobically digested and lime-stabilized biosolids were not significantly different from each other for Ba, Ni, and Zn.

6-A large majority of the metals leached in association with colloids, as the colloidal fraction contained more metal mass than the dissolved.

7-Barium, Cu, Ni, and Zn also moved laterally.

8-MINTEQA2 predicted that the majority of Ba, Cd, Ni, and Zn were present as free ions and over 70% of Cu and Pb would complex with fulvic acids. As time increased and pH decreased, the amount of association with fulvic acids decreased allowing more metals to be either found as free ions or bound to inorganic ligands. This would potentially increase the bioavailability of the metals. Copper and Pb did not show this trend, instead over 70% remained complexed with the fulvic acids.

9-Based on these results metal transport from high application of entrenched biosolids is limited; however, more research into the mechanisms would be beneficial.

# CHAPTER FIVE

## APPENDIX

## Leachate characteristics

Table 5.1: Leachate pH collected from zero tension lysimeters 15 cm below simulated trenches in surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ | b | | | 7.56 | 7.61 | 7.56 | 7.4 | 7.33 | 7.46 | 7.48 | 7.55 | 7.47 | 7.41 | 6.96 | 6.65 | | | | |
| | b | | 8.07 | | 7.58 | 6.76 | 7.54 | 7.03 | 7.48 | 7.48 | | | 7.42 | 6.7 | 6.71 | 6.87 | | | |
| | b | | | 7.54 | 7.69 | 7.69 | 7.55 | 7.61 | 7.88 | | | | 6.94 | | 6.85 | 6.77 | | 6.86 | |
| | b | | 8.44 | 8.25 | 7.84 | 7.76 | 7.71 | 7.60 | | | | | 7.62 | | 7.05 | 7.00 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ | b | 8.53 | | *** | *** | *** | *** | *** | *** | *** | *** | 7.59 | 6.37 | 6.87 | 6.94 | 6.97 | | | |
| | b | | 8.08 | *** | *** | *** | *** | *** | *** | *** | *** | | 7.27 | 6.89 | 6.79 | 6.73 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 7.25 | 7.02 | 6.88 | 7.05 | 6.60 | 7.38 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 7.25 | 6.91 | 6.84 | 6.88 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ | b | 7.97 | | *** | *** | *** | *** | *** | *** | *** | *** | 7.42 | 7.29 | 7.17 | 7.21 | 7.14 | 7.57 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 7.30 | 6.91 | 6.80 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 6.35 | | | | 6.86 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 6.47 | 6.82 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 7.55 | | 7.21 | 7.13 | | | 7.26 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 7.25 | 7.45 | | 6.74 | 6.89 | | | |
| | b | 8.16 | | *** | *** | *** | *** | *** | *** | *** | *** | | 7.18 | | 7.04 | 6.56 | 7.19 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 7.2 | | | 6.95 | | | |

*** Samples were not collected for these treatments.
Blanks indicate where sample was not collected due to lack of leachate.

Table 5.2: Leachate pH collected from zero tension lysimeters 15 cm below two rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | | 7.88 | 7.87 | 7.92 | 7.11 | 7.15 | 7.26 | 8.15 | 7.14 | 7.30 | 7.10 | 6.34 | 6.14 | 5.78 | 6.09 | 6.73 | 6.81 | 7.27 |
| | b | | 7.92 | 7.88 | 8.07 | 7.30 | 7.21 | 7.33 | 8.68 | | | | | 6.17 | 4.89 | 4.80 | 6.78 | 6.69 | 7.06 |
| | a | 7.69 | 8.08 | 7.83 | 7.72 | 6.63 | 6.85 | 7.30 | 7.26 | 7.01 | 6.72 | 6.50 | 6.63 | 6.50 | 6.72 | 6.94 | 6.89 | | |
| | b | 7.77 | 7.70 | 7.96 | 7.37 | 6.83 | 6.89 | 7.21 | 7.14 | 6.49 | 6.49 | 6.42 | 6.16 | 6.28 | 6.06 | 6.51 | 6.34 | | |
| | a | | 5.85 | 6.55 | 6.50 | 6.19 | 6.50 | 6.88 | 6.52 | 5.81 | | | 4.40 | 4.42 | | 6.19 | | 5.65 | |
| | b | | 8.14 | 7.79 | 7.74 | 7.21 | 7.20 | 7.14 | 7.96 | | | 6.64 | 6.74 | 6.48 | 6.28 | 6.49 | 5.88 | 5.60 | |
| | a | | 7.84 | 7.76 | 7.64 | 6.80 | 6.87 | 6.80 | 7.46 | 6.85 | 6.58 | 6.30 | 5.96 | 6.12 | 6.05 | 5.96 | 4.53 | 3.54 | 3.60 |
| | b | | 7.72 | 7.58 | 7.62 | 6.73 | 6.75 | 6.63 | 7.03 | 6.52 | 6.11 | 5.60 | 4.19 | 5.49 | 5.39 | 5.87 | 4.10 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | | 7.66 | 7.58 | 7.65 | 7.16 | 7.31 | 6.97 | 7.46 | 6.76 | 7.11 | | 6.99 | 6.82 | 6.63 | 6.71 | | | 6.40 |
| | b | 7.94 | 8.03 | 7.83 | 7.82 | 7.14 | 7.36 | 6.98 | 7.50 | 7.01 | 7.00 | 6.70 | 6.79 | 6.50 | 6.68 | 6.79 | | | |
| | a | 8.23 | 7.99 | 7.56 | 7.81 | 6.98 | 6.74 | 7.21 | 7.44 | 7.11 | 6.97 | 6.68 | 6.85 | 6.69 | 6.59 | 6.89 | 6.95 | 6.97 | 7.14 |
| | b | 8.09 | 8.2 | 7.28 | 7.76 | 6.66 | 7.21 | 7.23 | 7.38 | 6.88 | 7.00 | 6.65 | 6.68 | 6.24 | 6.19 | 6.79 | 6.47 | 6.79 | 6.75 |
| | a | | 8.13 | 7.99 | 7.61 | 7.03 | 7.43 | 7.11 | 8.64 | 6.65 | 6.71 | 6.35 | 5.85 | 4.74 | 4.60 | 5.56 | 4.41 | 4.06 | |
| | b | | 6.76 | 7.49 | 7.34 | 6.88 | 7.37 | 7.33 | 7.59 | 6.59 | 6.41 | 7.44 | 6.12 | 6.12 | 5.46 | 5.74 | 5.25 | 4.42 | 4.59 |
| | a | 7.64 | 7.61 | | 7.81 | 6.96 | 6.94 | 6.85 | | 6.88 | 6.63 | 6.71 | 6.44 | 6.46 | 6.02 | 6.33 | | 5.30 | 4.50 |
| | b | 7.55 | 7.16 | 7.33 | 6.98 | 6.52 | 6.59 | 6.63 | 6.67 | 6.18 | 6.08 | 6.02 | 5.74 | 5.71 | 5.80 | 6.16 | | 5.67 | 6.27 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | | 8.44 | 8.48 | 8.47 | 8.17 | 7.33 | 7.66 | 8.67 | 7.65 | 7.57 | 7.50 | 7.59 | 7.34 | 7.19 | 7.14 | 7.32 | 7.51 | 7.10 |
| | b | 8.65 | 7.91 | 8.24 | 7.78 | 7.36 | 7.37 | 6.88 | 7.34 | 7.03 | 6.98 | 6.97 | 6.66 | 6.66 | 6.12 | 6.64 | 6.61 | 7.05 | 7.26 |
| | a | 8.63 | 8.09 | 7.99 | 7.87 | 7.09 | 7.19 | 7.53 | 7.50 | 6.88 | 6.94 | 6.73 | 6.57 | 6.67 | 6.75 | 6.61 | 6.33 | 6.75 | 6.34 |
| | b | | 8.23 | 8.50 | 8.51 | 7.00 | 7.34 | 7.50 | 7.31 | 7.09 | 7.41 | 6.93 | 7.15 | 7.15 | 6.90 | 7.01 | 7.15 | 7.07 | 4.56 |
| | a | 8.27 | | 7.41 | 6.94 | 6.29 | 6.52 | 6.03 | 4.82 | 4.81 | | 4.66 | | 3.91 | 3.74 | 4.43 | | 3.39 | |
| | b | | | 6.72 | 6.76 | 6.96 | 6.72 | 6.21 | 6.80 | | | | | | 4.77 | 5.28 | | 5.00 | |
| | a | | | 7.60 | 7.76 | 7.31 | 7.67 | 7.37 | 7.59 | 7.48 | 7.16 | 6.95 | 7.19 | 6.94 | 6.76 | 6.53 | 6.92 | 6.56 | 6.99 |
| | b | | 7.77 | 8.06 | 7.75 | 6.69 | 7.09 | 6.92 | 7.57 | 6.89 | 6.48 | 6.39 | 6.24 | 6.24 | 6.38 | 6.24 | 6.56 | 6.01 | 6.38 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | | 8.34 | 8.84 | 8.26 | 7.71 | 7.63 | 7.67 | 8.38 | | 7.71 | 7.64 | 7.73 | 7.43 | 6.99 | 6.39 | | 4.42 | 3.80 |
| | b | | 7.43 | 7.99 | 8.12 | 7.27 | 7.36 | 7.06 | 8.54 | | 6.94 | | 4.60 | 4.18 | 4.04 | 4.36 | | | |
| | a | | 8.14 | 8.31 | 8.33 | 7.14 | 7.34 | 7.26 | 7.06 | 6.95 | 6.71 | | 6.55 | 6.04 | 5.82 | 6.52 | 6.19 | 6.56 | 6.74 |
| | b | | 7.53 | 8.29 | 7.97 | 7.3 | 7.37 | 7.38 | 7.76 | 7.64 | 7.54 | 7.35 | 7.29 | 7.03 | 6.89 | 6.91 | 6.95 | 6.75 | 7.01 |
| | a | | 7.38 | 7.92 | 8.16 | 7.75 | 7.21 | 7.17 | 8.38 | | 7.15 | 7.07 | 7.03 | 6.86 | 6.35 | 6.27 | | 5.92 | 6.56 |
| | b | 7.50 | 7.09 | 6.72 | 6.72 | 6.18 | 6.54 | 6.28 | 6.76 | 5.99 | 5.99 | 6.12 | 5.77 | 5.62 | 5.68 | 5.54 | 5.57 | 5.61 | 5.74 |
| | a | | 8.12 | 7.83 | 7.54 | 6.69 | 6.58 | 5.86 | 6.67 | 5.81 | | 5.63 | 4.60 | 4.44 | 4.39 | 5.20 | 4.26 | | 4.26 |
| | b | | 8.35 | 8.17 | 7.24 | 5.87 | 6.29 | 5.90 | 6.08 | 5.85 | 6.00 | | 5.08 | 5.86 | 5.34 | 5.96 | 5.54 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.3: Leachate dissolved oxygen (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches in surface applied fertilizer plots.

| Treatment | Trench | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ | b | 3.11 | 6.1 | 5.51 | 3.87 | 5.61 | 4.61 | 5.95 | 2.72 | 7.15 | 7.30 | | | | |
| | b | 4.98 | 7.61 | 5.59 | 5.86 | 6.55 | | | 4.25 | 10.57 | 7.92 | 7.34 | | | |
| | b | 4.52 | 7.44 | 6.40 | 9.34 | | | | 4.00 | | 9.06 | 6.53 | | 4.21 | |
| | b | 5.22 | 7.68 | 7.11 | | | | | 4.23 | | 10.23 | 7.01 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ | b | *** | *** | *** | *** | *** | *** | 3.06 | 6.65 | 6.80 | 6.99 | 7.08 | | | |
| | b | *** | *** | *** | *** | *** | *** | | 3.94 | 9.60 | 6.45 | 8.26 | | | |
| | b | *** | *** | *** | *** | *** | *** | 6.98 | 4.21 | 5.87 | 8.99 | 8.40 | 5.71 | | |
| | b | *** | *** | *** | *** | *** | *** | | 5.79 | 6.58 | 9.52 | 5.57 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ | b | *** | *** | *** | *** | *** | *** | 5.44 | 5.40 | 8.83 | 8.43 | 7.69 | 6.36 | | |
| | b | *** | *** | *** | *** | *** | *** | | | 6.87 | 6.18 | 6.50 | | | |
| | b | *** | *** | *** | *** | *** | *** | 5.24 | | | | 7.98 | | | |
| | b | *** | *** | *** | *** | *** | *** | | | | 10.87 | 6.66 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ | b | *** | *** | *** | *** | *** | *** | | 3.53 | | 8.48 | 6.08 | | | 5.39 |
| | b | *** | *** | *** | *** | *** | *** | 8.84 | 3.29 | | 7.47 | 6.86 | | | |
| | b | *** | *** | *** | *** | *** | *** | | 3.80 | | 5.86 | 7.22 | 5.52 | | |
| | b | *** | *** | *** | *** | *** | *** | | 5.05 | | | 6.00 | | | |

*** Samples were not collected for these treatments.
Blanks indicate where sample was not collected due to lack of leachate.

Table 5.4: Leachate dissolved oxygen (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | 6.47 | 5.01 | 6.53 | 5.48 | 8.13 | 4.44 | 2.80 | 3.84 | 6.46 | 4.5 | 6.15 | 4.06 | 3.90 | 4.80 |
| | b | 4.28 | 8.17 | 5.45 | 2.70 | | | | | 7.10 | 5.17 | 7.89 | 4.77 | 3.43 | 4.05 |
| | a | 3.77 | 5.82 | 5.09 | 5.38 | 8.87 | 4.98 | 4.87 | 2.62 | 6.00 | 5.89 | 5.06 | 3.51 | | |
| | b | 3.72 | 4.85 | 4.57 | 3.28 | 3.90 | 2.92 | 4.42 | 2.53 | 3.83 | 6.30 | 3.23 | 5.27 | | |
| | a | 4.21 | 5.60 | 5.87 | 5.91 | 7.15 | | | 3.44 | 3.90 | | 5.74 | | 4.30 | |
| | b | 3.98 | 6.12 | 5.14 | 5.30 | | | 6.70 | 2.32 | 3.32 | 4.83 | 3.75 | 3.67 | 3.22 | |
| | a | 4.26 | 5.04 | 4.75 | 3.98 | 7.52 | 5.10 | 3.56 | 4.61 | 6.96 | 8.03 | 6.34 | 5.30 | 3.87 | 5.06 |
| | b | 5.36 | 3.57 | 4.59 | 5.70 | 4.74 | 5.63 | 10.97 | 6.09 | 8.89 | 8.76 | 5.02 | 4.78 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | 4.74 | 5.89 | 4.41 | 2.68 | 4.80 | 5.46 | | 3.06 | 5.36 | 6.48 | 3.70 | | | 5.64 |
| | b | 4.39 | 4.76 | 4.72 | 5.15 | 7.06 | 5.83 | 4.83 | 3.40 | 6.31 | 6.96 | 4.70 | | | |
| | a | 4.22 | 4.85 | 4.06 | 3.95 | 6.60 | 4.76 | 4.68 | 2.90 | 6.37 | 7.82 | 5.05 | 4.19 | 3.04 | 2.13 |
| | b | 4.66 | 5.16 | 4.55 | 2.96 | 7.43 | 7.22 | 5.40 | 3.01 | 7.04 | 7.49 | 3.98 | 3.17 | 3.64 | 2.10 |
| | a | 3.30 | 6.02 | 6.31 | 4.57 | 3.95 | 3.77 | 4.75 | 3.10 | 5.22 | 6.19 | 5.77 | 5.33 | 4.11 | |
| | b | 3.72 | 6.53 | 5.68 | 4.25 | 6.55 | 4.33 | 4.06 | 4.08 | 6.18 | 6.06 | 4.84 | 4.66 | 4.14 | 5.32 |
| | a | 4.54 | 6.88 | 5.47 | | 7.76 | 3.56 | 5.43 | 4.55 | 6.26 | 7.53 | 5.54 | | 4.06 | 4.59 |
| | b | 4.74 | 5.85 | 5.88 | 4.29 | 6.20 | 4.86 | 4.97 | 2.12 | 3.12 | 6.99 | 2.44 | | 4.34 | 4.58 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.5: Leachate dissolved oxygen (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime Stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | 2.21 | 2.61 | 6.64 | 9.1 | 6.33 | 3.65 | 2.98 | 1.01 | 3.64 | 1.04 | 3.8 | 2.25 | 2.12 | 4.21 |
| | b | 4.46 | 4.29 | 3.48 | 4.07 | 6.27 | 5.23 | 4.86 | 2.83 | 6.21 | 7.18 | 4.39 | 3.33 | 3.72 | 5.33 |
| | a | 3.79 | 6.58 | 4.77 | 3.45 | 6.96 | 4.13 | 4.8 | 2.18 | 3.62 | 4.14 | 3.93 | 2.95 | 3.96 | 3.63 |
| | b | 4 | 5.48 | 4.3 | 4.36 | 4.61 | 6.65 | 6.23 | 1.61 | 4.28 | 2.48 | 1.3 | 1.08 | 1.13 | 2.5 |
| | a | 4.61 | 5.77 | 6.86 | 10.13 | 7.02 | | 8.69 | | 4.71 | 9.38 | 5.7 | | 4.53 | |
| | b | 5.1 | 7.04 | 6.64 | 8.89 | | | | | | 8.04 | 6.4 | | 5.15 | |
| | a | 4.34 | 5.92 | 5.12 | 3.43 | 5.82 | 5.57 | 4.34 | 3.2 | 3.3 | 8.28 | 4.72 | 4.05 | 3.72 | 4.11 |
| | b | 3.56 | 4.48 | 3.88 | 4.24 | 6.99 | 3.77 | 5.82 | 4.23 | 8.59 | 9.66 | 5.44 | 5.55 | 4.16 | 4.88 |
| Lime Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | 0.35 | 5.77 | 8.17 | 8.26 | | 2.95 | 5.8 | 5.08 | 2.89 | 2.54 | 6.8 | | 4 | 4.49 |
| | b | 4.5 | 6.33 | 6.7 | 6.97 | | 4.5 | | 7.7 | 4.4 | 5.7 | 6.72 | | | |
| | a | 3.86 | 6 | 3.73 | 4.32 | 8.71 | 4.06 | | 3.76 | 9.42 | 6.87 | 5.28 | 4.5 | 4.64 | 5.64 |
| | b | 3.93 | 4.34 | 3.17 | 4.83 | 6.39 | 6.35 | 4.82 | 2.74 | 9.45 | 6.16 | 3.8 | 2.44 | 2.71 | 3.08 |
| | a | 1.34 | 3.09 | 3.63 | 5.25 | | 3.18 | 1.98 | 2.15 | 2.7 | 4.56 | 5.92 | | 3.59 | 5.76 |
| | b | 4.51 | 4.3 | 5.4 | 5.56 | 7.65 | 2.5 | 4.27 | 3.26 | 7.02 | 7.4 | 4.59 | 5.24 | 3.54 | 6.63 |
| | a | 4.3 | 5.05 | 5.06 | 4.29 | 5.03 | | 7.97 | 6.4 | 10.65 | 8.17 | 6.13 | 5.97 | | 5.84 |
| | b | 4.82 | 5.1 | 7.32 | 7.89 | 9.8 | 4.06 | | 6.83 | 13.46 | 11.53 | 5.08 | 5.85 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.6: Leachate electrical conductivity ($\mu S\ cm^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches in surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ | b | | | 796 | 804 | 756 | 465 | 487 | 409 | 390 | 445.7 | 700 | 850 | 650 | 550 | 0 | | | |
| | b | | 756 | | 1025 | 941 | 383 | 367 | 333 | 282 | | | 680 | 390 | 610 | 970 | | | |
| | b | | | 754 | 779 | 728 | 494 | 308 | 282 | | | | 580 | | 550 | 360 | | 450 | |
| | b | | 597 | 567 | 604 | 512 | 481 | 454 | | | | | 460 | | 310 | 340 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ | b | 628 | | *** | *** | *** | *** | *** | *** | *** | *** | 430 | 880 | 1150 | 1010 | 910 | | | |
| | b | | 1289 | *** | *** | *** | *** | *** | *** | *** | *** | | 590 | 1300 | 860 | 810 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 280 | 540 | 760 | 880 | 990 | 690 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 690 | 1130 | 600 | 860 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ | b | 708 | | *** | *** | *** | *** | *** | *** | *** | *** | 660 | 620 | 750 | 800 | 390 | 350 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 1220 | 1460 | 1330 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 470 | | | | 460 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 530 | 550 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 850 | | 600 | 530 | | | 400 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 390 | 470 | | 360 | 400 | | | |
| | b | 1227 | 4850 | *** | *** | *** | *** | *** | *** | *** | *** | | 1310 | | 3000 | 2160 | 1910 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 280 | | | 800 | | | |

*** Samples were not collected for these treatments.
Blanks indicate where sample was not collected due to lack of leachate.

Table 5.7: Leachate electrical conductivity (µS cm$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | | 2270 | 2850 | 2720 | 19240 | 1125 | 306 | 285 | 331 | 1320 | 1640 | 1290 | 850 | 1950 | 1280 | 450 | 610 | 350 |
| | b | | 2380 | 3480 | 3460 | 2760 | 1167 | 173 | 2415 | | | | | 1300 | 2240 | 1380 | 440 | 410 | 350 |
| | a | 1010 | 964 | 1028 | 1070 | 657 | 270 | 306 | 274 | 247 | 427 | 290 | 540 | 620 | 450 | 310 | 610 | | |
| | b | 814 | 856 | 1050 | 1060 | 568 | 449 | 298 | 277 | 201 | 326 | 430 | 820 | 910 | 830 | 230 | 310 | | |
| | a | | 698 | 790 | 704 | 495 | 411 | 258 | 181 | 165 | | | 450 | 280 | | 530 | | 730 | |
| | b | | 2320 | 2130 | 2150 | 1654 | 407 | 614 | 560 | | | 460 | 1.06 | 640 | 740 | 750 | 1520 | 800 | |
| | a | | 1630 | 1636 | 1508 | 1037 | 813 | 360 | 379 | 280 | 315 | 310 | 660 | 370 | 440 | 2290 | 1171 | 900 | 860 |
| | b | | 3740 | 2810 | 2820 | 1240 | 418 | 481 | 348 | 277 | 303 | 270 | 240 | 540 | 420 | 1830 | 820 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | | 959 | 1066 | 1218 | 952 | 471 | 445 | 390 | 302 | 710 | | 690 | 940 | 490 | 460 | | | 270 |
| | b | 925 | 915 | 1048 | 1024 | 972 | 457 | 342 | 487 | 249 | 379 | 220 | 620 | 1060 | 540 | 480 | | | |
| | a | 2790 | 2540 | 2660 | 3180 | 1740 | 396 | 337 | 328 | 401 | 372 | 460 | 710 | 400 | 620 | 1370 | 730 | 650 | 820 |
| | b | 1160 | 919 | 1037 | 1137 | 679 | 276 | 482 | 331 | 302 | 373 | 330 | 370 | 400 | 290 | 350 | 400 | 390 | 260 |
| | a | | 3390 | 2390 | 2480 | 1819 | 304 | 495 | 488 | 405 | 860 | 420 | 360 | 1430 | 2550 | 1100 | 1060 | 940 | |
| | b | | 867 | 1960 | 1601 | 678 | 337 | 360 | 255 | 209 | 440 | 710 | 430 | 610 | 1090 | 660 | 860 | 590 | 560 |
| | a | 12220 | 1236 | | 1452 | 1339 | 272 | 305 | | 382 | 400 | 440 | 670 | 790 | 480 | 440 | | 580 | 440 |
| | b | 895 | 773 | 925 | 863 | 639 | 225 | 181 | 160 | 127 | 242 | 240 | 210 | 240 | 280 | 160 | | 230 | 170 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.8: Leachate electrical conductivity ($\mu S\ cm^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime Stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | | 11760 | 10410 | 10090 | 8120 | 166.2 | 220 | 267.3 | 232.6 | 346.8 | 1610 | 2670 | 3590 | 1770 | 1330 | 1570 | 1410 | 2140 |
| | b | 679 | 4220 | 2440 | 2300 | 1076 | 398.2 | 457 | 493.2 | 292.8 | 396.2 | 1000 | 700 | 480 | 780 | 330 | 400 | 360 | 470 |
| | a | 489 | 1117 | 1938 | 1560 | 495 | 149.9 | 350 | 144.7 | 258.5 | 304.2 | 280 | 440 | 700 | 340 | 420 | 370 | 430 | 410 |
| | b | | 2110 | 1981 | 1392 | 374 | 232 | 198.5 | 187 | 195.1 | 222.8 | 270 | 730 | 710 | 1090 | 700 | 730 | 580 | 450 |
| | a | 888 | | 6490 | 6790 | 4220 | 231.7 | 445.2 | 322.2 | 360.8 | | 410 | | 840 | 1000 | 1030 | | 930 | |
| | b | | | 1758 | 1860 | 1704 | 306.1 | 708 | 202 | | | | | | 800 | 820 | | 670 | |
| | a | | | 4780 | 4570 | 1335 | 496 | 288.2 | 268.9 | 249.2 | 320.9 | 350 | 670 | 1140 | 650 | 2180 | 1710 | 950 | 840 |
| | b | | | 3670 | 3090 | 1069 | 371.6 | 363.6 | 406 | 372.1 | 366 | 420 | 900 | 1540 | 1090 | 890 | 860 | 700 | 460 |
| Lime Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | | 12840 | 13460 | 12900 | 12640 | 168.7 | 439.8 | 1232 | | 9390 | 6690 | 6670 | 6800 | 5320 | 2340 | | 1860 | 2260 |
| | b | | 2600 | 6020 | 5270 | 4260 | 3126 | 203.6 | 103.4 | | 1620 | | 1490 | 1850 | 1810 | 1480 | | | |
| | a | | 4990 | 3770 | 2970 | 587 | 259.9 | 235.7 | 399.8 | 216 | 233.5 | | 830 | 1040 | 1280 | 2440 | 1090 | 910 | 770 |
| | b | | 896 | 19240 | 1828 | 331 | 495 | 452.9 | 244.8 | 297.2 | 363.6 | 380 | 580 | 860 | 870 | 530 | 560 | 470 | 440 |
| | a | | 1334 | 2660 | 2560 | 1716 | 305.6 | 290.8 | 309.6 | | 1720 | 800 | 1490 | 1680 | 1500 | 680 | | 590 | 490 |
| | b | 593 | 578 | 584 | 537 | 304 | 222.6 | 242.1 | 113.7 | 171 | 290 | 240 | 180 | 190 | 370 | 220 | 280 | 180 | 200 |
| | a | | 3290 | 1605 | 1479 | 932 | 319.2 | 449.4 | 334.9 | 284.9 | | 190 | 500 | 700 | 320 | 230 | 520 | | 200 |
| | b | | 1702 | 529 | 474 | 298 | 143.7 | 120 | 81.5 | 102.3 | 81 | | 150 | 300 | 180 | 430 | 310 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.9: Leachate volume (mL) collected from zero tension lysimeters 15 cm below simulated trenches in surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N ha$^{-1}$ yr$^{-1}$ | b | 330 | 9995† | 2840‡ | 550 | 380 | 290 | 280 | 670 | 530 | 300 | 200 | 680 | 500 | 900 | | | | |
| | b | | 9995 | 2840 | 750 | 2820 | 410 | 560 | 350 | 500 | 80 | | 680 | 420 | 860 | 330 | | | |
| | b | | 9995 | 2840 | 440 | 300 | 170 | 260 | 190 | | | | 300 | | 400 | 450 | | 360 | |
| | b | 420 | 9995 | 2840 | 220 | 120 | 150 | 190 | | | | | 320 | | 310 | 290 | | | |
| 150 kg N ha$^{-1}$ yr$^{-1}$ | b | 780 | 9995 | 2840 | 215 | 1500 | 380 | 800 | 740 | | 100 | 800 | 1260 | 730 | 1200 | 690 | | | |
| | b | 200 | 9995 | 2840 | 880 | 1900 | 570 | 330 | 730 | 230 | 100 | | 560 | 910 | 1800 | 570 | | | |
| | b | 580 | 9995 | 2840 | 320 | 525 | 200 | 410 | 200 | | 100 | 340 | 670 | 400 | 660 | 420 | 460 | | |
| | b | | 9995 | 2840 | 330 | 520 | 260 | | | | | | 390 | 320 | 520 | 430 | | | |
| 300 kg N ha$^{-1}$ yr$^{-1}$ | b | 420 | 9995 | 2840 | 775 | 790 | 210 | 280 | 600 | | 150 | 420 | 830 | 990 | 1400 | 740 | 560 | | |
| | b | | 9995 | 2840 | 405 | 550 | 310 | 270 | 490 | | 50 | | | 330 | 1250 | 550 | | | |
| | b | | 9995 | 2840 | 250 | 480 | 150 | | 200 | | | 180 | | | | 210 | | | |
| | b | | 9995 | 2840 | 335 | 430 | 140 | 150 | 175 | 130 | | | | | 300 | 250 | | | |
| 450 kg N ha$^{-1}$ yr$^{-1}$ | b | | 9995 | 2840 | 250 | 335 | 210 | 190 | 190 | | | | 325 | | 350 | 470 | | | 240 |
| | b | | 9995 | 2840 | 935 | 1230 | 610 | 600 | 500 | 460 | 100 | 275 | 560 | | 1100 | 500 | | | |
| | b | 360 | 9995 | 2840 | 200 | 235 | 160 | 160 | 120 | | | | 380 | | 340 | 520 | 310 | | |
| | b | 550 | 9995 | 2840 | 330 | 560 | 210 | 140 | | | | | 490 | | | 390 | | | |

† Due to a tropical depression preceding the sampling date we were unable to completely evacuate the lysimeters; therefore, we assumed all rainfall was present within the lysimeters.

‡ Due to incomplete evacuation of the lysimeters in early September, we used rainfall totals to approximate metal mass transport per sampling period.

