CATTLE GRAZING ON RECLAIMED MINE TAILINGS
AT HIGHLAND VALLEY COPPER – A REVIEW

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ABSTRACT

Revegetation and sustainable cattle grazing are major objectives in the program for the reclamation of mine tailings at the Highland Valley Copper mine in British Columbia, Canada. Residual molybdenum (Mo) in the tailings is imbibed by vegetation and can accumulate to extremely high levels (> 25 ppm Mo on a dry matter basis). Accordingly, grazing studies were initiated with cattle to determine the feasibility of utilizing the Bethlehem and Highmont tailings sites for livestock production. Molybdenum levels in forages were at least ten times higher at Highmont than at Bethlehem. A total of 262 cow-calf pairs grazed the Bethlehem site for four consecutive years (1994 – 1997) and the Highmont site for five consecutive years (1998 – 2002). Cattle at Bethlehem did not show clinical signs of Mo toxicity or copper deficiency. In contrast, cattle at Highmont showed clinical signs including lameness, diarrhea and haircoat depigmentation. The onset and severity of the affliction appeared to be related, in part, to prevailing moisture conditions, which affected Mo availability in forage. The cattle recovered by the end of each trial and haircoat problems were resolved by the next spring. Preventative measures were attempted using copper supplements that can alleviate Mo toxicity. Copper boluses did not provide adequate protection in 2001 but copper sulphate supplementation in loose salt prevented the onset of clinical signs in 2002.

INTRODUCTION

The Highland Valley Copper (HVC) mine, near Logan Lake, B.C. is in the process of restoring range on land disturbed by mining. Mining has been ongoing for 20 years. Of primary concern are the tailings ponds. These areas contain elevated levels of molybdenum (Mo), a residue from the copper (Cu) and Mo extraction process. With a milling recovery of 50% (HVC, 1996), Mo is a prominent residue in the tailings.

Environmental reclamation of tailings areas consists primarily of establishing agronomic vegetation with the aid of fertilizers (C.E. Jones and Associates Ltd., 1999; 2000). The objective is to permit hay production and livestock grazing, thus restoring the land to sustainable agricultural use. Studies have shown that residual Mo in the tailings is imbibed by vegetation and can accumulate to extremely high levels (> 25 ppm Mo on a dry matter basis) depending on plant
species and site (Gardner et al., 2003; Majak et al., 2003). Animal health guidelines recommend a maximum level of 5 ppm Mo in feed for beef cattle (NRC, 1996). Accordingly, grazing studies were initiated to determine the feasibility of utilizing these mine sites for cattle production. The studies have been ongoing for 9 years and are scheduled for completion in 2003. We are unaware of any other long-term grazing studies utilizing high Mo forage. Forages are also very high in Mo on reclaimed lands at the URAD mine in Colorado but long-term grazing trials have not been initiated (Trlica and Brown, 2000).

Elevated levels of Mo in forage can induce molybdenosis, a form of Mo toxicity in ruminants. Molybdenosis, also referred to as secondary Cu deficiency, can result in the reduction of biologically available Cu. Molybdenum in forage at HVC is presumed to exist as the inorganic molybdate anion (Surridge et al., 2001) and the ion has also been detected in the soil at Highmont (D. Steinke, unpublished data). In the rumen, molybdate can react anaerobically with sulphide to form thiomolybdates, which can bind free Cu rendering it biologically unavailable (Mason, 1981). However, formation of sulphide requires reduction of sulphate, which is inhibited at very high levels (> 200 ppm) of dietary molybdate (Bryden and Bray, 1972). The clinical signs of molybdenosis include lameness with a characteristic stiff gait, severe diarrhea, weight loss, depigmentation of hair coat and death (Ward, 1978, Swan et al., 1998).

