GS-18 Tissue elemental analysis of plants growing on the Gunnar minesite tailings, southeastern Manitoba (part of NTS 52L14)

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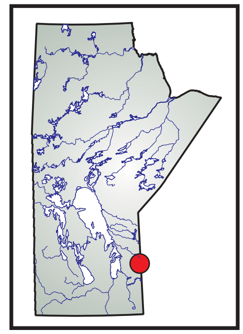

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Summary

Under certain conditions, plants will naturally colonize mine tailings. Little information is available on metal accumulation of these plants and variation between species. *Equisetum arvense* and *Solidago graminifolia* shoots, as well as *Salix lucida*, *Populus balsamifera*, *Larix laricina* and *Picea mariana* leaves, were collected at the naturally vegetated area of the tailings at the Gunnar minesite. The plant tissues were analyzed for elemental composition and concentration. The concentration of metallic elements in tissues is far below those previously found in plants from these tailings. Results show that the heavy metal accumulation in the plants is species specific. Certain elements (As, Cd, Cr) were found at potentially toxic levels in *E. arvense, S. lucida* and *P. balsamifera*, but are not significantly elevated in the other plant species tested. Other species-specific results include high levels of Zn in *S. lucida*, and potentially elevated levels of aluminum in *E. arvense* and *S. graminifolia*. These results show that elemental concentrations in one species cannot be used to predict the levels in others.

Introduction

Manitoba has approximately 20 abandoned or orphaned mines, one of which is the Gunnar gold mine (50°51.37'N, 95°15.31'W) located within the Archean Rice Lake greenstone belt in southeastern Manitoba. The Gunnar gold mine was in operation from 1936 to 1943 (Slivitzky, 1996). Since the mine closure, natural revegetation has been largely limited to two areas–a willow/sedge-dominated wetland, where tailings are permanently submerged, and a *P. mariana* dominated forest. Previous work (Renault et al., 2006, 2007) has shown that the limitation in plant growth could be attributed to the chemical and physical properties of the tailings (low organic matter content, high bulk density, low levels of nutrients and elevated concentrations of potentially toxic elements; Slivitzky, 1996). While the natural vegetation seems healthy and invading the site at a steady rate (Markham et al., 2008), plants, especially in the early stages of colonization, are exposed to potentially toxic levels of elements that far exceed levels found in soil. Additionally, most research on interactions between plants and mine tailings tend to deal with introduced and agronomic species whose physiology and ecology is likely quite different from the boreal species that have been colonizing the Gunnar minesite.

Objective of the study

The objective of this study was to determine the level of accumulation of trace elements in the naturally occurring vegetation growing on the tailings. Species chosen spanned a range of successional stages (Markham et al., 2008) from the first colonizer (*E. arvense*) to an early forb (*S. graminifolia)* to the first woody species (*S. lucida*) to the later successional tree species (*P. balsamifera*, *L. laricina*, *P. mariana*).

Analytical methods

In June 2008, four transects were sampled along the southwest side of the tailings pond running into the natural vegetation (Markham et al., 2008). Five more transects were added in June 2009 (Young et al., 2009). Transects were set up by selecting points approximately every 30 m along the edge of the vegetation (starting where less than 1% vegetation cover occurred) and running perpendicularly from the line of the invading vegetation to the edge of the tailings pond. In the summer of 2010, *E. arvense* and *S. graminifolia* shoots, as well as *S. lucida* and *P. balsamifera* leaves, were collected where the vegetation began to colonize the tailings at 0, 5 and 10 m along the transects. The plant tissues were washed with double distilled water and oven dried at 65 ±5°C for 48 hours. Samples were ashed at 475°C for 24 hours. Subsequently, 0.25 g of ash was digested in aqua regia (concentrated hydrochloric and nitric acids) at 95°C for two hours. Plant tissues were analyzed for elements by inductively coupled plasma–mass spectrometry (ICP-MS) by Activation Laboratories Ltd. (Ancaster, Ontario). Concentrations of individual elements were compared between species using ANOVA followed by Tukey's HSD post-hoc test with JMP® 8.0.1. Multivariate comparisons of the elements were restricted to those elements where the mean concentration in tissues was greater than 1 µg/g. The species were compared by using principle co-ordinate analysis using labdsv (version package in R, version 2.6.2).