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.10: Leachate volume (mL) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | | 9995† | 2840‡ | 1250 | 1420 | 400 | 760 | 1400 | 300 | 300 | 500 | 420 | 830 | 1100 | 510 | 570 | 300 | 370 |
| | b | | 9995 | 2840 | 900 | 675 | 210 | 270 | 670 | | | | | 550 | 1000 | 260 | 880 | 610 | 450 |
| | a | 430 | 9995 | 2840 | 2380 | 11000 | 1225 | 2050 | 1600 | 1020 | 790 | 550 | 1190 | 700 | 1800 | 850 | 950 | | |
| | b | 1700 | 9995 | 2840 | 5620 | 11370 | 2640 | 3210 | 4200 | 910 | 990 | 1560 | 1940 | 1000 | 9540 | 1150 | 450 | | |
| | a | | 9995 | 2840 | 1075 | 1025 | 620 | 250 | 480 | 320 | | | 380 | 550 | | 580 | | 470 | |
| | b | | 9995 | 2840 | 725 | 1240 | 320 | 210 | 550 | | | 240 | 700 | 480 | 1020 | 1150 | 920 | 1110 | |
| | a | | 9995 | 2840 | 2060 | 2320 | 990 | 1500 | 410 | 1080 | 600 | 620 | 880 | 910 | 3380 | 790 | 300 | 340 | 190 |
| | b | | 9995 | 2840 | 450 | 3500 | 250 | 1050 | 1135 | 530 | 260 | 580 | 390 | 750 | 1940 | 310 | 440 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | 310 | 9995 | 2840 | 2340 | 620 | 380 | 2360 | 1500 | 650 | 1350 | | 1680 | 1020 | 3200 | 1670 | | | 300 |
| | b | 380 | 9995 | 2840 | 450 | 550 | 3000 | 1350 | 4800 | 1530 | 2000 | 1810 | 2290 | 2000 | 2900 | 1600 | | | |
| | a | 340 | 9995 | 2840 | 875 | 5530 | 2100 | 2220 | 10770 | 2690 | 1950 | 2190 | 1940 | 3500 | 3000 | 1200 | 1100 | 1000 | 1380 |
| | b | 420 | 9995 | 2840 | 3620 | 3100 | 1000 | 2600 | 14000 | 930 | 1500 | 900 | 2000 | 4200 | 3200 | 1200 | 1040 | 750 | 1800 |
| | a | 730 | 9995 | 2840 | 2015 | 1900 | 1350 | 740 | 1400 | 790 | 750 | 350 | 420 | 710 | 520 | 590 | 400 | 300 | |
| | b | | 9995 | 2840 | 6100 | 10000 | 1000 | 3950 | 3600 | 1600 | 1000 | 420 | 1960 | 1760 | 3150 | 1040 | 680 | 650 | 300 |
| | a | 550 | 9995 | 2840 | 550 | 970 | 510 | 710 | | 1150 | 950 | 400 | 1900 | 570 | 680 | 860 | | 400 | 360 |
| | b | 230 | 9995 | 2840 | 2370 | 1750 | 700 | 1890 | 1650 | 420 | 610 | 375 | 890 | 690 | 510 | 1050 | | 280 | 290 |

† Due to a tropical depression preceding the sampling date we were unable to completely evacuate the lysimeters; therefore, we assumed all rainfall was present within the lysimeters.
‡ Due to incomplete evacuation of the lysimeters in early September, we used rainfall totals to approximate metal mass transport per sampling period.
Blanks indicate where sample was not collected due to lack of leachate.

Table 5.11: Leachate volume (mL) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime Stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) | a | 0 | 9995† | 2840‡ | 290 | 290 | 150 | 800 | 790 | 320 | 450 | 360 | 960 | 830 | 1300 | 810 | 530 | 580 | 600 |
| | b | 460 | 9995 | 2840 | 10635 | 11060 | 2950 | 9900 | 7800 | 2000 | 1600 | 2280 | 3150 | 2800 | 3600 | 1350 | 950 | 700 | 350 |
| | a | 740 | 9995 | 2840 | 1545 | 500 | 1346 | 1600 | 1650 | 900 | 900 | 1480 | 1920 | 2250 | 2000 | 1000 | 780 | 420 | 590 |
| | b | 0 | 9995 | 2840 | 1785 | 11090 | 2490 | 2880 | 4730 | 930 | 1200 | 1080 | 1520 | 2500 | 3900 | 1200 | 780 | 850 | 960 |
| | a | 430 | 9995 | 2840 | 2275 | 720 | 1100 | 960 | 340 | 310 | 0 | 190 | 0 | 520 | 1360 | 760 | 0 | 310 | 0 |
| | b | 0 | 9995 | 2840 | 550 | 1290 | 410 | 390 | 250 | 0 | 0 | 0 | 0 | 0 | 380 | 300 | 0 | 180 | 0 |
| | a | 0 | 9995 | 2840 | 1360 | 11100 | 560 | 700 | 530 | 530 | 270 | 270 | 600 | 620 | 1260 | 800 | 485 | 520 | 450 |
| | b | 0 | 9995 | 2840 | 3880 | 11040 | 1650 | 2260 | 1610 | 1600 | 870 | 1140 | 1400 | 1130 | 3580 | 1100 | 730 | 380 | 410 |
| Lime Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | a | 0 | 9995 | 2840 | 350 | 220 | 190 | 430 | 1100 | 0 | 410 | 240 | 400 | 1000 | 870 | 460 | 0 | 570 | 420 |
| | b | 0 | 9995 | 2840 | 865 | 1480 | 315 | 440 | 960 | 0 | 350 | 0 | 350 | 600 | 780 | 360 | 0 | 0 | 0 |
| | a | 0 | 9995 | 2840 | 3540 | 11000 | 670 | 3080 | 2130 | 1460 | 1020 | 0 | 1400 | 2600 | 3100 | 1500 | 780 | 330 | 290 |
| | b | 0 | 9995 | 2840 | 6600 | 11100 | 680 | 270 | 1640 | 1000 | 1190 | 1280 | 1100 | 2400 | 3400 | 1150 | 1050 | 780 | 760 |
| | a | 0 | 9995 | 2840 | 360 | 310 | 300 | 450 | 940 | 0 | 350 | 370 | 630 | 720 | 1050 | 500 | 0 | 400 | 250 |
| | b | 1710 | 9995 | 2840 | 6655 | 11000 | 1580 | 5500 | 4080 | 1200 | 900 | 420 | 1550 | 1900 | 3950 | 1200 | 380 | 790 | 250 |
| | a | 50 | 9995 | 2840 | 1530 | 2260 | 710 | 650 | 950 | 640 | 0 | 170 | 260 | 680 | 670 | 410 | 240 | 0 | 260 |
| | b | 0 | 9995 | 2840 | 2600 | 4090 | 830 | 1800 | 2080 | 860 | 380 | 0 | 350 | 1010 | 1420 | 860 | 360 | 0 | 0 |

† Due to a tropical depression preceding the sampling date we were unable to completely evacuate the lysimeters; therefore, we assumed all rainfall was present within the lysimeters.

‡ Due to incomplete evacuation of the lysimeters in early September, we used rainfall totals to approximate metal mass transport per sampling period.

Blanks indicate where sample was not collected due to lack of leachate.

# Metal concentrations of zero tension lysimeter leachate

Table 5.12: Ag concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches in surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.006 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.006 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.13: Ag concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.014 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.033 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | 0.006 | 0.006 | | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.14: Ag concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0.005 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | 0.006 | | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0.006 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.040 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | 0.006 | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | a | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | b | | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.15: Ba concentrations (mg L$^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | 0.105 | 0.081 | 0.059 | 0.075 | 0.075 | 0.091 | 0.089 | 0.080 | 0.093 | 0.075 | 0.085 | 0.096 | | | | |
| | b | | 0.098 | | 0.095 | 0.149 | 0.093 | 0.120 | 0.097 | 0.095 | | | 0.098 | 0.108 | 0.104 | 0.150 | | | |
| | b | | | 0.143 | 0.102 | 0.149 | 0.178 | 0.092 | 0.126 | | | | 0.104 | | 0.152 | 0.176 | | 0.190 | |
| | b | | 0.076 | 0.067 | 0.049 | 0.049 | 0.080 | | | | | | 0.054 | | 0.061 | 0.089 | | | |
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | 0.007 | 0.007 | 0.002 | 0.002 | 0.004 | 0.017 | 0.017 | 0.015 | 0.009 | 0.007 | 0.010 | 0.014 | | | | |
| | b | | 0.011 | 0.020 | 0.012 | 0.020 | 0.016 | 0.012 | 0.024 | 0.024 | | | 0.022 | 0.023 | 0.013 | 0.027 | | | |
| | b | | | 0.011 | 0.016 | 0.015 | 0.007 | 0.010 | 0.026 | | | | 0.011 | | 0.031 | 0.016 | | 0.048 | |
| | b | | 0.007 | 0.012 | 0.008 | 0.003 | 0.006 | | | | | | 0.011 | | 0.015 | 0.015 | | | |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0.033 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.022 | 0.047 | 0.120 | 0.128 | 0.122 | | | |
| | b | | 0.1498 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.114 | 0.245 | 0.221 | 0.238 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.076 | 0.101 | 0.174 | 0.244 | 0.220 | 0.239 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.145 | 0.158 | 0.229 | 0.241 | | | |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.008 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.007 | 0.048 | 0.040 | 0.019 | | | |
| | b | | 0.024 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.025 | 0.076 | 0.076 | 0.059 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.018 | 0.010 | 0.077 | 0.076 | 0.067 | 0.063 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.022 | 0.034 | 0.036 | 0.057 | | | |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0.098 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.047 | 0.048 | 0.052 | 0.064 | 0.070 | 0.064 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.765 | 1.899 | 1.498 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.107 | | | | 0.185 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.194 | 0.208 | | | |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.010 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.012 | 0.007 | 0.018 | 0.017 | 0.004 | 0.013 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.201 | 0.217 | 0.235 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.026 | | | | 0.028 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.023 | 0.027 | | | |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.058 | | 0.072 | 0.091 | | | 0.112 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.034 | 0.049 | | 0.077 | 0.058 | | | |
| | b | 0.073 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.085 | | 0.380 | 0.414 | 0.725 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.086 | | | 0.251 | | | |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.007 | | 0.016 | 0.014 | | | 0.028 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.008 | 0.007 | | 0.009 | 0.001 | | | |
| | b | 0.016 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.022 | | 0.114 | 0.141 | 0.225 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.011 | | | 0.016 | | | |

*** Samples were not collected for these treatments.

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.16: Ba concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.230 | 0.342 | 0.241 | 0.142 | 0.192 | 0.220 | 0.141 | 0.219 | 0.224 | 0.231 | 0.464 | 0.514 | 0.603 | 0.573 | | | 0.544 |
| | b | | 0.286 | 0.555 | 0.230 | 0.126 | 0.188 | 0.217 | 0.211 | | | | | 0.593 | 0.840 | 0.895 | | | |
| | a | 0.277 | 0.161 | 0.234 | 0.149 | 0.089 | 0.122 | 0.116 | 0.125 | 0.121 | 0.078 | 0.087 | 0.088 | 0.092 | 0.144 | 0.127 | 0.105 | | |
| | b | 0.280 | 0.119 | 0.213 | 0.228 | 0.063 | 0.074 | 0.071 | 0.089 | 0.076 | 0.096 | 0.160 | 0.191 | 0.253 | 0.880 | 0.541 | 0.526 | | |
| | a | | 0.205 | 0.292 | 0.227 | 0.259 | 0.226 | 0.237 | 0.217 | 0.309 | | | 0.687 | 1.233 | | 1.408 | | 1.442 | |
| | b | | 0.476 | 0.705 | 0.462 | 0.454 | 0.479 | 0.305 | 0.366 | | | 0.400 | 0.397 | 0.514 | 1.039 | 1.600 | 1.429 | 1.603 | |
| | a | | 0.251 | 0.342 | 0.301 | 0.299 | 0.194 | 0.203 | 0.201 | 0.201 | 0.200 | 0.216 | 0.320 | 0.440 | 1.189 | 0.456 | 0.413 | 0.399 | 0.362 |
| | b | | 0.366 | 0.373 | 0.325 | 0.252 | 0.335 | 0.313 | 0.256 | 0.266 | 0.336 | 0.374 | 0.343 | 0.686 | 0.629 | 1.059 | 1.104 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.009 | 0.001 | 0.009 | 0.004 | 0.001 | 0.006 | 0.006 | 0.034 | 0.038 | 0.050 | 0.127 | 0.162 | 0.136 | 0.152 | | | 0.193 |
| | b | | 0.012 | 0.001 | 0.008 | 0.0003 | 0.000 | 0.001 | 0.004 | | | | | 0.207 | 0.105 | 0.202 | | | |
| | a | 0.024 | 0.024 | 0.031 | 0.036 | 0.011 | 0.029 | 0.021 | 0.040 | 0.037 | 0.033 | 0.030 | 0.026 | 0.018 | 0.024 | 0.013 | 0.027 | | |
| | b | 0.022 | 0.026 | 0.027 | 0.029 | 0.003 | 0.009 | 0.005 | 0.031 | 0.026 | 0.033 | 0.057 | 0.071 | 0.076 | 0.089 | 0.071 | 0.117 | | |
| | a | | 0.047 | 0.050 | 0.055 | 0.026 | 0.028 | 0.045 | 0.067 | 0.083 | | | 0.086 | 0.108 | | 0.174 | | 0.344 | |
| | b | | 0.014 | 0.011 | 0.008 | 0.004 | 0.008 | 0.013 | 0.050 | | | 0.076 | 0.060 | 0.057 | 0.060 | 0.094 | 0.177 | 0.323 | |
| | a | | 0.047 | 0.048 | 0.046 | 0.013 | 0.023 | 0.045 | 0.067 | 0.065 | 0.064 | 0.067 | 0.088 | 0.114 | 0.101 | 0.079 | 0.096 | 0.145 | 0.122 |
| | b | | 0.042 | 0.057 | 0.064 | 0.039 | 0.052 | 0.057 | 0.079 | 0.083 | 0.094 | 0.084 | 0.079 | 0.137 | 0.061 | 0.174 | 0.226 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.053 | 0.142 | 0.154 | 0.037 | 0.092 | 0.076 | 0.067 | 0.065 | 0.046 | | 0.045 | 0.041 | 0.062 | 0.082 | 0.068 | 0.061 | 0.063 |
| | b | 0.281 | 0.153 | 0.228 | 0.220 | 0.111 | 0.184 | 0.141 | 0.141 | 0.137 | 0.099 | 0.091 | 0.105 | 0.137 | 0.153 | 0.163 | 0.148 | 0.139 | 0.128 |
| | a | 0.461 | 0.376 | 0.456 | 0.245 | 0.154 | 0.111 | 0.133 | 0.114 | 0.070 | 0.069 | 0.073 | 0.090 | 0.103 | 0.107 | 0.108 | 0.091 | 0.099 | 0.096 |
| | b | 0.323 | 0.217 | 0.261 | 0.143 | 0.122 | 0.113 | 0.089 | 0.071 | 0.086 | 0.088 | 0.080 | 0.099 | 0.112 | 0.187 | 0.153 | 0.161 | 0.161 | 0.159 |
| | a | | 0.403 | 0.638 | 0.311 | 0.150 | 0.317 | 0.219 | 0.185 | 0.211 | 0.147 | 0.321 | 0.646 | 3.893 | 4.884 | 3.415 | 3.457 | 3.794 | |
| | b | | 0.098 | 0.472 | 0.403 | 0.139 | 0.210 | 0.175 | 0.205 | 0.213 | 0.197 | 0.184 | 0.194 | 0.457 | 0.706 | 1.080 | 1.019 | 1.420 | 1.617 |
| | a | 0.195 | 0.092 | | 0.243 | 0.094 | 0.147 | 0.143 | | 0.134 | 0.109 | 0.096 | 0.120 | 0.216 | 0.629 | 1.646 | | 3.360 | 4.343 |
| | b | 0.249 | 0.259 | 0.354 | 0.344 | 0.231 | 0.195 | 0.173 | 0.181 | 0.214 | 0.196 | 0.184 | 0.254 | 0.316 | 0.413 | 0.524 | | 0.549 | 0.480 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.029 | 0.027 | 0.016 | 0.002 | 0.002 | 0.006 | 0.013 | 0.017 | 0.000 | | 0.005 | 0.006 | 0.015 | 0.013 | 0.015 | 0.014 | 0.012 |
| | b | 0.025 | 0.029 | 0.031 | 0.020 | 0.009 | 0.009 | 0.013 | 0.023 | 0.032 | 0.012 | 0.027 | 0.015 | 0.044 | 0.032 | 0.024 | 0.033 | 0.039 | 0.033 |
| | a | 0.005 | 0.007 | 0.007 | 0.001 | 0.002 | 0.000 | 0.003 | 0.021 | 0.020 | 0.019 | 0.021 | 0.018 | 0.010 | 0.024 | 0.016 | 0.024 | 0.031 | 0.025 |
| | b | 0.007 | 0.010 | 0.018 | 0.022 | 0.027 | 0.018 | 0.020 | 0.028 | 0.030 | 0.029 | 0.027 | 0.025 | 0.032 | 0.021 | 0.044 | 0.041 | 0.054 | 0.046 |
| | a | | 0.015 | 0.017 | 0.012 | 0.001 | 0.003 | 0.006 | 0.008 | 0.054 | 0.017 | 0.071 | 0.067 | 0.421 | 0.333 | 0.399 | 0.628 | 0.852 | |
| | b | | 0.028 | 0.023 | 0.025 | 0.010 | 0.013 | 0.019 | 0.042 | 0.061 | 0.025 | 0.052 | 0.036 | 0.124 | 0.159 | 0.097 | 0.292 | 0.529 | 0.464 |
| | a | 0.019 | 0.025 | | 0.010 | 0.004 | 0.003 | 0.006 | | 0.025 | 0.030 | 0.026 | 0.018 | 0.030 | 0.067 | 0.163 | | 0.870 | 1.195 |
| | b | 0.066 | 0.053 | 0.068 | 0.066 | 0.037 | 0.029 | 0.038 | 0.059 | 0.073 | 0.068 | 0.065 | 0.072 | 0.064 | 0.118 | 0.068 | | 0.192 | 0.170 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.17: Ba concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.425 | 0.263 | 0.245 | 0.210 | 0.172 | 0.142 | 0.125 | 0.106 | 0.119 | 0.123 | 0.119 | 0.205 | 0.221 | 0.213 | 0.236 | 0.194 | 0.482 |
| | b | 0.165 | 0.140 | 0.292 | 0.176 | 0.087 | 0.081 | 0.071 | 0.090 | 0.080 | 0.089 | 0.085 | 0.087 | 0.077 | 0.137 | 0.154 | 0.167 | 0.249 | 0.237 |
| | a | 0.162 | 0.030 | 0.090 | 0.044 | 0.012 | 0.028 | 0.035 | 0.036 | 0.031 | 0.031 | 0.023 | 0.034 | 0.072 | 0.098 | 0.132 | 0.118 | 0.168 | 0.235 |
| | b | | 0.300 | 0.236 | 0.113 | 0.025 | 0.039 | 0.046 | 0.046 | 0.042 | 0.044 | 0.035 | 0.096 | 0.195 | 0.258 | 0.217 | 0.290 | 0.264 | 0.232 |
| | a | 0.082 | | 0.433 | 0.500 | 0.503 | 0.348 | 0.563 | 0.541 | 0.575 | | 0.456 | | 1.097 | 1.135 | 1.856 | | 1.329 | |
| | b | | | 0.377 | 0.322 | 0.504 | 0.490 | 0.377 | 0.507 | | | | | | 0.550 | 0.544 | | 0.486 | |
| | a | | | 0.440 | 0.177 | 0.046 | 0.072 | 0.087 | 0.073 | 0.075 | 0.082 | 0.070 | 0.096 | 0.091 | 0.193 | 0.322 | 0.313 | 0.310 | 0.289 |
| | b | | 0.675 | 0.582 | 0.526 | 0.130 | 0.122 | 0.097 | 0.138 | 0.122 | 0.099 | 0.085 | 0.099 | 0.218 | 0.227 | 0.317 | 0.239 | 0.198 | 0.190 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.018 | 0.010 | 0.005 | 0.003 | 0.006 | 0.005 | 0.004 | 0.006 | 0.006 | 0.006 | 0.003 | 0.003 | 0.001 | 0.005 | 0.006 | 0.006 | 0.138 |
| | b | 0.044 | 0.015 | 0.008 | 0.009 | 0.002 | 0.002 | 0.006 | 0.013 | 0.024 | 0.026 | 0.027 | 0.023 | 0.023 | 0.038 | 0.037 | 0.042 | 0.039 | 0.071 |
| | a | 0.036 | 0.013 | 0.004 | 0.002 | 0 | 0.0002 | 0.002 | 0.010 | 0.010 | 0.010 | 0.010 | 0.004 | 0.015 | 0.014 | 0.028 | 0.033 | 0.055 | 0.080 |
| | b | | 0.015 | 0.009 | 0.003 | 0.001 | 0.001 | 0.006 | 0.014 | 0.014 | 0.013 | 0.013 | 0.008 | 0.005 | 0.008 | 0.003 | 0.021 | 0.029 | 0.071 |
| | a | 0.016 | | 0.129 | 0.063 | 0.128 | 0.103 | 0.125 | 0.125 | 0.195 | | 0.108 | | 0.185 | 0.227 | 0.322 | | 0.375 | |
| | b | | | 0.069 | 0.053 | 0.070 | 0.069 | 0.086 | 0.108 | | | | | | 0.051 | 0.086 | | 0.144 | |
| | a | | | 0.025 | 0.010 | 0.002 | 0 | 0.003 | 0.017 | 0.017 | 0.021 | 0.019 | 0.019 | 0.008 | 0.014 | 0.064 | 0.073 | 0.068 | 0.082 |
| | b | | 0.259 | 0.183 | 0.109 | 0.024 | 0.010 | 0.015 | 0.045 | 0.039 | 0.035 | 0.032 | 0.038 | 0.076 | 0.069 | 0.095 | 0.075 | 0.067 | 0.064 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.393 | 0.301 | 0.424 | 0.350 | 0.346 | 0.277 | 0.244 | | 0.191 | 0.218 | 0.113 | 0.246 | 0.656 | 3.309 | | 3.357 | 3.258 |
| | b | | 0.046 | 0.228 | 0.150 | 0.046 | 0.143 | 0.094 | 0.055 | | 0.198 | | 0.830 | 1.529 | 1.774 | 1.912 | | | |
| | a | | 0.230 | 0.287 | 0.243 | 0.056 | 0.082 | 0.080 | 0.177 | 0.123 | 0.107 | | 0.216 | 0.976 | 1.297 | 0.764 | 0.698 | 0.623 | 0.561 |
| | b | | 0 | 0.200 | 0.182 | 0.017 | 0.108 | 0.085 | 0.059 | 0.040 | 0.039 | 0.026 | 0.060 | 0.071 | 0.068 | 0.112 | 0.117 | 0.115 | 0.094 |
| | a | | 0.300 | 0.990 | 0.641 | 0.197 | 0.286 | 0.449 | 0.360 | | 0.140 | 0.217 | 0.155 | 0.260 | 0.297 | 0.342 | | 0.503 | 0.317 |
| | b | 0.090 | 0.148 | 0.257 | 0.225 | 0.115 | 0.105 | 0.102 | 0.144 | 0.138 | 0.151 | 0.154 | 0.189 | 0.235 | 0.273 | 0.491 | 0.430 | 0.504 | 0.637 |
| | a | | 0.536 | 0.320 | 0.289 | 0.257 | 0.381 | 0.451 | 0.630 | 0.760 | | 0.201 | 1.151 | 1.275 | 0.307 | 1.326 | 1.219 | | 1.029 |
| | b | | 0.596 | 0.237 | 0.259 | 0.315 | 0.202 | 0.178 | 0.178 | 0.200 | 0.187 | | 0.192 | 0.330 | 1.280 | 0.489 | 0.438 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.013 | 0.008 | 0.009 | 0.005 | 0.004 | 0.010 | 0.003 | | 0.006 | 0.006 | 0.009 | 0.024 | 0.091 | 0.393 | | 0.489 | 0.616 |
| | b | | 0.037 | 0.012 | 0.006 | 0.003 | 0.002 | 0.015 | 0.003 | | 0.054 | | 0.163 | 0.353 | 0.384 | 0.431 | | | |
| | a | | 0.009 | 0.008 | 0.006 | 0.003 | 0.003 | 0.010 | 0.057 | 0.039 | 0.035 | | 0.060 | 0.294 | 0.346 | 0.219 | 0.227 | 0.211 | 0.194 |
| | b | | 0.014 | 0.005 | 0.004 | 0.001 | 0.007 | 0.002 | 0.006 | 0.007 | 0.010 | 0.006 | 0.012 | 0.009 | 0.008 | 0.009 | 0.020 | 0.021 | 0.020 |
| | a | | 0.040 | 0.033 | 0.011 | 0.0004 | 0.0001 | 0.002 | 0.004 | | 0.001 | 0.024 | 0.007 | 0.045 | 0.033 | 0.028 | | 0.113 | 0.102 |
| | b | 0.049 | 0.047 | 0.046 | 0.044 | 0.012 | 0.020 | 0.029 | 0.033 | 0.048 | 0.050 | 0.031 | 0.061 | 0.073 | 0.065 | 0.044 | 0.120 | 0.160 | 0.192 |
| | a | | 0.036 | 0.030 | 0.035 | 0.051 | 0.071 | 0.131 | 0.206 | 0.262 | | 0.061 | 0.354 | 0.389 | 0.082 | 0.213 | 0.368 | | 0.345 |
| | b | | 0.102 | 0.042 | 0.057 | 0.059 | 0.051 | 0.051 | 0.059 | 0.068 | 0.066 | | 0.068 | 0.082 | 0.400 | 0.112 | 0.143 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.18: Cd concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | b | | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0.004 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.004 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | | 0.004 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.004 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | 0.004 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.19: Cd concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0.012 | 0.014 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0.020 | 0.007 | 0.005 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | a | | 0.007 | 0.001 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0.023 | 0.029 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0.008 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.016 | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.002 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.002 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0.012 | 0.006 | 0.002 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0.038 | 0.027 | 0.026 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0.020 | 0.017 | 0.012 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0.004 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.037 | 0.005 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0.022 | 0.023 | | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0.003 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | 0.004 | 0.004 | | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.20: Cd concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.008 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0.016 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0.010 | | 0 | 0 | 0 | 0 | 0.001 | *** | *** | *** | 0 | | *** | *** | *** | *** | 0 | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | 0 | *** |
| | a | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | 0.004 | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | | *** | *** | *** | *** | 0.004 | *** |
| | b | | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | 0.004 | *** |
| | a | | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.005 | 0.003 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.009 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0.028 | 0.021 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0.001 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.001 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | b | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | 0.004 | *** |
| | a | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.21: Cu concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0.035 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| | b | | 0.991 | | 0 | 0 | 1.349 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | | | |
| | b | | | 0 | 0 | 0 | 1.043 | 0 | 0 | | | | 0 | | 0 | 0 | | 0 | |
| | b | | 1.131 | 0 | 0 | 0 | 1.825 | | | | | | 0 | | 0 | 0 | | | |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.006 | 0.006 | 0.006 | 0.019 | 0.029 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | | | |
| | b | | 0.032 | | 0.006 | 0.006 | 0.120 | 0.006 | 0.006 | 0.006 | | | 0.006 | 0.006 | 0.006 | 0.006 | | | |
| | b | | | 0.006 | 0.006 | 0.006 | 0.008 | 0.006 | 0.006 | | | | 0.006 | | 0.006 | 0.006 | | 0.006 | |
| | b | | 0.033 | 0.006 | 0.006 | 0.006 | 0.042 | 0.101 | | | | | 0.006 | | 0.006 | 0.006 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0.862 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0.001 | | | |
| | b | | 0.553 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0.001 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0.015 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.051 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | | |
| | b | | 0.065 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | 0.006 | 0.006 | 0.006 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | 0.006 | 0.006 | 0.006 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0.902 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0 | 0 | 0 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | | | 0.007 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0 | 0.001 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.039 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.006 | 0.006 | 0.006 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | | | | 0.006 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.006 | 0.006 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | | | 0 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | | 0 | 0 | | | |
| | b | 2.227 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0.000 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | | 0.001 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | | 0.006 | 0.006 | | | 0.049 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | | 0.006 | 0.006 | | | |
| | b | 0.120 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | | 0.006 | 0.006 | 0.006 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.006 | | | 0.006 | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.22: Cu concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.351 | 0.029 | 0 | 0.442 | 0.026 | 1.220 | 0 | 0.008 | 0.057 | 0 | 0 | 0 | 0 | 0 | | | 0.006 |
| | b | | 0.288 | 0 | 0 | 0 | 0.050 | 2.414 | 0.014 | | | | | 0 | 0.030 | 0.074 | | | |
| | a | 1.601 | 0 | 0 | 0 | 0.154 | 0.289 | 0.389 | 0 | 1.175 | 0 | 0 | 0 | 0 | 0.002 | 0 | 0 | | |
| | b | 0.853 | 0.282 | 0 | 0 | 0 | 0.420 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | a | | 0.083 | 0 | 0 | 0 | 0.783 | 1.471 | 0 | 0.003 | | | 0.069 | 0.062 | | 0.023 | | 0 | |
| | b | | 0.178 | 0 | 0 | 0 | 1.494 | 1.399 | 0 | | | 0.013 | 0 | 0.014 | 0.006 | 0 | 0 | 0 | |
| | a | | 0.292 | 0 | 0 | 0 | 0 | 0.001 | 0 | 0.001 | 0 | 0 | 0 | 0 | 0 | 0.003 | 0.041 | 0.118 | 0.209 |
| | b | | 0.583 | 0.041 | 0.004 | 0 | 0.026 | 0.030 | 0.009 | 0 | 0.008 | 0.007 | 0.007 | 0.044 | 0.003 | 0.016 | 0.050 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.067 | 0.006 | 0.006 | 0.057 | 0.004 | 0.055 | 0.006 | 0 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | | 0 |
| | b | | 0.077 | 0.006 | 0.006 | 0.011 | 0.016 | 0.159 | 0.006 | | | | | 0.006 | 0.002 | 0.015 | | | |
| | a | 0.036 | 0.007 | 0.047 | 0.006 | 0.025 | 0.080 | 0.068 | 0.006 | 0.170 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | |
| | b | 0.012 | 0.035 | 0.006 | 0.006 | 0.006 | 0.056 | 0.015 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | |
| | a | | 0.085 | 0.006 | 0.006 | 0.006 | 0.128 | 0.229 | 0.006 | 0.007 | | | 0.020 | 0.010 | | 0.006 | | 0.006 | |
| | b | | 0.087 | 0.006 | 0.006 | 0.006 | 0.097 | 0.109 | 0.006 | | | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | |
| | a | | 0.056 | 0.017 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.004 | 0.040 | 0.166 |
| | b | | 0.072 | 0.006 | 0.010 | 0.006 | 0.006 | 0.000 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.001 | 0.006 | 0.008 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.136 | 0 | 0 | 0 | 0.989 | 0.003 | 0 | 0 | 0 | | 0 | 0 | 0.002 | 0 | 0 | 0 | 0.006 |
| | b | 1.876 | 0.222 | 0 | 0 | 0 | 0.942 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.005 | 0 | 0 | 0.006 |
| | a | 1.485 | 0.084 | 0 | 0 | 0 | 0.478 | 0 | 0.006 | 0.004 | 0 | 0.014 | 0.043 | 0.022 | 0.018 | 0.002 | 0.007 | 0.009 | 0.019 |
| | b | 1.391 | 0 | 0 | 0.091 | 0 | 0.754 | 1.485 | 0 | 0.738 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.006 |
| | a | | 0.871 | 0 | 0 | 0.004 | 2.435 | 1.976 | 0 | 0 | 0 | 0 | 0.003 | 0.035 | 0.026 | 0.020 | 0.039 | 0.119 | |
| | b | | 0.068 | 0 | 0 | 0 | 1.946 | 0.581 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.029 | 0.070 |
| | a | 0.937 | 0.054 | | 0 | 0 | 0.865 | 0.003 | | 0.003 | 0 | 0 | 0.001 | 0 | 0 | 0 | | 0.038 | 0.074 |
| | b | 1.268 | 0.703 | 0 | 0 | 0.463 | 0.654 | 0.939 | 0.005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0.006 | 0.006 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.016 | 0.015 | 0.006 | 0.006 | 0.055 | 0.006 | 0.006 | 0.006 | 0.006 | | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0 |
| | b | 0.037 | 0.013 | 0.006 | 0.006 | 0.006 | 0.018 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0 |
| | a | 0.175 | 0.085 | 0.006 | 0.006 | 0.006 | 0.014 | 0.006 | 0.006 | 0.002 | 0.006 | 0.006 | 0.005 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.019 |
| | b | 0.026 | 0.011 | 0.006 | 0.038 | 0.006 | 0.143 | 0.278 | 0.006 | 0.152 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0 |
| | a | | 0.098 | 0.006 | 0.006 | 0.002 | 0.185 | 0.090 | 0.006 | 0.002 | 0.006 | 0.006 | 0.006 | 0.006 | 0.003 | 0.006 | 0.005 | 0.031 | |
| | b | | 0.006 | 0.006 | 0.006 | 0.006 | 0.105 | 0.009 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.005 | 0.064 |
| | a | 0.027 | 0.018 | | 0.006 | 0.006 | 0.022 | 0.006 | | 0.006 | 0.006 | 0.006 | 0.002 | 0.006 | 0.006 | 0.006 | | 0.005 | 0.069 |
| | b | 0.168 | 0.050 | 0.006 | 0.006 | 0.050 | 0.093 | 0.216 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | 0.000 | 0 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.23: Cu concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 2.457 | 0 | 0.005 | 0 | 0.074 | 4.963 | 0.106 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0.008 | 0 | 0 | 0.006 |
| | b | 1.440 | 0.402 | 0 | 0.032 | 0 | 0.702 | 0.004 | 0 | 0.005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 0.883 | 0 | 0 | 0 | 0.220 | 1.002 | 0.563 | 0 | 0.486 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | | 0.380 | 0 | 0 | 0.005 | 0.693 | 0 | 0 | 0.000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 2.969 | | 0.007 | 0.009 | 0 | 0.743 | 1.014 | 0.104 | 0.059 | | 0.040 | | 0.064 | 0.054 | 0.049 | | 0.066 | |
| | b | | | 0 | 0 | 0 | 0.877 | 0.024 | 0.020 | | | | | | 0.249 | 0.043 | | 0.034 | |
| | a | | | 0.073 | 0.045 | 0 | 0.021 | 0 | 0.004 | 0.010 | 0.038 | 0.019 | 0.012 | 0.010 | 0.005 | 0.031 | 0.023 | 0.031 | 0.015 |
| | b | | 0.357 | 0 | 0 | 0 | 4.269 | 0.020 | 0.009 | 0 | 0.011 | 0.002 | 0 | 0 | 0 | 0.007 | 0.002 | 0.001 | 0.003 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 1.027 | 0.006 | 0.002 | 0.006 | 0.037 | 1.546 | 0.02 | 0.0006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | b | 0.269 | 0.175 | 0.012 | 0.006 | 0.006 | 0.060 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.066 |
| | a | 0.116 | 0.026 | 0.006 | 0.006 | 0.028 | 0.054 | 0.359 | 0.006 | 0.0679 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | b | | 0.165 | 0.006 | 0.006 | 0.000 | 0.095 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.020 |
| | a | 0.228 | | 0.017 | 0.003 | 0.002 | 0.307 | 0.338 | 0.0249 | 0.015 | | 0.002 | | 0.010 | 0.016 | 0.011 | | 0.031 | |
| | b | | | 0.321 | 0.006 | 0.006 | 0.230 | 0.004 | 0.006 | | | | | | 0.003 | 0.009 | | 0.007 | |
| | a | | | 0.048 | 0.020 | 0.004 | 0.006 | 0.116 | 0.006 | 0.006 | 0.0043 | 0.006 | 0.006 | 0.006 | 0.010 | 0.001 | 0.006 | 0.001 | 0.000 |
| | b | | 0.235 | 0.016 | 0.005 | 0.006 | 1.179 | 0.003 | 0.0011 | 0.006 | 0.005 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 1.568 | 0 | 0 | 0 | 0.042 | 6.782 | 0.053 | | 0.075 | 0.141 | 0.223 | 0.128 | 0.088 | 0.026 | | 0.069 | 0.175 |
| | b | | 0.051 | 0.102 | 0.080 | 0.041 | 0.113 | 0.091 | 0.042 | | 0.027 | | 0.046 | 0.072 | 0.080 | 0.127 | | | |
| | a | | 0.914 | 0.016 | 0.022 | 0.550 | 1.722 | 0 | 1.616 | 0.031 | 0.008 | | 0.005 | 0.053 | 0.049 | 0.080 | 0.0412 | 0.031 | 0.026 |
| | b | | 0 | 0 | 0 | 0 | 0.082 | 0 | 0 | 2.180 | 0 | 0 | 0 | 0 | 0 | 0 | 0.006 | 0 | 0 |
| | a | | 0.056 | 0 | 0.061 | 0.447 | 0.030 | 4.743 | 0 | | 0 | 0 | 0.006 | 0 | 0 | 0 | | 0.006 | 0 |
| | b | 0.143 | 0.472 | 0 | 0 | 0.550 | 0 | 0.442 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.006 | 0 | 0 |
| | a | | 3.880 | 0 | 0 | 0 | 0 | 0.025 | 0.003 | 0.014 | | 0.152 | 0.105 | 0.104 | 0.056 | 0.071 | 0.0888 | | 0.065 |
| | b | | 0.411 | 0 | 0 | 0 | 0 | 0.004 | 0.023 | 0.012 | 0 | | 0.002 | 0 | 0.073 | 0.001 | 0.006 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.751 | 0.011 | 0.006 | 0.006 | 0.006 | 2.096 | 0.0009 | | 0.0323 | 0.030 | 0.062 | 0.026 | 0.028 | 0.006 | | 0.036 | 0.042 |
| | b | | 0.161 | 0.057 | 0.034 | 0.020 | 0.035 | 0.037 | 0.0113 | | 0.0003 | | 0.015 | 0.006 | 0.023 | 0.032 | | | |
| | a | | 0.319 | 0.025 | 0.015 | 0.113 | 0.282 | 0.006 | 0.3432 | 0.006 | 0.006 | | 0.006 | 0.005 | 0.014 | 0.016 | 0.002 | 0.004 | 0.000 |
| | b | | 0.184 | 0.012 | 0.000 | 0.006 | 0.021 | 0.006 | 0.006 | 0.2856 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | a | | 0.028 | 0.006 | 0.006 | 0.006 | 0.012 | 0.486 | 0.006 | | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | 0.013 | 0.006 |
| | b | 0.101 | 0.157 | 0.028 | 0.006 | 0.164 | 0.006 | 0.113 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | a | | 0.513 | 0.006 | 0.006 | 0.006 | 0.006 | 0.002 | 0.006 | 0.005 | | 0.006 | 0.032 | 0.020 | 0.006 | 0.022 | 0.019 | | 0.009 |
| | b | | 0.117 | 0.031 | 0.004 | 0.010 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | | 0.006 | 0.006 | 0.022 | 0.006 | 0.006 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.24: Ni concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 | 0 | 0 | 0 | 0 | | | | |
| | b | | 0.090 | | 0 | 0 | 0.149 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | | | |
| | b | | | 0 | 0 | 0 | 0.065 | 0 | 0 | | | | 0 | | 0 | 0 | | 0 | |
| | b | | 0.191 | 0 | 0 | 0 | 0.080 | | | | | | 0 | | 0 | 0 | | | |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | | |
| | b | | 0.023 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | 0.008 | 0.008 | 0.008 | 0.008 | | | |
| | b | | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | | 0.008 | | 0.008 | 0.008 | | 0.008 | |
| | b | | 0.031 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | | | 0.008 | | 0.008 | 0.008 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0.084 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | | | |
| | b | | 0.110 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.023 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | |
| | b | | 0.027 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.008 | 0.008 | 0.008 | 0.008 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.008 | 0.008 | 0.008 | 0.008 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0.214 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0 | 0 | 0 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | | | 0 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0 | 0 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.043 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.008 | 0.008 | 0.008 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.008 | | | | 0.008 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.008 | 0.008 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | | | 0 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | | 0 | 0 | | | |
| | b | 0.173 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | | 0 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.008 | | 0.008 | 0.008 | | | 0.008 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.008 | 0.008 | | 0.008 | 0.008 | | | |
| | b | 0.028 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.008 | | 0.008 | 0.008 | 0.008 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.008 | | | 0.008 | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.25: Ni concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.030 | 0.011 | 0.018 | 0.043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |
| | b | | 0.039 | 0.043 | 0.037 | 0.024 | 0 | 0.108 | 0.031 | | | | | 0.003 | 0.035 | 0.071 | | | |
| | a | 0.353 | 0 | 0 | 0 | 0.023 | 0 | 0 | 0 | 0.199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | 0.195 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | a | | 0.075 | 0 | 0 | 0 | 0.047 | 0.162 | 0 | 0 | | | 0.027 | 0.025 | | 0.024 | | 0.023 | |
| | b | | 0.033 | 0.001 | 0 | 0 | 0.058 | 0.077 | 0 | | | 0.005 | 0 | 0 | 0 | 0.007 | 0.006 | 0.008 | |
| | a | | 0.043 | 0.004 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.008 | 0.007 | 0 | 0.001 | 0.038 | 0.073 | 0.129 | 0.173 |
| | b | | 0.071 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.011 | 0.007 | 0.009 | 0.003 | 0 | 0.047 | 0.051 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.018 | 0.008 | 0 | 0.010 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | 0.008 |
| | b | | 0.027 | 0.008 | 0.012 | 0.006 | 0.008 | 0.008 | 0.005 | | | | | 0.008 | 0.004 | 0.017 | | | |
| | a | 0.066 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.020 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | |
| | b | 0.031 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | |
| | a | | 0.030 | 0.008 | 0.008 | 0.008 | 0.008 | 0.035 | 0.008 | 0.008 | | | 0.006 | 0.005 | | 0.005 | | 0.003 | |
| | b | | 0.022 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | 0.003 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | |
| | a | | 0.017 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.0002 | 0.001 | 0.008 | 0.008 | 0.008 | 0.019 | 0.046 | 0.055 |
| | b | | 0.018 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.001 | 0.008 | 0.008 | 0.008 | 0.010 | 0.012 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.005 | 0 | 0 | 0 | 0.035 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | 0.262 | 0.019 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 0.414 | 0.060 | 0.019 | 0.117 | 0.009 | 0.031 | 0 | 0 | 0.023 | 0 | 0 | 0.031 | 0.021 | 0.005 | 0.011 | 0.026 | 0.009 | 0.051 |
| | b | 0.340 | 0 | 0 | 0 | 0 | 0.059 | 0.124 | 0 | 0.096 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | | 0.049 | 0 | 0 | 0 | 0.134 | 0.057 | 0 | 0 | 0 | 0 | 0.029 | 0.026 | 0.039 | 0.056 | 0.065 | 0.078 | |
| | b | | 0.026 | 0 | 0 | 0 | 0.071 | 0 | 0 | 0 | 0 | 0 | 0.007 | 0 | 0.008 | 0.008 | 0.012 | 0.036 | 0.052 |
| | a | 0.219 | 0.020 | | 0 | 0 | 0.041 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 | | 0.047 | 0.069 |
| | b | 0.246 | 0.064 | 0 | 0 | 0.057 | 0.038 | 0.044 | 0 | 0.006 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.019 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | b | 0.047 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.001 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | a | 0.096 | 0.039 | 0.018 | 0.032 | 0.000 | 0.008 | 0.008 | 0.008 | 0.004 | 0.008 | 0.007 | 0.009 | 0.002 | 0.008 | 0.008 | 0.002 | 0.008 | 0.011 |
| | b | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.011 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | a | | 0.029 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.005 | 0.010 | 0.008 | 0.003 | 0.010 | 0.015 | 0.023 | |
| | b | | 0.026 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.001 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.013 |
| | a | 0.042 | 0.008 | | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.010 | 0.018 |
| | b | 0.086 | 0.036 | 0.008 | 0.008 | 0.004 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | 0.008 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.26: Ni concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.152 | 0.118 | 0.106 | 0.088 | 0.078 | 0.144 | 0.052 | 0.086 | 0.037 | 0.013 | 0.012 | 0.125 | 0.075 | 0.044 | 0.034 | 0.037 | 0.042 |
| | b | 0.208 | 0.013 | 0.014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 0.176 | 0 | 0 | 0 | 0.037 | 0.048 | 0.036 | 0 | 0.053 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | | 0.027 | 0.005 | 0 | 0 | 0 | 0 | 0 | 0.003 | 0 | 0 | 0.022 | 0.053 | 0.019 | 0.021 | 0.012 | 0.006 | 0.038 |
| | a | 0.289 | | 0.033 | 0.020 | 0.037 | 0.073 | 0.127 | 0.062 | 0.086 | | 0.056 | | 0.068 | 0.082 | 0.096 | | 0.119 | |
| | b | | | 0.002 | 0 | 0.005 | 0.091 | 0 | 0.036 | | | | | | 0.058 | 0.047 | | 0.045 | |
| | a | | | 0.005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | | 0.082 | 0 | 0 | 0 | 0.265 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.056 | 0.008 | 0.018 | 0.017 | 0.008 | 0.041 | 0.008 | 0.006 | 0.005 | 0.009 | 0.006 | 0.040 | 0.020 | 0.009 | 0.006 | 0.005 | 0.005 |
| | b | 0.051 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | a | 0.035 | 0.008 | 0.008 | 0.008 | 0.006 | 0.008 | 0.008 | 0.008 | 0.011 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | b | | 0.023 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.012 | 0.017 | 0.002 | 0.002 | 0.008 | 0.008 | 0.004 |
| | a | 0.043 | | 0.008 | 0.008 | 0.005 | 0.023 | 0.031 | 0.015 | 0.019 | | 0.021 | | 0.023 | 0.021 | 0.028 | | 0.036 | |
| | b | | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.003 | | | | | | 0.005 | 0.010 | | 0.011 | |
| | a | | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | b | | 0.039 | 0.008 | 0.008 | 0.008 | 0.043 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.197 | 0.449 | 0.346 | 0.233 | 0.235 | 0.307 | 0.174 | | 0.161 | 0.135 | 0.170 | 0.120 | 0.071 | 0.137 | | 0.260 | 0.456 |
| | b | | 0.082 | 0.019 | 0.018 | 0 | 0 | 0 | 0 | | 0 | | 0.015 | 0.045 | 0.065 | 0.087 | | | |
| | a | | 0.044 | 0.021 | 0.015 | 0.069 | 0.134 | 0 | 0.244 | 0 | 0 | | 0 | 0 | 0.008 | 0 | 0 | 0 | 0 |
| | b | | 0 | 0 | 0 | 0 | 0.075 | 0 | 0.002 | 0.317 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.003 |
| | a | | 0.067 | 0 | 0 | 0 | 0 | 0.155 | 0 | | 0 | 0 | 0.006 | 0 | 0 | 0 | | 0.012 | 0.014 |
| | b | 0.073 | 0.138 | 0 | 0 | 0.033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.010 | 0.042 |
| | a | | 0.666 | 0 | 0 | 0 | 0 | 0 | 0 | 0.025 | | 0.017 | 0.061 | 0.070 | 0.006 | 0.084 | 0.099 | | 0.114 |
| | b | | 0.075 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 | 0.047 | | 0.012 | 0.003 | 0.074 | 0.021 | 0.029 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.008 | 0.056 | 0.081 | 0.058 | 0.047 | 0.072 | 0.047 | | 0.039 | 0.047 | 0.062 | 0.034 | 0.021 | 0.040 | | 0.089 | 0.161 |
| | b | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | | 0.006 | 0.010 | 0.013 | 0.023 | | | |
| | a | | 0.034 | 0.008 | 0.002 | 0.015 | 0.023 | 0.008 | 0.032 | 0.008 | 0.008 | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | b | | 0.036 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.028 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | a | | 0.037 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | 0.008 | 0.002 | 0.008 | 0.008 | 0.008 | | 0.008 | 0.008 |
| | b | 0.036 | 0.037 | 0.008 | 0.008 | 0.002 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.005 |
| | a | | 0.149 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.003 | 0.026 | 0.019 | 0.008 | 0.022 | 0.028 | | 0.038 |
| | b | | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.005 | 0.008 | 0.017 | 0.002 | 0.003 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.27: Pb concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | 0 | 0 | 0 | 0 | 0 | | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | b | | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | 0.016 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | | 0.016 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | 0.016 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.016 | | *** | *** | *** | *** | | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | 0.016 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.28: Pb concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | 0.016 | 0.016 | | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.29: Pb concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | | *** | *** | *** | *** | 0 | *** |
| | b | | | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | 0 | *** |
| | a | | | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | 0.016 | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | | *** | *** | *** | *** | 0.016 | *** |
| | b | | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | 0.016 | *** |
| | a | | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0.016 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | b | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | 0.016 | *** |
| | a | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | b | | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.30: Sn concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.027 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.027 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.027 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.31: Sn concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | 0.027 | 0.027 | | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments.

