CREATING A SUSTAINABLE COVER FOR A SAND TAILINGS DAM USING BIOSOLIDS AND LOG YARD DEBRIS

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ABSTRACT

A reclamation approach of utilizing two different types of biosolids from the GVRD and log-yard debris from the Weyerhaeuser lumber mill was tested on the sand tailings impoundment of the Smelter Lake Tailings Storage Facility at the Similco Mine, located near Princeton, BC. The purpose of this research study was targeted at creating a sustainable cover by incorporating these two products together with the top layer of the sand on the impoundment. Four test plots, each approximately 0.25 Ha in size, were created with different mixtures of log-yard debris, dewatered biosolids and land-dried biosolids. Parameters such as moisture content at 15cm and 30cm depth, physical and chemical characterization of the growth medium, vegetative yield, vegetative metal uptake and metal bioavailability of the growth medium were evaluated in an attempt to determine the effectiveness of any particular plot, or some other combination, for the reclamation of the sand impoundment. The principles of sustainable development were integral to this research project, in an effort to reclaim an old tailings facility in the most effect manner.

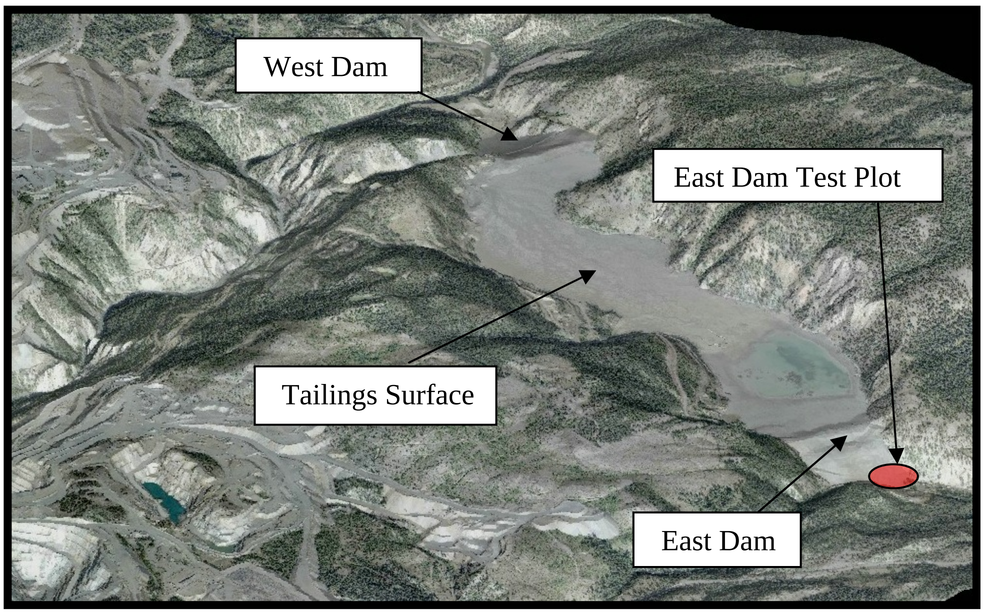
INTRODUCTION

The Similco Mine, located near Princeton, BC, Canada, has produced copper concentrate in some form or another for most of the past 100 years. As part of the development of this mine, the Smelter Lake Tailings Storage Facility (SLTSF) was created starting in the 1970's and received tailings until 1996. The impoundments of the SLTSF were constructed with cycloned sand, where only the coarse fraction of the tailings stream is utilized, with the fine fraction being deposited inside the facility. This construction technique is very useful, as it utilizes part of the waste product (tailings sand) to hold back the remaining portion of the waste (full tailings stream). When considering the reclamation of the impoundments that have been constructed in this manner, the same free-draining properties that make the sand such a good construction material work against the goal of reclaiming the impoundments with a self-sustaining vegetative cover.