**Grazing trials at the Bethlehem site (1994 – 1997)**

In 1994, a joint study involving HVC, the British Columbia Cattlemen’s Association and Agriculture & Agri-Food Canada (AAFC) was initiated to determine the feasibility of grazing beef cattle on the reclaimed Bethlehem mine tailings site (Gardner et al., 2003; Gardner, 1997). Forage on the site, including crested wheatgrass (*Agropyron cristatum*), pubescent wheatgrass (*A. trichophorum*), smooth brome (*Bromus inermus*) and orchardgrass (*Dactylis glomerata*), contained approximately 32 ppm Mo. The objective of this project was to determine if beef cattle could graze the revegetated area without ill effects. The study included: i) a three year pasture trial where cattle grazed the Bethlehem site (elevation 1400 m) for 12 weeks each year with fresh water provided; ii) a feedlot trial where weaned calves received Mo-enriched hay as part of their backgrounding ration; iii) a carcass trial where finished animals were slaughtered and selected tissues were analyzed for heavy metals; and iv) a one year water quality trial where cattle grazed Bethlehem forage but with tailings seepage water as their only source of drinking water for a 12 week period.
The Bethlehem pasture trial utilized 32 cow-calf pairs that grazed the tailings site from July to September in 1994, 1995 and 1996 (Table 1). Sixteen cows were given boluses (ALL TRACE, Agrimin Ltd., UK) designed to continuously release Cu, other essential minerals and vitamins for 8 months. The other 16 served as the control group. All cattle had access to cobalt iodized salt. A similar design was used in the water quality study in 1997. The drinking water in the water quality study contained 0.1 ppm Mo. During each grazing trial, cattle were weighed and blood, milk, liver and forage samples were collected and analyzed. Levels of Mo in blood, milk and liver tissues increased during the trials but Cu levels remained within the normal range (Gardner et al., 2003). There were no adverse effects on animal health or performance and no indication of a Cu deficiency regardless of water source.

In feedlot trials during 1994 and 1995, two groups of 16 weaned calves were fed backgrounds rations consisting of grass-alfalfa hay harvested either locally in Kamloops or harvested at the Highmont tailings pond at HVC. Local hay contained 1.7 ppm Mo, while the Mo content in hay from Highmont was 72 ppm Mo. Feed intake and average daily gains were monitored and blood, liver and feed samples were collected periodically from October to January. Significant differences in animal performance were not detected between the two groups nor were there any signs of a Cu deficiency induced by excess Mo (Gardner, 1997). For the carcass trial, the calves were finished and slaughtered at approximately 14 months of age. Tissue samples from each animal were analyzed for heavy metals. There were no indications of accumulated levels of Mo or other heavy metals in animal tissues. Feeding Mo-enriched hay from the mine site for extended periods did not induce a Cu deficiency nor did it produce adverse effects on animal health or performance. The exposure resulted in the accumulation of Mo in blood, milk and liver, but the levels were normal at slaughter time, 1 to 4 months after removal from the Mo-enriched diet. Cattle grazing the Bethlehem tailings area over a 4-year period showed no clinical signs of Mo toxicity or Cu deficiency suggesting that cattle could utilize the site without ill effects (Gardner, 1997). It should be noted that cattle in the above study, when not on test, were held at the Range Research Unit in Kamloops (elevation 317 m).
Table 1. Stocking rates at Highmont pastures at HVC and number of cows showing clinical signs

