ELK VALLEY COAL WASTE AS A GROWTH MEDIUM – RESULTS OF SOIL AND VEGETATION ANALYSIS FROM ELK VALLEY COAL'S FORDING RIVER, GREENHILLS AND LINE CREEK MINES

Justin Straker[1]
Roger Berdusco[2]
Carol Jones[1]
Ron Jones[2]
Sara Harrison[1]

[1] C.E. Jones and Associates Ltd.
Suite 104 – 645 Fort Street
Victoria, B.C.
V8W 1G2

[2] Elk Valley Coal Corporation
Elkford/Sparwood, B.C.

ABSTRACT

The Fording River, Greenhills and Line Creek Operations are three surface coal mines located adjacent to each other in the Fording and Elk River valleys of southeastern British Columbia. These mines are operated by Elk Valley Coal Corporation, and produce high-quality metallurgical coal. Active programs of reclamation research have been conducted on all three properties. One of the primary objectives of this research has been to evaluate the feasibility of reclamation directly on coal waste, as opposed to reclamation utilizing an overlying capping material. This paper reports on the results, both historic and recent, of this research, and presents conclusions on the success of this practice, as well as future directions for confirming this success.

INTRODUCTION

Fording River, Greenhills and Line Creek Operations of Elk Valley Coal Corporation are located in the Fording and Elk River valleys in southeastern British Columbia. Reclamation research on these properties began on the Fording River site in 1969, prior to commencement of mining operations, and continues to date. Results of this research have been integrated into successful reclamation of an approximate 1400 combined ha at the three mine sites.

One of the initial components of the reclamation research program at Fording River involved evaluation of mine waste materials as growth media, particularly in comparison to local overburden materials that were available for waste capping. Research on this topic was conducted periodically between 1972 and 1995. More recent research efforts have been focussed on evaluating the reclamation suitability and nutrient capital of mine waste material through the bioassay or vegetation sampling approach. This paper provides information on methods and results of both the waste/overburden materials and bioassay approaches, and on conclusions on the suitability of coal waste for direct reclamation.

INITIAL CHARACTERIZATION OF MINE WASTE MATERIALS

In 1972, research was begun at Cominco's Fording Operations (now Fording River) on the suitability of mine and mill waste as a growth medium for plants. This program was initiated to investigate potential chemical- and physical-property problems in mine waste rock that might be detrimental to plant growth. The tested waste rock consisted of "a mixture of sandstone, mudstone, shale and coal, with a particle size that varies from 'soil sized fragments to large boulders'". Samples of waste rock for testing were obtained from the Greenhills and Clode pits, and were the first samples of waste material available for testing following authorization of surface work at the mine site. These waste materials were compared to glacial till overburden materials disturbed during construction of the Fording River plantsite, and associated roads and waste rock dumps. Results of laboratory analyses of these materials (0-15 cm depth) are presented in Table 1.

Table 1. Mean chemical and physical properties of mine waste and overburden samples

					Available Nutrients (ppm)				
Material	pH	EC (mmhos/ cm)	Organic Matter (%)	% <2.36 mm	NO3	P	Ca	Mg	K
Mine Waste	7.7	0.38	25	32	3	6	2291	342	81
Glacial Till	7.2	0.20	8	51	n.a.	49	2579	393	109

Based on this information, Cominco's researchers concluded that the waste rock samples originating in Clode and Greenhills pits were non-saline, deficient in phosphorus, but had adequate calcium and magnesium for plant growth. Clode waste rock was also deficient in potassium. Clode rock was slightly acid to alkaline, while Greenhills rock was slightly alkaline. The glacial till was slightly acid to alkaline, non-saline, and had adequate potassium, calcium and magnesium, and in most cases phosphorus, for plant growth. Nitrogen was deficient in all materials. Chemical testing of both tailings and rejects/refuse materials indicated similar nutrient characteristics as those reported above in Table 1 for waste rock. All materials were considered to have an adequate fines content for vegetation growth. Fine-fraction textures of waste rock materials ranged from sandy loams to loams, while mill wastes were coarser, with tailings having a loamy sand texture, and coarse rejects having a sand texture. Local glacial till generally had a loam texture (C.E. Jones and Associates Ltd., 1995). Organic matter levels in the coal waste rock were substantially higher than the glacial till, but this result is due to the presence of residual coal in the waste, which has different properties than "standard" soil organic matter derived from decomposition and incorporation of surface-deposited plant litter. The researchers conducting this early work at Fording River concluded that there were no properties of mine waste that would restrict plant growth directly in this material, provided that nitrogen, phosphorus and potassium deficiencies were addressed through the addition of chemical fertilizer (Gardiner, 1973).