Since the early 1990's, the Greater Vancouver Regional District (GVRD) had been demonstrating the ability of biosolids to reclaim old tailings facilities in the Princeton area. Specifically, they had successfully created a vegetative cover on the Granby Tailings (GVRD, 1997). However, using only biosolids to reclaim a sand tailings impoundment is somewhat more difficult than for a tailings pond, as the tailings inside the facility consists of both the coarse and fine tailings fractions. Hence, a modified approach to reclaiming the sand impoundments of the SLTSF was adopted. As the lack of water holding capacity of the sand was believed to be the main difficulty in creating a self-sustaining vegetative cover, two additional products were included with the dewatered biosolids, in order to increase the water holding capacity to a high enough level that could sustain vegetation in the long term. Specifically, log-yard debris, brought in from the local Princeton Weyerhaeuser lumber mill, and land dried biosolids, brought in from the storage facility on Iona Island, located in the GVRD. These three materials were then incorporated with the tailings sand to a nominal depth of 30cm, creating a growth medium that was much different than the tailings sand alone or the tailings sand amended only with dewatered biosolids.

Four plots were created, each approximately 0.25 Ha in area, to test mixtures of these products at different application rates. After the vegetation had established itself, data was collected from the plots, to evaluate the success of this reclamation technique for the purpose of reclaiming the sand tailings impoundments. The growth medium was analysed for moisture content, as well as physical and chemical characteristics. The vegetation was analysed for chemical characteristics, in addition to species composition and percent coverage. Samples were also collected from the West Dam Sand (WDS), where reclamation had been attempted several years earlier, but with limited success. Additionally, samples were collected from the Tailings Surface (TS), to collect information on particle size distribution, comparing the tailings to the sand. Figure 1 provides an overall perspective of the SLTSF at the Similco Mine.

Figure 1 – General Arrangement of the Smelter Lake Tailings Storage Facility



RESEARCH METHODOLOGY

Four different prescriptions were chosen to test on the plots. Since the theory to successfully reclaiming the sand impoundments was to increase the water holding capacity of the growth medium in some manner, log-yard debris was added equally across all plots, with varying rates of dewatered and land-dried biosolids applied. One plot received only the Lulu dewatered biosolids, while one other only received the Iona land-dried biosolids. The remaining two plots received both types of biosolids, but at different rates of application. Table 1 provides the specific information of application rates for each of the products that were used to create this growth medium.

Table 1 – Test Plot Treatments of Log-Yard Debris, Dewatered Biosolids and Land-Dried Biosolids

Plot #	Area (ha) (approximate)	Lulu (dt/ha)	Iona (dt/ha)	Log-Yard Debris (m^3/ha)	Total Biosolids Application Rate (dt/ha)
1	0.25	113	-	555	113
2	0.25	127	271	555	398
3	0.25	103	260	555	363
4	0.25	-	370	555	370

Application Methods

The four test plots were laid out at the base of the East Dam of the SLTSF, each with an area of approximately 0.25 Ha. Log-yard debris was trucked to the site by the supplier of the material, Weyerhaeuser, from their Princeton lumber mill. As it was received, a D6 push cat was employed to spread the log-yard debris across the four test plots equally, to a nominal thickness of 15cm. Dewatered biosolids from the Lulu WWTP and land-dried biosolids from the Iona WWTP stockpile were trucked to the site and stockpiled near the base of the test plots by the supplier, the GVRD. A front-end loader was used to transport the biosolids to each plot, where the bucket loads were placed equally across each plot. The bucket size of the front-end loader was measured in order to determine how many loads of each type of biosolids would be placed on each plot, so the targeted application rate was achieved. A D4 cat was then brought in to spread the biosolids across the plots and to incorporate the dewatered and land-dried biosolids, the log-yard debris and the tailings sand to a nominal depth of 30cm. Once the growth medium was prepared appropriately, all plots were seeded with a grass and legume mixture suitable for the region. The plots were first seeded in the late fall of 2002, several months after the preparation was complete. They were seeded for a second time in the early spring of 2004, as the germination of seed from the first seeding was not sufficient. While the seed mixtures for both years were very similar in composition, there were minor differences, as can be seen in Table 2.

