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BIOSOLIDS AMENDMENT OF WASTE ROCK AND TAILINGS AS AN ALTERNATIVE RECLAMATION TREATMENT AT HIGHLAND VALLEY COPPER

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ABSTRACT

A research program was initiated at the Highland Valley Copper mine in 1996 to test the effectiveness of biosolids application as a potential reclamation treatment on different waste materials and to assess the possible benefits and deleterious effects of the application of biosolids to waste areas. The test sites were located on tailings and waste rock areas of Bethlehem property. Two different application methods were tested: topdressing with biosolids at application rates ranging from 25 to 50 dry tonnes per hectare and incorporation of biosolids at application rates ranging from 100 to 200 dry tonnes per hectare. Control treatments were included in the study design to allow for comparison of biosolids treatment with standard reclamation treatments using annual application of chemical fertilizers during the first three to four years of vegetation establishment. Sites selected for the trial locations represented challenging reclamation sites where a till capping or other soil amendment had been prescribed to improve the water holding capacity of the sites. The biosolids research program included monitoring to assess the changes to soil, ground water and vegetation chemistry, and effects on vegetation cover and biomass production on the treated sites. Chemical data will be presented to identify chemical impacts to soil, water and foliar chemistry attributable to the application of biosolids.

INTRODUCTION

Highland Valley Copper is one of the largest porphyry copper-mofybdenum mines in North America. To date, approximately 6200 hectares have been disturbed by mining within the area of Highland Valley Copper's Reclamation Permits. To guide reclamation activities for each area of the mine, an end land use plan for the property has been developed. Establishment of forages for cattle grazing, native shrubs and trees for wildlife browse, and conifers for wildlife corridors comprise important components of the revegetation goals at the mine site.

The physical and chemical characteristics of mine waste material at Highland Valley Copper that potentially limit the capability of some reclamation areas to achieve the revegetation goals include:

- mine waste materials have no organic matter and low fertility;
- mine waste materials typically have a low water holding capacity due to high coarse fragment content and coarse texture;

- elevated concentrations of copper, molybdenum and sulphur in vegetation due to metal uptake from some mine waste materials potentially limit site suitability for grazing and wildlife end land use;
- the mine waste material is alkaline and may negatively impact conifer reforestation success; and,
- insufficient suitable overburden materials available for capping all mine disturbances.

Reclamation treatments include direct seeding or planting on waste rock and tailings sites. Where necessary, overburden materials are used for capping waste rock dumps that are either chemically or physically unsuitable for direct revegetation. However, the availability of reclamation suitable overburden material is limited due to coarse texture, molybdenum concentrations and hauling distance.

On waste materials with adequate water holding capacity, self-sustaining vegetation can be established through 3 to 4 years of maintenance fertilizer application. On materials with low water and nutrient holding capacity, vegetation has not achieved a self-sustaining condition. This has been observed on coarse tailings areas, certain waste rock types resistant to weathering, and older waste rock dumps that have been capped with overburden at either insufficient depth or with material having an excessively coarse texture. It was recognized that incorporation of organic matter to these waste materials could potentially improve revegetation success.

Biosolids application represents a reclamation treatment that provides a source of organic matter to amend soil conditions and improve nutrient and water availability. Although biosolids do not initially change the texture of waste materials on reclaimed areas, they may supplement the nutrient and water holding capacity to a level that is sufficient for vegetation establishment. In addition, biosolids may reduce soil pH to a range that is more widely tolerated by plants, and provide soil micro-organisms.

BIOSOLIDS RESEARCH TRIALS

In 1996, Highland Valley Copper initiated a research program to investigate the effectiveness of biosolids application as an alternative treatment to improve revegetation success on certain sites. The program includes monitoring to assess the vegetation response, and to document any changes in vegetation, soil chemistry and soil water quality attributable to biosolids application

Research trials were installed in 1996 and 1997. Biosolids were supplied and applied by the Greater Vancouver Regional District. Plots were established to test:

- two application methods: topdressing and incorporation;
- two waste material types: waste rock and tailings; and,
- various application rates in comparison to chemical fertilizers.

Topdressed trials

Topdressing vegetation with relatively light application rates of biosolids as a fertilizer and mulch is an attempt to improve vegetation production on sites that had been previously revegetated but were not considered self-sustaining. These sites had an existing plant cover consisting of forages and native shrubs; however, productivity and density of plant cover had diminished since the discontinuation of maintenance fertilizer application. Biosolids topdressing plots were established on both a tailings and an overburden capped waste rock site. Application rates were 25 dry tonnes per hectare (dt/ha) and 50 dt/ha. Control treatments (no biosolids application) were included in the study design to allow comparison of the biosolids treatments with a typically employed reclamation treatment of chemical fertilizer each spring for three to four years during vegetation establishment.