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.32: Sn concentrations (mg L$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | 0.027 | | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0.027 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | 0.027 | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | a | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | b | | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.33: Zn concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0.068 | 0 | 0 | 0.022 | 0 | 0.028 | 0.016 | 0.024 | 0.030 | 0.033 | 0.015 | 0.029 | | | | |
| | b | | 0.430 | | 0 | 0.005 | 0.657 | 0.021 | 0.005 | 0.033 | | | 0.029 | 0.076 | 0.015 | 0.041 | | | |
| | b | | | 0.077 | 0 | 0.046 | 0.788 | 0.013 | 0.051 | | | | 0.018 | | 0.041 | 0.018 | | 0.039 | |
| | b | | 0.701 | 0.073 | 0.010 | 0 | 0.637 | | | | | | 0.036 | | 0.012 | 0.002 | | | |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.004 | 0.004 | 0.004 | 0.005 | 0.024 | 0.004 | 0.004 | 0.004 | 0.004 | 0.001 | 0.003 | 0.007 | | | | |
| | b | | 0.011 | 0.004 | 0.000 | 0.001 | 0.030 | 0.004 | 0.004 | 0.004 | | | 0.001 | 0.011 | 0.006 | 0.002 | | | |
| | b | | | 0.004 | 0.000 | 0.001 | 0.004 | 0.004 | 0.0001 | | | | 0.001 | | 0.008 | 0.004 | | 0.002 | |
| | b | | 0.019 | 0.004 | 0.004 | 0.003 | 0.015 | 0.052 | | | | | 0.001 | | 0.006 | 0.004 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0.301 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.025 | 0.008 | 0.024 | 0.015 | 0.006 | | | |
| | b | | 0.372 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.053 | 0.024 | 0.024 | 0.031 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.010 | 0.046 | 0.014 | 0.030 | 0.030 | 0.062 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.053 | 0.011 | 0.015 | 0.007 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.007 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | 0.001 | 0.010 | 0.004 | 0.004 | | | |
| | b | | 0.017 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.002 | 0.006 | 0.008 | 0.004 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.003 | 0.000 | 0.006 | 0.007 | 0.004 | 0.004 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.003 | 0.002 | 0.003 | 0.004 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0.602 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.004 | 0 | 0.038 | 0.014 | 0.004 | 0.006 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.045 | 0.018 | 0.027 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.054 | | | | 0.049 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.034 | 0.127 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.014 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.017 | 0.000 | 0.005 | 0.006 | 0.004 | 0.002 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.007 | 0.003 | 0.004 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.001 | | | | 0.004 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.008 | 0.014 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.055 | | 0.027 | 0.007 | | | 0.051 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.032 | 0.016 | | 0.012 | 0 | | | |
| | b | 0.686 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.053 | | 0.022 | 0.005 | 0.031 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.039 | | | 0.014 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.004 | | 0.001 | 0.004 | | | 0.044 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.002 | 0.004 | | 0.005 | 0.004 | | | |
| | b | 0.024 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.001 | | 0.004 | 0.004 | 0.006 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.001 | | | 0.004 | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.34: Zn concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.306 | 0.064 | 0 | 0.166 | 0.025 | 0.594 | 0.008 | 0.079 | 0.120 | 0.200 | 2.244 | 0.614 | 0.723 | 0.437 | | | 0.326 |
| | b | | 0.184 | 0.086 | 0 | 0 | 0.048 | 0.941 | 0.036 | | | | | 0.928 | 2.798 | 5.589 | | | |
| | a | 0.567 | 0.026 | 0.065 | 0 | 0.135 | 0.115 | 0.302 | 0.092 | 0.485 | 0.079 | 0.086 | 0.183 | 0.030 | 0.112 | 0.066 | 0.167 | | |
| | b | 0.305 | 0.083 | 0.054 | 0.043 | 0.044 | 0.242 | 0.044 | 0.093 | 0.092 | 0.116 | 0.197 | 0.509 | 0.164 | 0.319 | 0.258 | 0.161 | | |
| | a | | 1.886 | 0.468 | 0.091 | 0.155 | 0.752 | 1.239 | 0.717 | 1.066 | | | 5.886 | 1.789 | | 1.114 | | 0.597 | |
| | b | | 0.156 | 0.085 | 0 | 0.018 | 0.705 | 0.829 | 0.008 | | | 0.608 | 0.164 | 0.182 | 0.315 | 0.368 | 0.358 | 0.386 | |
| | a | | 0.127 | 0.173 | 0.056 | 0.103 | 0.121 | 0.160 | 0.322 | 0.283 | 0.372 | 0.489 | 1.326 | 0.624 | 0.690 | 1.435 | 3.581 | 5.180 | 4.832 |
| | b | | 0.570 | 0.428 | 0.095 | 0.112 | 0.188 | 0.216 | 0.281 | 0.359 | 1.063 | 1.295 | 2.733 | 0.945 | 0.720 | 0.976 | 1.522 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.010 | 0.004 | 0.004 | 0.003 | 0.004 | 0.009 | 0.004 | 0 | 0.005 | 0.024 | 0.229 | 0.179 | 0.186 | 0.109 | | | 0.119 |
| | b | | 0.008 | 0.004 | 0.004 | 0.004 | 0.004 | 0.007 | 0.004 | | | | | 0.242 | 0.913 | 1.877 | | | |
| | a | 0.013 | 0.004 | 0.004 | 0.004 | 0.012 | 0.032 | 0.021 | 0.029 | 0.106 | 0.053 | 0.022 | 0.019 | 0.017 | 0.014 | 0.004 | 0.041 | | |
| | b | 0.007 | 0.017 | 0.004 | 0.001 | 0.002 | 0.014 | 0.014 | 0.033 | 0.030 | 0.043 | 0.055 | 0.060 | 0.020 | 0.037 | 0.060 | 0.049 | | |
| | a | | 0.697 | 0.118 | 0.044 | 0.037 | 0.200 | 0.366 | 0.249 | 0.352 | | | 0.893 | 0.717 | | 0.396 | | 0.201 | |
| | b | | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.006 | 0.004 | | | 0.180 | 0.018 | 0.021 | 0.047 | 0.089 | 0.114 | 0.129 | |
| | a | | 0.041 | 0.035 | 0.025 | 0.003 | 0.007 | 0.033 | 0.099 | 0.068 | 0.121 | 0.142 | 0.164 | 0.224 | 0.107 | 0.485 | 1.268 | 1.885 | 1.722 |
| | b | | 0.041 | 0.009 | 0.019 | 0.012 | 0.026 | 0.033 | 0.087 | 0.120 | 0.345 | 0.443 | 0.405 | 0.359 | 0.243 | 0.340 | 0.538 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.167 | 0 | 0 | 0 | 0.431 | 0.016 | 0.033 | 0.058 | 0.023 | | 0.050 | 0.039 | 0.072 | 0.095 | 0.096 | 0.097 | 0.091 |
| | b | 0.782 | 0.090 | 0.011 | 0 | 0 | 0.410 | 0.001 | 0.008 | 0.020 | 0 | 0.060 | 0.228 | 0.167 | 0.192 | 0.155 | 0.122 | 0.105 | 0.091 |
| | a | 0.651 | 0.107 | 0 | 0 | 0.028 | 0.283 | 0.009 | 0.010 | 0 | 0.034 | 0.043 | 0.103 | 0.072 | 0.089 | 0.033 | 0.027 | 0.040 | 0.036 |
| | b | 0.617 | 0.084 | 0 | 0.126 | 0.016 | 0.445 | 0.912 | 0.049 | 0.456 | 0.018 | 0.038 | 0.075 | 0.042 | 0.059 | 0.030 | 0.048 | 0.063 | 0.043 |
| | a | | 0.243 | 0.010 | 0 | 0.019 | 1.184 | 0.729 | 0.005 | 0 | 0.002 | 0.233 | 2.501 | 1.411 | 1.388 | 1.509 | 2.165 | 3.567 | |
| | b | | 0.277 | 0.003 | 0 | 0.001 | 0.764 | 0.338 | 0.131 | 0.035 | 0.016 | 0.098 | 0.265 | 0.293 | 0.830 | 0.745 | 1.113 | 2.815 | 3.371 |
| | a | 0.373 | 0.027 | | 0.001 | 0.004 | 0.791 | 0.029 | | 0.079 | 0.084 | 0.038 | 0.146 | 0.063 | 0.265 | 0.522 | | 3.090 | 4.187 |
| | b | 0.519 | 0.483 | 0.112 | 0.010 | 0.359 | 0.428 | 0.644 | 0.109 | 0.159 | 0.258 | 0.304 | 0.711 | 0.344 | 0.412 | 0.367 | | 0.419 | 0.323 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.033 | 0.014 | 0.002 | 0.002 | 0.004 | 0.002 | 0.004 | 0.003 | 0.004 | | 0.004 | 0.002 | 0.013 | 0.009 | 0.014 | 0.015 | 0.007 |
| | b | 0.014 | 0.029 | 0.006 | 0.004 | 0.000 | 0.007 | 0.004 | 0.004 | 0.004 | 0.004 | 0.010 | 0.005 | 0.043 | 0.022 | 0.014 | 0.010 | 0.017 | 0.006 |
| | a | 0.005 | 0.004 | 0.005 | 0.004 | 0.001 | 0.004 | 0.004 | 0.004 | 0.058 | 0.003 | 0.015 | 0.007 | 0.008 | 0.016 | 0.004 | 0.007 | 0.008 | 0.007 |
| | b | 0.004 | 0.004 | 0.004 | 0.039 | 0.003 | 0.060 | 0.128 | 0.004 | 0.144 | 0.004 | 0.009 | 0.006 | 0.013 | 0.005 | 0.008 | 0.008 | 0.012 | 0.008 |
| | a | | 0.009 | 0.004 | 0.004 | 0.004 | 0.006 | 0.006 | 0.004 | 0.071 | 0.004 | 0.089 | 0.275 | 0.554 | 0.377 | 0.544 | 0.784 | 1.240 | |
| | b | | 0.053 | 0.004 | 0.000 | 0.004 | 0.016 | 0.021 | 0.004 | 0.067 | 0.004 | 0.030 | 0.036 | 0.110 | 0.295 | 0.334 | 0.405 | 1.031 | 1.214 |
| | a | 0.019 | 0.137 | | 0.004 | 0.002 | 0.000 | 0.004 | | 0.004 | 0.002 | 0.008 | 0.015 | 0.010 | 0.044 | 0.080 | | 1.142 | 1.486 |
| | b | 0.103 | 0.128 | 0.013 | 0.006 | 0.049 | 0.065 | 0.180 | 0.033 | 0.047 | 0.095 | 0.110 | 0.102 | 0.094 | 0.142 | 0.115 | | 0.154 | 0.128 |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.35: Zn concentrations (mg $L^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.799 | 0.116 | 0.049 | 0.044 | 0.080 | 1.160 | 0.041 | 0.047 | 0.031 | 0.038 | 0.036 | 0.040 | 0.043 | 0.068 | 0.055 | 0.025 | 0.071 |
| | b | 0.541 | 0.283 | 0.023 | 0.041 | 0 | 0.269 | 0.003 | 0.024 | 0.012 | 0 | 0.030 | 0.067 | 0.049 | 0.042 | 0.037 | 0.033 | 0.025 | 0.025 |
| | a | 0.376 | 0.013 | 0 | 0 | 0.105 | 0.408 | 0.305 | 0.024 | 0.372 | 0.019 | 0.040 | 0.048 | 0.022 | 0.060 | 0.052 | 0.050 | 0.055 | 0.078 |
| | b | | 0.164 | 0.005 | 0 | 0.029 | 0.214 | 0.008 | 0 | 0.016 | 0.039 | 0.018 | 0.033 | 0.037 | 0.031 | 0.034 | 0.039 | 0.037 | 0.046 |
| | a | 0.828 | | 0.308 | 0.249 | 0.602 | 1.083 | 1.800 | 1.006 | 1.248 | | 1.095 | | 0.769 | 1.083 | 0.799 | | 1.113 | |
| | b | | | 0.504 | 0.368 | 0.543 | 1.135 | 0.860 | 1.254 | | | | | | 2.462 | 2.093 | | 1.820 | |
| | a | | | 0.145 | 0.005 | 0 | 0.025 | 0 | 0.023 | 0.020 | 0.041 | 0.069 | 0.102 | 0.015 | 0.043 | 0.069 | 0.090 | 0.061 | 0.051 |
| | b | | 0.252 | 0.119 | 0.013 | 0.011 | 1.351 | 0.032 | 0.130 | 0.043 | 0.036 | 0.069 | 0.135 | 0.047 | 0.045 | 0.075 | 0.048 | 0.052 | 0.041 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.026 | 0.017 | 0.005 | 0.008 | 0.009 | 0.109 | 0.003 | 0.001 | 0.004 | 0.005 | 0 | 0.010 | 0.004 | 0.003 | 0.004 | 0.002 | 0.003 |
| | b | 0.114 | 0.007 | 0.004 | 0 | 0.003 | 0.009 | 0.004 | 0.004 | 0.002 | 0.003 | 0.006 | 0.004 | 0.005 | 0.008 | 0.003 | 0.003 | 0.003 | 0.014 |
| | a | 0.030 | 0.005 | 0.004 | 0.004 | 0.005 | 0.004 | 0.174 | 0.004 | 0.121 | 0.003 | 0.009 | 0.0004 | 0.011 | 0.005 | 0.004 | 0.012 | 0.018 | 0.020 |
| | b | | 0.005 | 0.004 | 0.004 | 0.000 | 0.002 | 0.004 | 0.004 | 0.004 | 0.004 | 0.002 | 0.001 | 0.006 | 0.003 | 0.004 | 0.002 | 0.001 | 0.010 |
| | a | 0.104 | | 0.064 | 0.048 | 0.151 | 0.448 | 0.618 | 0.333 | 0.441 | | 0.392 | | 0.298 | 0.383 | 0.264 | | 0.411 | |
| | b | | | 0.142 | 0.078 | 0.148 | 0.383 | 0.269 | 0.349 | | | | | | 0.521 | 0.729 | | 0.666 | |
| | a | | | 0.024 | 0.002 | 0.0002 | 0.002 | 0.061 | 0.011 | 0.004 | 0.002 | 0.004 | 0.008 | 0.008 | 0.002 | 0.006 | 0.007 | 0.003 | 0.002 |
| | b | | 0.101 | 0.016 | 0.010 | 0.010 | 0.045 | 0.004 | 0.034 | 0.006 | 0.012 | 0.018 | 0.006 | 0.020 | 0.014 | 0.020 | 0.016 | 0.017 | 0.006 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0.462 | 0.171 | 0.202 | 0.181 | 0.213 | 1.501 | 0.131 | | 0.111 | 0.302 | 0.282 | 0.086 | 0.088 | 1.433 | | 5.162 | 7.426 |
| | b | | 1.143 | 0.098 | 0.027 | 0.008 | 0.080 | 0.014 | 0.008 | | 0.110 | | 4.963 | 3.756 | 4.295 | 4.819 | | | |
| | a | | 0.432 | 0 | 0.027 | 0.216 | 0.762 | 0 | 0.767 | 0.037 | 0.020 | | 0.129 | 0.112 | 0.115 | 0.073 | 0.078 | 0.093 | 0.098 |
| | b | | 0 | 0 | 0.026 | 0 | 0.074 | 0.084 | 0.023 | 1.199 | 0 | 0.025 | 0.055 | 0.044 | 0.019 | 0.015 | 0.028 | 0.030 | 0.026 |
| | a | | 0.112 | 0.014 | 0.065 | 0.269 | 0.027 | 1.906 | 0.020 | | 0.015 | 0.028 | 0.050 | 0.129 | 0.097 | 0.105 | | 0.634 | 0.195 |
| | b | 0.600 | 0.676 | 0.275 | 0.260 | 0.336 | 0.057 | 0.305 | 0.077 | 0.092 | 0.088 | 0.084 | 0.206 | 0.106 | 0.089 | 0.148 | 0.153 | 0.205 | 0.391 |
| | a | | 2.965 | 0.692 | 0.017 | 0.022 | 0.111 | 0.263 | 0.735 | 0.955 | | 1.644 | 5.483 | 1.861 | 0.229 | 1.425 | 1.201 | | 0.969 |
| | b | | 0.821 | 0.201 | 0.139 | 0.164 | 0.259 | 0.197 | 0.182 | 0.214 | 0.226 | | 0.733 | 0.234 | 1.411 | 0.323 | 0.267 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 0.055 | 0.035 | 0.020 | 0.016 | 0.023 | 0.202 | 0.011 | | 0.012 | 0.015 | 0.014 | 0.004 | 0.027 | 0.300 | | 1.830 | 2.623 |
| | b | | 0.225 | 0.004 | 0.004 | 0.004 | 0.004 | 0.032 | 0.004 | | 0.006 | | 0.737 | 1.352 | 1.454 | 1.634 | | | |
| | a | | 0.012 | 0.018 | 0.004 | 0.011 | 0.005 | 0.004 | 0.200 | 0.004 | 0.006 | | 0.013 | 0.027 | 0.033 | 0.012 | 0.025 | 0.020 | 0.023 |
| | b | | 0.013 | 0.004 | 0.004 | 0.004 | 0.007 | 0.002 | 0.004 | 0.107 | 0.014 | 0.002 | 0.000 | 0.001 | 0.002 | 0.004 | 0.004 | 0 | 0.001 |
| | a | | 0.021 | 0.007 | 0.004 | 0.004 | 0.004 | 0.002 | 0.004 | | 0.004 | 0.001 | 0.004 | 0.016 | 0.008 | 0.014 | | 0.199 | 0.058 |
| | b | 0.221 | 0.207 | 0.068 | 0.067 | 0.113 | 0.010 | 0.104 | 0.014 | 0.029 | 0.032 | 0.018 | 0.029 | 0.035 | 0.027 | 0.037 | 0.047 | 0.068 | 0.126 |
| | a | | 0.112 | 0.034 | 0.003 | 0.006 | 0.005 | 0.067 | 0.242 | 0.339 | | 0.144 | 0.809 | 0.705 | 0.078 | 0.511 | 0.414 | | 0.368 |
| | b | | 0.129 | 0.014 | 0.023 | 0.054 | 0.077 | 0.059 | 0.070 | 0.072 | 0.083 | | 0.103 | 0.095 | 0.498 | 0.107 | 0.089 | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