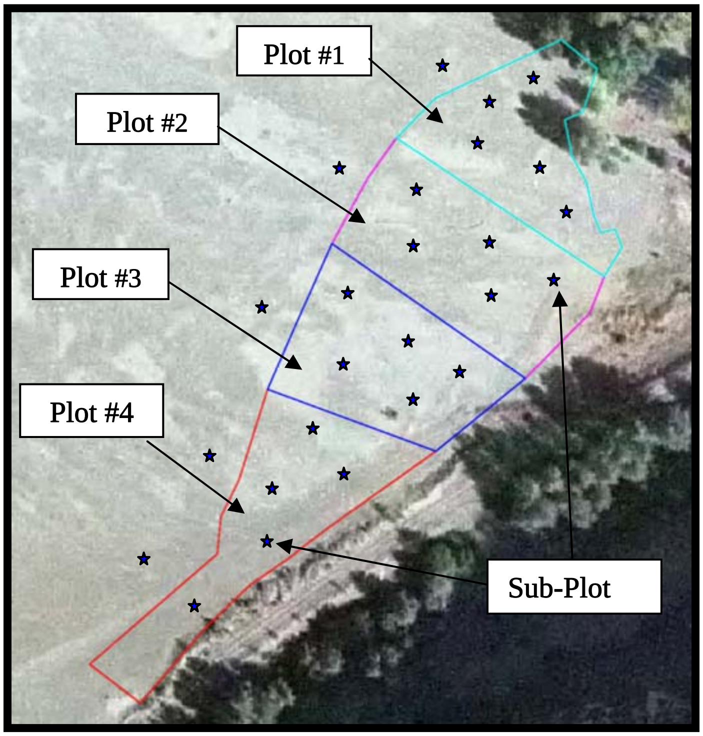
Table 2 – Seed Mixtures Used for the Test Plots in Fall 2002 and Spring 2004

Seed		Type of Plant	% of Mixture	
Common Name	Scientific Name		2002	2004
Tall fescue	*Festuca arundincea*	Agronomic Grass	22%	25%
Annual rye	*Lolium multiforum*	Annual Cereal	20%	20%
Creeping red fescue	*Festuca rubra*	Native Grass	12%	9%
Crested Wheatgrass	*Agropyron cristatum*	Agronomic Grass	10%	10%
Smooth Bromegrass	*Bromus inermis*	Agronomic Grass	10%	10%
Orchardgrass	*Dactylis glomerata*	Agronomic Grass	3%	3%
Canada Bluegrass	*Poa compressa*	Agronomic Grass	1%	1%
S.C. Red Clover	*Trifolium pratense*	Legume	15%	8%
Alfalfa	*Medicago sativa*	Legume	7%	10%
Alsike Clover	*Trifolium hybridum*	Legume	0%	4%
Total	**Total**		**100%**	**100%**

Data Collection Methods

In July 2004, data collection from the test plots commenced. To provide for a representative sample from each plot, five sub-plots within each plot were laid out equally, for a total of 20 sample locations across the four plots. Figure 2 presents the test plot layout and sub-plot sampling locations for the East Dam Sand. Growth medium samples were collected at 15cm and 30cm, and were analysed for moisture content. Additional growth medium samples were collected separately, without selecting the samples at any specific depth, and were analysed for macronutrients, micronutrients, particle size distribution, among other parameters. The $1m^2$ sub-plots for the vegetation were analysed first by estimating the percent ground cover that each species occupied. Secondly, all vegetation within the sub-plots were cut to ground level, grouped by legume, grass or native (weed) category and then weighed, both green and dry. Thirdly, the legumes and grasses were analysed for their metal content.

