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# Nitrate Leaching from Mine Tailings Amended with Biosolids as Affected by Plants.

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ABSTRACT

Leaching column experiments were conducted in a greenhouse to determine the impact of biosolids and plants on nitrate leaching from mine tailings. Columns were packed with 7.7 kg of mine tailings and 0.168 kg of biosolids. The biosolids were applied in two ways: surface application and mixed with the mine tailings. Half of the columns were seeded with ryegrass (*Lolium perenne*, L) to evaluate the effect of plants on nitrate leaching and on the volume of the leachate. All leachates were collected weekly during 146 days and analysed for nitrate, pH, electrical conductivity and chemical oxygen demand. Water was applied though drip irrigation system at a rate equivalent to 758 mm per year. Nitrate leaching was significantly lower in vegetated columns and when biosolids were mixed with mine tailings. In these treatments the water quality standards for organic matter loading and for nitrate concentrations were met.

INTRODUCTION

Mine tailings are waste products generated during mining operations. Surface deposition of these materials results in an environmental threat from blowing dust, erosion and runoff. An alternative to stabilize these materials is to establish a plant cover. However, mine tailings are difficult to revegetate due to nutrient deficiencies and potential metal toxicities (Bradshaw and Johnson, 1992; Shu 1997). Due to the lack of organic matter and severe nutrient limitations of mine tailings, an amendment of biosolids could ameliorate the harsh edaphic conditions through the addition of available nutrients, improvement of physical soil properties and possible lowering of toxic metal availability through complexation with the organic matter (Haering et al, 2000; Peppas et al, 2000; Ye et al, 2002; Sparling et al, 2003). Nevertheless, biosolids have a high organic nitrogen content which undergo transformations into plant-available N forms, either as ammonium-N ($NH_4$-N) or nitrate-N ($NO_3$-N). Ammonium, being held tightly on the negatively-charged surfaces of clay complexes and organic matter, is not readily lost through leaching. By contrast, the highly water soluble $NO_3$-N, which is held rather weakly by the soil and organic matter, moves freely with soil water and can be lost through leaching readily (Rowell et al, 2001; Gilmour et al, 2003). Nitrate contamination of ground or surface water has an important health and environmental implications (Follet 1989). Hence, 10 mg/L $NO_3$-N (44 mg/L $NO_3^-$) is considered the maximum safe level for drinking water (USEPA, 1986). The objective of this study was to evaluate impact of biosolids application and plant cover on potential nitrate leaching from mine tailings.

## MATERIALS AND METHODS

A leaching column experiment was established in a greenhouse. The mine tailings were taken from "Las Tórtolas" tailing dam located in Central Chile (32º12´S, 70º10´W). This material was air dried, passed through a 5 mm sieve and homogenized. PVC cylindrical tubes of 60 cm height and 11 cm diameter were packed with 7.7 kg of mine tailings. At the bottom of the columns a layer of quartz grains and a plastic net were fitted in order to avoid the movement of particles into the leachate. The columns were fitted with plastic funnels underneath, which facilitated the collection of the leachate in dark bottles of 1.5 L capacity. Biosolids from a wastewater treatment were applied at a rate of 0.168 kg to the tops of the columns in two ways: surface application and incorporated with the mine tailings in the first 20 cm of the column. Six treatments were established with three replicates. Half of the columns were seeded with 0.6 g of ryegrass seeds (*Lolium perenne*, L). Deionized water was supplied to the columns by a drip irrigation system in a total regime equivalent to 758 mm of rainfall during 146 days. The leachate was collected weekly and volume measured, passed through a 0.45 $\mu$m filter to remove particles and analyzed for nitrate concentration by Kjeldahl distillation (Keeney and Nelson, 1982); pH (by potenciometry); electrical conductivity (by electrometry). At the middle and end of the experiment chemical oxygen demand (COD) of the leachate was determined by Spectroquant cell test from Merck (USEPA Method 410.4). Analysis of variance (Statgraphics plus 2.1), with column type (vegetated or unvegetated) and type of biosolid application (surface or mixed) as factors and the multiple range test ($p < 0.05$) were used for statistical analyses.

## RESULTS AND DISCUSSION

The pH values of leachates ranged from 6.96 to 7.42, with no significant differences among treatments and showed no variations with time. These neutral and slightly alkaline values are probably the result of the high Ca concentrations found in the tailings. The evolution in time of electrical conductivity shows that initially the water produces an important removal of soluble electrolytes and after 75 days an equilibrium is reached. All treatments presented no saline leachates. At the begining of the experiment the electrical conductivity ranged from 3.15 to 3.01 and at the end of the experiment ranged from 1.79 to 1.58 with no significant differences among treatments.

The organic load of the leachates in terms of chemical oxygen demand (COD) decreased with time from very high values at 63 days to relatively medium ones by the end of the study. At the middle of the experiment, the leachates collected from columns amended with biosolids presented levels of COD above the discharge standards of USEPA (125 mg COD $L^{-1}$). Nevertheless, at the end of the experiment all leachates presented a COD which consistently met the COD discharge standards, except treatment corresponding to column unvegetated and with biosolids applied mixed with the mine tailings.

Differences in precipitation patterns have a significant influence on the amount of N leaching out of the root zone (Nakamura et al, 2004). Intense precipitations were simulated in this study. These intensities were twofold above the normal precipitation regime of the study zone, which represented the worst case scenario with regard to the leaching of nitrate.

Results shows that the amounts of leachates differed with treatments. The largest volume of leachate was obtained from the control (unvegetated and no application of biosolid column). The unvegetated columns had a higher percolation rates than vegetated ones. The volume of leachates collected in vegetated columns on average was reduced by 32 percent compared with unvegetated columns. This means that the presence of plant cover on the column surface minimizes significantly the vertical movement of water through the column. For this, it might be expected a decrease of nitrate leaching risk. Also, it was found that the application of biosolids decreased the volume of leachate, which may result from the amount of organic matter of biosolids which increase the water holding capacity and the vigorous growth of plants in vegetated columns.

With regard to nitrate leaching, vegetated columns reduced nitrate concentration in leachates on average by 36 percent compared with unvegetated columns. On the other hand, treatments in which biosolids were applied mixed with tailings reduced nitrate concentrations in leachates on average by 17 percent compared with treatments in which biosolids were surface applied.

All treatments presented leachates with a nitrate concentration which met the maximum concentration for safe drinking water (USEPA, 1986). However, the treatment corresponding to the column unvegetated and with surface application of biosolids exceeded 10 mg $L^{-1}$ of nitrate with a total $NO_3^-$-N loading of 53 kg $ha^{-1}$.

Total nitrate leaching was significantly lower in treatments where biosolids were mixed with mine tailings compared with treatments where biosolids were surface applied. This results indicates that probably the biosolids provide more favorable conditions for nitrogen mineralization than these materials mixed with tailings. In the mixtures, the mineralization process might have been slowed down and inhibited owing to toxic substances found in the tailings and due to a “dilution effect” on nutrient and microorganisms contents.

## CONCLUSIONS

The plant cover minimizes significantly the vertical movement of water and nitrate leaching. These effects were probably due to the increase of water demand through evapotranspiration and the root uptake of $NO_3$-N released by mineralization, which reduces nitrate mobility.

The nitrate leaching was affected by the form of biosolids application. A higher nitrate leaching was observed in columns with surface application of biosolids than columns in which biosolids were mixed with the mine tailings.

Thus, there is a potential for reducing $NO_3$-N leaching by the establishment of plant cover and mixing biosolids with the mine tailings.

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