<table>
<thead>
<tr>
<th>Year</th>
<th>Duration of trial (d)</th>
<th>Pasture area (ha)</th>
<th>No. of cow-calf pairs</th>
<th>Stocking rate (ha / AUM)</th>
<th>No. of affected cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bethlehem</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>75</td>
<td>55</td>
<td>32</td>
<td>0.85</td>
<td>0</td>
</tr>
<tr>
<td>1995</td>
<td>81</td>
<td>55</td>
<td>32</td>
<td>0.85</td>
<td>0</td>
</tr>
<tr>
<td>1996</td>
<td>76</td>
<td>55</td>
<td>32</td>
<td>0.85</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>73</td>
<td>55</td>
<td>31</td>
<td>0.82</td>
<td>0</td>
</tr>
<tr>
<td>Highmont</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>56</td>
<td>25</td>
<td>0³</td>
<td>1.67</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>77</td>
<td>34</td>
<td>20³</td>
<td>0.57</td>
<td>4</td>
</tr>
<tr>
<td>2000</td>
<td>75</td>
<td>55</td>
<td>30³</td>
<td>0.63</td>
<td>21</td>
</tr>
<tr>
<td>2001</td>
<td>77</td>
<td>64</td>
<td>34</td>
<td>0.68</td>
<td>9</td>
</tr>
<tr>
<td>2002</td>
<td>35</td>
<td>55</td>
<td>53</td>
<td>0.89</td>
<td>10</td>
</tr>
</tbody>
</table>

1 Includes calves, bulls and fistulated steers; ha per animal unit month.
2 Six fistulated steers on test.
3 Two fistulated steers on test in addition to cow-calf pairs.
Grazing trials at the Highmont site (1998 – 2002)

In 1998, the focus of the studies was shifted to the Highmont tailings area (elevation 1500 m) where Mo levels in forages are among the highest in the area, exceeding 400 ppm Mo (Majak et al., 2003). In addition, drinking water contained on average 7 ppm Mo (Majak et al., 2003), which is well above the acceptable limit of 0.06 ppm Mo (Puls, 1994). Trials were initiated to determine whether cattle grazing was a viable option for the reclamation plan at the Highmont tailings pond.

1998 Trial

The preliminary study was an eight-week trial conducted from July to September 1998 on the Highmont tailings area (Stager, 1998). Six ruminally fistulated mature Jersey steers grazed the 25 ha pasture (Table 1) dominated by orchardgrass and alfalfa (Medicago sativa) containing on average 286 ppm Mo. Elevated levels of Mo were found in rumen digesta (on average 175 ppm), liver (8 ppm), serum (8 ppm) and feces (285 ppm), but as indicated by Stager (1998), there was no evidence of clinical disorders. Normal Mo levels are < 10 ppm for digesta and feces, < 2 ppm for liver and < 0.1 for serum (Puls, 1994), which indicated that there was uptake, absorption and excretion of Mo by cattle at Highmont in 1998.

Subsequent trials used cattle that were native to the Highland Valley area, which would be representative of cattle going to Highmont. The Rey Creek Ranch supplied the cow-calf pairs which, when not on test, were held at the ranch or on range near the mine. It should be noted that forages in the general area of the Highland Valley contain elevated levels of Mo (Steinke and Majak, 2003; Majak et al., 2003) in excess of the safe upper limit of 5 ppm (NRC, 1996). During 1999 – 2002, cattle were subjected to very high levels of Mo at Highmont, but they were also exposed to excess Mo before the study began. In 1999, 2000 and 2001, cattle grazed the Highmont site for 11 weeks during July to October and the pasture was expanded from 25 to 64 ha (Table 1).

1999 Trial

In 1999, twenty cow-calf pairs, a dry cow, a bull and two fistulated steers were released into the pasture (Table 1). Clinical abnormalities were observed in four cows and a calf after approximately 4-5 weeks of grazing and the signs persisted for 10 to 20 days. The cattle with abnormalities displayed a stiff, shuffling gait and favored their tiptoes when travelling. All other functions including temperature, pulse, respiration and body condition appeared normal to a
consulting veterinarian. The abnormalities did not persist and each animal had fully recovered by the end of the trial. Liver and serum levels of Mo and Cu were examined in affected and unaffected animals, but differences were not detected (Majak and Steinke, 2000). Tissue samples showed adequate Cu levels but potentially toxic levels of Mo.

Rumen digesta and feces were obtained from the steers for total Mo determination before, during and after the trials in 1999 and 2000. Analysis confirmed rapid uptake of Mo by the grazing steers (Figure 1). The results also showed that within two weeks of removal from the Mo-enriched forage, digesta and fecal levels returned to near normal. The rapid decline in Mo levels suggested that long-term accumulation in tissues was unlikely because the Mo was rapidly eliminated from the gastrointestinal system.