Figure 2 – Sampling Locations for the East Dam Test Plots and the East Dam Sand



Data Analysis Methods

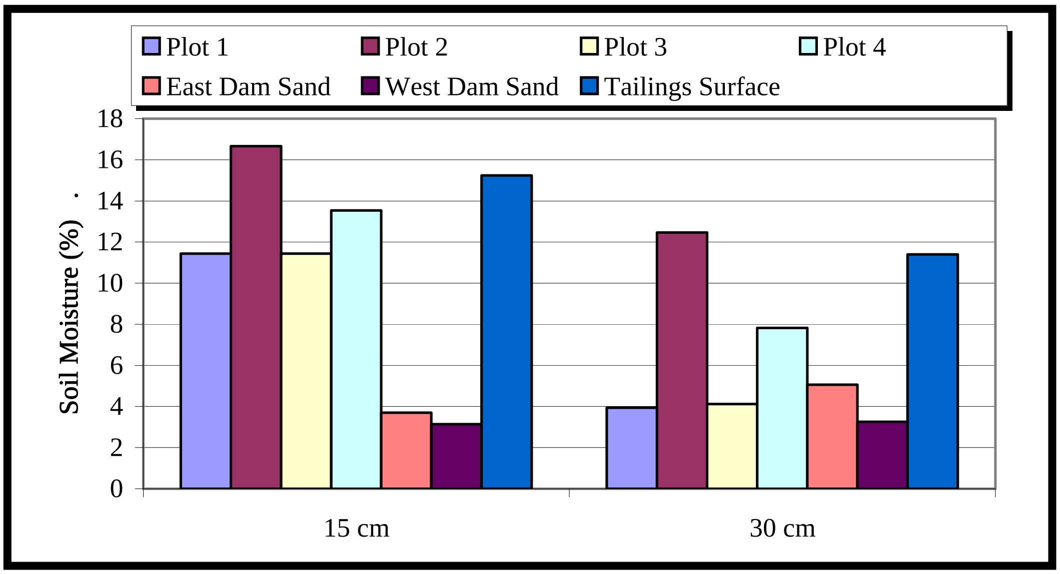
For each of the samples collected, whether it were the growth medium samples for moisture analysis or the vegetation samples for metals analysis, the mean values were calculated for each plot by using the data collected from each of the sub-plots. Once these values were determined, several statistical analyses were conducted, to establish the significance of the results. For any value to be considered statistically significant, it had to pass the 95% confidence limit. A two-tailed students t-test was performed to compare mean values against control values. For instance, for the moisture content of the growth medium in each plot, the mean values at each depth were compared to the EDS control samples, where no soil amendments had been applied at all.

STUDY RESULTS AND DISCUSSION

Depth Interval Moisture Characterization

At the 15cm depth, all four plots had percent moisture values statistically significantly higher than the mean of the EDS samples. Plots 1 thru 4 had mean moisture contents at the 15cm depth of 11.4%, 16.7%, 11.4% and 13.5%, respectively. These values compared to a mean of 3.7% for the EDS samples at the same depth. At the 30cm depth, the comparison of the means of each plot to the mean of the EDS samples is much different than is seen for the 15cm depth. All four plots did not pass the student's t-test at the 95% significance level. Plots 1 thru 4 had mean moisture contents at the 30cm depth of 3.9%, 12.5%, 4.1% and 7.8%, respectively. These values compared to a mean of 5.1% for the EDS samples at the same depth. As can be seen in Figure 3, the corresponding moisture contents for all four plots are higher at the 15cm depth than at the 30cm depth, while the converse is the case for the EDS samples.

Figure 3 – Mean Moisture Content at 15cm and 30cm



To provide some insight into how the moisture content of the sand may be affected if only biosolids were applied, a comparison of the moisture contents of the EDS and WDS is provided. While the mean values of the EDS samples were greater than the means of the WDS samples, at both the 15cm and 30cm depths, there is no significant difference. Effectively, there is no difference in moisture content for the sand on the East Dam (no historical amendments) and the sand on West Dam (biosolids added in 1999 & 2000).