## Metal concentrations of suction lysimeter leachate

Table 5.36: Ag concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.006 | | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | 0.006 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.006 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** |
| | 0.006 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | | 0.006 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.006 | 0.006 | *** | *** | *** | *** | *** | *** | *** | 0.006 | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.006 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.37: Ba concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.109 | | 0.220 | 2.224 | | | | | | | | | | |
| | 0.544 | | | 0.339 | 0.271 | 0.139 | | | 0.239 | | 0.052 | | 0.245 | | | | |
| | 0.620 | | 0.903 | 0.519 | | | | | | | | | | | | | |
| | 0.568 | | | 0.147 | 0.208 | 0.322 | 0.150 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.009 | | 0.047 | 0.477 | | | | | | | | | | |
| | 0.054 | | | 0.056 | 0.050 | 0.032 | | | 0.057 | | 0.013 | | 0.046 | | | | |
| | 0.078 | | 0.194 | 0.121 | | | | | | | | | | | | | |
| | 0.077 | | | 0.039 | 0.025 | 0.062 | 0.036 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.095 | 0.207 | 0.177 | 0.217 | | | | | | 0.364 | | | | |
| | 0.620 | 0.254 | 0.225 | 0.095 | 0.182 | 0.292 | 0.253 | 0.157 | 0.147 | 0.186 | 0.270 | | 0.425 | | | | |
| | | | | 0.274 | | 0.691 | | | | | | | | | | | |
| | | | | 0.165 | 0.870 | 0.510 | | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.001 | 0.007 | 0.039 | 0.039 | | | | | | 0.050 | | | | |
| | 0.128 | 0.055 | 0.062 | 0.021 | 0.049 | 0.085 | 0.073 | 0.052 | 0.041 | 0.053 | 0.061 | | 0.065 | | | | |
| | | | | 0.072 | | 0.114 | | | | | | | | | | | |
| | | | | 0.015 | 0.130 | 0.087 | | | | | | | | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0.185 | 0.358 | | 0.227 | | 0.488 | 0.351 | 0.394 | 0.466 | | 0.307 | | 0.362 | | | | 0.335 |
| | 0.174 | 0.185 | 0.227 | 0.103 | 0.131 | 0.085 | 0.086 | 0.101 | 0.069 | 0.086 | 0.090 | | 0.116 | | | | |
| | 1.144 | | | 0.445 | | 0.230 | 0.395 | | | | | | | | | | |
| | 0.524 | 0.297 | | 0.221 | 0.122 | 0.156 | 0.132 | 0.129 | 0.180 | | 0.225 | | 0.480 | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.036 | 0.069 | | 0.039 | | 0.102 | 0.095 | 0.133 | 0.160 | | 0.055 | | 0.050 | | | | 0.126 |
| | 0.015 | 0.048 | 0.049 | 0.025 | 0.018 | 0.020 | 0.017 | 0.026 | 0.009 | 0.018 | 0.017 | | 0.021 | | | | |
| | 0.064 | | | 0.050 | | 0.048 | 0.101 | | | | | | | | | | |
| | 0.071 | 0.045 | | 0.042 | 0.026 | 0.032 | 0.044 | 0.046 | 0.045 | | 0.073 | | 0.051 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.178 | | | 0.291 | | | | | | | | | | |
| | 0.250 | 0.308 | 0.541 | 0.108 | 0.078 | 0.128 | 0.162 | 0.105 | 0.095 | 0.093 | | | 0.286 | | | | |
| | | | 0.232 | 0.169 | 0.149 | 0.161 | 0.173 | | | | | | | | | | |
| | 0.567 | | 1.230 | 0.171 | 0.278 | 0.459 | 1.380 | | | | | | 0.312 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.040 | | | 0.024 | | | | | | | | | | |
| | 0.047 | 0.077 | 0.148 | 0.033 | 0.021 | 0.019 | 0.032 | 0.037 | 0.017 | 0.017 | | | 0.076 | | | | |
| | | | 0.039 | 0.027 | 0.027 | 0.029 | 0.037 | | | | | | | | | | |
| | 0.062 | | 0.143 | 0.051 | 0.047 | 0.086 | 0.417 | | | | | | 0.035 | | | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.38: Cd concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0 | | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | | | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | 0 | | 0 | 0 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | | | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.004 | | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.004 | | | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | 0.004 | | 0.004 | 0.004 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.004 | | | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | | | | 0 | | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | | | | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | | | | 0.004 | | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | | | | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0 | 0 | | 0 | | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | 0 | | | 0 | | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | 0 | | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.004 | 0.004 | | 0.004 | | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | 0.004 | *** | *** | *** | *** | | *** |
| | 0.004 | | | 0.004 | | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.004 | 0.004 | | 0.004 | 0.004 | 0.004 | *** | *** | *** | | 0.004 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | | *** | *** | *** | *** | | *** |
| | | | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.004 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | 0.004 | | *** | *** | *** | *** | | *** |
| | | | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.004 | | 0.004 | 0.004 | 0.004 | 0.004 | *** | *** | *** | | | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.39: Cu concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 1.739 | | 0.951 | 0.020 | | | | | | | | | | |
| | 0 | | | 0.772 | 0.364 | 0.639 | | | 0.015 | | 0 | | 0 | | | | |
| | 0 | | 0.026 | 0.474 | | | | | | | | | | | | | |
| | 0 | | | 0.315 | 1.051 | 4.402 | 0 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.302 | | 0.282 | 0.004 | | | | | | | | | | |
| | 0.006 | | | 0.190 | 0.100 | 0.132 | | | 0.006 | | 0.006 | | 0.006 | | | | |
| | 0.006 | | 0.017 | 0.082 | | | | | | | | | | | | | |
| | 0.006 | | | 0.104 | 0.303 | 1.411 | 0.006 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.927 | 1.355 | 1.385 | 0.018 | | | | | | 0.007 | | | | |
| | 0 | 0 | 0 | 0.683 | 1.253 | 1.216 | 0.026 | 0 | 0 | 0.912 | 0 | | 0.003 | | | | |
| | | | | 0.580 | | 1.621 | | | | | | | | | | | |
| | | | | 0.957 | 0.626 | 1.587 | | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.065 | 0.216 | 0.245 | 0.002 | | | | | | 0.001 | | | | |
| | 0.006 | 0.006 | 0.006 | 0.101 | 0.257 | 0.259 | 0.006 | 0.006 | 0.006 | 0.238 | 0.006 | | 0 | | | | |
| | | | | 0.103 | | 0.374 | | | | | | | | | | | |
| | | | | 0.286 | 0.120 | 0.545 | | | | | | | | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0 | 0 | | 0.457 | | 0.627 | 0 | 0 | 0 | | 0 | | 0 | | | | 0.001 |
| | 0 | 0 | 0 | 0.425 | 0.561 | 1.329 | 0 | 0 | 0 | 0.867 | 0 | | 0.016 | | | | |
| | 0 | | | 0.730 | | 1.766 | 0.013 | | | | | | | | | | |
| | 0 | 0.031 | | 0.528 | 0.398 | 0.808 | 0 | 0 | 0 | | 0 | | 0.006 | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.017 | 0.006 | | 0.154 | | 0.174 | 0.006 | 0.006 | 0.006 | | 0.006 | | 0.006 | | | | 0.006 |
| | 0.006 | 0.006 | 0.006 | 0.053 | 0.044 | 0.160 | 0.006 | 0.006 | 0.006 | 0.088 | 0.006 | | 0.002 | | | | |
| | 0.006 | | | 0.251 | | 0.611 | 0.001 | | | | | | | | | | |
| | 0.006 | 0.020 | | 0.189 | 0.077 | 0.221 | 0.006 | 0.006 | 0.006 | | 0.006 | | 0.006 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.832 | | | 0.003 | | | | | | | | | | |
| | 0 | 0 | 0 | 2.184 | 4.741 | 0.886 | 0.001 | 0 | 0 | 0 | | | 0 | | | | |
| | | | 0 | 0.696 | 0.787 | 1.691 | 0.005 | | | | | | | | | | |
| | 0 | | 0 | 0.533 | 0.433 | 0.944 | 0 | | | | | | 0 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.120 | | | 0.006 | | | | | | | | | | |
| | 0.006 | 0.006 | 0.006 | 0.443 | 0.771 | 0.232 | 0.006 | 0.006 | 0.006 | 0.006 | | | 0.006 | | | | |
| | | | 0.006 | 0.265 | 0.048 | 0.503 | 0.006 | | | | | | | | | | |
| | 0.006 | | 0.006 | 0.042 | 0.106 | 0.217 | 0.006 | | | | | | 0.006 | | | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.40: Ni concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.1309 | | 0.283 | 0.071 | | | | | | | | | | |
| | 0 | | | 0.050 | 0 | 0 | | | 0 | | 0 | | 0 | | | | |
| | 0.266 | | 0.092 | 0.035 | | | | | | | | | | | | | |
| | 0.259 | | | 0.042 | 0.050 | 0.288 | 0.007 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.027 | | 0.088 | 0.017 | | | | | | | | | | |
| | 0.008 | | | 0.005 | 0.008 | 0.008 | | | 0.008 | | 0.008 | | 0.008 | | | | |
| | 0.100 | | 0.026 | 0.005 | | | | | | | | | | | | | |
| | 0.111 | | | 0.011 | 0.008 | 0.068 | 0.008 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.131 | 0.185 | 0.112 | 0.014 | | | | | | 0 | | | | |
| | 0.0237 | 0.009 | 0 | 0.049 | 0.067 | 0.059 | 0 | 0 | 0 | 0.189 | 0 | | 0 | | | | |
| | | | | 0.047 | | 0.255 | | | | | | | | | | | |
| | | | | 0.101 | 0.183 | 0.138 | | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.037 | 0.037 | 0.008 | 0.008 | | | | | | 0.008 | | | | |
| | 0.025 | 0.008 | 0.008 | 0.002 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.017 | 0.008 | | 0.008 | | | | |
| | | | | 0.006 | | 0.065 | | | | | | | | | | | |
| | | | | 0.027 | 0.036 | 0.026 | | | | | | | | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0.422 | 0.101 | | 0.033 | | 0.028 | 0 | 0 | 0 | | 0 | | 0 | | | | 0.013 |
| | 0 | 0 | 0 | 0.027 | 0 | 0.068 | 0 | 0 | 0 | 0.135 | 0 | | 0 | | | | |
| | 0.118 | | | 0.058 | | 0.202 | 0.007 | | | | | | | | | | |
| | 0.101 | 0.068 | | 0.054 | 0 | 0.031 | 0 | 0 | 0 | | 0 | | 0 | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.173 | 0.033 | | 0.006 | | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | | 0.008 | | | | 0.001 |
| | 0.008 | 0.008 | 0.008 | 0.002 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.009 | 0.008 | | 0.008 | | | | |
| | 0.057 | | | 0.012 | | 0.053 | 0.008 | | | | | | | | | | |
| | 0.059 | 0.027 | | 0.012 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | 0.008 | | 0.008 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.082 | | | 0.085 | | | | | | | | | | |
| | 0.103 | 0.030 | 0 | 0.123 | 0.502 | 0 | 0 | 0 | 0 | 0 | | | 0 | | | | |
| | | | 0.089 | 0.048 | 0.206 | 0.144 | 0.030 | | | | | | | | | | |
| | 0.219 | | 0.063 | 0.052 | 0 | 0.146 | 0.033 | | | | | | 0.0088 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.011 | | | 0.008 | | | | | | | | | | |
| | 0.040 | 0.008 | 0.008 | 0.023 | 0.020 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | | | 0.008 | | | | |
| | | | 0.019 | 0.011 | 0.043 | 0.035 | 0.005 | | | | | | | | | | |
| | 0.100 | | 0.017 | 0.011 | 0.008 | 0.008 | 0.006 | | | | | | 0.008 | | | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.41: Pb concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0 | | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | | | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | 0 | | 0 | 0 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | | | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.016 | | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.016 | | | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | 0.016 | | 0.016 | 0.016 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.016 | | | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | | | | 0 | | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | | | | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | | | | 0.016 | | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | | | | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0 | 0 | | 0 | | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | 0 | | | 0 | | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | 0 | | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.016 | 0.016 | | 0.016 | | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | 0.016 | *** | *** | *** | *** | | *** |
| | 0.016 | | | 0.016 | | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.016 | 0.016 | | 0.016 | 0.016 | 0.016 | *** | *** | *** | | 0.016 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | | *** | *** | *** | *** | | *** |
| | | | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.016 | | | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | 0.016 | | *** | *** | *** | *** | | *** |
| | | | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | 0.016 | | 0.016 | 0.016 | 0.016 | 0.016 | *** | *** | *** | | | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.42: Sn concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.027 | | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | 0.027 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.027 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** |
| | 0.027 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | | 0.027 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.027 | 0.027 | *** | *** | *** | *** | *** | *** | *** | 0.027 | | *** | *** | *** | *** | *** | *** |
| | | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | 0.027 | | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.43: Zn concentrations (mg $L^{-1}$) collected from suction lysimeters adjacent to two application rates of entrenched anaerobically digested and lime-stabilized biosolids.

| Treatment | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.622 | | 1.761 | 0.260 | | | | | | | | | | |
| | 1.162 | | | 0.424 | 0.276 | 0.386 | | | 0.071 | | 0.045 | | 0.154 | | | | |
| | 1.915 | | 1.006 | 0.436 | | | | | | | | | | | | | |
| | 0.587 | | | 0.308 | 0.472 | 2.033 | 0.134 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.013 | | 0.572 | 0.103 | | | | | | | | | | |
| | 0.370 | | | 0.094 | 0.020 | 0.070 | | | 0.016 | | 0.004 | | 0.013 | | | | |
| | 0.552 | | 0.373 | 0.129 | | | | | | | | | | | | | |
| | 0.198 | | | 0.116 | 0.164 | 0.643 | 0.034 | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.510 | 0.865 | 0.816 | 0.110 | | | | | | 0.097 | | | | |
| | 0.299 | 0.445 | 0.172 | 0.392 | 0.522 | 0.542 | 0.042 | 0.034 | 0.033 | 0.545 | 0.163 | | 0.072 | | | | |
| | | | | 0.438 | | 1.327 | | | | | | | | | | | |
| | | | | 0.871 | 1.340 | 1.253 | | | | | | | | | | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.001 | 0.004 | 0.134 | 0.001 | | | | | | 0.006 | | | | |
| | 0.060 | 0.057 | 0.037 | 0.053 | 0.099 | 0.124 | 0.059 | 0.013 | 0.011 | 0.157 | 0.016 | | 0.011 | | | | |
| | | | | 0.116 | | 0.360 | | | | | | | | | | | |
| | | | | 0.008 | 0.012 | 0.419 | | | | | | | | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | 1.480 | 0.209 | | 0.230 | | 0.316 | 0.046 | 0.023 | 0.050 | | 0.290 | | 0.069 | | | | 0.766 |
| | 0.498 | 0.424 | 0.244 | 0.255 | 0.225 | 0.533 | 0.023 | 0.030 | 0.031 | 0.601 | 0.074 | | 0.195 | | | | |
| | 2.969 | | | 0.455 | | 1.868 | 0.105 | | | | | | | | | | |
| | 1.091 | 0.312 | | 0.389 | 0.239 | 0.342 | 0.061 | 0.022 | 0.037 | | 0.345 | | 0.173 | | | | |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | 0.426 | 0.077 | | 0.086 | | 0.112 | 0.011 | 0.011 | 0.019 | | 0.043 | | 0.025 | | | | 0.305 |
| | 0.007 | 0.051 | 0.027 | 0.022 | 0.011 | 0.044 | 0.001 | 0.004 | 0 | 0.062 | 0.003 | | 0.022 | | | | |
| | 0.915 | | | 0.164 | | 0.634 | 0.041 | | | | | | | | | | |
| | 0.361 | 0.098 | | 0.147 | 0.061 | 0.113 | 0.013 | 0.007 | 0.002 | | 0.032 | | 0.016 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | | | | 0.708 | | | 0.552 | | | | | | | | | | |
| | 0.093 | 0.133 | 0.365 | 0.918 | 1.419 | 0.305 | 0.036 | 0.032 | 0.014 | 0.026 | | | 0.044 | | | | |
| | | | 0.312 | 0.459 | 0.655 | 0.820 | 0.140 | | | | | | | | | | |
| | 0.363 | | 0.153 | 0.381 | 0.232 | 0.471 | 0.041 | | | | | | 0.148 | | | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | | | | 0.051 | | | 0.003 | | | | | | | | | | |
| | 0.012 | 0.020 | 0.032 | 0.229 | 0.345 | 0.018 | 0.003 | 0.016 | 0.004 | 0.003 | | | 0.007 | | | | |
| | | | 0.110 | 0.172 | 0.071 | 0.256 | 0.053 | | | | | | | | | | |
| | 0.117 | | 0.058 | 0.027 | 0.066 | 0.126 | 0.019 | | | | | | 0.050 | | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