Incorporated trials

To investigate the potential for biosolids as a soil amendment prior to revegetation, incorporated plots were installed on tailings and waste rock. Application rates were 100, 150 and 200 dt/ha. Biosolids were tilled into the tailings and ripped into the waste rock materials to a depth of approximately 20 centimetres. Tailings plots were seeded with grasses and legumes. Waste rock plots were subdivided to allow for seeding grasses and legumes on two thirds of the plot, with native shrub and tree plantings on the remaining one third of the plot. Control treatments (no biosolids application) were included in the study design.

INITIAL MONITORING RESULTS

To assess the effects of biosolids application on soils, soil water and vegetation, Highland Valley Copper has undertaken a comprehensive monitoring program designed to continue for at least five years. One objective of the monitoring program is to assess changes in forage production attributable to biosolids application. A second objective is to assess changes in the concentration and availability of elements known to be present in both the mine waste materials and the applied biosolids, and determine the potential impacts on forage quality, water quality, and soils.

Copper and molybdenum comprise the primary elements that are occur in elevated concentrations in the mine waste material. Elements that are known to occur in biosolids include: arsenic, cadmium, cobalt, chromium, copper, lead, mercury, molybdenum, nickel, selenium, sulphur and zinc. Biosolids, like chemical fertilizers, also have the potential to contribute nitrates to soil, aquatic and vegetation systems. Statistically significant findings (confidence interval of 95 percent) from the first two years of the study and a discussion of how they may impact end land use goals are discussed. For the analysis, data from the first two years of the study were grouped to identify statistically significant findings. Reported findings are based on analysis of the group data unless otherwise noted.

Vegetation Production and Sustainability

One of the principal goals of reclamation is to return sites to a productive end land use. Production of grasses and legumes for grazing and shrubs for browsing is critical to achieving Highland Valley's end land use objectives. Biomass production on the research plots is assessed to evaluate changes in production due to biosolids application as compared to chemical fertilizer.

On the topdressed trials, biomass production was statistically higher on the biosolids treatments compared to the'chemically fertilized controls on both the overburden capped waste rock dump and one-of the tailings trials during the year following biosolids application. However, on a second tailings trial with more limited soil moisture conditions due to a south facing slope and coarse sand material, no increase in productivity was seen from the biosolids application. Statistically significant increases in productivity were not noted by applying the higher topdressing rate of 50 dt/ha as opposed to 25 dt/ha on any of the topdressing trials.

Biomass production data is not yet available for the incorporated biosolids trials as the standard practice at Highland Valley Copper is to wait for approximately two to three years following seeding for vegetation to become established on a site.

The degree to which biosolids amendments improve vegetation sustainability will be assessed through several years of tracking vegetation response through monitoring changes in biomass production and species composition on these sites.

Forage and Shrub Quality for Ruminants

Elevated concentrations of molybdenum in forage and browse species may limit a site's suitability for cattle grazing and possibly wild ungulate use due to the susceptibility of ruminants to molybdenosis. Vegetation

monitoring includes sampling grasses, legumes and shrubs during the growing season to assess foliar nutrient and metal concentrations.

Molybdenum concentrations in alfalfa and wheatgrass on the topdressed tailings and overburden capped waste rock and incorporated tailings trials were statistically lower on the biosolids treatments compared to the control. Similar results were documented for molybdenum concentrations in willow leaves sampled from biosolid topdressed plots on the tailings.

In addition to molybdenum, concentrations of copper in vegetation are of particular interest due to the metabolic interaction between these elements. It is generally recognized that ingestion of forage with elevated molybdenum concentrations can potentially induce a copper deficiency symptomatic of molybdenosis. For this reason, maintaining a higher copper concentration is potentially desirable to minimize copper induced deficiency of molybdenosis. Foliar copper concentrations on the topdressed tailings trials were variable over the two year monitoring period and displayed no statistically significant differences between biosolids treatments and controls. However, on the topdressed wasterock trial, foliar copper concentrations were statistically higher on the 50dt/ha treatment compared to the control and 25 dt/ha treatment. On the incorporated trial, mean copper concentrations were statistically lower on the biosolids topdressed plots on tailings. Additional sampling will be required to assess whether these differences in copper concentrations are due to sample variability or response to biosolids application.

In addition to dietary considerations, toxicity to plants is of concern where copper concentrations are elevated. While no symptoms of copper toxicity have been observed in forages, chlorosis of willow leaves has been observed in the tailings biosolids topdressed plots. Chlorosis can be associated with a copper toxicity, as well as many other metals. Composite foliar samples were collected to compare elemental concentrations in chlorotic leaves to green, apparently healthy leaves. Copper concentrations in chlorotic leaves were statistically greater than in leaves of green, healthy willows and this difference was statistically greater on biosolids treated plots compared to the control plots. No shrub mortality has been observed and the impact of biosolids application on shrub survival and growth will be further assessed in 1998.