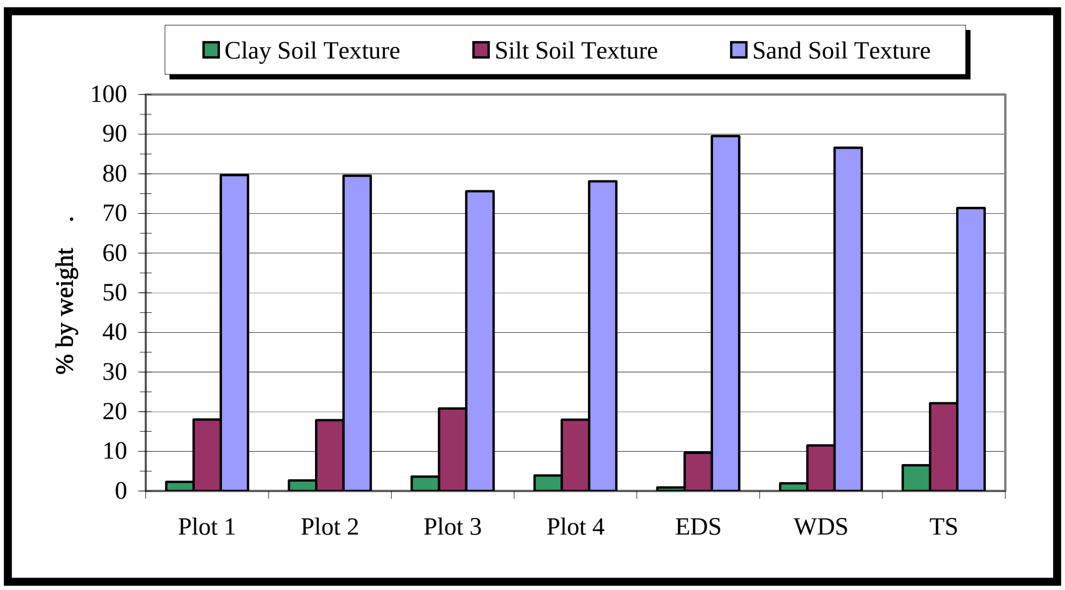
The moisture content clearly increased in the growth medium of the East Dam test plots down to a depth of 15cm, but this conclusion cannot be maintained down to a depth of 30cm, as there was a lack of significance to this depth. The higher moisture content at the 15cm depth may be due to the application technique, where the biosolids, log-yard debris and tailings sand were only incorporated to a nominal depth of 30cm. That is, there would be an increasing content of sand towards the 30cm depth, as this was the limit of mixing. Furthermore, because the top 15cm was able to hold more water, less water may have been available to percolate through the growth medium to the lower depths. Plot 2 had the highest moisture content of all four plots at both depths, but it also had the highest variance of each of the plots. Summarily, there was no great difference in the moisture contents between each of the four test plots.

While there were no specific trials created to compare the individual contribution of biosolids and log-yard debris to the increase in moisture content, the information from the WDS trials can be considered partially valid, as those trials received dewatered biosolids from the same WWTP. Since the moisture content at both the 15cm and 30cm depths is not statistically significantly different between the WDS trials from 1999/2000 and the EDS, it appears that it was the log-yard debris that provided the missing component to increase the moisture holding capacity enough to lead to a sustainable vegetative cover.

Particle Size Distribution of Growth Medium

There have been many good examples of reclaiming tailings ponds by incorporating only biosolids with the tailings (GVRD, 1997; GVRD, 2001; and GVRD & HVC, 2001). Since the moisture content of the tailings is much higher than the sand, it would follow that we needed to change the particle size distribution of the sand impoundment surface, in order to hold more water for successful reclamation. With the trials on the EDS, this was attempted by applying biosolids in conjunction with log-yard debris. Figure 4 compares the content of clay, silt and sand size particles between the EDS, the four test plots on the EDS and the tailings surface (TS).