## Metal mass transport per sampling period of metals

Table 5.44: Ag mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.04 | 0.12 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | | *** | *** | *** | *** | *** | *** | *** | | 0.12 | *** | *** | *** | *** | *** | *** |
| | b | | | 0.50 | *** | *** | *** | *** | *** | *** | *** | | 0.05 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | | 0.06 | *** | *** | *** | *** | *** | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.14 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.14 | 0.22 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.10 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.06 | 0.12 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.07 | *** | *** | *** | *** | *** | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.07 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.07 | 0.15 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.03 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.06 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.05 | 0.10 | *** | *** | *** | *** | *** | *** |
| | b | 0.06 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.07 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.09 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.45: Ag mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.26 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.57 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.09 | 0.07 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0.08 | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.10 | 0.21 | *** | *** | *** | *** | *** | *** |
| | b | 0.30 | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.28 | 0.34 | *** | *** | *** | *** | *** | *** |
| | a | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | | 0.07 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.04 | 0.12 | *** | *** | *** | *** | *** | *** |
| | a | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.11 | 0.16 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.10 | 0.07 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | | 0.60 | *** | *** | *** | *** | *** | *** |
| | b | 0.13 | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.64 | 0.81 | *** | *** | *** | *** | *** | *** |
| | a | 0.12 | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.78 | 0.69 | *** | *** | *** | *** | *** | *** |
| | b | 0.15 | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.32 | 0.71 | *** | *** | *** | *** | *** | *** |
| | a | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.12 | 0.15 | *** | *** | *** | *** | *** | *** |
| | b | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.15 | 0.70 | *** | *** | *** | *** | *** | *** |
| | a | 0.20 | 3.55 | | *** | *** | *** | *** | *** | *** | *** | 0.14 | 0.67 | *** | *** | *** | *** | *** | *** |
| | b | 0.08 | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.13 | 0.32 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.46: Ag mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0.04 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.00 | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.06 | 0.17 | *** | *** | *** | *** | *** | *** |
| | b | 0.08 | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.40 | 0.56 | *** | *** | *** | *** | *** | *** |
| | a | 0.13 | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.26 | 0.34 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.19 | 0.27 | *** | *** | *** | *** | *** | *** |
| | a | 0.08 | | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.03 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0.50 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.05 | 0.11 | *** | *** | *** | *** | *** | *** |
| | b | | 1.78 | 0.50 | *** | *** | *** | *** | *** | *** | *** | 0.20 | 0.25 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0.40 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0.47 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.09 | 0.14 | *** | *** | *** | *** | *** | *** |
| | b | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | | 0.12 | *** | *** | *** | *** | *** | *** |
| | a | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | | 0.50 | *** | *** | *** | *** | *** | *** |
| | b | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.45 | 0.39 | *** | *** | *** | *** | *** | *** |
| | a | 0.61 | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.13 | 0.22 | *** | *** | *** | *** | *** | *** |
| | b | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.15 | 0.55 | *** | *** | *** | *** | *** | *** |
| | a | | 3.55 | 1.01 | *** | *** | *** | *** | *** | *** | *** | 0.06 | 0.09 | *** | *** | *** | *** | *** | *** |
| | b | | 3.55 | 0.54 | *** | *** | *** | *** | *** | *** | *** | | 0.12 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.47: Ba mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | 8.82 | 1.32 | 0.67 | 0.65 | 0.62 | 1.80 | 1.39 | 0.71 | 0.55 | 1.51 | 1.25 | 2.56 | | | | |
| | b | | 28.85 | | 2.11 | 12.43 | 1.13 | 1.99 | 1.01 | 1.41 | | | 1.97 | 1.35 | 2.65 | 1.47 | | | |
| | b | | | 12.02 | 1.33 | 1.32 | 0.90 | 0.71 | 0.71 | | | | 0.92 | | 1.80 | 2.34 | | 2.02 | |
| | b | | 22.49 | 5.62 | 0.32 | 0.18 | 0.35 | | | | | | 0.51 | | 0.56 | 0.76 | | | |
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | 0.61 | 0.12 | 0.02 | 0.02 | 0.03 | 0.34 | 0.27 | 0.14 | 0.06 | 0.13 | 0.14 | 0.36 | | | | |
| | b | | 3.23 | | 0.28 | 1.68 | 0.20 | 0.20 | 0.24 | 0.35 | | | 0.44 | 0.29 | 0.33 | 0.26 | | | |
| | b | | | 0.89 | 0.21 | 0.13 | 0.03 | 0.08 | 0.15 | | | | 0.10 | | 0.37 | 0.22 | | 0.51 | |
| | b | | 2.01 | 1.00 | 0.05 | 0.01 | 0.03 | | | | | | 0.10 | | 0.14 | 0.13 | | | |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0.77 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.52 | 1.74 | 2.60 | 4.54 | 2.48 | | | |
| | b | | 37.13 | *** | *** | *** | *** | *** | *** | *** | *** | | 1.88 | 6.61 | 11.77 | 4.01 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.77 | 2.01 | 2.05 | 4.77 | 2.73 | 3.25 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 1.67 | 1.50 | 3.52 | 3.07 | | | |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.18 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.15 | 0.27 | 1.03 | 1.42 | 0.38 | | | |
| | b | | 7.19 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.41 | 2.05 | 4.07 | 1.00 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.18 | 0.21 | 0.91 | 1.48 | 0.83 | 0.85 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.25 | 0.33 | 0.55 | 0.72 | | | |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 1.22 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.58 | 1.17 | 1.53 | 2.67 | 1.53 | 1.06 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 7.47 | 70.28 | 24.39 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.57 | | | | 1.15 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 1.72 | 1.54 | | | |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.12 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.15 | 0.16 | 0.54 | 0.70 | 0.08 | 0.22 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 1.97 | 8.03 | 3.83 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.14 | | | | 0.17 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.20 | 0.20 | | | |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.56 | | 0.75 | 1.27 | | | 0.79 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.27 | 0.81 | | 2.52 | 0.85 | | | |
| | b | 0.77 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.96 | | 3.83 | 6.38 | 6.66 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 1.25 | | | 2.89 | | | |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.07 | | 0.16 | 0.20 | | | 0.20 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.06 | 0.12 | | 0.28 | 0.01 | | | |
| | b | 0.17 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.25 | | 1.15 | 2.17 | 2.06 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.17 | | | 0.18 | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.48: Ba mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 68.14 | 28.71 | 8.91 | 5.98 | 2.28 | 4.94 | 5.86 | 1.95 | 1.99 | 3.42 | 5.77 | 12.64 | 19.64 | 8.66 | | | 4.83 |
| | b | | 84.60 | 46.65 | 6.14 | 2.51 | 1.17 | 1.73 | 4.18 | | | | | 9.66 | 24.86 | 6.89 | | | |
| | a | 3.53 | 47.58 | 19.66 | 10.47 | 29.11 | 4.43 | 7.06 | 5.90 | 3.67 | 1.81 | 1.41 | 3.10 | 1.91 | 7.68 | 3.19 | 2.95 | | |
| | b | 14.09 | 35.27 | 17.88 | 37.85 | 21.21 | 5.77 | 6.78 | 11.09 | 2.06 | 2.80 | 7.40 | 10.98 | 7.48 | 248.44 | 18.42 | 7.00 | | |
| | a | | 60.66 | 24.55 | 7.22 | 7.87 | 4.15 | 1.75 | 3.08 | 2.92 | | | 7.73 | 20.08 | | 24.17 | | 20.06 | |
| | b | | 140.79 | 59.27 | 9.91 | 16.65 | 4.54 | 1.90 | 5.96 | | | 2.84 | 8.23 | 7.30 | 31.38 | 54.48 | 38.92 | 52.66 | |
| | a | | 74.36 | 28.75 | 18.36 | 20.54 | 5.67 | 9.03 | 2.44 | 6.42 | 3.55 | 3.96 | 8.33 | 11.85 | 118.98 | 10.66 | 3.67 | 4.01 | 2.03 |
| | b | | 108.39 | 31.39 | 4.32 | 26.08 | 2.48 | 9.74 | 8.60 | 4.18 | 2.59 | 6.41 | 3.95 | 15.23 | 36.13 | 9.72 | 14.38 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 2.75 | 0.09 | 0.34 | 0.15 | 0.02 | 0.13 | 0.23 | 0.30 | 0.34 | 0.74 | 1.58 | 3.97 | 4.43 | 2.29 | | | 1.72 |
| | b | | 3.46 | 0.08 | 0.20 | 0.01 | 0.00 | 0.01 | 0.08 | | | | | 3.36 | 3.10 | 1.55 | | | |
| | a | 0.31 | 7.10 | 2.61 | 2.56 | 3.71 | 1.06 | 1.24 | 1.89 | 1.12 | 0.77 | 0.49 | 0.92 | 0.37 | 1.29 | 0.34 | 0.75 | | |
| | b | 1.09 | 7.81 | 2.26 | 4.81 | 1.14 | 0.67 | 0.49 | 3.80 | 0.69 | 0.96 | 2.65 | 4.07 | 2.25 | 25.22 | 2.40 | 1.55 | | |
| | a | | 13.79 | 4.24 | 1.76 | 0.80 | 0.52 | 0.34 | 0.95 | 0.79 | | | 0.96 | 1.76 | | 2.98 | | 4.79 | |
| | b | | 4.20 | 0.90 | 0.18 | 0.14 | 0.08 | 0.08 | 0.82 | | | 0.54 | 1.25 | 0.81 | 1.81 | 3.20 | 4.83 | 10.62 | |
| | a | | 13.88 | 4.07 | 2.79 | 0.87 | 0.68 | 2.00 | 0.81 | 2.08 | 1.14 | 1.22 | 2.29 | 3.08 | 10.08 | 1.85 | 0.85 | 1.46 | 0.69 |
| | b | | 12.40 | 4.75 | 0.86 | 3.99 | 0.38 | 1.77 | 2.65 | 1.30 | 0.73 | 1.44 | 0.92 | 3.04 | 3.52 | 1.60 | 2.94 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 31.60 | 23.81 | 21.34 | 1.36 | 2.06 | 10.55 | 5.92 | 2.49 | | | 4.51 | 2.50 | 11.82 | 8.06 | 2.31 | 1.08 | 1.37 |
| | b | 6.32 | 90.60 | 38.31 | 5.85 | 3.60 | 32.68 | 11.27 | 40.16 | 12.37 | 11.75 | 9.73 | 14.26 | 16.22 | 26.18 | 15.42 | 7.71 | 5.02 | 3.40 |
| | a | 9.28 | 222.51 | 76.59 | 12.71 | 50.55 | 13.85 | 17.53 | 72.88 | 11.16 | 7.97 | 9.44 | 10.33 | 21.28 | 18.93 | 7.69 | 5.92 | 5.87 | 7.80 |
| | b | 8.03 | 128.66 | 43.85 | 30.54 | 22.32 | 6.68 | 13.62 | 58.44 | 4.74 | 7.80 | 4.27 | 11.76 | 27.88 | 35.51 | 10.86 | 9.89 | 7.13 | 16.96 |
| | a | | 238.61 | 107.23 | 37.13 | 16.83 | 25.35 | 9.58 | 15.36 | 9.86 | 6.54 | 6.65 | 16.06 | 163.64 | 150.36 | 119.29 | 81.87 | 67.40 | |
| | b | | 58.23 | 79.40 | 145.55 | 82.00 | 12.40 | 41.02 | 43.65 | 20.21 | 11.68 | 4.58 | 22.45 | 47.66 | 131.62 | 66.51 | 41.01 | 54.64 | 28.72 |
| | a | 6.36 | 54.68 | | 7.90 | 5.40 | 4.44 | 5.99 | | 9.10 | 6.11 | 2.27 | 13.49 | 7.30 | 25.31 | 83.83 | | 79.58 | 92.57 |
| | b | 3.39 | 152.98 | 59.58 | 48.30 | 23.90 | 8.08 | 19.36 | 17.66 | 5.31 | 7.08 | 4.08 | 13.38 | 12.91 | 12.47 | 32.58 | | 9.10 | 8.25 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 16.93 | 4.47 | 2.16 | 0.07 | 0.03 | 0.82 | 1.11 | 0.66 | | | 0.47 | 0.34 | 2.88 | 1.28 | 0.51 | 0.26 | 0.26 |
| | b | 0.57 | 17.34 | 5.25 | 0.54 | 0.28 | 1.53 | 1.02 | 6.62 | 2.94 | 1.44 | 2.94 | 2.09 | 5.21 | 5.41 | 2.27 | 1.70 | 1.39 | 0.87 |
| | a | 0.09 | 4.38 | 1.16 | 0.05 | 0.79 | 0.00 | 0.45 | 13.45 | 3.11 | 2.17 | 2.70 | 2.06 | 2.13 | 4.30 | 1.11 | 1.56 | 1.84 | 2.02 |
| | b | 0.18 | 5.92 | 3.03 | 4.78 | 4.88 | 1.07 | 3.12 | 22.96 | 1.63 | 2.58 | 1.41 | 3.00 | 7.83 | 3.98 | 3.15 | 2.54 | 2.39 | 4.91 |
| | a | | 8.64 | 2.84 | 1.41 | 0.09 | 0.23 | 0.25 | 0.67 | 2.54 | 0.75 | 1.46 | 1.68 | 17.71 | 10.26 | 13.95 | 14.86 | 15.12 | |
| | b | | 16.45 | 3.80 | 8.96 | 6.10 | 0.75 | 4.54 | 9.04 | 5.73 | 1.49 | 1.28 | 4.17 | 12.96 | 29.67 | 5.94 | 11.75 | 20.37 | 8.23 |
| | a | 0.63 | 14.68 | | 0.34 | 0.23 | 0.08 | 0.25 | | 1.67 | 1.66 | 0.61 | 1.97 | 1.02 | 2.71 | 8.32 | | 20.61 | 25.46 |
| | b | 0.89 | 31.07 | 11.38 | 9.23 | 3.82 | 1.22 | 4.27 | 5.72 | 1.81 | 2.44 | 1.44 | 3.77 | 2.62 | 3.55 | 4.25 | | 3.17 | 2.91 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.49: Ba mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 125.73 | 22.08 | 2.10 | 1.80 | 0.76 | 3.37 | 2.92 | 1.00 | 1.58 | 1.31 | 3.39 | 5.04 | 8.50 | 5.12 | 3.70 | 3.33 | 8.57 |
| | b | 2.24 | 41.45 | 24.51 | 55.35 | 28.49 | 7.08 | 20.87 | 20.78 | 4.75 | 4.21 | 5.75 | 8.13 | 6.38 | 14.61 | 6.14 | 4.70 | 5.16 | 2.45 |
| | a | 3.55 | 9.00 | 7.56 | 2.01 | 0.17 | 1.12 | 1.63 | 1.76 | 0.82 | 0.83 | 1.03 | 1.94 | 4.76 | 5.81 | 3.91 | 2.72 | 2.09 | 4.10 |
| | b | | 88.65 | 19.80 | 5.96 | 8.21 | 2.86 | 3.95 | 6.40 | 1.17 | 1.55 | 1.13 | 4.32 | 14.45 | 29.78 | 7.71 | 6.70 | 6.65 | 6.58 |
| | a | 1.05 | | 36.43 | 33.70 | 10.71 | 11.34 | 16.00 | 5.45 | 5.27 | | 2.56 | | 16.88 | 45.71 | 41.76 | | 12.20 | |
| | b | | | 31.68 | 5.24 | 19.24 | 5.94 | 4.35 | 3.75 | | | | | | 6.18 | 4.83 | | 2.59 | |
| | a | | | 36.97 | 7.13 | 14.98 | | 1.79 | 1.14 | 1.17 | 0.66 | 0.56 | 1.70 | 1.67 | 7.20 | 7.63 | 4.50 | 4.77 | 3.85 |
| | b | | 199.58 | 48.94 | 60.45 | 42.32 | 5.96 | 6.46 | 6.57 | 5.77 | 2.56 | 2.86 | 4.09 | 7.30 | 24.10 | 10.31 | 5.17 | 2.23 | 2.30 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 5.30 | 0.82 | 0.04 | 0.02 | 0.03 | 0.11 | 0.10 | 0.06 | 0.08 | 0.07 | 0.09 | 0.08 | 0.02 | 0.12 | 0.10 | 0.10 | 2.45 |
| | b | 0.60 | 4.53 | 0.68 | 2.90 | 0.65 | 0.15 | 1.64 | 3.09 | 1.40 | 1.25 | 1.84 | 2.13 | 1.91 | 4.04 | 1.47 | 1.17 | 0.81 | 0.73 |
| | a | 0.80 | 3.73 | 0.33 | 0.10 | 0.00 | 0.01 | 0.10 | 0.46 | 0.27 | 0.26 | 0.46 | 0.21 | 0.98 | 0.84 | 0.81 | 0.76 | 0.69 | 1.39 |
| | b | | 4.56 | 0.71 | 0.16 | 0.33 | 0.10 | 0.52 | 1.97 | 0.39 | 0.47 | 0.40 | 0.36 | 0.38 | 0.91 | 0.12 | 0.49 | 0.72 | 2.03 |
| | a | 0.20 | | 10.82 | 4.27 | 2.72 | 3.36 | 3.54 | 1.26 | 1.79 | | 0.61 | | 2.84 | 9.14 | 7.25 | | 3.44 | |
| | b | | | 5.78 | 0.86 | 2.66 | 0.84 | 0.99 | 0.80 | | | | | | 0.57 | 0.76 | | 0.77 | |
| | a | | | 2.08 | 0.39 | 0.53 | | 0.06 | 0.27 | 0.27 | 0.17 | 0.15 | 0.33 | 0.15 | 0.51 | 1.51 | 1.05 | 1.05 | 1.09 |
| | b | | 76.67 | 15.34 | 12.46 | 7.88 | 0.48 | 1.02 | 2.13 | 1.83 | 0.90 | 1.08 | 1.56 | 2.55 | 7.33 | 3.10 | 1.62 | 0.76 | 0.78 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 232.63 | 50.68 | 8.78 | 4.56 | 3.89 | 7.06 | 15.88 | | 4.65 | 3.10 | 2.69 | 14.55 | 33.77 | 90.12 | | 113.28 | 81.02 |
| | b | | 27.22 | 38.36 | 7.67 | 3.99 | 2.67 | 2.44 | 3.11 | | 4.10 | | 17.19 | 54.31 | 81.91 | 40.76 | | | |
| | a | | 136.23 | 48.29 | 50.85 | 36.60 | 3.25 | 14.61 | 22.32 | 10.65 | 6.47 | | 17.86 | 150.31 | 238.02 | 67.86 | 32.23 | 12.16 | 9.64 |
| | b | | 0.00 | 33.63 | 70.92 | 11.11 | 4.34 | 1.36 | 5.71 | 2.39 | 2.71 | 2.00 | 3.88 | 10.12 | 13.63 | 7.65 | 7.27 | 5.31 | 4.23 |
| | a | | 177.36 | 166.50 | 13.66 | 3.62 | 5.09 | 11.95 | 20.01 | | 2.89 | 4.76 | 5.78 | 11.09 | 18.48 | 10.13 | | 11.91 | 4.69 |
| | b | 9.08 | 87.53 | 43.16 | 88.46 | 74.83 | 9.84 | 33.15 | 34.69 | 9.83 | 8.02 | 3.84 | 17.30 | 26.46 | 63.80 | 34.91 | 9.68 | 23.57 | 9.43 |
| | a | | 317.20 | 53.88 | 26.16 | 34.38 | 16.02 | 17.35 | 35.42 | 28.80 | | 2.02 | 17.71 | 51.35 | 12.16 | 32.19 | 17.32 | | 15.84 |
| | b | | 352.94 | 43.05 | 39.92 | 76.23 | 9.94 | 19.00 | 21.97 | 10.17 | 4.20 | | 3.97 | 19.72 | 107.63 | 24.90 | 9.34 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 7.87 | 1.31 | 0.18 | 0.07 | 0.05 | 0.25 | 0.20 | | 0.14 | 0.09 | 0.22 | 1.39 | 4.68 | 10.69 | | 16.49 | 15.32 |
| | b | | 22.13 | 2.07 | 0.30 | 0.29 | 0.03 | 0.39 | 0.15 | | 1.12 | | 3.38 | 12.55 | 17.75 | 9.20 | | | |
| | a | | 5.33 | 1.35 | 1.30 | 1.82 | 0.12 | 1.73 | 7.21 | 3.41 | 2.10 | | 4.97 | 45.26 | 63.43 | 19.44 | 10.46 | 4.13 | 3.33 |
| | b | | 8.40 | 0.84 | 1.52 | 0.59 | 0.27 | 0.03 | 0.62 | 0.39 | 0.67 | 0.44 | 0.79 | 1.25 | 1.67 | 0.62 | 1.26 | 0.99 | 0.91 |
| | a | | 23.49 | 5.62 | 0.23 | 0.01 | 0.00 | 0.06 | 0.22 | | 0.02 | 0.53 | 0.26 | 1.94 | 2.07 | 0.82 | | 2.67 | 1.50 |
| | b | 4.93 | 27.52 | 7.75 | 17.46 | 7.49 | 1.83 | 9.44 | 7.97 | 3.38 | 2.64 | 0.76 | 5.63 | 8.17 | 15.20 | 3.15 | 2.69 | 7.50 | 2.85 |
| | a | | 21.30 | 4.98 | 3.17 | 6.76 | 2.98 | 5.03 | 11.59 | 9.92 | | 0.61 | 5.44 | 15.67 | 3.24 | 5.16 | 5.23 | | 5.31 |
| | b | | 60.48 | 3.76 | 8.82 | 14.29 | 2.49 | 5.38 | 7.24 | 3.46 | 1.47 | | 1.40 | 4.93 | 33.66 | 5.68 | 3.05 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.50: Cd mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | 0.34 | 0.07 | 0.04 | 0.03 | 0.03 | *** | *** | *** | 0.02 | 0.08 | *** | *** | *** | *** | | *** |
| | b | | 1.18 | | 0.09 | 0.33 | 0.05 | 0.07 | *** | *** | *** | | 0.08 | *** | *** | *** | *** | | *** |
| | b | | | 0.34 | 0.05 | 0.04 | 0.02 | 0.03 | *** | *** | *** | | 0.04 | *** | *** | *** | *** | 0.04 | *** |
| | b | | 1.18 | 0.34 | 0.03 | 0.01 | 0.02 | | *** | *** | *** | | 0.04 | *** | *** | *** | *** | | *** |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.09 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.09 | 0.15 | *** | *** | *** | *** | | *** |
| | b | | 1.18 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.07 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.04 | 0.08 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.05 | *** | *** | *** | *** | | *** |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.05 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.05 | 0.10 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.02 | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.04 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.03 | 0.07 | *** | *** | *** | *** | | *** |
| | b | 0.04 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.04 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.06 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.51: Cd mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0.15 | 4.20 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 1.01 | 2.07 | 0.39 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | a | | 1.95 | 0.12 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 6.86 | 2.47 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 2.37 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.16 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 1.18 | 0.34 | 0.15 | 0.17 | 0.05 | 0.09 | *** | *** | *** | 0.06 | 0.05 | *** | *** | *** | *** | | *** |
| | b | | 1.18 | 0.34 | 0.11 | 0.08 | 0.02 | 0.03 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0.05 | 1.18 | 0.34 | 0.28 | 1.30 | 0.15 | 0.24 | *** | *** | *** | 0.07 | 0.14 | *** | *** | *** | *** | | *** |
| | b | 0.20 | 1.18 | 0.34 | 0.67 | 1.35 | 0.31 | 0.38 | *** | *** | *** | 0.18 | 0.23 | *** | *** | *** | *** | | *** |
| | a | | 1.18 | 0.34 | 0.13 | 0.12 | 0.07 | 0.03 | *** | *** | *** | | 0.04 | *** | *** | *** | *** | 0.06 | *** |
| | b | | 1.18 | 0.34 | 0.09 | 0.15 | 0.04 | 0.02 | *** | *** | *** | 0.03 | 0.08 | *** | *** | *** | *** | 0.13 | *** |
| | a | | 1.18 | 0.34 | 0.24 | 0.27 | 0.12 | 0.18 | *** | *** | *** | 0.07 | 0.10 | *** | *** | *** | *** | 0.02 | *** |
| | b | | 1.18 | 0.34 | 0.05 | 0.41 | 0.03 | 0.12 | *** | *** | *** | 0.07 | 0.05 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 1.12 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0.27 | 3.55 | 0.40 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0.76 | 16.10 | 4.30 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0.50 | 9.82 | 1.98 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 2.37 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.07 | *** |
| | b | | 21.90 | 0.91 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.02 | *** |
| | a | 0.72 | 13.37 | | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 1.78 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 3.14 | 0.67 | 0.55 | 0.15 | 0.09 | 0.56 | *** | *** | *** | | 0.40 | *** | *** | *** | *** | 0.07 | *** |
| | b | 0.09 | 2.37 | 0.67 | 0.11 | 0.13 | 0.71 | 0.32 | *** | *** | *** | 0.43 | 0.54 | *** | *** | *** | *** | 0.14 | *** |
| | a | 0.08 | 2.37 | 0.67 | 0.21 | 1.31 | 0.50 | 0.53 | *** | *** | *** | 0.52 | 0.46 | *** | *** | *** | *** | 0.24 | *** |
| | b | 0.10 | 2.37 | 0.67 | 0.86 | 0.73 | 0.24 | 0.62 | *** | *** | *** | 0.21 | 0.47 | *** | *** | *** | *** | 0.18 | *** |
| | a | | 2.37 | 0.67 | 0.48 | 0.45 | 0.32 | 0.18 | *** | *** | *** | 0.08 | 0.10 | *** | *** | *** | *** | 0.07 | *** |
| | b | | 2.37 | 0.67 | 1.44 | 2.37 | 0.24 | 0.94 | *** | *** | *** | 0.10 | 0.46 | *** | *** | *** | *** | 0.15 | *** |
| | a | 0.13 | 2.37 | | 0.13 | 0.23 | 0.12 | 0.17 | *** | *** | *** | 0.09 | 0.45 | *** | *** | *** | *** | 0.09 | *** |
| | b | 0.05 | 2.37 | 0.67 | 0.56 | 0.41 | 0.17 | 0.45 | *** | *** | *** | 0.09 | 0.21 | *** | *** | *** | *** | 0.07 | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.52: Cd mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 2.37 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 4.73 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0.13 | | 0 | 0 | 0 | 0 | 0.03 | *** | *** | *** | 0 | | *** | *** | *** | *** | 0 | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | 0 | *** |
| | a | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 1.18 | 0.34 | 0.03 | 0.03 | 0.02 | 0.09 | *** | *** | *** | 0.04 | 0.11 | *** | *** | *** | *** | 0.07 | *** |
| | b | 0.05 | 1.18 | 0.34 | 1.26 | 1.31 | 0.35 | 1.17 | *** | *** | *** | 0.27 | 0.37 | *** | *** | *** | *** | 0.08 | *** |
| | a | 0.09 | 1.18 | 0.34 | 0.18 | 0.06 | 0.16 | 0.19 | *** | *** | *** | 0.18 | 0.23 | *** | *** | *** | *** | 0.05 | *** |
| | b | | 1.42 | 0.34 | 0.21 | 1.31 | 0.29 | 0.34 | *** | *** | *** | 0.13 | 0.18 | *** | *** | *** | *** | 0.10 | *** |
| | a | 0.05 | | 0.34 | 0.27 | 0.09 | 0.13 | 0.11 | *** | *** | *** | 0.02 | | *** | *** | *** | *** | 0.04 | *** |
| | b | | | 0.34 | 0.07 | 0.15 | 0.05 | 0.05 | *** | *** | *** | | | *** | *** | *** | *** | 0.02 | *** |
| | a | | | 0.34 | 0.16 | 1.31 | 0.07 | 0.08 | *** | *** | *** | 0.03 | 0.07 | *** | *** | *** | *** | 0.06 | *** |
| | b | | 1.18 | 0.34 | 0.46 | 1.31 | 0.20 | 0.27 | *** | *** | *** | 0.13 | 0.17 | *** | *** | *** | *** | 0.04 | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 2.96 | 0.44 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0.29 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 16.81 | 3.60 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0.01 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0.31 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 2.37 | 0.67 | 0.08 | 0.05 | 0.04 | 0.10 | *** | *** | *** | 0.06 | 0.09 | *** | *** | *** | *** | 0.03 | *** |
| | b | | 2.37 | 0.67 | 0.20 | 0.35 | 0.07 | 0.10 | *** | *** | *** | | 0.08 | *** | *** | *** | *** | | *** |
| | a | | 2.37 | 0.67 | 0.84 | 2.61 | 0.16 | 0.73 | *** | *** | *** | | 0.33 | *** | *** | *** | *** | 0.08 | *** |
| | b | | 2.37 | 0.67 | 1.56 | 2.63 | 0.16 | 0.06 | *** | *** | *** | 0.30 | 0.26 | *** | *** | *** | *** | 0.18 | *** |
| | a | | 2.37 | 0.67 | 0.09 | 0.07 | 0.07 | 0.11 | *** | *** | *** | 0.09 | 0.15 | *** | *** | *** | *** | 0.09 | *** |
| | b | 0.40 | 2.37 | 0.67 | 1.58 | 2.61 | 0.37 | 1.30 | *** | *** | *** | 0.10 | 0.37 | *** | *** | *** | *** | 0.19 | *** |
| | a | | 2.37 | 0.67 | 0.36 | 0.54 | 0.17 | 0.15 | *** | *** | *** | 0.04 | 0.06 | *** | *** | *** | *** | | *** |
| | b | | 2.37 | 0.36 | 0.62 | 0.97 | 0.20 | 0.43 | *** | *** | *** | | 0.08 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.53: Cu mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0.30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| | b | | 293.08 | | 0 | 0 | 16.37 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | | | |
| | b | | | 0 | 0 | 0 | 5.25 | 0 | 0 | | | | 0 | | 0 | 0 | | 0 | |
| | b | | 334.72 | 0 | 0 | 0 | 8.10 | | | | | | 0 | | 0 | 0 | | | |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.50 | 0.10 | 0.07 | 0.16 | 0.24 | 0.12 | 0.09 | 0.05 | 0.04 | 0.12 | 0.09 | 0.16 | | | | |
| | b | | 9.38 | | 0.13 | 0.50 | 1.46 | 0.10 | 0.06 | 0.09 | | | 0.12 | 0.07 | 0.15 | 0.06 | | | |
| | b | | | 0.50 | 0.08 | 0.05 | 0.04 | 0.05 | 0.03 | | | | 0.05 | | 0.07 | 0.08 | | 0.06 | |
| | b | | 9.71 | 0.50 | 0.04 | 0.02 | 0.19 | | | | | | 0.06 | | 0.06 | 0.05 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 19.91 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0.03 | | | |
| | b | | 163.60 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0.01 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0.20 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 1.18 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.14 | 0.22 | 0.13 | 0.21 | 0.12 | | | |
| | b | | 19.09 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.10 | 0.16 | 0.32 | 0.10 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.06 | 0.12 | 0.07 | 0.12 | 0.07 | 0.08 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.07 | 0.06 | 0.09 | 0.08 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 11.21 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0 | 0 | 0 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | | | 0.04 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0 | 0.01 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.48 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.07 | 0.15 | 0.18 | 0.25 | 0.13 | 0.10 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.06 | 0.22 | 0.10 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.03 | | | | 0.04 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.05 | 0.04 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | | | 0 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | | 0 | 0 | | | |
| | b | 23.73 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | | 0.01 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.06 | | 0.06 | 0.08 | | | 0.35 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.05 | 0.10 | | 0.20 | 0.09 | | | |
| | b | 1.28 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.07 | | 0.06 | 0.09 | 0.06 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.09 | | | 0.07 | | | |