EFFECTS OF SUBSTRATE ON RECLAIMED VEGETATION

In order to test conclusions based on laboratory analyses of mine waste samples, waste material was to be collected for grass/legume growth chamber experiments, which were to be initiated in the winter of 1973-74. However, in the interim, the excellent establishment of agronomic grass and legume species on the waste dumps negated the need for such an experimental approach. Growth chamber experiments were initiated for tailings and coarse refuse materials (Gardiner, 1974).

Having established the viability of vegetation growth directly in mine waste, in the late 1970s, growth media research at Fording River focussed on comparison of growth and nutrient status of agronomic grasses and legumes growing on both waste rock and rock capped with glacial till (the bioassay approach). These comparisons indicated the following:

- Vegetative cover, legume content and biomass were significantly improved on waste rock relative to glacial till overburden.
- Higher phosphorus application rates (approximately double) were required on glacial till relative to waste rock to produce similar organic matter and nitrogen production.
- The glacial till capping exhibited unfavourable physical characteristics, including susceptibility to erosion, and formation of a hard surface crust following wet-dry cycles, which impeded seedling emergence.

It was concluded based on this work that there were no short-term benefits to be derived from covering mine rock with glacial till overburden excavated at depth (Stathers and Gardiner, 1979). In 1981, these conclusions were confirmed for another mine waste material, coarse rejects, placed to form a north aspect slope for revegetation. Assessment of reclaimed vegetation on this site indicated no significant short-term improvement in vegetation production for a 15-cm cover of glacial till, and indicated reductions with thicker covers, in comparison to uncapped waste materials (Rusnell *et al.*, 1982).

EFFECTS OF RECLAIMED VEGETATION ON SUBSTRATE

In 1995, sampling of reclaimed coal waste was conducted to investigate the effects of a nitrogen-fixing legume cover on soil and tree seedling nutrient status. The sampled area was a resloped section of C Spoil, which had been established in the mid 1980s as a trial to test the effects of delayed ground-cover interseeding on container seedling survival, and to test whether interseeding with nitrogen-fixing legume species would have a measurable impact on tree productivity. Trees in this trial were planted between 1986 and 1988, and were interseeded with birdsfoot trefoil in May of 1990. Thus, at the time of soil sampling in 1995, the trees on site had been established for 8-10 growing seasons, while the ground cover had been established for 6 growing seasons. Soil samples were collected from the 10-20 cm depth at 96 locations on the C Spoil site, and at an additional 10 locations on a waste rock dump reclaimed with a grass/legume mix at the Greenhills North Dump. These samples were analyzed in the laboratory for chemical properties (C.E. Jones and Associates Ltd., 1996).

Results from these lab analyses indicate similar properties as those presented in Table 1, but provide some valuable additional information:

- The mean organic carbon content of the coal waste rock samples was 6.3 percent. Values were determined by Walkley-Black wet oxidation, which does not recover mineral carbon forms such as carbonates, and thus is a better measure of soil organic matter content for materials such as coal waste than the analysis reported in Table 1. (Table 1 data should be multiplied by approximately 0.57 to provide approximate organic carbon, as opposed to organic matter, values.)
- The mean total nitrogen (TKN) concentration of the coal waste samples was 0.30 percent.

A comparison of these values to similar data from surface undisturbed forest soils is interesting, in that it challenges the conventional conception of uncapped coal waste as a harsh growth medium. Analysis of soil properties samples collected at similar depths on the Line Creek mine area prior to development shows organic carbon contents between approximately 0.8-5.5 percent, with a mean of 2.2 percent, substantially lower than the coal waste mean of 6.3 percent (B.C. Research, 1977). Total nitrogen concentrations were not analyzed in these Line Creek samples, but a comparison to published forest soil data indicates that total nitrogen levels reported in coal waste at Fording River are comparable to or higher than those reported by Klinka *et al.* (1994) for mineral soil in a study of 116 lodgepole pine and hybrid white spruce stands in interior B.C. (range = 0.06-0.82 percent, mean = 0.17 percent). These comparisons of organic carbon content and total nitrogen concentrations are important for interpretations of potential productivity of undisturbed versus coal waste substrates, as nitrogen is likely the element most limiting to forest growth in temperate forests in Canada, and as its status in the soil is largely dependent on organic matter (as measured by organic carbon) content. Thus, these comparisons indicate coal waste to be a relatively favourable substrate for supporting productive reclamation and eventually productive forest growth, in an appropriate comparison to undisturbed soil materials.

The soils assessment of the interseeded trials on C Spoil indicated not only that uncapped coal waste has favourable characteristics for reclamation and vegetation growth, but that these characteristics can be enhanced through the reclamation process itself. Interseeding with nitrogen fixing legumes was shown to increase both total and mineralizable (plant-available) nitrogen over concentrations found in unseeded plots (interseeded values for total and mineralizable nitrogen were 1.4 and 5.3 times, respectively, the unseeded values). In this way, successful reclamation has formed a positive feedback loop that is increasing site productivity and promoting reclamation sustainability.