Figure 4 – Clay, Silt and Sand Distribution Comparison

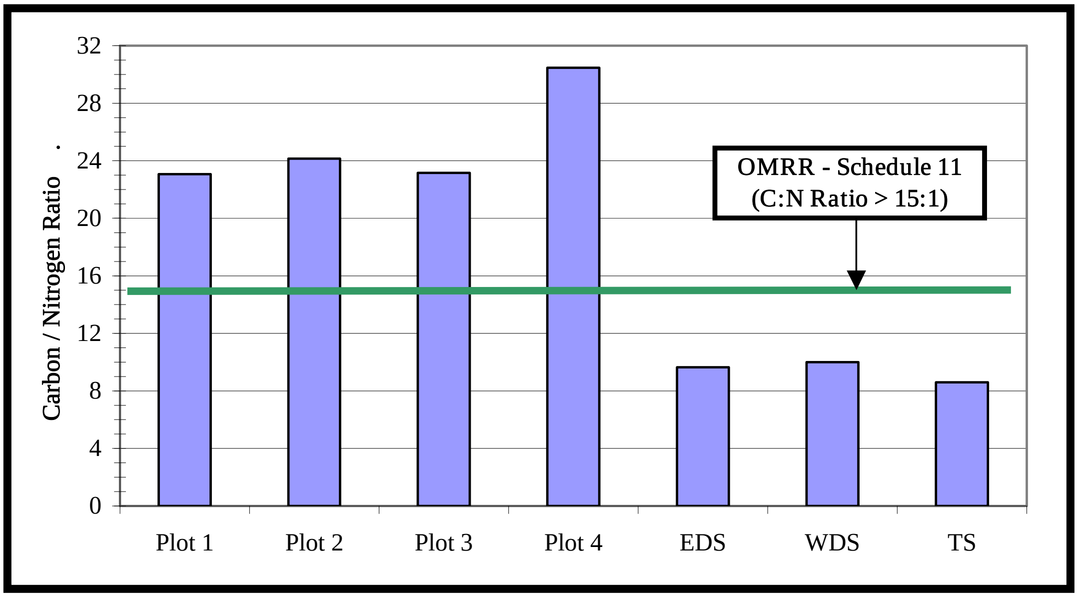


The TS had the greatest content of clay and silt particles, with mean values of 6.5% and 22.1%, respectively. It also had the lowest content of sand particles, with a mean value of 71.4%. The EDS had the lowest content of clay and silt particles, with mean values of 0.9% and 9.6%, respectively. It then follows that the EDS would also have the highest sand particle content, with a mean value of 89.5%. It is interesting to see that the mean values of the four test plots on the EDS had clay and silt fractions that were statistically significantly greater than those of the EDS, in addition to having a statistically significantly lower sand content. While the sand content of the test plots is not as low as the tailings itself, nor is the clay and silt content as high, the particle distribution more closely resembles that of the TS, which has been shown on other sites to hold enough water without the need to add an additional amendment such as log-yard debris. Effectively, the combination of biosolids, log-yard debris and sand has a particle size distribution that is suitable to retaining a greater volume of water.

Carbon/Nitrogen Ratio

Since a great deal of carbon was applied to the test plots, in the form of the log-yard debris, the ratio of Carbon to Nitrogen was important to evaluate if this growth medium would have the correct balance of these nutrients. As seen in Figure 5, the C:N ratio for all four test plots is in the range of 23 to 30, with all values exceeding the OMRR, Schedule 11 minimum of 15 (MWLAP, 2002).

Figure 5 – Mean Carbon / Nitrogen Ratios



Metal Levels in Growth Medium & Vegetation

Metal levels in the growth medium of the four test plots were compared to the CCME Soil Quality Guidelines and to the OMRR, Schedule 4 limits (CCME, 2003 and MWLAP, 2002). Metal levels in the vegetation were compared to the Generalized Dietary Tolerances for Beef Cattle and the Plant Nutrient Guidelines (PNG) (Bennett, 1993 and Puls, 1994).

With the exception of only two metals, Cu and Sn, all metals listed fell below the CCME guidelines and OMRR, Schedule 4 limits. With respect to Cu, it appears that most of the Cu in the growth medium is not readily available for plant uptake, as only 1% to 3% of the Cu was actually absorbed by the vegetation. With these absorption levels, the Cu concentration of the legumes and grasses collected fell below the Normal/Adequate tolerance (N/A) for beef cattle. As for the nutrinet needs of the vegetation, the Cu concentration for both the legumes and grasses fell within the PNG range. The concentration of Sn barely exceeded the CCME guideline for plots 3 and 4. As for the vegetation, all values were at the MDL.