*** Samples were not collected for these treatments.

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.54: Cu mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 103.74 | 2.46 | 0 | 18.59 | 0.31 | 27.44 | 0 | 0.07 | 0.50 | 0 | 0 | 0 | 0 | 0 | | | 0 |
| | b | | 85.28 | 0 | 0 | 0 | 0.31 | 19.30 | 0.28 | | | | | 0 | 0.89 | 0.57 | | | |
| | a | 15.62 | 0 | 0 | 0 | 50.02 | 10.49 | 23.60 | 0 | 35.47 | 0 | 0 | 0 | 0 | 0.12 | 0 | 0 | | |
| | b | 42.93 | 83.41 | 0 | 0 | 0 | 32.86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | a | | 24.62 | 0 | 0 | 0 | 14.38 | 10.89 | 0 | 0.03 | | | 0.78 | 1.00 | | 0.40 | | 0 | |
| | b | | 52.79 | 0 | 0 | 0 | 14.15 | 8.70 | 0 | 0 | | 0.09 | 0 | 0.20 | 0.17 | 0 | 0 | 0 | |
| | a | | 86.46 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.07 | 0.37 | 1.18 | 0.93 |
| | b | | 172.51 | 3.41 | 0.06 | 0 | 0.19 | 0.92 | 0.31 | 0 | 0.06 | 0.12 | 0.08 | 0.98 | 0.20 | 0.14 | 0.65 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 19.77 | 0.50 | 0.22 | 2.38 | 0.04 | 1.24 | 0.25 | 0 | 0.05 | 0.09 | 0.07 | 0.15 | 0.20 | 0.09 | | | 0.05 |
| | b | | 22.90 | 0.50 | 0.16 | 0.22 | 0.10 | 1.27 | 0.12 | | | | | 0.10 | 0.07 | 0.11 | | | |
| | a | 0.31 | 2.19 | 3.91 | 0.42 | 8.21 | 2.90 | 4.15 | 0.28 | 5.13 | 0.14 | 0.10 | 0.21 | 0.12 | 0.32 | 0.15 | 0.17 | | |
| | b | 0.62 | 10.39 | 0.50 | 1.00 | 2.02 | 4.39 | 1.42 | 0.75 | 0.16 | 0.18 | 0.28 | 0.34 | 0.18 | 1.69 | 0.20 | 0.08 | | |
| | a | | 25.09 | 0.50 | 0.19 | 0.18 | 2.35 | 1.69 | 0.09 | 0.07 | | | 0.22 | 0.15 | | 0.10 | | 0.08 | |
| | b | | 25.68 | 0.50 | 0.13 | 0.22 | 0.92 | 0.68 | 0.10 | | | 0.04 | 0.12 | 0.09 | 0.18 | 0.20 | 0.16 | 0.20 | |
| | a | | 16.45 | 1.45 | 0.37 | 0.41 | 0.18 | 0.27 | 0.07 | 0.19 | 0.11 | 0.11 | 0.16 | 0.16 | 0.60 | 0.14 | 0.04 | 0.40 | 0.24 |
| | b | | 21.25 | 0.50 | 0.13 | 0.62 | 0.04 | 0 | 0.20 | 0.09 | 0.05 | 0.10 | 0.07 | 0.13 | 0.03 | 0.06 | 0.10 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 80.72 | 0 | 0 | 0 | 22.24 | 0.42 | 0 | 0 | 0 | | 0 | 0 | 0.38 | 0 | 0 | 0 | 0 |
| | b | 31.31 | 131.14 | 0 | 0 | 0 | 167.27 | 0 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.44 | 0 | 0 | 0 |
| | a | 29.89 | 49.41 | 0 | 0 | 0 | 59.40 | 0 | 3.95 | 0.62 | 0 | 1.87 | 4.95 | 4.64 | 3.20 | 0.17 | 0.44 | 0.51 | 1.59 |
| | b | 34.60 | 0 | 0 | 19.40 | 0 | 44.62 | 228.52 | 0 | 40.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | | 515.51 | 0 | 0 | 0.45 | 194.60 | 86.55 | 0 | 0 | 0 | 0 | 0.07 | 1.47 | 0.79 | 0.68 | 0.91 | 2.12 | |
| | b | | 40.36 | 0 | 0 | 0 | 115.20 | 135.81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.11 | 1.13 |
| | a | 30.53 | 31.90 | | 0 | 0 | 26.13 | 0.13 | | 0.20 | 0 | 0 | 0.13 | 0 | 0 | 0 | | 0.90 | 1.47 |
| | b | 17.26 | 415.85 | 0 | 0 | 47.97 | 27.08 | 105.10 | 0.53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0.10 | 0 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 9.47 | 2.47 | 0.83 | 0.22 | 1.24 | 0.84 | 0.53 | 0.23 | 0.48 | | 0.60 | 0.36 | 1.14 | 0.59 | 0.20 | 0.11 | 2.47 |
| | b | 1.95 | 7.57 | 1.01 | 0.16 | 0.20 | 3.11 | 0.48 | 1.71 | 0.54 | 0.71 | 0.64 | 0.81 | 0.71 | 1.03 | 0.57 | 0.31 | 0.22 | 0.16 |
| | a | 3.52 | 50.01 | 1.01 | 0.31 | 1.96 | 1.78 | 0.79 | 3.83 | 0.37 | 0.69 | 0.78 | 0.52 | 1.24 | 1.07 | 0.43 | 0.39 | 0.36 | 0 |
| | b | 0.65 | 6.33 | 1.01 | 8.08 | 1.10 | 8.46 | 42.72 | 4.97 | 8.38 | 0.53 | 0.32 | 0.71 | 1.49 | 1.14 | 0.43 | 0.37 | 0.27 | 0.64 |
| | a | | 58.05 | 1.01 | 0.72 | 0.22 | 14.80 | 3.93 | 0.50 | 0.11 | 0.27 | 0.12 | 0.15 | 0.25 | 0.09 | 0.21 | 0.11 | 0.55 | |
| | b | | 3.55 | 1.01 | 2.17 | 3.55 | 6.22 | 2.03 | 1.28 | 0.57 | 0.36 | 0.15 | 0.70 | 0.63 | 1.12 | 0.37 | 0.24 | 0.18 | 0.11 |
| | a | 0.87 | 10.47 | | 0.20 | 0.34 | 0.66 | 0.25 | | 0.41 | 0.34 | 0.14 | 0.27 | 0.20 | 0.24 | 0.31 | | 0.12 | 0.12 |
| | b | 2.28 | 29.41 | 1.01 | 0.84 | 5.22 | 3.83 | 24.15 | 0.59 | 0.15 | 0.22 | 0.13 | 0.32 | 0.25 | 0.18 | 0.37 | | 0 | 0.10 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.55: Cu mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 727.10 | 0 | 0.04 | 0 | 0.33 | 117.55 | 2.48 | 0.21 | 0 | 0 | 0 | 0 | 0 | 0.19 | 0 | 0 | 0.10 |
| | b | 24.02 | 119.01 | 0 | 9.92 | 0 | 61.29 | 1.06 | 0 | 0.31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 19.34 | 0 | 0 | 0 | 3.25 | 39.91 | 26.68 | 0 | 12.94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | | 112.47 | 0 | 0 | 1.58 | 51.09 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 37.79 | | 0.62 | 0.58 | 0 | 24.18 | 28.82 | 1.04 | 0.54 | | 0.23 | | 0.99 | 2.19 | 1.10 | | 0.60 | |
| | b | | | 0 | 0 | 0 | 10.64 | 0.28 | 0.15 | 0 | | | | | 2.80 | 0.38 | | 0.18 | |
| | a | | | 6.10 | 1.80 | 0 | 0.35 | 0 | 0.07 | 0.16 | 0.30 | 0.15 | 0.22 | 0.18 | 0.19 | 0.73 | 0.33 | 0.48 | 0.20 |
| | b | | 105.63 | 0 | 0 | 0 | 208.51 | 1.34 | 0.41 | 0 | 0.29 | 0.08 | 0 | 0 | 0 | 0.21 | 0.03 | 0.01 | 0.03 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 303.74 | 0.50 | 0.01 | 0.05 | 0.17 | 36.62 | 0.47 | 0.01 | 0.08 | 0.06 | 0.17 | 0.15 | 0.23 | 0.14 | 0.09 | 0.10 | 0.11 |
| | b | 2.79 | 51.90 | 1.02 | 1.73 | 1.96 | 5.20 | 1.76 | 1.39 | 0.36 | 0.28 | 0.40 | 0.56 | 0.50 | 0.64 | 0.24 | 0.17 | 0.12 | 0.68 |
| | a | 2.54 | 7.75 | 0.50 | 0.27 | 0.41 | 2.16 | 17.00 | 0.29 | 1.81 | 0.16 | 0.26 | 0.34 | 0.40 | 0.36 | 0.18 | 0.14 | 0.07 | 0.10 |
| | b | | 48.79 | 0.50 | 0.32 | 0 | 7.02 | 0.51 | 0.84 | 0.17 | 0.21 | 0.19 | 0.27 | 0.44 | 0.69 | 0.21 | 0.14 | 0.15 | 0.58 |
| | a | 2.91 | | 1.45 | 0.22 | 0.04 | 9.98 | 9.61 | 0.25 | 0.14 | | 0.01 | | 0.16 | 0.64 | 0.25 | | 0.29 | |
| | b | | | 26.96 | 0.10 | 0.23 | 2.80 | 0.05 | 0.04 | | | | | | 0.03 | 0.08 | | 0.04 | |
| | a | | | 3.99 | 0.79 | 1.45 | 0.10 | 2.39 | 0.09 | 0.09 | 0.03 | 0.05 | 0.11 | 0.11 | 0.36 | 0.02 | 0.09 | 0.01 | 0 |
| | b | | 69.59 | 1.30 | 0.57 | 1.96 | 57.61 | 0.19 | 0.05 | 0.28 | 0.13 | 0.20 | 0.25 | 0.20 | 0.64 | 0.20 | 0.13 | 0.07 | 0.07 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 927.99 | 0 | 0 | 0 | 0.47 | 172.65 | 3.47 | | 1.83 | 2.00 | 5.28 | 7.55 | 4.53 | 0.70 | | 2.32 | 4.36 |
| | b | | 30.42 | 17.13 | 4.11 | 3.62 | 2.11 | 2.36 | 2.39 | | 0.57 | | 0.96 | 2.56 | 3.69 | 2.71 | | | |
| | a | | 541.07 | 2.67 | 4.67 | 358.01 | 68.31 | 0 | 203.85 | 2.65 | 0.48 | | 0.38 | 8.22 | 9.01 | 7.14 | 1.80 | 0.61 | 0.44 |
| | b | | 0 | 0 | 0 | 0 | 3.28 | 0 | 0 | 129.06 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | | 33.38 | 0 | 1.30 | 8.20 | 0.54 | 126.36 | 0 | | 0 | 0 | 0.22 | 0 | 0 | | | 0.13 | 0 |
| | b | 14.45 | 279.50 | 0 | 0 | 358.40 | 0 | 143.80 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | | 2296.20 | 0 | 0 | 0 | 0 | 0.97 | 0.17 | 0.55 | | 1.53 | 1.62 | 4.20 | 2.21 | 1.73 | 1.00 | | 0.99 |
| | b | | 243.40 | 0 | 0 | 0 | 0 | 0.40 | 2.81 | 0.63 | 0 | | 0.04 | 0 | 6.16 | 0.03 | 0 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 444.37 | 1.85 | 0.12 | 0.08 | 0.07 | 53.35 | 0.06 | | 0.78 | 0.42 | 1.46 | 1.51 | 1.43 | 0.16 | | 1.22 | 1.05 |
| | b | | 95.28 | 9.53 | 1.73 | 1.73 | 0.65 | 0.97 | 0.64 | | 0.01 | | 0.32 | 0.21 | 1.06 | 0.67 | | | |
| | a | | 188.60 | 4.15 | 3.12 | 73.27 | 11.18 | 1.09 | 43.28 | 0.52 | 0.36 | | 0.50 | 0.83 | 2.55 | 1.44 | 0.10 | 0.09 | 0 |
| | b | | 108.89 | 2.09 | 0.04 | 3.94 | 0.83 | 0.10 | 0.58 | 16.91 | 0.42 | 0.45 | 0.39 | 0.85 | 1.21 | 0.41 | 0.37 | 0.28 | 0.27 |
| | a | | 16.45 | 1.01 | 0.13 | 0.11 | 0.21 | 12.95 | 0.33 | | 0.12 | 0.13 | 0.22 | 0.26 | 0.37 | 0.18 | | 0.32 | 0.09 |
| | b | 10.22 | 92.62 | 4.71 | 2.36 | 106.88 | 0.56 | 36.73 | 1.45 | 0.43 | 0.32 | 0.15 | 0.55 | 0.67 | 1.40 | 0.43 | 0.13 | 0.28 | 0.09 |
| | a | | 303.53 | 1.01 | 0.54 | 0.80 | 0.25 | 0.07 | 0.34 | 0.20 | | 0.06 | 0.49 | 0.81 | 0.24 | 0.54 | 0.26 | | 0.14 |
| | b | | 69.42 | 2.77 | 0.57 | 2.40 | 0.29 | 0.64 | 0.74 | 0.31 | 0.13 | | 0.12 | 0.36 | 1.84 | 0.31 | 0.13 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.56: Ni mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | | | | |
| | b | | 26.57 | | 0 | 0 | 1.81 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | | | |
| | b | | | 0 | 0 | 0 | 0.33 | 0 | 0 | | | | 0 | | 0 | 0 | | 0 | |
| | b | | 56.55 | 0 | 0 | 0 | 0.36 | | | | | | 0 | | 0 | 0 | | | |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.67 | 0.13 | 0.09 | 0.07 | 0.07 | 0.16 | 0.13 | 0.07 | 0.05 | 0.16 | 0.12 | 0.21 | | | | |
| | b | | 6.86 | | 0.18 | 0.67 | 0.10 | 0.13 | 0.08 | 0.12 | | | 0.16 | 0.10 | 0.20 | 0.08 | | | |
| | b | | | 0.67 | 0.10 | 0.07 | 0.04 | 0.06 | 0.04 | | | | 0.07 | | 0.09 | 0.11 | | 0.09 | |
| | b | | 9.08 | 0.67 | 0.05 | 0.03 | 0.04 | | | | | | 0.08 | | 0.07 | 0.07 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 1.95 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | | | |
| | b | | 32.58 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | 0 | 0 | 0 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.53 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.19 | 0.30 | 0.17 | 0.28 | 0.16 | | | |
| | b | | 7.84 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.13 | 0.22 | 0.43 | 0.13 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.08 | 0.16 | 0.09 | 0.16 | 0.10 | 0.11 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.09 | 0.08 | 0.12 | 0.10 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 2.66 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0 | 0 | | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | | | 0 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0 | 0 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.54 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.10 | 0.20 | 0.23 | 0.33 | 0.18 | 0.13 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.08 | 0.30 | 0.13 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.04 | | | | 0.05 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.07 | 0.06 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | | | 0 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | | 0 | 0 | | | |
| | b | 1.85 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | 0 | 0 | 0 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | | | 0 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.08 | | 0.08 | 0.11 | | | 0.06 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.07 | 0.13 | | 0.26 | 0.12 | | | |
| | b | 0.30 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.09 | | 0.08 | 0.12 | 0.07 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.12 | | | 0.09 | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.57: Ni mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 8.85 | 0.96 | 0.67 | 1.81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |
| | b | | 11.60 | 3.58 | 0.98 | 0.49 | 0 | 0.87 | 0.60 | | | | | 0.06 | 1.05 | 0.55 | | | |
| | a | 4.49 | 0 | 0 | 0 | 7.42 | 0 | 0 | 0 | 5.99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | b | 9.81 | 2.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | a | | 22.16 | 0 | 0 | 0 | 0.86 | 1.20 | 0 | 0 | | | 0.31 | 0.41 | | 0.41 | | 0.32 | |
| | b | | 9.85 | 0.12 | 0 | 0 | 0.55 | 0.48 | 0 | | | 0.04 | 0 | 0 | 0 | 0.24 | 0.15 | 0.26 | |
| | a | | 12.78 | 0.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.14 | 0.17 | 0 | 0.06 | 0.89 | 0.65 | 1.30 | 0.97 |
| | b | | 20.98 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0.12 | 0.11 | 0.08 | 0 | 0.43 | 0.66 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 5.24 | 0.67 | 0 | 0.41 | 0.09 | 0.18 | 0.33 | 0.07 | 0.07 | 0.12 | 0.10 | 0.20 | 0.26 | 0.12 | | | 0.07 |
| | b | | 7.87 | 0.67 | 0.33 | 0.12 | 0.05 | 0.06 | 0.09 | | | | | 0.13 | 0.12 | 0.13 | | | |
| | a | 0.84 | 2.37 | 0.67 | 0.56 | 2.61 | 0.29 | 0.49 | 0.38 | 0.62 | 0.19 | 0.13 | 0.28 | 0.17 | 0.43 | 0.20 | 0.22 | | |
| | b | 1.57 | 2.37 | 0.67 | 1.33 | 2.69 | 0.63 | 0.76 | 0.99 | 0.22 | 0.23 | 0.37 | 0.46 | 0.24 | 2.26 | 0.27 | 0.11 | | |
| | a | | 8.97 | 0.67 | 0.25 | 0.24 | 0.15 | 0.26 | 0.11 | 0.08 | | | 0.07 | 0.09 | | 0.09 | | 0.04 | |
| | b | | 6.48 | 0.67 | 0.17 | 0.29 | 0.08 | 0.05 | 0.13 | | | 0.02 | 0.17 | 0.11 | 0.24 | 0.27 | 0.22 | 0.26 | |
| | a | | 5.15 | 0.67 | 0.49 | 0.55 | 0.23 | 0.36 | 0.10 | 0.26 | 0.14 | 0.00 | 0.03 | 0.22 | 0.80 | 0.19 | 0.17 | 0.47 | 0.31 |
| | b | | 5.36 | 0.67 | 0.11 | 0.83 | 0.06 | 0.25 | 0.27 | 0.13 | 0.06 | 0.02 | 0.09 | 0.18 | 0.46 | 0.09 | 0.15 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 2.90 | 0 | 0 | 0 | 0.78 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | 5.89 | 11.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 8.34 | 35.39 | 3.14 | 6.08 | 2.95 | 3.85 | 0 | 0 | 3.65 | 0 | 0.67 | 3.58 | 4.29 | 0.92 | 0.80 | 1.70 | 0.53 | 4.17 |
| | b | 8.45 | 0 | 0 | 0 | 0 | 3.52 | 19.09 | 0 | 5.28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | | 29.23 | 0 | 0 | 0 | 10.71 | 2.48 | 0 | 0 | 0 | 0 | 0.71 | 1.10 | 1.20 | 1.95 | 1.54 | 1.39 | |
| | b | | 15.62 | 0 | 0 | 0 | 4.20 | 0 | 0 | 0.01 | 0 | 0 | 0.84 | 0 | 1.45 | 0.50 | 0.48 | 1.39 | 0.92 |
| | a | 7.13 | 12.07 | | 0 | 0 | 1.24 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | | 1.11 | 1.47 |
| | b | 3.36 | 37.58 | 0 | 0 | 5.89 | 1.58 | 4.88 | 0 | 0.16 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 11.42 | 1.35 | 1.11 | 0.29 | 0.18 | 1.12 | 0.71 | 0.31 | 0.64 | | 0.80 | 0.48 | 1.52 | 0.79 | 0.27 | 0.14 | 0.18 |
| | b | 1.05 | 4.73 | 1.35 | 0.21 | 0.26 | 1.42 | 0.64 | 2.27 | 0.72 | 0.95 | 0.13 | 1.08 | 0.95 | 1.37 | 0.76 | 0.42 | 0.29 | 0.21 |
| | a | 1.94 | 22.84 | 3.01 | 1.63 | 0.13 | 0.99 | 1.05 | 5.10 | 0.57 | 0.92 | | 1.06 | 0.39 | 1.42 | 0.57 | 0.14 | 0.47 | 0.88 |
| | b | 0.20 | 4.73 | 1.35 | 1.71 | 1.47 | 0.47 | 1.23 | 6.63 | 0.61 | 0.71 | 0.89 | 0.95 | 1.99 | 1.52 | 0.57 | 0.49 | 0.36 | 0.85 |
| | a | | 17.04 | 1.35 | 0.95 | 0.90 | 0.64 | 0.35 | 0.66 | 0.37 | 0.36 | 0.10 | 0.26 | 0.34 | 0.08 | 0.36 | 0.34 | 0.40 | |
| | b | | 15.62 | 1.35 | 2.89 | 4.74 | 0.47 | 1.87 | 1.71 | 0.76 | 0.47 | 0.20 | 0.09 | 0.83 | 1.49 | 0.49 | 0.32 | 0.29 | 0.24 |
| | a | 1.35 | 4.73 | | 0.26 | 0.46 | 0.24 | 0.34 | | 0.54 | 0.45 | 0.19 | 0.90 | 0.27 | 0.32 | 0.41 | | 0.24 | 0.39 |
| | b | 1.17 | 21.48 | 1.35 | 1.12 | 0.41 | 0.33 | 0.90 | 0.78 | 0.20 | 0.29 | 0.18 | 0.42 | 0.33 | 0.24 | 0.50 | | 0.13 | 0.14 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.58: Ni mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 45.04 | 9.92 | 0.91 | 0.76 | 0.35 | 3.40 | 1.20 | 0.81 | 0.49 | 0.14 | 0.35 | 3.08 | 2.89 | 1.04 | 0.54 | 0.64 | 0.75 |
| | b | 2.83 | 3.96 | 1.19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | a | 3.86 | 0 | 0 | 0 | 0.55 | 1.92 | 1.72 | 0 | 1.42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | | 7.87 | 0.39 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0 | 0 | 0.99 | 3.89 | 2.14 | 0.75 | 0.27 | 0.16 | 1.08 |
| | a | 3.68 | | 2.74 | 1.37 | 0.79 | 2.38 | 3.61 | 0.63 | 0.79 | | 0.32 | | 1.05 | 3.28 | 2.16 | | 1.09 | |
| | b | | | 0.15 | 0 | 0.19 | 1.10 | 0 | 0.27 | | | | | | 0.65 | 0.42 | | 0.24 | |
| | a | | | 0.42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | | 24.32 | 0.03 | 0 | 0 | 12.92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 16.51 | 0.67 | 0.16 | 0.15 | 0.04 | 0.96 | 0.19 | 0.05 | 0.07 | 0.09 | 0.17 | 0.98 | 0.76 | 0.22 | 0.10 | 0.08 | 0.09 |
| | b | 0.69 | 2.37 | 0.67 | 2.52 | 2.62 | 0.70 | 2.34 | 1.85 | 0.47 | 0.38 | 0.54 | 0.75 | 0.66 | 0.85 | 0.32 | 0.22 | 0.17 | 0.08 |
| | a | 0.77 | 2.37 | 0.67 | 0.37 | 0.08 | 0.32 | 0.38 | 0.39 | 0.29 | 0.21 | 0.35 | 0.45 | 0.53 | 0.47 | 0.24 | 0.18 | 0.10 | 0.14 |
| | b | | 6.81 | 0.67 | 0.42 | 2.63 | 0.59 | 0.68 | 1.12 | 0.22 | 0.28 | 0.26 | 0.54 | 1.22 | 0.24 | 0.09 | 0.18 | 0.20 | 0.12 |
| | a | 0.55 | | 0.67 | 0.54 | 0.10 | 0.74 | 0.89 | 0.15 | 0.18 | | 0.12 | | 0.36 | 0.85 | 0.64 | | 0.33 | |
| | b | | | 0.67 | 0.13 | 0.31 | 0.10 | 0.09 | 0.02 | | | | | | 0.05 | 0.09 | | 0.06 | |
| | a | | | 0.67 | 0.32 | 2.63 | 0.13 | 0.17 | 0.13 | 0.13 | 0.06 | 0.06 | 0.14 | 0.15 | 0.30 | 0.19 | 0.11 | 0.12 | 0.11 |
| | b | | 11.48 | 0.67 | 0.92 | 2.61 | 2.10 | 0.54 | 0.38 | 0.38 | 0.21 | 0.27 | 0.33 | 0.27 | 0.85 | 0.26 | 0.17 | 0.09 | 0.10 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 116.35 | 75.55 | 7.17 | 3.04 | 2.64 | 7.83 | 11.35 | | 3.91 | 1.91 | 4.04 | 7.08 | 3.67 | 3.73 | | 8.78 | 11.33 |
| | b | | 48.29 | 3.13 | 0.94 | 0 | 0 | 0 | 0 | | 0 | | 0.30 | 1.60 | 2.99 | 1.86 | | | |
| | a | | 25.98 | 3.60 | 3.19 | 45.00 | 5.33 | 0 | 30.75 | 0 | 0 | | 0 | 0 | 1.51 | 0 | 0 | 0 | 0 |
| | b | | 0 | 0 | 0 | 0 | 3.01 | 0 | 0.21 | 18.77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.13 |
| | a | | 39.71 | 0 | | 0 | 0 | 4.14 | 0 | | 0 | 0 | 0.22 | 0 | 0 | 0 | | 0.28 | 0.21 |
| | b | 7.42 | 81.90 | 0 | 0 | 21.69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.46 | 0.63 |
| | a | | 393.90 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0.95 | | 0.17 | 0.93 | 2.82 | 0.24 | 2.05 | 1.41 | 0 | 1.75 |
| | b | | 44.27 | 0.63 | 0 | 0 | 0 | 0 | 0 | 0.07 | 1.05 | | 0.24 | 0.16 | 6.24 | 1.06 | 0.62 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 4.73 | 9.40 | 1.67 | 0.76 | 0.53 | 1.84 | 3.03 | | 0.95 | 0.66 | 1.46 | 2.02 | 1.08 | 1.09 | | 2.99 | 4.00 |
| | b | | 4.73 | 1.35 | 0.41 | 0.70 | 0.15 | 0.21 | 0.45 | | 0.17 | | 0.12 | 0.34 | 0.62 | 0.49 | | | |
| | a | | 20.06 | 1.35 | 0.38 | 9.44 | 0.89 | 1.46 | 3.99 | 0.69 | 0.48 | | 0.66 | 1.23 | 1.47 | 0.71 | 0.37 | 0.16 | 0.14 |
| | b | | 21.30 | 1.35 | 3.13 | 5.26 | 0.32 | 0.13 | 0.78 | 1.65 | 0.56 | 0.61 | 0.52 | 1.14 | 1.61 | 0.54 | 0.50 | 0.37 | 0.36 |
| | a | | 21.72 | 1.35 | | 0.15 | 0.14 | 0.21 | 0.45 | | 0.17 | 0.18 | 0.08 | 0.34 | 0.50 | 0.24 | | 0.19 | 0.12 |
| | b | 3.61 | 21.90 | 1.35 | 3.15 | 1.37 | 0.75 | 2.61 | 1.93 | 0.57 | 0.43 | 0.20 | 0.73 | 0.90 | 1.87 | 0.57 | 0.18 | 0.37 | 0.07 |
| | a | | 88.41 | 1.35 | 0.72 | 1.07 | 0.34 | 0.31 | 0.45 | 0.30 | | 0.03 | 0.40 | 0.75 | 0.32 | 0.54 | 0.40 | | 0.58 |
| | b | | 4.73 | 0.72 | 1.23 | 1.94 | 0.39 | 0.85 | 0.99 | 0.41 | 0.18 | | 0.10 | 0.48 | 1.41 | 0.11 | 0.06 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.59: Pb mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | 1.35 | 0.26 | 0.18 | 0.14 | 0.13 | *** | *** | *** | 0.09 | 0.32 | *** | *** | *** | *** | | *** |
| | b | | 4.73 | | 0.36 | 1.34 | 0.19 | 0.27 | *** | *** | *** | | 0.32 | *** | *** | *** | *** | | *** |
| | b | | | 1.35 | 0.21 | 0.14 | 0.08 | 0.12 | *** | *** | *** | | 0.14 | *** | *** | *** | *** | 0.17 | *** |
| | b | | 4.73 | 1.35 | 0.10 | 0.06 | 0.07 | | *** | *** | *** | | 0.15 | *** | *** | *** | *** | | *** |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.37 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.38 | 0.60 | *** | *** | *** | *** | | *** |
| | b | | 4.73 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.27 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.16 | 0.32 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.18 | *** | *** | *** | *** | | *** |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.20 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.20 | 0.39 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.09 | | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.15 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.13 | 0.27 | *** | *** | *** | *** | | *** |
| | b | 0.17 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.18 | *** | *** | *** | *** | | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.23 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.60: Pb mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 4.73 | 1.35 | 0.59 | 0.67 | 0.19 | 0.36 | *** | *** | *** | 0.24 | 0.20 | *** | *** | *** | *** | | *** |
| | b | | 4.73 | 1.35 | 0.43 | 0.32 | 0.10 | 0.13 | *** | *** | *** | | | *** | *** | *** | *** | | *** |
| | a | 0.20 | 4.73 | 1.35 | 1.13 | 5.21 | 0.58 | 0.97 | *** | *** | *** | 0.26 | 0.56 | *** | *** | *** | *** | | *** |
| | b | 0.81 | 4.73 | 1.35 | 2.66 | 5.39 | 1.25 | 1.52 | *** | *** | *** | 0.74 | 0.92 | *** | *** | *** | *** | | *** |
| | a | | 4.73 | 1.35 | 0.51 | 0.49 | 0.29 | 0.12 | *** | *** | *** | | 0.18 | *** | *** | *** | *** | 0.22 | *** |
| | b | | 4.73 | 1.35 | 0.34 | 0.59 | 0.15 | 0.10 | *** | *** | *** | 0.11 | 0.33 | *** | *** | *** | *** | 0.53 | *** |
| | a | | 4.73 | 1.35 | 0.98 | 1.10 | 0.47 | 0.71 | *** | *** | *** | 0.29 | 0.42 | *** | *** | *** | *** | 0.16 | *** |
| | b | | 4.73 | 1.35 | 0.21 | 1.66 | 0.12 | 0.50 | *** | *** | *** | 0.27 | 0.18 | *** | *** | *** | *** | | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0 | | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 9.47 | 2.69 | 2.22 | 0.59 | 0.36 | 2.24 | *** | *** | *** | | 1.59 | *** | *** | *** | *** | 0.28 | *** |
| | b | 0.36 | 9.47 | 2.69 | 0.43 | 0.52 | 2.84 | 1.28 | *** | *** | *** | 1.71 | 2.17 | *** | *** | *** | *** | 0.58 | *** |
| | a | 0.32 | 9.47 | 2.69 | 0.83 | 5.24 | 1.99 | 2.10 | *** | *** | *** | 2.07 | 1.84 | *** | *** | *** | *** | 0.95 | *** |
| | b | 0.40 | 9.47 | 2.69 | 3.43 | 2.94 | 0.95 | 2.46 | *** | *** | *** | 0.85 | 1.89 | *** | *** | *** | *** | 0.71 | *** |
| | a | | 9.47 | 2.69 | 1.91 | 1.80 | 1.28 | 0.70 | *** | *** | *** | 0.33 | 0.40 | *** | *** | *** | *** | 0.28 | *** |
| | b | | 9.47 | 2.69 | 5.78 | 9.47 | 0.95 | 3.74 | *** | *** | *** | 0.40 | 1.86 | *** | *** | *** | *** | 0.62 | *** |
| | a | 0.52 | 9.47 | | 0.52 | 0.92 | 0.48 | 0.67 | *** | *** | *** | 0.38 | 1.80 | *** | *** | *** | *** | 0.38 | *** |
| | b | 0.22 | 9.47 | 2.69 | 2.25 | 1.66 | 0.66 | 1.79 | *** | *** | *** | 0.36 | 0.84 | *** | *** | *** | *** | 0.27 | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.61: Pb mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | 0 | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | | *** | *** | *** | *** | 0 | *** |
| | b | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | | *** | *** | *** | *** | 0 | *** |
| | a | | | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 4.73 | 1.35 | 0.14 | 0.14 | 0.07 | 0.38 | *** | *** | *** | 0.17 | 0.45 | *** | *** | *** | *** | 0.27 | *** |
| | b | 0.22 | 4.73 | 1.35 | 5.04 | 5.24 | 1.40 | 4.69 | *** | *** | *** | 1.08 | 1.49 | *** | *** | *** | *** | 0.33 | *** |
| | a | 0.35 | 4.73 | 1.35 | 0.73 | 0.24 | 0.64 | 0.76 | *** | *** | *** | 0.70 | 0.91 | *** | *** | *** | *** | 0.20 | *** |
| | b | | 4.73 | 1.35 | 0.85 | 5.25 | 1.18 | 1.36 | *** | *** | *** | 0.51 | 0.72 | *** | *** | *** | *** | 0.40 | *** |
| | a | 0.20 | | 1.35 | 1.08 | 0.34 | 0.52 | 0.45 | *** | *** | *** | 0.09 | | *** | *** | *** | *** | 0.15 | *** |
| | b | | | 1.35 | 0.26 | 0.61 | 0.19 | 0.18 | *** | *** | *** | | | *** | *** | *** | *** | 0.09 | *** |
| | a | | | 1.35 | 0.64 | 5.26 | 0.27 | 0.33 | *** | *** | *** | 0.13 | 0.28 | *** | *** | *** | *** | 0.25 | *** |
| | b | | 4.73 | 1.35 | 1.84 | 5.23 | 0.78 | 1.07 | *** | *** | *** | 0.54 | 0.66 | *** | *** | *** | *** | 0.18 | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | 0 | *** |
| | b | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | 0 | *** |
| | a | | 0 | 0 | 0 | 0 | 0 | 0 | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | | *** |
| | b | | 0 | 1.25 | 0 | 0 | 0 | 0 | *** | *** | *** | | 0 | *** | *** | *** | *** | | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 9.47 | 2.69 | 0.33 | 0.21 | 0.18 | 0.41 | *** | *** | *** | 0.23 | 0.38 | *** | *** | *** | *** | 0.54 | *** |
| | b | | 9.47 | 2.69 | 0.82 | 1.40 | 0.30 | 0.42 | *** | *** | *** | | 0.33 | *** | *** | *** | *** | | *** |
| | a | | 9.47 | 2.69 | 3.35 | 10.42 | 0.63 | 2.92 | *** | *** | *** | | 1.33 | *** | *** | *** | *** | 0.31 | *** |
| | b | | 9.47 | 2.69 | 6.25 | 10.52 | 0.64 | 0.26 | *** | *** | *** | 1.21 | 1.04 | *** | *** | *** | *** | 0.74 | *** |
| | a | | 9.47 | 2.69 | 0.34 | 0.29 | 0.28 | 0.43 | *** | *** | *** | 0.35 | 0.60 | *** | *** | *** | *** | 0.38 | *** |
| | b | 1.62 | 9.47 | 2.69 | 6.30 | 10.42 | 1.50 | 5.21 | *** | *** | *** | 0.40 | 1.47 | *** | *** | *** | *** | 0.75 | *** |
| | a | | 9.47 | 2.69 | 1.45 | 2.14 | 0.67 | 0.62 | *** | *** | *** | 0.16 | 0.25 | *** | *** | *** | *** | | *** |
| | b | | 9.47 | 1.44 | 2.46 | 3.87 | 0.79 | 1.71 | *** | *** | *** | | 0.33 | *** | *** | *** | *** | | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.62: Sn mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 0 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.16 | 0.54 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | | *** | *** | *** | *** | *** | *** | *** | | 0.54 | *** | *** | *** | *** | *** | *** |
| | b | | | 2.27 | *** | *** | *** | *** | *** | *** | *** | | 0.24 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | | 0.26 | *** | *** | *** | *** | *** | *** |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 150 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.62 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.64 | 1.01 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.45 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.27 | 0.54 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.31 | *** | *** | *** | *** | *** | *** |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 300 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | 0.34 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.34 | 0.66 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.14 | | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| 450 kg N ha$^{-1}$ yr$^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.26 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.22 | 0.45 | *** | *** | *** | *** | *** | *** |
| | b | 0.29 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.30 | *** | *** | *** | *** | *** | *** |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.39 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.63: Sn mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.40 | 0.34 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | 0.34 | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.44 | 0.95 | *** | *** | *** | *** | *** | *** |
| | b | 1.36 | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 1.25 | 1.55 | *** | *** | *** | *** | *** | *** |
| | a | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | | 0.30 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.19 | 0.56 | *** | *** | *** | *** | *** | *** |
| | a | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.50 | 0.70 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.46 | 0.31 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | | 2.69 | *** | *** | *** | *** | *** | *** |
| | b | 0.61 | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 2.89 | 3.66 | *** | *** | *** | *** | *** | *** |
| | a | 0.54 | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 3.50 | 3.10 | *** | *** | *** | *** | *** | *** |
| | b | 0.67 | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 1.44 | 3.20 | *** | *** | *** | *** | *** | *** |
| | a | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.56 | 0.67 | *** | *** | *** | *** | *** | *** |
| | b | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.67 | 3.13 | *** | *** | *** | *** | *** | *** |
| | a | 0.88 | 15.98 | | *** | *** | *** | *** | *** | *** | *** | 0.64 | 3.04 | *** | *** | *** | *** | *** | *** |
| | b | 0.37 | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.60 | 1.42 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.64: Changes in Sn mass transport per sampling period (g ha$^{-1}$) as collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids at a mine reclamation site.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | 0 | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | | *** | *** | *** | *** | *** | *** |
| | b | | | 0 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.29 | 0.77 | *** | *** | *** | *** | *** | *** |
| | b | 0.37 | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 1.82 | 2.52 | *** | *** | *** | *** | *** | *** |
| | a | 0.59 | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 1.18 | 1.53 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.86 | 1.21 | *** | *** | *** | *** | *** | *** |
| | a | 0.34 | | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.15 | | *** | *** | *** | *** | *** | *** |
| | b | | | 2.27 | *** | *** | *** | *** | *** | *** | *** | | | *** | *** | *** | *** | *** | *** |
| | a | | | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.22 | 0.48 | *** | *** | *** | *** | *** | *** |
| | b | | 7.99 | 2.27 | *** | *** | *** | *** | *** | *** | *** | 0.91 | 1.12 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | 0 | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | a | | 0 | 0 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | *** | *** | *** | *** | *** | *** |
| | b | | 0 | 2.11 | *** | *** | *** | *** | *** | *** | *** | | 0 | *** | *** | *** | *** | *** | *** |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.38 | 0.64 | *** | *** | *** | *** | *** | *** |
| | b | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | | 0.56 | *** | *** | *** | *** | *** | *** |
| | a | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | | 2.24 | *** | *** | *** | *** | *** | *** |
| | b | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 2.05 | 1.76 | *** | *** | *** | *** | *** | *** |
| | a | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.59 | 1.01 | *** | *** | *** | *** | *** | *** |
| | b | 2.73 | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.67 | 2.48 | *** | *** | *** | *** | *** | *** |
| | a | | 15.98 | 4.54 | *** | *** | *** | *** | *** | *** | *** | 0.27 | 0.42 | *** | *** | *** | *** | *** | *** |
| | b | | 15.98 | 2.43 | *** | *** | *** | *** | *** | *** | *** | | 0.56 | *** | *** | *** | *** | *** | *** |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.65: Zn mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | 5.73 | 0 | 0 | 0.19 | 0 | 0.55 | 0.25 | 0.21 | 0.18 | 0.67 | 0.23 | 0.78 | | | | |
| | b | | 127.18 | | 0 | 0.39 | 7.97 | 0.35 | 0.06 | 0.49 | | | 0.58 | 0.94 | 0.38 | 0.40 | | | |
| | b | | | 6.44 | 0 | 0.41 | 3.96 | 0.10 | 0.28 | | | | 0.16 | | 0.48 | 0.25 | | 0.41 | |
| | b | | 207.39 | 6.14 | 0.06 | 0 | 2.83 | | | | | | 0.34 | | 0.11 | 0.02 | | | |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | 0.34 | 0.07 | 0.04 | 0.04 | 0.20 | 0.08 | 0.06 | 0.04 | 0.02 | 0.01 | 0.04 | 0.18 | | | | |
| | b | | 3.31 | | 0 | 0.06 | 0.36 | 0.07 | 0.04 | 0.06 | | | 0.02 | 0.14 | 0.16 | 0.02 | | | |
| | b | | | 0.34 | 0 | 0.01 | 0.02 | 0.03 | 0.00 | | | | 0.01 | | 0.09 | 0.05 | | 0.02 | |
| | b | | 5.53 | 0.34 | 0.02 | 0.01 | 0.07 | | | | | | 0.01 | | 0.06 | 0.03 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 6.96 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.60 | 0.29 | 0.51 | 0.52 | 0.12 | | | |
| | b | | 110.04 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.88 | 0.66 | 1.30 | 0.53 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.10 | 0.90 | 0.17 | 0.59 | 0.37 | 0.85 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.61 | 0.10 | 0.23 | 0.09 | | | |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.16 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.09 | 0.02 | 0.21 | 0.15 | 0.08 | | | |
| | b | | 4.88 | *** | *** | *** | *** | *** | *** | *** | *** | | 0.03 | 0.17 | 0.40 | 0.07 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.03 | 0.00 | 0.07 | 0.14 | 0.05 | 0.05 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.04 | 0.02 | 0.05 | 0.05 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 7.49 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.05 | 0 | 1.10 | 0.59 | 0.08 | 0.09 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.44 | 0.68 | 0.44 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.29 | | | | 0.30 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.30 | 0.94 | | | |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 0.17 | | *** | *** | *** | *** | *** | *** | *** | *** | 0.21 | 0 | 0.14 | 0.24 | 0.09 | 0.04 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | 0.07 | 0.11 | 0.07 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.00 | | | | 0.02 | | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | | | 0.07 | 0.10 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.53 | | 0.28 | 0.10 | | | 0.37 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.26 | 0.27 | | 0.37 | 0 | | | |
| | b | 7.31 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.60 | | 0.22 | 0.08 | 0.29 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.56 | | | 0.17 | | | |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.04 | | 0.01 | 0.06 | | | 0.31 |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | 0.02 | 0.07 | | 0.17 | 0.06 | | | |
| | b | 0.26 | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.01 | | 0.04 | 0.06 | 0.05 | | |
| | b | | | *** | *** | *** | *** | *** | *** | *** | *** | | 0.02 | | | 0.05 | | | |