As well as molybdenum and copper concentrations, the means and ranges of the remaining elemental concentrations in forages are compared to the generalized dietary elemental tolerances for beef cattle. Trace element loading as a result of biosolids applications is a key issue in agricultural soils, if repeat biosolids

applications are contemplated, and increased elemental concentrations in forages could impact the grazing end land use goals. In 1996 and 1997, statistically significant changes in foliar elemental concentrations as a result of biosolids application were limited to nickel and cadmium. Incorporated biosolids application on tailings resulted in statistically lower nickel concentrations in alfalfa and wheatgrass. These results did not correlate with total nickel concentrations in the soil, which were variable but showed a statistically significant increase on the tailings after incorporation. Concentrations of cadmium in alfalfa were statistically higher on incorporated biosolids plots than the control plots. Soil cadmium concentrations were also statistically higher on the biosolids treated plots than on the control plots but were below the Ministry of Environment, Lands and Parks (MELP) Draft Guidelines (MELP, 1996) recommendations. All foliar concentrations of nickel and cadmium were well within normal concentrations for cattle consumption.

Excessive application of high nitrogen fertilizer can cause short term elevated nitrate concentrations in forages, risking nitrate toxicity to grazing animals. All nitrate-N concentrations in grasses and legumes sampled on the trials were below the 1200 ppm generally considered safe for cattle consumption. Nitrate concentrations in wheatgrass foliage were statistically reduced in 1997 on the topdressed trials. Highest nitrate concentrations may be expected during the first few growing seasons following biosolids application.

The concentration of nutrients, metals and trace elements will be monitored in foliage for a period of years in order to evaluate any overall impact on end land use goals.

Water Quality for Livestock Watering and Fisheries

Soil water collection lysimeters were installed to respond to concerns raised by the BC Ministry of Energy and Mines with regard to the potential for mobilization of metals contained in the mine waste by the addition of the organic biosolids. Since application of any organic material or chemical fertilizers with high concentrations of available nitrogen may have groundwater impacts, nitrate and nitrite losses through leachate are also monitored. Soil water represents rainfall and other runoff that has seeped through the biosolids and mine waste materials and collected within the lysimeters at an approximate depth of two metres below the ground surface. The soil water is collected twice per year; once during spring runoff and again at the end of the growing season. Analysis of the water provides an indication of the leaching of metals, trace elements or nutrients in the mine waste that could potentially affect water resources. Analytical results are compared to Canadian Council of Ministers of the Environment (CCME) water quality guidelines for freshwater aquatic systems and livestock watering (CCME, 1991). The leachate data

presented below pertains to tailings sites only. Lysimeters were installed at one waste rock site during 1997; however, the data is presently limited due to low rainfall and minimal water collection during 1997. Elements which were above the CCME water quality guidelines included copper, nitrate, molybdenum and zinc.

Mean dissolved copper concentrations in leachate on all treatments and controls exceeded the freshwater aquatic limit of 0.004 ppm but were less than the livestock watering limit of 1 ppm. A statistically significant increase in leachate copper concentration was observed on the biosolids treated plots compared to the control on the incorporated trial but not on the topdressed trial.

All mean dissolved molybdenum concentrations in leachate for both trials exceeded the livestock watering criteria of 0.5 ppm. Molybdenum in leachate showed different trends than copper. No statistically significant differences were identified on the incorporated trials. However, on the topdressed trials, molybdenum concentrations were lower on the treatments than on the control. No statistically significant difference was identified between the two application rates on the topdressed trial.

Statistically significant differences in dissolved zinc concentrations between biosolids treatments and controls were not observed. However, concentrations of dissolved zinc in leachate exceeded the freshwater aquatic water quality guidelines on the 150 and 200 dt/ha incorporated trials in the spring and summer months of 1997. Zinc concentrations were statistically lower in the fall on all trials and were generally below the freshwater aquatic water quality guidelines.

A statistically significant impact of biosolids application on nitrate-N concentrations was noted early in the 1997 growing season following snow melt. Biosolids incorporation statistically increased the concentrations of nitrate-N in leachate over chemical fertilization; however, topdressing biosolids did not. At this sampling event, nitrate concentrations exceeded the livestock watering criteria on all of the incorporated treatments, and on the 50 dt/ha topdressed treatments. The nitrate concentration of the 200 dt/ha treatment was statistically greater than the other two lower application rates. Leachate nitrate-N for each application rate were statistically lower in October as compared to June; however, nitrate-N concentrations remained above the livestock watering limit on the 200 dt/ha treatment throughout the summer of 1997.