CONIFER FOLIAR BIOASSAYS

Since 2000, assessment of conifer foliar nutrient status has been conducted at the Fording River mine on operational plantations on reclaimed coal waste, and on comparable off-site second-growth stands. Sampled stands have been approximately 8-13 years old. Sampling has followed methods presented by Ballard and Carter (1985). Foliar nutrient assessments are being conducted because they are a more direct and integrative measure than soil analysis of the capacity of the substrate to supply nutrients to vegetation. Mean results of foliar nitrogen analyses from 8 reclaimed and 7 off-site stands are presented in Table 2.

Table 2. Mean foliar nitrogen content by species and substrate		
Substrate	Species	Foliar Nitrogen (%)
Forest Soil	Pine	1.04
Coal Waste	Pine	0.98
Forest Soil	Spruce	1.02
Coal Waste	Spruce	1.04

These results indicate comparable nutrient status provided both by harvested forest soils and by reclaimed coal waste. This observation suggests that the reclaimed coal waste is capable of achieving equivalent (to pre-disturbance) forest capability, and of sustaining this capability for a number of years after cessation of management inputs (*e.g.* fertilizer additions) to the reclaimed sites. The long-term capability of these sites will be assessed through continuing monitoring of agronomic vegetation and forest stand success on reclaimed sites.

FUTURE DIRECTIONS

In 2005, Elk Valley Coal initiated a program at its Fording River, Greenhills and Line Creek mine sites to examine long-term trends in vegetation success on reclaimed sites, and on the effects of maintenance fertilizer (where used) withdrawal on these sites. This monitoring will also include a limited waste material sampling program to characterize waste properties and establish the similarities and range of these properties across the mine site. These research programs will add to the bioassay data currently being collected on reclaimed forest stands, and provide additional information on the properties of coal waste and the reclaimed vegetation it supports.

In addition, Elk Valley Coal is examining techniques for evaluating nutrient cycling processes on older reclaimed stands. These processes will become important as reclaimed sites transition from young, open-canopy stands to juvenile forests in which internal cycling through litterfall and forest floor decomposition is the primary driver in productivity and sustainability. Characterization and assessment of these cycling processes will aid in confirmation of the capacity of reclaimed coal spoil to sustainably support vegetation post mine-closure.

CONCLUSIONS

Reclamation research began at the Fording River mine site even prior to shipping of the first coal product from the mine site. Much of this early work focussed on assessing the viability of reclamation directly in coal waste, as opposed to reclamation using a capping material overlying the mine waste. Results of this research indicated not only that direct reclamation in coal waste was feasible, but that there were productivity advantages to this technique in comparison to capping. Research continues to date on the Fording River, Greenhills and Line Creek mine sites to assess the success of reclamation on coal waste, and to develop techniques of enhancing the capability and sustainability of this reclamation. Results to date indicate that the direct reclamation on these sites is successfully achieving its objective of returning sites to their equivalent to pre-disturbance capabilities, and that these successful trends have been maintained over the assessment periods, spanning over two decades.

REFERENCES

Ballard, T. and R. Carter, 1985. Evaluating Forest Stand Nutrient Status. Land Management Report no. 20. B.C. Ministry of Forests, Victoria, B.C.

B.C. Research, 1977. Stage 2 Environmental Study of the Line Creek Project. Prepared for Crows Nest Industries, Fernie, B.C. Submitted to the B.C. Ministry of Energy and Mines, Victoria, B.C.

C.E. Jones and Associates Ltd., 1995. Fording Coal Ltd. – Annual Reclamation Research Report 1995. Submitted to the B.C. Ministry of Energy and Mines, Victoria, B.C.

C.E. Jones and Associates Ltd., 1995. Fording Coal Ltd. – Review of Reclamation Studies. Internal Report prepared for Fording Coal Ltd., Elkford, B.C.

Gardiner, R., 1974. Report on Fording Coal Limited Reclamation Research, 1973. Submitted to the B.C. Ministry of Energy and Mines, Victoria, B.C.

Gardiner, R., 1973. Report on Fording Coal Limited Reclamation Research, 1972. Submitted to the B.C. Ministry of Energy and Mines, Victoria, B.C.

Klinka, K., Wang, Q. and G. Kayahara, 1994. Quantitative characterization of nutrient regimes in some boreal forest soils. Can. J. Soil Sci. 74: 29-38.

Rusnell, D., Frew, R. and R. Gardiner, 1982. Fording Coal Ltd. – Annual Reclamation Research Report for 1981. Submitted to the B.C. Ministry of Energy and Mines, Victoria, B.C.

Stathers, J. and R. Gardiner, 1979. Fording Coal Ltd. – Annual Reclamation Research Report for 1978. Submitted to the B.C. Ministry of Energy and Mines, Victoria, B.C.