*** Samples were not collected for these treatments. Blanks indicate where sample was not collected due to lack of leachate.

Table 5.66: Zn mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 90.43 | 5.38 | 0 | 6.97 | 0.30 | 13.36 | 0.33 | 0.70 | 1.07 | 2.97 | 27.90 | 15.08 | 23.55 | 6.60 | | | 2.90 |
| | b | | 54.47 | 7.26 | 0 | 0 | 0.30 | 7.52 | 0.71 | | | | | 15.11 | 82.83 | 43.02 | | | |
| | a | 7.21 | 7.81 | 5.50 | 0 | 44.09 | 4.18 | 18.33 | 4.35 | 14.63 | 1.85 | 1.40 | 6.45 | 0.62 | 5.96 | 1.67 | 4.70 | | |
| | b | 15.35 | 24.44 | 4.51 | 7.19 | 14.74 | 18.91 | 4.13 | 11.55 | 2.48 | 3.41 | 9.12 | 29.24 | 4.85 | 90.01 | 8.78 | 2.14 | | |
| | a | | 557.97 | 39.33 | 2.90 | 4.69 | 13.80 | 9.17 | 10.19 | 10.10 | | | 66.22 | 29.12 | | 19.13 | | 8.31 | |
| | b | | 46.25 | 7.13 | 0 | 0.68 | 6.68 | 5.15 | 0.13 | | | 4.32 | 3.39 | 2.58 | 9.50 | 12.53 | 9.75 | 12.68 | |
| | a | | 37.46 | 14.53 | 3.40 | 7.09 | 3.54 | 7.10 | 3.91 | 9.05 | 6.61 | 8.98 | 34.54 | 16.80 | 69.04 | 33.56 | 31.80 | 52.14 | 27.18 |
| | b | | 168.69 | 36.00 | 1.26 | 11.62 | 1.39 | 6.71 | 9.44 | 5.63 | 8.18 | 22.24 | 31.55 | 20.98 | 41.34 | 8.96 | 19.82 | | |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 2.96 | 0.34 | 0.15 | 0.14 | 0.05 | 0.20 | 0.17 | 0 | 0.04 | 0.35 | 2.84 | 4.39 | 6.07 | 1.65 | | | 1.05 |
| | b | | 2.34 | 0.34 | 0.11 | 0.08 | 0.02 | 0.05 | 0.08 | | | | | 3.94 | 27.03 | 14.45 | | | |
| | a | 0.17 | 1.24 | 0.34 | 0.28 | 3.91 | 1.16 | 1.28 | 1.38 | 3.21 | 1.24 | 0.36 | 0.68 | 0.35 | 0.72 | 0.10 | 1.14 | | |
| | b | 0.33 | 4.97 | 0.34 | 0.10 | 0.61 | 1.06 | 1.34 | 4.15 | 0.80 | 1.25 | 2.52 | 3.45 | 0.60 | 10.36 | 2.05 | 0.65 | | |
| | a | | 206.21 | 9.92 | 1.41 | 1.13 | 3.67 | 2.71 | 3.54 | 3.33 | | | 10.05 | 11.68 | | 6.80 | | 2.80 | |
| | b | | 1.15 | 0.34 | 0.09 | 0.15 | 0.04 | 0.03 | 0.07 | | | 1.28 | 0.37 | 0.30 | 1.43 | 3.04 | 3.11 | 4.23 | |
| | a | | 12.07 | 2.93 | 1.50 | 0.22 | 0.20 | 1.48 | 1.20 | 2.19 | 2.15 | 2.61 | 4.28 | 6.03 | 10.67 | 11.35 | 11.26 | 18.97 | 9.69 |
| | b | | 12.16 | 0.77 | 0.25 | 1.25 | 0.20 | 1.03 | 2.92 | 1.88 | 2.65 | 7.61 | 4.67 | 7.97 | 13.93 | 3.12 | 7.00 | | |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 98.95 | 0 | 0 | 0 | 9.71 | 2.18 | 2.92 | 2.24 | 1.84 | | 5.01 | 2.35 | 13.70 | 9.36 | 3.23 | 1.73 | 2.00 |
| | b | 17.60 | 53.02 | 1.85 | 0 | 0 | 72.83 | 0.10 | 2.41 | 1.79 | 0 | 6.39 | 30.94 | 19.80 | 32.88 | 14.66 | 6.36 | 3.77 | 2.42 |
| | a | 13.10 | 63.03 | 0 | 0 | 9.10 | 35.19 | 1.18 | 6.67 | 0 | 3.96 | 5.51 | 11.84 | 14.98 | 15.88 | 2.37 | 1.75 | 2.39 | 2.94 |
| | b | 15.33 | 49.95 | 0 | 27.05 | 2.96 | 26.37 | 140.44 | 40.34 | 25.12 | 1.57 | 2.03 | 8.87 | 10.47 | 11.14 | 2.11 | 2.97 | 2.78 | 4.54 |
| | a | | 144.04 | 1.75 | 0 | 2.16 | 94.66 | 31.92 | 0.45 | 0 | 0.09 | 4.82 | 62.19 | 59.31 | 42.74 | 52.71 | 51.27 | 63.36 | |
| | b | | 163.81 | 0.44 | 0 | 0.36 | 45.22 | 79.12 | 27.94 | 3.27 | 0.97 | 2.43 | 30.73 | 30.49 | 154.82 | 45.86 | 44.80 | 108.32 | 59.88 |
| | a | 12.16 | 15.74 | | 0.02 | 0.21 | | 1.22 | | 5.37 | 4.70 | 0.90 | 16.45 | 2.11 | 10.66 | 26.59 | | 73.18 | 89.25 |
| | b | 7.06 | 285.60 | 18.78 | 1.42 | 37.23 | 20.42 | 72.03 | 10.65 | 3.95 | 9.33 | 6.74 | 37.48 | 14.05 | 12.44 | 22.79 | | 6.95 | 5.54 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 19.29 | 2.29 | 0.33 | 0.08 | 0.09 | 0.28 | 0.36 | 0.10 | 0.32 | | 0.40 | 0.14 | 2.48 | 0.92 | 0.48 | 0.26 | 0.15 |
| | b | 0.31 | 17.40 | 1.01 | 0.11 | 0 | 1.17 | 0.32 | 1.14 | 0.36 | 0.47 | 1.03 | 0.68 | 5.04 | 3.76 | 1.28 | 0.51 | 0.62 | 0.17 |
| | a | 0.09 | 2.43 | 0.79 | 0.21 | 0.26 | 0.50 | 0.53 | 2.55 | 9.24 | 0.39 | 1.91 | 0.75 | 1.72 | 2.91 | 0.26 | 0.44 | 0.47 | 0.54 |
| | b | 0.10 | 2.37 | 0.67 | 8.27 | 0.57 | 3.55 | 19.69 | 3.32 | 7.94 | 0.37 | 0.47 | 0.75 | 3.16 | 0.91 | 0.59 | 0.49 | 0.51 | 0.83 |
| | a | | 5.09 | 0.67 | 0.48 | 0.45 | 0.47 | 0.28 | 0.33 | 3.34 | 0.18 | 1.85 | 6.83 | 23.28 | 11.62 | 19.01 | 18.56 | 22.02 | |
| | b | | 31.60 | 0.67 | 0 | 2.37 | 0.94 | 4.84 | 0.85 | 6.31 | 0.24 | 0.75 | 4.18 | 11.44 | 55.04 | 20.55 | 16.29 | 39.69 | 21.56 |
| | a | 0.61 | 81.19 | | 0.13 | 0.10 | | 0.17 | | 0.27 | 0.13 | 0.20 | 1.73 | 0.33 | 1.75 | 4.07 | | 27.05 | 31.66 |
| | b | 1.41 | 75.63 | 2.20 | 0.80 | 5.03 | 0.00 | 20.15 | 3.23 | 1.16 | 3.43 | 2.44 | 5.40 | 3.84 | 4.30 | 7.12 | | 2.55 | 2.19 |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.67: Zn mass transport per sampling period (g ha$^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | 10-Aug-06 | 8-Sep-06 | 6-Oct-06 | 3-Nov-06 | 1-Dec-06 | 15-Dec-06 | 5-Jan-07 | 19-Jan-07 | 9-Feb-07 | 2-Mar-07 | 23-Mar-07 | 13-Apr-07 | 11-May-07 | 8-Jun-07 | 10-Jul-07 | 9-Aug-07 | 7-Sep-07 | 12-Oct-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 236.51 | 9.73 | 0.42 | 0.38 | 0.36 | 27.47 | 0.96 | 0.44 | 0.41 | 0.40 | 1.01 | 0.98 | 1.65 | 1.63 | 0.87 | 0.43 | 1.25 |
| | b | 7.36 | 83.80 | 1.90 | 12.85 | 0 | 23.49 | 0.94 | 5.46 | 0.68 | 0 | 2.02 | 6.26 | 4.09 | 4.42 | 1.47 | 0.93 | 0.52 | 0.26 |
| | a | 8.23 | 3.79 | 0 | 0 | 1.56 | 16.24 | 14.45 | 1.16 | 9.91 | 0.49 | 1.74 | 2.75 | 1.44 | 3.58 | 1.53 | 1.15 | 0.68 | 1.36 |
| | b | | 48.50 | 0.45 | 0 | 9.46 | 15.78 | 0.68 | | 0.43 | 1.37 | 0.57 | 1.49 | 2.76 | 3.59 | 1.19 | 0.89 | 0.94 | 1.32 |
| | a | 10.54 | | 25.85 | 16.74 | 12.82 | 35.28 | 51.16 | 10.12 | 11.45 | | 6.16 | | 11.84 | 43.59 | 17.97 | | 10.21 | |
| | b | | | 42.36 | 5.99 | 20.75 | 13.77 | 9.93 | 9.28 | | | | | | 27.69 | 18.59 | | 9.70 | |
| | a | | | 12.17 | 0.22 | 0 | 0.42 | 0 | 0.36 | 0.31 | 0.33 | 0.55 | 1.81 | 0.28 | 1.60 | 1.63 | 1.29 | 0.94 | 0.68 |
| | b | | 74.48 | 10.02 | 1.49 | 3.69 | 65.98 | 2.17 | 6.19 | 2.04 | 0.94 | 2.31 | 5.59 | 1.57 | 4.80 | 2.43 | 1.04 | 0.59 | 0.50 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 7.78 | 1.39 | 0.04 | 0.07 | 0.04 | 2.58 | 0.08 | 0.01 | 0.05 | 0.05 | 0 | 0.24 | 0.14 | 0.06 | 0.06 | 0.03 | 0.06 |
| | b | 1.55 | 2.19 | 0.34 | 0 | 0.95 | 0.80 | 1.17 | 0.92 | 0.14 | 0.14 | 0.42 | 0.38 | 0.42 | 0.84 | 0.10 | 0.10 | 0.05 | 0.14 |
| | a | 0.66 | 1.48 | 0.34 | 0.18 | 0.07 | 0.16 | 8.22 | 0.20 | 3.23 | 0.09 | 0.41 | 0.02 | 0.76 | 0.28 | 0.12 | 0.27 | 0.22 | 0.35 |
| | b | | 1.39 | 0.34 | 0.21 | 0 | 0.14 | 0.34 | | 0.11 | 0.14 | 0.07 | 0.06 | 0.42 | 0.38 | 0.14 | 0.05 | 0.03 | 0.29 |
| | a | 1.32 | | 5.39 | 3.21 | 3.21 | 14.58 | 17.55 | 3.35 | 4.04 | | 2.20 | | 4.58 | 15.41 | 5.94 | | 3.77 | |
| | b | | | 11.92 | 1.28 | 5.65 | 4.65 | 3.10 | 2.58 | | | | | | 5.86 | 6.48 | | 3.55 | |
| | a | | | 2.00 | 0.07 | 0.07 | 0.03 | 1.26 | 0.17 | 0.06 | 0.02 | 0.03 | 0.14 | 0.15 | 0.07 | 0.15 | 0.10 | 0.05 | 0.03 |
| | b | | 29.91 | 1.31 | 1.19 | 3.37 | 2.20 | 0.27 | 1.61 | 0.30 | 0.32 | 0.62 | 0.25 | 0.68 | 1.47 | 0.63 | 0.34 | 0.19 | 0.07 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | | 273.53 | 28.77 | 4.19 | 2.36 | 2.39 | 38.21 | 8.50 | | 2.71 | 4.30 | 6.68 | 5.11 | 4.55 | 39.02 | | 174.21 | 184.65 |
| | b | | 676.30 | 16.55 | 1.38 | 0.70 | 1.49 | 0.37 | 0.44 | | 2.28 | | 102.84 | 133.43 | 198.36 | 102.72 | | | |
| | a | | 255.65 | 0 | 5.74 | 140.61 | 30.23 | 0 | 96.72 | 3.19 | 1.21 | | 10.67 | 17.26 | 21.11 | 6.48 | 3.62 | 1.81 | 1.68 |
| | b | | 0 | 0 | 10.00 | 0 | 2.98 | 1.35 | 2.25 | 70.99 | 0 | 1.86 | 3.58 | 6.22 | 3.74 | 1.02 | 1.74 | 1.39 | 1.16 |
| | a | | 66.16 | 2.34 | 1.38 | 4.93 | 0.49 | 50.79 | 1.09 | | 0.32 | 0.62 | 1.87 | 5.51 | 6.02 | 3.10 | | 15.01 | 2.88 |
| | b | 60.79 | 400.17 | 46.21 | 102.25 | 218.57 | 5.34 | 99.35 | 18.61 | 6.52 | 4.66 | 2.08 | 18.90 | 11.88 | 20.72 | 10.49 | 3.43 | 9.57 | 5.79 |
| | a | | 1754.48 | 116.33 | 1.53 | 2.97 | 4.67 | 10.11 | 41.32 | 36.21 | | 16.55 | 84.40 | 74.92 | 9.10 | 34.60 | 17.06 | | 14.91 |
| | b | | 485.62 | 34.85 | 21.38 | 39.59 | 12.73 | 21.03 | 22.36 | 10.91 | 5.09 | | 15.19 | 14.00 | 118.64 | 16.43 | 5.68 | | |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | | 32.43 | 5.83 | 0.41 | 0.21 | 0.25 | 5.13 | 0.71 | | 0.30 | 0.22 | 0.32 | 0.22 | 1.38 | 8.16 | | 61.75 | 65.21 |
| | b | | 133.03 | 0.71 | 0.20 | 0.35 | 0.07 | 0.84 | 0.23 | | 0.12 | | 15.27 | 48.01 | 67.13 | 34.82 | | | |
| | a | | 6.98 | 2.99 | 0.84 | 7.23 | 0.21 | 0.73 | 25.21 | 0.31 | 0.36 | | 1.07 | 4.11 | 6.02 | 1.08 | 1.13 | 0.40 | 0.39 |
| | b | | 7.40 | 0.67 | 1.56 | 2.83 | 0.26 | 0.03 | 0.39 | 6.33 | 1.01 | 0.17 | 0.02 | 0.20 | 0.40 | 0.27 | 0.25 | 0 | 0.02 |
| | a | | 12.55 | 1.13 | 0.09 | 0.07 | 0.07 | 0.06 | 0.22 | | 0.08 | 0.01 | 0.15 | 0.67 | 0.51 | 0.40 | | 4.71 | 0.86 |
| | b | 22.42 | 122.50 | 11.47 | 26.20 | 73.86 | 0.93 | 33.77 | 3.31 | 2.05 | 1.69 | 0.45 | 2.64 | 3.98 | 6.41 | 2.63 | 1.07 | 3.20 | 1.87 |
| | a | | 66.46 | 5.72 | 0.24 | 0.80 | 0.22 | 2.59 | 13.59 | 12.84 | | 1.45 | 12.45 | 28.37 | 3.08 | 12.41 | 5.89 | | 5.67 |
| | b | | 76.22 | 1.23 | 3.53 | 13.10 | 3.79 | 6.32 | 8.57 | 3.66 | 1.86 | | 2.13 | 5.69 | 41.88 | 5.45 | 1.90 | | |

Blanks indicate where sample was not collected due to lack of leachate.

Table 5.68: Fifteen-month cumulative metal mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below simulated trenches within surface applied fertilizer plots.

| Treatment | Trench | Ba | Cu | Ni | Zn |
|---|---|---|---|---|---|
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 24.86 | 0.54 | 2.06 | 10.10 |
| | b | 57.79 | 311.68 | 31.82 | 141.30 |
| | b | 24.06 | 5.25 | 0.33 | 12.50 |
| | b | 31.42 | 343.85 | 59.98 | 217.58 |
| 0 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 2.81 | 2.01 | 2.24 | 1.28 |
| | b | 9.53 | 13.03 | 10.14 | 4.71 |
| | b | 2.69 | 1.02 | 1.35 | 0.57 |
| | b | 3.64 | 11.35 | 10.92 | 6.46 |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 15.37 | 23.30 | 4.16 | 13.15 |
| | b | 63.04 | 164.99 | 34.17 | 114.55 |
| | b | 18.45 | 1.17 | 2.38 | 3.95 |
| | b | 20.38 | 0 | 4.54 | 3.33 |
| 150 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 3.91 | 2.66 | 2.07 | 1.15 |
| | b | 15.11 | 20.02 | 9.29 | 5.76 |
| | b | 5.04 | 0.69 | 0.92 | 0.57 |
| | b | 4.34 | 0.71 | 1.79 | 0.75 |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 11.43 | 12.79 | 4.05 | 11.20 |
| | b | 105.00 | 5.21 | 6.50 | 6.51 |
| | b | 4.98 | 1.45 | 4.99 | 2.65 |
| | b | 3.26 | 0.01 | 0 | 1.23 |
| 300 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 2.14 | 1.57 | 1.97 | 1.03 |
| | b | 14.18 | 0.79 | 1.84 | 0.62 |
| | b | 0.93 | 0.25 | 1.29 | 0.29 |
| | b | 0.41 | 0.10 | 0.13 | 0.18 |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Colloidal Fraction | b | 5.06 | 1.61 | 4.87 | 3.98 |
| | b | 6.67 | 2.11 | 0.87 | 2.22 |
| | b | 20.27 | 25.04 | 6.19 | 10.59 |
| | b | 5.96 | 1.05 | 3.50 | 3.08 |
| 450 kg N $ha^{-1}$ $yr^{-1}$ - Dissolved Fraction | b | 1.06 | 1.05 | 1.53 | 0.84 |
| | b | 0.92 | 0.75 | 1.14 | 0.60 |
| | b | 6.28 | 1.75 | 1.71 | 0.55 |
| | b | 0.67 | 0.31 | 1.12 | 0.28 |

Table 5.69: Fifteen-month cumulative metal mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched anaerobically digested biosolids.

| Treatment | Trench | Ba | Cu | Ni | Zn |
|---|---|---|---|---|---|
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | 183.70 | 153.03 | 12.10 | 197.37 |
| | b | 188.38 | 106.46 | 19.77 | 211.03 |
| | a | 153.44 | 129.71 | 15.14 | 128.49 |
| | b | 454.52 | 156.87 | 11.18 | 250.84 |
| | a | 184.23 | 51.90 | 25.45 | 770.94 |
| | b | 579.09 | 83.79 | 80.56 | 646.70 |
| | a | 332.61 | 87.88 | 17.01 | 366.71 |
| | b | 283.58 | 179.61 | 22.15 | 393.81 |
| Anaerobically Digested Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | 19.08 | 25.11 | 7.93 | 20.40 |
| | b | 11.85 | 25.55 | 9.57 | 48.43 |
| | a | 26.53 | 28.72 | 10.45 | 17.56 |
| | b | 61.89 | 24.20 | 15.16 | 34.57 |
| | a | 33.66 | 30.73 | 11.01 | 263.25 |
| | b | 47.40 | 31.53 | 30.84 | 170.58 |
| | a | 49.83 | 21.34 | 10.13 | 98.78 |
| | b | 42.27 | 23.38 | 8.73 | 67.42 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | 134.49 | 98.59 | 3.68 | 154.64 |
| | b | 350.86 | 330.17 | 17.74 | 266.22 |
| | a | 659.26 | 179.32 | 110.40 | 698.08 |
| | b | 624.73 | 486.74 | 138.74 | 1985.47 |
| | a | 1071.74 | 803.16 | 48.95 | 609.32 |
| | b | 891.35 | 293.22 | 24.99 | 798.45 |
| | a | 404.33 | 91.07 | 23.10 | 282.44 |
| | b | 438.41 | 613.64 | 52.65 | 572.45 |
| Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | 32.23 | 21.79 | 21.30 | 27.97 |
| | b | 59.41 | 21.89 | 18.82 | 35.38 |
| | a | 60.46 | 71.23 | 52.18 | 132.91 |
| | b | 124.77 | 98.37 | 57.67 | 465.50 |
| | a | 92.48 | 81.11 | 24.50 | 114.46 |
| | b | 151.23 | 24.23 | 33.84 | 217.33 |
| | a | 80.24 | 14.93 | 11.10 | 149.39 |
| | b | 93.58 | 69.06 | 29.96 | 140.89 |

Table 5.70: Fifteen-month cumulative metal mass transport per sampling period (g $ha^{-1}$) collected from zero tension lysimeters 15 cm below two application rates of entrenched lime-stabilized biosolids.