Metal concentrations of Al, As, Cr, Pb, Mo, Se, Si and U all exceeded the N/A tolerance for beef cattle in some form. Mo concentrations only exceeded the N/A tolerance limit of plots 2 and 4, but still fell below the bottom range of the high tolerance limit. The MDL for Se in the vegetative analysis is much higher than the MDL in the growth medium analysis. Furthermore, as all vegetative samples returned values at this higher MDL, the Se concentration of the growth medium is considered more reflective of the actual Se concentration in the vegetation, which is typically much less than the N/A tolerance limit.

Since there are cattle grazing in the area of this sand impoundment, the ratio of Cu to Mo was evaluated, as it can be an important indicator as to the potential for the vegetation to cause molybdenosis in cattle or wild ruminants. The Cu:Mo ratio for the legumes and grasses on the four test plots averaged 3.4:1. Some studies indicate that molybdenosis may occur in ratios below 2:1, while others saw effects with even lower ratios, in the range of 0.44:1 (Miltimore and Mason, 1971; Gardener and Broersma, 1999 – as cited in Taylor and McKee, 1999). Taylor and McKee (1999) did a study on wild ruminants, providing evidence that forge with a Cu:Mo ratio of 0.05:1 did not lead to molybdenosis at Brenda Mines. Hence, the average ratio seen on these four test plots is expected to be protective against the potential for this ruminant defect.

Ca, Co, Fe, Na and V concentrations all exceeded the PNG for some or all of the four test plots, but not always both the legumes and grasses. Only P concentrations failed to reach the bottom range of the PNG, indicating that P may need to be added in the future, in order to keep a balanced nutrient mix in the growth medium.

Vegetative Cover and Biomass Yield

Plot 1 had the highest percentage of coverage from grasses, while plot 4 had the highest coverage from legumes and natives (weeds). Plots 2 and 3 had a more balanced coverage from both grasses and legumes. Total biomass production rates for plots 1 thru 4 were: 3.19 T/Ha, 2.84 T/Ha, 3.78 T/Ha and 4.29 T/Ha, respectively. These rates correspond well with values obtained on the Granby Tailings Biosolids Project, where biomass production rates seen one, two and three years after biosolids application were in the order of 1.8 T/Ha to 5.8 T/Ha (GVRD, 1997). Although growing legumes is beneficial from the point of view of nitrogen fixation, growing grasses has it's own benefits, providing vegetative coverage and a forage crop. So in order to create a balance of each vegetative species on the sand impoundment, incorporating both dewatered and land-dried biosolids together seems to achieve this goal more effectively than incorporating only dewatered or land-dried biosolids.

CONCLUSIONS

Combining dewatered and land-dried biosolids, with log-yard debris and tailings sand, proved effective in attaining a sustainable vegetative cover for test plots on the sand tailings impoundments at the Similco Mine. The moisture content of the incorporated growth medium was statistically significantly greater than the control site down to a depth of 15cm. The particle size distribution of the growth medium changed considerably compared to the control site, which more closely resembled the distribution of the surface of the tailings beach. Nearly all metals of the growth medium fell below the CCME guidelines and OMRR, Schedule 4 limits. Furthermore, the majority of metals absorbed by the vegetation were sufficient for the nutrient needs of the legumes and grasses, while at the same time within tolerance ranges for beef cattle. Only P failed to reach the lower limits for plant nutrient needs. Reclaiming sand impoundments in this manner demonstrates that, through cooperative partnerships, multiple problems can be turned into benefits for all. Bringing biosolids, log-yard debris and tailings sand together for the purpose of reclaiming a sand tailings impoundment has provided Weyerhaeuser and the GVRD a location to beneficially use their materials, helping to close the loop on each of their respective industries, while at the same time satisfying the needs of Similco Mines to reclaim their tailings storage facility.

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PHOTOS OF TEST PLOTS ON EAST DAM SAND

Photo 1 (July 2004)

East Dam Sand Impoundment

- No reclamation (foreground)
- Test Plots (centre photo, lighter green strip)

Photo 2 (September 2002)

Incorporation of biosolids, log-yard debris and tailings sand to 30cm

Photo 3 (July 2004)

East Dam Test Plots after two seasons of growth
(Unreclaimed sand at top of photo)