In addition to elevated nitrate-N concentrations in the spring of 1997, leachate nitrite-N exceeded the freshwater aquatic water quality limit on all the incorporated treatments and the 50 dt/ha topdressed treatment. Nitrite-N concentrations remained elevated throughout 1997 on the highest application rate treatments of both the topdressing and incorporation trials.

In attempt to predict potential mineralized nitrogen losses to groundwater, soil nitrate concentrations are monitored. Soil nitrate concentrations on topdressed plots appear to peak following the first growing season. However, soil nitrate concentrations on incorporated plots have remained elevated through two growing seasons. Nitrate concentrations will continue to be monitored to determine the magnitude and duration of the nitrate loading.

Trace Elements in Soils

A key issue in the initial and subsequent applications of biosolids in agricultural systems is trace element loading in soils. Soil samples were collected before the application of biosolids, in the spring and fall during the first two years following the application of biosolids, and will be sampled annually in the spring for the duration of the study.

Mine waste materials at Highland Valley Copper typically display elevated concentrations of molybdenum and copper. In contrast to typical agricultural soils, copper and molybdenum concentrations are inherently high in the mine tailings and waste rock and were above the MELP Draft Guidelines and CCME recommended concentrations of 100 ppm copper and 4 to 5 ppm molybdenum.

A decrease in soil pH following the application of biosolids could be expected from organic matter decomposition. This could potentially improve the suitability of waste materials for conifer growth which may be restricted in some materials due to soil alkalinity. Biosolids application may result in changes in molybdenum and copper availability for plant uptake through changes in soil pH. The availability of these elements for plant uptake is pH sensitive: molybdenum is generally more available at higher pH values and copper is more available at lower pH values. Monitoring to date has shown seasonal variations in soil pH. In the fall of 1997, pH was statistically lower on most biosolids treated plots than on the chemically fertilized control plots; however, statistically significant differences between treatments and controls were not noted in spring months, possibly due to maintenance fertilizer application to the control plots in the spring.

Of those elements known to be present in the applied biosolids, arsenic, cobalt and selenium in treated soils were below the Draft Guidelines and CCME recommended limits. Inherently high levels of copper and molybdenum in tailings and waste rock, and of nickel in waste rock were reflected in soil concentrations of these elements where the Draft Guidelines recommendations for soils were exceeded regardless of treatment. Lead, chromium and cadmium concentrations were higher on the biosolids treated plots than on the control plots but remained below the Draft Guidelines recommendations. Mercury exceeded the Draft Guidelines and CCME criteria on some incorporated tailings plots and exceeded the Draft Guidelines criteria on the 50 dt/ha treatment on topdressed waste rock. Mercury concentrations were statistically higher on the biosolids treated plots than on the control plots on both incorporated tailings and topdressed waste rock. Zinc concentrations were statistically higher on all biosolids treated plots than on controls, but were below the Draft Guidelines criteria. Concentrations of these elements in leachate and forage will continue to be monitored to assess potential impacts on land use.

BIOSOLIDS USE AND RECLAMATION PLANNING

By providing organic matter and nutrients, biosolids has the potential for being a reclamation tool for establishing productive forages, shrubs, and possibly conifers on mine waste materials presently incapable of sustaining plant growth using chemical fertilizers. Initial monitoring results indicate improved vegetation production on both overburden capped waste rock and tailings. Several years of vegetation monitoring is required to confirm impacts of biosolids application on vegetation sustainability. Earl)' monitoring results also indicate that increased vegetation growth may not result on all sites where soil moisture limitations are too restrictive. On those sites, other alternatives, such as overburden capping, may still be required. However, biosolids show a potential for decreasing molybdenum availability for plant uptake and increasing the soil water holding capacity which might result in Highland Valley Copper decreasing the thickness of the applied overburden layer or utilizing overburden materials for capping presently rejected due to coarse texture or molybdenum concentrations.

In addition to research plot studies described in this paper, Highland Valley Copper and the Greater Vancouver Regional District have also initiated field applications on larger reclaimed areas. The field scale trials allow an evaluation of the logistical requirements for biosolids amendment to large areas with variable terrain and waste materials. From this program, the most effective application and incorporation techniques

on waste rock and tailings sites will be defined. Additional trials are also underway to assess the suitability of biosolids and biosolids plus woodwaste for amending mine spoil destined for conifer reforestation.

The data collected from the research plots and the experience gained from field scale applications will be used to identify sites where future biosolids application will provide the most benefit towards end land use goals. This will also provide some guidance in determining the most cost effective application technique and application rate on a site specific basis.

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