| Treatment | Trench | Ba | Cu | Ni | Zn |
|---|---|---|---|---|---|
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Colloidal Fraction | a | 200.31 | 847.81 | 72.30 | 284.89 |
| | b | 263.06 | 212.69 | 7.99 | 155.45 |
| | a | 54.80 | 94.01 | 7.11 | 69.79 |
| | b | 215.85 | 164.61 | 17.18 | 88.65 |
| | a | 239.06 | 98.63 | 23.88 | 263.73 |
| | b | 83.81 | 0 | 2.96 | 158.06 |
| | a | 96.92 | 8.05 | 0.12 | 22.15 |
| | b | 436.99 | 315.21 | 34.83 | 185.82 |
| Lime-stabilized Biosolids Entrenched at 45 cm (w) by 75 cm (d) - Dissolved Fraction | a | 9.58 | 342.70 | 21.30 | 12.69 |
| | b | 30.99 | 71.71 | 18.21 | 10.66 |
| | a | 12.19 | 34.77 | 8.32 | 17.07 |
| | b | 14.63 | 61.05 | 16.28 | 4.68 |
| | a | 51.24 | 25.95 | 6.12 | 84.56 |
| | b | 14.03 | 30.33 | 1.52 | 45.06 |
| | a | 9.61 | 9.68 | 5.42 | 4.40 |
| | b | 137.50 | 133.45 | 21.62 | 44.73 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Colloidal Fraction | a | 677.34 | 1132.28 | 269.45 | 787.34 |
| | b | 283.72 | 72.63 | 58.44 | 1236.85 |
| | a | 857.35 | 1209.31 | 114.98 | 595.45 |
| | b | 177.85 | 24.75 | 1.86 | 97.21 |
| | a | 467.93 | 169.57 | 44.08 | 162.50 |
| | b | 587.60 | 791.99 | 111.63 | 1045.34 |
| | a | 677.79 | 2310.97 | 404.28 | 2219.15 |
| | b | 742.99 | 250.01 | 53.63 | 823.49 |
| Lime-stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) - Dissolved Fraction | a | 48.25 | 507.78 | 35.13 | 174.37 |
| | b | 69.35 | 112.80 | 9.74 | 300.80 |
| | a | 175.38 | 331.09 | 43.48 | 59.06 |
| | b | 21.27 | 138.04 | 40.12 | 21.80 |
| | a | 39.44 | 32.88 | 25.99 | 21.58 |
| | b | 136.37 | 259.98 | 42.55 | 320.43 |
| | a | 106.40 | 309.29 | 95.96 | 171.76 |
| | b | 156.12 | 80.03 | 13.60 | 175.32 |

## MINTEQA2 inputs

Table 5.71a: Various parameter data gathered on September 8, 2006 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | pH | DOC † | $Cl^-$ † | $SO_4^{2-}$ † | $NO_3^-$ † | $PO_4^{3-}$ † | $HCO_3^-$ † | Al † | Fe † | Mn † | Ca † | Mg † |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | | | | | | | | | | | | |
| | | 8.07 | 9.255 | 20 | 205 | 15.111 | 0.038 | 12.700 | 0.002 | 0.004 | 0.002 | 103.769 | 31.880 |
| | | | | | | | | | | | | | |
| | | 8.44 | 7.600 | 24 | 160 | 8.369 | 0.042 | 6.540 | 0.002 | 0.004 | 0.015 | 64.820 | 14.051 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 7.66 | 14.050 | 15 | 278 | 0.291 | 0.007 | 23.950 | 0.002 | 0.017 | 0.449 | 154.365 | 37.542 |
| | | 8.03 | 13.950 | 20 | 245 | 0.027 | 0.007 | 22.050 | 0.002 | 0.019 | 0.472 | 148.532 | 41.944 |
| | | 7.99 | | | | 0.048 | 0.034 | | 0.002 | 0.051 | 0.166 | 16.545 | 25.229 |
| | | 8.20 | 11.100 | 19 | 60 | 0.116 | 0.007 | 41.500 | 0.002 | 0.009 | 0.239 | 39.704 | 29.080 |
| | | 8.13 | | 30 | 171 | 0.052 | 0.007 | | 0.005 | 0.071 | 0.025 | 19.396 | 35.719 |
| | | 6.76 | 24.600 | 20 | 365 | 0.033 | 0.041 | 24.950 | 0.002 | 0.385 | 1.363 | 106.596 | 32.790 |
| | | 7.61 | 17.100 | 25 | 343 | 0.017 | 0.007 | 33.900 | 0.002 | 0.080 | 0.435 | 84.301 | 39.086 |
| | | 7.16 | 14.400 | 20 | 243 | 1.627 | 0.007 | 16.350 | 0.002 | 0.004 | 1.373 | 73.626 | 21.993 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 8.34 | 871.000 | 35 | 76 | 0.042 | 0.190 | 129.000 | 0.002 | 1.665 | 0.208 | 17.109 | 14.340 |
| | | 7.43 | 28.350 | 18 | 409 | 150.799 | 0.018 | 96.050 | 0.002 | 0.155 | 0.153 | 42.483 | 16.476 |
| | | 8.14 | | 26 | 125 | 435.582 | 0.065 | | 0.002 | 0.044 | 0.006 | 13.392 | 33.839 |
| | | 7.53 | 79.550 | 32 | 6 | 0.211 | 0.007 | 48.300 | 0.002 | 0.024 | 0.034 | 28.595 | 35.737 |
| | | 7.38 | 109.000 | 29 | 202 | 0.068 | 0.007 | 30.950 | 0.002 | 0.010 | 0.592 | 114.909 | 28.944 |
| | | 7.09 | 6.355 | 25 | 167 | 8.057 | 0.007 | 6.405 | 0.002 | 0.028 | 0.272 | 70.976 | 17.998 |
| | | 8.12 | | 27 | 475 | 311.457 | 0.027 | | 0.010 | 0.047 | 0.106 | 28.842 | 23.315 |
| | | 8.35 | 14.300 | 25 | 304 | 129.365 | 0.007 | 10.450 | 0.002 | 0.004 | 0.217 | 87.891 | 20.994 |

Blanks indicate where sample was not collected due to lack of leachate.
† Units = mg $L^{-1}$

Table 5.71b: Various parameter data gathered on September 8, 2006 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | Ba † | Cd † | Cu † | Ni † | Pb † | Zn † |
|---|---|---|---|---|---|---|---|
| 8-Sep-06 | Control | | | | | | |
| | | 0.011 | 0.004 | 0.032 | 0.023 | 0.016 | 0.011 |
| | | | | | | | |
| | | 0.007 | 0.004 | 0.033 | 0.031 | 0.016 | 0.019 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.029 | 0.005 | 0.016 | 0.019 | 0.016 | 0.033 |
| | | 0.029 | 0.004 | 0.013 | 0.008 | 0.016 | 0.029 |
| | | 0.007 | 0.004 | 0.085 | 0.039 | 0.016 | 0.004 |
| | | 0.010 | 0.004 | 0.011 | 0.008 | 0.016 | 0.004 |
| | | 0.015 | 0.004 | 0.098 | 0.029 | 0.016 | 0.009 |
| | | 0.028 | 0.004 | 0.006 | 0.026 | 0.016 | 0.053 |
| | | 0.025 | 0.004 | 0.018 | 0.008 | 0.016 | 0.137 |
| | | 0.053 | 0.004 | 0.050 | 0.036 | 0.016 | 0.128 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.013 | 0.004 | 0.751 | 0.008 | 0.016 | 0.055 |
| | | 0.037 | 0.004 | 0.161 | 0.008 | 0.016 | 0.225 |
| | | 0.009 | 0.004 | 0.319 | 0.034 | 0.016 | 0.012 |
| | | 0.014 | 0.004 | 0.184 | 0.036 | 0.016 | 0.013 |
| | | 0.040 | 0.004 | 0.028 | 0.037 | 0.016 | 0.021 |
| | | 0.047 | 0.004 | 0.157 | 0.037 | 0.016 | 0.207 |
| | | 0.036 | 0.004 | 0.513 | 0.149 | 0.016 | 0.112 |
| | | 0.102 | 0.004 | 0.117 | 0.008 | 0.016 | 0.129 |

Blanks indicate where sample was not collected due to lack of leachate.
† Units = mg $L^{-1}$

Table 5.72a: Various parameter data gathered on November 3, 2006 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | pH | DOC † | $Cl^-$ † | $SO_4^{2-}$ † | $NO_3^-$ † | $PO_4^{3-}$ † | $HCO_3^-$ † | Al † | Fe † | Mn † | Ca † | Mg † |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Nov-06 | Control | 7.61 | 6.000 | 22 | 296 | | | 16.887 | 0.002 | 0.004 | 0.010 | 128.091 | 36.285 |
| | | 7.58 | 4.265 | 24 | 221 | 2.228 | 0 | 8.627 | 0.002 | 0.004 | 0.000 | 146.239 | 44.985 |
| | | 7.69 | 11.265 | 18 | 174 | 6.408 | 0.002 | 8.497 | 0.002 | 0.010 | 0.005 | 122.272 | 22.832 |
| | | 7.84 | 5.105 | 15 | 253 | 0.563 | 0.011 | 9.687 | 0.002 | 0.000 | 0.002 | 87.808 | 15.600 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 7.65 | 10.015 | 15 | 276 | 0.139 | 0.000 | 33.037 | 0.002 | 0.033 | 0.205 | 108.400 | 32.563 |
| | | 7.82 | 7.920 | 13 | 109 | 0.233 | 0.002 | 20.387 | 0.002 | 0.004 | 0.381 | 90.488 | 44.063 |
| | | 7.81 | 462.015 | 11 | 96 | 42.166 | 1.101 | 106.687 | 0.002 | 0.047 | 0.096 | 13.477 | 18.467 |
| | | 7.76 | 10.165 | 10 | 127 | 0.167 | 0.012 | 24.437 | 0.002 | 0.002 | 0.037 | 59.720 | 35.590 |
| | | 7.61 | 9.665 | 13 | 63 | 0.162 | 0.000 | 128.687 | 0.002 | 0.010 | 0.064 | 27.156 | 26.620 |
| | | 7.34 | 41.415 | 19 | 404 | 0.100 | 0.000 | 91.587 | 0.002 | 0.003 | 0.372 | 57.614 | 29.859 |
| | | 7.81 | 12.815 | 18 | 272 | 0.552 | 0.000 | 44.487 | 0.002 | 0.004 | 0.253 | 65.167 | 33.592 |
| | | 6.98 | 10.715 | 15 | 149 | 1.687 | 1.117 | 20.287 | 0.002 | 0.006 | 1.051 | 61.370 | 19.126 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 8.26 | 0.000 | 16 | 202 | 220.773 | 0.059 | 0.687 | 0.002 | 2.336 | 0.130 | 15.022 | 11.753 |
| | | 8.12 | 0.000 | 14 | 288 | 134.005 | 0.020 | 0.687 | 0.002 | 0.004 | 0.011 | 11.953 | 20.245 |
| | | 8.33 | 0.000 | 14 | 53 | 1.788 | 0.005 | 128.687 | 0.002 | 0.004 | 0.004 | 12.926 | 21.944 |
| | | 7.97 | 10.765 | 8 | 9 | 0.184 | 0.004 | 128.687 | 0.002 | 0.051 | 0.009 | 13.329 | 24.105 |
| | | 8.16 | 10.665 | 18 | 141 | 10.335 | 0.003 | 128.187 | 0.002 | 0.027 | 0.071 | 33.683 | 37.706 |
| | | 6.72 | 3.720 | 17 | 150 | 79.452 | 0.005 | 5.232 | 0.002 | 0.000 | 0.203 | 61.320 | 16.279 |
| | | 7.54 | 8.535 | 17 | 80 | 19.982 | 0.005 | 31.137 | 0.002 | 0.000 | 0.057 | 37.972 | 14.894 |
| | | 7.24 | 8.905 | | | | | 9.012 | 0.002 | 0.000 | 0.242 | 31.068 | 6.590 |

Blanks indicate where sample was not collected due to lack of leachate.

† Units = mg $L^{-1}$

Table 5.72b: Various parameter data gathered on November 3, 2006 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | **Ba †** | **Cd †** | **Cu †** | **Ni †** | **Pb †** | **Zn †** |
|---|---|---|---|---|---|---|---|
| 3-Nov-06 | Control | 0.007 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.012 | 0.004 | 0.006 | 0.008 | 0.016 | 0.000 |
| | | 0.016 | 0.004 | 0.006 | 0.008 | 0.016 | 0.000 |
| | | 0.008 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.016 | 0.004 | 0.006 | 0.008 | 0.016 | 0.002 |
| | | 0.020 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.001 | 0.004 | 0.006 | 0.032 | 0.016 | 0.004 |
| | | 0.022 | 0.004 | 0.038 | 0.008 | 0.016 | 0.039 |
| | | 0.012 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.025 | 0.004 | 0.006 | 0.008 | 0.016 | 0.000 |
| | | 0.010 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.066 | 0.004 | 0.006 | 0.008 | 0.016 | 0.006 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.009 | 0.004 | 0.006 | 0.081 | 0.016 | 0.020 |
| | | 0.006 | 0.004 | 0.034 | 0.008 | 0.016 | 0.004 |
| | | 0.006 | 0.004 | 0.015 | 0.002 | 0.016 | 0.004 |
| | | 0.004 | 0.004 | 0.000 | 0.008 | 0.016 | 0.004 |
| | | 0.011 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.044 | 0.004 | 0.006 | 0.008 | 0.016 | 0.067 |
| | | 0.035 | 0.004 | 0.006 | 0.008 | 0.016 | 0.003 |
| | | 0.057 | 0.004 | 0.004 | 0.008 | 0.016 | 0.023 |

Blanks indicate where sample was not collected due to lack of leachate.
† Units = mg $L^{-1}$

Table 5.73a: Various parameter data gathered on January 5, 2007 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | pH | DOC † | $Cl^-$ † | $SO_4^{2-}$ † | $NO_3^-$ † | $PO_4^{3-}$ † | $HCO_3^-$ † | Al † | Fe † | Mn † | Ca † | Mg † |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5-Jan-07 | Control | 7.33 | 7.124 | 15 | 260 | | | 10.140 | 0.002 | 0.004 | 0.003 | 105.516 | 34.875 |
| | | 7.03 | 5.784 | 15 | 185 | 3.734 | 0.004 | 12.140 | 0.002 | 0.011 | 0.002 | 85.015 | 30.008 |
| | | 7.61 | 9.259 | 20 | 183 | 5.770 | 0.006 | 8.185 | 0.002 | 0.014 | 0.001 | 107.795 | 18.818 |
| | | 7.6 | 4.654 | 14 | 143 | 0.312 | 0.000 | 5.930 | 0.002 | 0.027 | 0.011 | 82.468 | 15.250 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 6.97 | 6.724 | 14 | 86 | 0.105 | 0.002 | 39.290 | 0.002 | 0.004 | 0.017 | 54.399 | 24.065 |
| | | 6.98 | 5.719 | 11 | 60 | 0.089 | 0.000 | 37.790 | 0.002 | 0.004 | 0.185 | 66.194 | 31.532 |
| | | 7.21 | 5.609 | 12 | 22 | 16.883 | 0.002 | 44.590 | 0.002 | 0.004 | 0.074 | 6.979 | 6.900 |
| | | 7.23 | 5.739 | 12 | 66 | 0.547 | 0.000 | 15.340 | 0.002 | 0.004 | 0.058 | 36.393 | 17.639 |
| | | 7.11 | 13.959 | 15 | 140 | 0.726 | 0.000 | 62.340 | 0.002 | 0.004 | 0.029 | 11.070 | 18.798 |
| | | 7.33 | 3.784 | 17 | 100 | 0.127 | 0.000 | 21.740 | 0.002 | 0.004 | 0.111 | 15.958 | 7.126 |
| | | 6.85 | 9.909 | 17 | 304 | 1.867 | 0.004 | 32.140 | 0.002 | 0.004 | 0.057 | 29.511 | 22.826 |
| | | 6.63 | 3.364 | 13 | 102 | 0.313 | 0.660 | 11.190 | 0.002 | 0.004 | 0.495 | 29.397 | 8.750 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 7.67 | 0.000 | 13 | 55 | 175.486 | 0.011 | 0.740 | 0.002 | 1.701 | 0.072 | 12.009 | 12.520 |
| | | 7.06 | 63.659 | 15 | 288 | 13.804 | 0.000 | 56.040 | 0.002 | 0.024 | 0.001 | 16.261 | 20.330 |
| | | 7.26 | 6.729 | 15 | 55 | 0.425 | 0.005 | 21.440 | 0.002 | 0.004 | 0.064 | 30.472 | 11.758 |
| | | 7.38 | | | | 0.222 | 0.003 | | 0.002 | 0.048 | 0.004 | 10.479 | 11.125 |
| | | 7.17 | | 8 | 9 | 5.137 | 0.000 | | 0.002 | 0.052 | 0.010 | 7.972 | 36.956 |
| | | 6.28 | 1.794 | 13 | 56 | 96.263 | 0.004 | 5409.480 | 0.002 | 0.004 | 0.238 | 13.733 | 3.371 |
| | | 5.86 | 3.464 | 12 | 44 | 9.647 | 0.004 | 9779.480 | 0.002 | 0.004 | 0.706 | 84.438 | 14.946 |
| | | 5.9 | 2.634 | 13 | 16 | | | 1479.48 | 0.002 | 0.004 | 0.104 | 17.117 | 3.196 |

Blanks indicate where sample was not collected due to lack of leachate.

† Units = mg $L^{-1}$

Table 5.73b: Various parameter data gathered on January 5, 2007 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | **Ba †** | **Cd †** | **Cu †** | **Ni †** | **Pb †** | **Zn †** |
|---|---|---|---|---|---|---|---|
| 5-Jan-07 | Control | 0.004 | 0.004 | 0.029 | 0.008 | 0.016 | 0.024 |
| | | 0.012 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.010 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.012 | 0.004 | 0.101 | 0.008 | 0.016 | 0.052 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.006 | 0.004 | 0.006 | 0.008 | 0.016 | 0.002 |
| | | 0.013 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.003 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.020 | 0.004 | 0.278 | 0.008 | 0.016 | 0.128 |
| | | 0.006 | 0.004 | 0.090 | 0.008 | 0.016 | 0.006 |
| | | 0.019 | 0.004 | 0.009 | 0.008 | 0.016 | 0.021 |
| | | 0.006 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.038 | 0.004 | 0.216 | 0.008 | 0.016 | 0.180 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.010 | 0.004 | 2.096 | 0.072 | 0.016 | 0.202 |
| | | 0.015 | 0.004 | 0.037 | 0.008 | 0.016 | 0.032 |
| | | 0.010 | 0.004 | 0.006 | 0.008 | 0.016 | 0.004 |
| | | 0.002 | 0.004 | 0.006 | 0.008 | 0.016 | 0.002 |
| | | 0.002 | 0.004 | 0.486 | 0.008 | 0.016 | 0.002 |
| | | 0.029 | 0.004 | 0.113 | 0.008 | 0.016 | 0.104 |
| | | 0.131 | 0.004 | 0.002 | 0.008 | 0.016 | 0.067 |
| | | 0.051 | 0.004 | 0.006 | 0.008 | 0.016 | 0.059 |

Blanks indicate where sample was not collected due to lack of leachate.
† Units = mg $L^{-1}$

Table 5.74a: Various parameter data gathered on June 8, 2007 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | pH | DOC † | $Cl^-$ † | $SO_4^{2-}$ † | $NO_3^-$ † | $PO_4^{3-}$ † | $HCO_3^-$ † | Al † | Fe † | Mn † | Ca † | Mg † |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Jun-07 | Control | 6.65 | 10.040 | 13 | 106 | | | 0.528 | 0.002 | 0.004 | 0.001 | 127.252 | 30.704 |
| | | 6.71 | 4.935 | 15 | 49 | 7.730 | 0.000 | 5.218 | 0.002 | 0.004 | 0.002 | 84.590 | 28.352 |
| | | 6.85 | 16.260 | 15 | 197 | 8.156 | 0.022 | 7.168 | 0.005 | 0.004 | 0.009 | 113.325 | 19.361 |
| | | 7.05 | 12.110 | 13 | 163 | 101.903 | 0.002 | 18.718 | 0.002 | 0.004 | 0.001 | 118.535 | 16.851 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 6.63 | 1.690 | 12 | 20 | 65.657 | 0.000 | 21.168 | 0.002 | 0.004 | 0.073 | 104.430 | 31.104 |
| | | 6.68 | 3.620 | 11 | 16 | 38.606 | 0.019 | 15.468 | 0.002 | 0.004 | 0.048 | 102.580 | 33.330 |
| | | 6.59 | 15.210 | 12 | 67 | 37.912 | 0.000 | 44.668 | 0.002 | 0.004 | 0.054 | 22.181 | 8.769 |
| | | 6.19 | 3.920 | 14 | 40 | 203.553 | 0.000 | 3.918 | 0.002 | 0.004 | 0.041 | 53.365 | 18.971 |
| | | 4.6 | 8.910 | 9 | 14 | 139.935 | 0.000 | 7.768 | 0.663 | 0.004 | 1.702 | 114.123 | 32.694 |
| | | 5.46 | 4.830 | 10 | 42 | 93.922 | 0.000 | 0.000 | 0.002 | 0.004 | 0.797 | 101.278 | 32.141 |
| | | 6.02 | 9.410 | 10 | 46 | 18.853 | 0.000 | 8.218 | 0.002 | 0.004 | 0.569 | 77.924 | 23.777 |
| | | 5.8 | 5.565 | 11 | 15 | 441.461 | 0.014 | 0.000 | 0.002 | 0.004 | 0.688 | 27.480 | 7.302 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 6.99 | | | | 195.011 | 0.000 | | 0.054 | 0.026 | 0.340 | 44.336 | 25.469 |
| | | 4.04 | 7.570 | 13 | 16 | 231.457 | 0.000 | 0.000 | 22.093 | 0.036 | 0.848 | 111.459 | 22.972 |
| | | 5.82 | 12.560 | 13 | 18 | 3.675 | 0.000 | 2.368 | 0.002 | 0.004 | 0.607 | 301.434 | 62.420 |
| | | 6.89 | 7.950 | 15 | 121 | 63.456 | 0.000 | 27.818 | 0.002 | 0.004 | 0.037 | 70.329 | 18.071 |
| | | 6.35 | 17.410 | 15 | 271 | 25.959 | 0.010 | 11.768 | 0.002 | 0.004 | 0.081 | 127.635 | 26.807 |
| | | 5.68 | 1.910 | 12 | 15 | 37.819 | 0.000 | 0.000 | 0.002 | 0.004 | 0.497 | 28.061 | 8.518 |
| | | 4.39 | 12.010 | 10 | 12 | 94.061 | 0.000 | 0.168 | 0.002 | 0.004 | 0.030 | 44.339 | 9.056 |
| | | 5.34 | 2.985 | 4 | 6 | 42.011 | 0.011 | 0.000 | 3.859 | 0.077 | 1.352 | 83.792 | 15.247 |

Blanks indicate where sample was not collected due to lack of leachate.

† Units = mg $L^{-1}$

Table 5.74b: Various parameter data gathered on June 8, 2007 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | **Ba †** | **Cd †** | **Cu †** | **Ni †** | **Pb †** | **Zn †** |
|---|---|---|---|---|---|---|---|
| 8-Jun-07 | Control | 0.014 | *** | 0.006 | 0.008 | *** | 0.007 |
| | | 0.013 | *** | 0.006 | 0.008 | *** | 0.006 |
| | | 0.031 | *** | 0.006 | 0.008 | *** | 0.008 |
| | | 0.015 | *** | 0.006 | 0.008 | *** | 0.006 |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.015 | *** | 0.006 | 0.008 | *** | 0.013 |
| | | 0.032 | *** | 0.006 | 0.008 | *** | 0.022 |
| | | 0.024 | *** | 0.006 | 0.008 | *** | 0.016 |
| | | 0.021 | *** | 0.006 | 0.008 | *** | 0.005 |
| | | 0.333 | *** | 0.003 | 0.003 | *** | 0.377 |
| | | 0.159 | *** | 0.006 | 0.008 | *** | 0.295 |
| | | 0.067 | *** | 0.006 | 0.008 | *** | 0.044 |
| | | 0.118 | *** | 0.006 | 0.008 | *** | 0.142 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.091 | *** | 0.028 | 0.021 | *** | 0.027 |
| | | 0.384 | *** | 0.023 | 0.013 | *** | 1.454 |
| | | 0.346 | *** | 0.014 | 0.008 | *** | 0.033 |
| | | 0.008 | *** | 0.006 | 0.008 | *** | 0.002 |
| | | 0.033 | *** | 0.006 | 0.008 | *** | 0.008 |
| | | 0.065 | *** | 0.006 | 0.008 | *** | 0.027 |
| | | 0.082 | *** | 0.006 | 0.008 | *** | 0.078 |
| | | 0.400 | *** | 0.022 | 0.017 | *** | 0.498 |

*** Samples were not collected for these treatments.
Blanks indicate where sample was not collected due to lack of leachate.
† Units = mg $L^{-1}$

Table 5.75a: Various parameter data gathered on September 7, 2007 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | pH | DOC † | $Cl^-$ † | $SO_4^{2-}$ † | $NO_3^-$ † | $PO_4^{3-}$ † | $HCO_3^-$ † | Al † | Fe † | Mn † | Ca † | Mg † |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-Sep-07 | Control | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | 6.86 | 9.115 | 22 | 228 | 55.607 | 0.014 | 14.021 | 0.002 | 0.001 | 0.013 | 125.110 | 20.639 |
| | | | | | | | | | | | | | |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 6.81 | 4.960 | 18 | 27 | 30.968 | 0.010 | 20.371 | 0.002 | 0.003 | 0.036 | 91.437 | 36.797 |
| | | 6.69 | 10.610 | 17 | 27 | 16.434 | 0.015 | 69.971 | 0.002 | 0.004 | 0.029 | 113.040 | 36.974 |
| | | 6.97 | 17.810 | 12 | 71 | 15.633 | 0.026 | 83.521 | 0.002 | 0.004 | 0.057 | 29.134 | 11.256 |
| | | 6.79 | 6.375 | 13 | 48 | 20.941 | 0.012 | 19.521 | 0.002 | 0.015 | 0.125 | 83.703 | 21.585 |
| | | 4.06 | 5.555 | 9 | 11 | 186.593 | 0.005 | 1.231 | 9.942 | 0.040 | 2.865 | 178.509 | 50.248 |
| | | 4.42 | 3.260 | 9 | 11 | 114.020 | 0.003 | 4.061 | 1.683 | 0.012 | 1.899 | 146.843 | 47.229 |
| | | 5.3 | 6.995 | 6 | 8 | 34.879 | 0.003 | 1.566 | 0.236 | 0.002 | 2.938 | 112.488 | 30.761 |
| | | 5.67 | 3.470 | 14 | 18 | 472.428 | 0.330 | 3.481 | 0.075 | 0.011 | 0.865 | 42.620 | 10.953 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 4.42 | 31.010 | 14 | 62 | 245.198 | 0.003 | 1.061 | 5.046 | 0.136 | 8.533 | 331.762 | 40.415 |
| | | | | | | | | | | | | | |
| | | 6.56 | 10.760 | 15 | 66 | 62.622 | 0.007 | 5.916 | 0.000 | 0.004 | 0.070 | 301.952 | 56.338 |
| | | 6.75 | 9.410 | 14 | 112 | 2.842 | 0.004 | 42.971 | 0.002 | 0.020 | 0.108 | 138.956 | 24.485 |
| | | 5.92 | 16.410 | 14 | 191 | 35.120 | 0.003 | 12.721 | 0.018 | 0.004 | 0.377 | 188.656 | 28.757 |
| | | 5.61 | 5.635 | 10 | 14 | | | 1.016 | 0.000 | 0.004 | 0.595 | 41.169 | 11.191 |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

Blanks indicate where sample was not collected due to lack of leachate.

† Units = mg $L^{-1}$

Table 5.75b: Various parameter data gathered on September 7, 2007 from the dissolved fraction of the leachate collected 15 cm below the entrenched anaerobically digested and lime-stabilized biosolids. The treatment averages were used as inputs in the computer speciation program MINTEQA2.

| Sampling Date | Treatment | **Ba †** | **Cd †** | **Cu †** | **Ni †** | **Pb †** | **Zn †** |
|---|---|---|---|---|---|---|---|
| 7-Sep-07 | Control | | | | | | |
| | | | | | | | |
| | | 0.048 | 0.004 | 0.006 | 0.008 | 0.016 | 0.002 |
| | | | | | | | |
| | Anaerobically Digested Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.014 | 0.004 | 0.006 | 0.008 | 0.016 | 0.015 |
| | | 0.039 | 0.004 | 0.006 | 0.008 | 0.016 | 0.017 |
| | | 0.031 | 0.004 | 0.006 | 0.008 | 0.016 | 0.008 |
| | | 0.054 | 0.004 | 0.006 | 0.008 | 0.016 | 0.012 |
| | | 0.852 | 0.004 | 0.031 | 0.023 | 0.016 | 1.240 |
| | | 0.529 | 0.004 | 0.005 | 0.008 | 0.016 | 1.031 |
| | | 0.870 | 0.004 | 0.005 | 0.010 | 0.016 | 1.142 |
| | | 0.192 | 0.004 | 0.000 | 0.008 | 0.016 | 0.154 |
| | Lime-Stabilized Biosolids Entrenched at 90 cm (w) by 75 cm (d) | 0.489 | 0.001 | 0.036 | 0.089 | 0.016 | 1.830 |
| | | | | | | | |
| | | 0.211 | 0.004 | 0.004 | 0.008 | 0.016 | 0.020 |
| | | 0.021 | 0.004 | 0.006 | 0.008 | 0.016 | 0.000 |
| | | 0.113 | 0.004 | 0.013 | 0.008 | 0.016 | 0.199 |
| | | 0.160 | 0.004 | 0.006 | 0.008 | 0.016 | 0.068 |
| | | | | | | | |
| | | | | | | | |

Blanks indicate where sample was not collected due to lack of leachate.
† Units = mg $L^{-1}$