2000 Trial

In 2000, the objective was to reproduce the clinical abnormalities that were first seen in 1999. Thirty cow-calf pairs grazed the pasture at Highmont in 2000 (Table 1). Disorders were observed in animals within a week of arrival to Highmont and two-thirds of the herd eventually showed clinical signs (Table 1). Abnormalities included a stiff, shuffling gait favoring their tiptoes when traveling, severe diarrhea and haircoat depigmentation. Lameness was the major disorder. The observed diarrhea and condition of haircoat, which was most apparent at the end of the trial, were considered secondary signs. Liver and serum levels of Mo were elevated in all cattle. Some affected animals were treated with Cu injections to no avail (Majak and Steinke, 2001; 2002). All affected cattle had fully recovered by the end of the trial, except for haircoat problems, which were resolved by next spring.

2001 Trial

In 2001, the focus of the project was shifted from strictly clinical observation to include therapy that might alleviate the disorder. An experiment was proposed to test the efficacy of a Cu bolus that might alleviate a possible Cu deficiency. Fifteen randomly selected cows received Cu boluses (ALLTRACE, Agrimin Ltd., UK) and the other fifteen served as controls. A clinical grading system (Table 2) developed by Dr. Jason McGillivray (Kamloops Large Animal Veterinary Clinic, Kamloops, B.C.) was also introduced in 2001. Clinical disorders were again evident at Highmont in 2001. Four bolus cows, five control cows, one calf and the bull suffered varying degrees of lameness 3 weeks after arrival to the site. Except for the haircoat depigmentation, all animals had fully recovered by the end of the trial.
Table 2: Guidelines for Determining Severity of Clinical Signs in Cattle at Highmont

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lameness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Mild</td>
<td>Stiff on rising, slow shuffling gait, warms out of it</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>Reluctant to move, always trailing the herd, shuffling, tiptoe gait</td>
<td>2</td>
</tr>
<tr>
<td>Severe</td>
<td>Recumbent, cannot go to water, gaunt</td>
<td>3</td>
</tr>
<tr>
<td>Diarrhea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>Normal consistency for green alfalfa / grass diet</td>
<td>0</td>
</tr>
<tr>
<td>Moderate</td>
<td>Fluid feces, fecal staining on tail / perineum / hocks</td>
<td>1</td>
</tr>
<tr>
<td>Severe</td>
<td>Watery feces, explosive diarrhea</td>
<td>2</td>
</tr>
<tr>
<td>Haircoat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Dull</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Faded</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Hair Loss</td>
<td>(Other than mechanical)</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 1. Average (± SE) accumulation of Mo in rumen digesta (open bar) and excretion in feces (solid bar) of fistulated steers (n = 4) at Highmont during 1999 and 2000.
Liver Cu levels were elevated in the bolus group (> 200 ppm) compared to the controls (< 60 ppm), but serum values of Cu (< 1.5 ppm) were unaffected by the bolus. On average, liver levels of Mo increased from 2 to 18 ppm and serum levels of Mo increased from 0.1 to 5 ppm during the 11 week grazing period at Highmont (Majak and Steinke, 2002).

The proportion of cows that were affected and displayed clinical signs of lameness was 20%, 70% and 30% in 1999, 2000 and 2001 respectively. The proportions of affected cattle were similar in 1999 and 2001 but were significantly higher in 2000 (Majak et al., 2003). The onset and frequency of clinical signs could be linked to prevailing moisture conditions, which may have affected plant growth and biomass. The earliest signs and highest proportion of cases were seen in 2000 when precipitation during the growing season (May to September) was two to threefold greater than in 1999 or 2001 (HVC, 1999; 2000; 2001). The resultant increase in forage biomass would also enhance Mo availability. Conversely, the drier years would yield less biomass and forage Mo would be less abundant.

The 2000 and 2001 studies were aimed at replicating and documenting the onset of abnormalities first seen in 1999. Despite these abnormalities, average daily gains (ADG) were similar between affected and unaffected cows. On average, cows gained 0.79 kg head$^{-1}$ day$^{-1}$ and the calves gained 1.33 kg head$^{-1}$ day$^{-1}$ during 1999 – 2001 (Majak et al., 2003), which is indicative of healthy cattle.

**2002 Trial**

The 2002 grazing trial at Highmont was conducted for 5 weeks from August to October, with further emphasis on the prevention of clinical disorders (Steinke and Majak, 2003). The herd was randomly divided into two groups and turned out to separate pastures. Copper sulphate (CuSO$_4$.5H$_2$O), 2.5% in loose salt, was provided free choice to one group, while the other group, which served as a control, was given only loose salt. Addition of CuSO$_4$ to the diet (2 to 6 g head$^{-1}$ day$^{-1}$) can alleviate Mo toxicity (Puls, 1994; Underwood and Suttle, 1999).

Clinical signs were prominent again at Highmont in 2002. Lameness was observed in one-quarter of the control group within a week of arrival to Highmont. The rapid onset of clinical signs could be partially attributed to the delayed turnout in August 2002. Previously (1999 – 2001), cattle
were turned out in July, which was 7 weeks earlier than in 2002. The delayed turnout in 2002 permitted more forage growth, with the resultant increase in the availability of Mo. The strategy behind the delayed turnout was, in part, to reduce the risk of bloat by advancing the growth stage of alfalfa (Thompson et al., 2000). A cow-calf pair had succumbed to bloat at Highmont in 1999 (Majak and Steinke, 2000).

There was an obvious difference in the general condition of the control group compared to the supplement group. Supplement cows never exhibited clinical signs, which suggests that the addition of CuSO₄ to the loose salt mix was an effective treatment. Acute signs were clearly evident in the control group. One third of the control cows showed moderate to severe signs of lameness in 2002. The supplement group showed an increase in liver Cu during the trial, while the levels in the control group appeared to decrease (Steinke and Majak, 2003). The enhanced Cu levels in the supplement group were attributed to CuSO₄ supplementation. Liver and serum levels of Mo increased as in previous years. The ADG for supplement cows (1.66 kg head⁻¹ day⁻¹) was twice as great as the ADG for control cows (0.76 kg head⁻¹ day⁻¹). The ADG for supplement calves was also enhanced compared to the control calves (Steinke and Majak, 2003).

CONCLUSIONS

In summary, cattle at Bethlehem did not show signs of affliction. This may be due to the lower Mo in the grazed forage or the normal Mo in the home forage. In contrast, cattle at Highmont were exposed to excess forage Mo before arrival to the mine site. As well, Mo levels in forages were at least ten times higher at Highmont than at Bethlehem. In general, in a herd of cattle, milking cows are most susceptible to toxic stress, which was also the situation at Highmont. Lameness, the primary clinical sign was resolved in all animals by the end of the trial. Diarrhea was also resolved and haircoats returned to normal by the following spring. At Highmont, forage biomass probably increased in response to rainfall in 2000 and in response to delayed turnout in 2002 with a resultant increase in the availability of Mo. Concomitantly, the frequency of clinical signs also increased. Copper boluses did not provide sufficient protection in 2001 but CuSO₄ supplements in loose salt appeared to prevent the onset of clinical disorders in 2002. The efficacy of the CuSO₄ supplement will be tested again in 2003.
ACKNOWLEDGEMENTS

The authors would like to thank Highland Valley Copper for their financial support and especially Mark Freberg and Bob Hamaguchi who promoted the project. The authors would also like to thank Judy Lamont and Rip Gray for checking livestock, Keith Ogilvie and Leo Stroesser for livestock handling and sample collection and Gordon Garthwaite, Rey Creek Ranch, for providing cattle for this study.

REFERENCES