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Results and discussion

Table GS-18-1 shows the concentration of elements in the different plant species. Levels on the plant tissues commonly are a number of times lower than those found in the tailings (Markham et al., 2008) and in no case did the level in the plants exceed the level in the tailings. Although most elements found in the tailings are not expected to be toxic due to the reduced availability at the neutral pH of the tailings, the concentrations of most trace metals were higher than those commonly found in most plant tissues away from tailings. In general, *E. arvense* tends to have higher levels of elements than the other species. Elements such as B, Cu, Mn and Zn, which play an essential role as micronutrients in plants, were present at concentrations determined to be 'sufficient' for growth (Adriano, 1986). Therefore, toxicity is not expected for those elements, except in *S. lucida* which has a concentration of Zn greater than 400 µg/g, a level that has been shown to reduce yield in some plants (Adriano, 1986). Elements like B, Ba, Co, Ni, Ti and V are present at concentrations below the toxicity levels whereas other elements including As, Cd and Cr reached potentially toxic levels in *E. arvense*, *P. balsamifera* and *S. Lucida* with the exception of Cd in *E. arvense*. Aluminium is present in *E. arvense* and *S. graminifolia* at concentrations that have been shown to cause toxicity in *Glycine max*, however, higher concentrations are required to cause toxicity in *Sorghum* (Rout et al., 2001). These results show that phytotoxicity of elements varies depending on the plant species and elements. Little information is available on Rb and Ru toxicity in plants.

The multivariate analysis shows that plant species can be discriminated based on their elemental concentrations (Figure GS-18-1). The first two axes of analysis account for 29 and 19% of the total variation, respectively. Linear correlations show that the first axis is most strongly related to Zn concentrations (r=0.923). The first axis also significantly correlates with levels of As (r=0.401), B (r=0.381), Ba (r=0.567), Cd (r=0.749), Co (r=0.566), Mg (r=0.359) and Ni (r=0.587). The second axis most strongly correlates with Mn (r=–0.816), and significantly correlates with levels of B (r=–0.390), Cr (r=0.365), Rb (r=0.386) and Ti (r=0.379). There appears to be very little overlap between species and, in most cases, all samples from a species form a tight cluster. The two flowering trees, *P. balsamifera* and *S. lucida*, form a distinct group from the other species along the first multivariate axis. The remaining species separate along the second axis. This confirms the results from the univariate analysis suggesting that uptake of elements is species specific, even if their elemental concentrations are not high. It may therefore be possible to use the elemental signatures as a

Table GS-18-1: Element contents of *Equisetum arvense*, *Solidago graminifolia*, *Salix lucida*, *Populus balsamifera*, *Larix laricina* and *Picea mariana* along sampling transects. Values (means ± standard deviations) followed by the same letter are not significantly different (α = 0.05).

Element[1]	*Equisetum arvense*	*Salix lucida*	*Solidago graminifolia*	*Populus balsamifera*	*Larix laricina*	*Picea mariana*
Al	78.4 ± 92.3[ab]	17.5 ± 7.0[b]	94.6 ± 112.2[a]	28.6 ± 21.8[ab]	34.1.3+13.3[ab]	17.5+7.7[b]
As	2.5 ± 2.5[a]	1.3 ± 0.4[ab]	0.5 ± 0.2[b]	2.1 ± 1.3[a]	0.4+0.3[b]	0.9+0.2[ab]
B	39.7 ± 4.5[b]	44.5 ± 6.3[a]	30.9 ± 5.1[b]	23.6 ± 3.5[b]	40.2+9.9[a]	14.5+7.1[c]
Ba	7.6 ± 2.1[a]	1.4 ± 0.4[b]	0.9 ± 0.2[b]	0.8 ± 0.2[b]	6.2+2.2[a]	6.3+2.8[a]
Ca (ppt)	17.3 ± 3.9[a]	11.2 ± 2.9[b]	4.8 ± 1.0[cd]	7.6 ± 1.0[c]	3.3+0.8[d]	8.1+3.6[bc]
Cd	0.2 ± 0.2[b]	4.5 ± 1.6[a]	0.7 ± 0.5[b]	1.1 ± 0.4[b]	0.0+0.0[b]	0.0+0.0[b]
Co	0.9 ± 0.4[bc]	1.8 ± 0.8[b]	0.3 ± 0.2[c]	6.7 ± 2.3[a]	0.1+0.1[c]	0.0+0.0[c]
Cr	14.3 ± 7.1[a]	6.6 ± 2.2[b]	4.2 ± 0.7[bc]	5.5 ± 1.0[bc]	1.0+0.9[c]	2.1+2.6[c]
Cu	6.9 ± 0.9[b]	6.6 ± 1.7[b]	15.2 ± 7.6[a]	6.1 ± 1.1[b]	6.3+4.9[ab]	1.8+0.5[b]
Fe (ppt)	0.26 ± 0.22[ab]	0.09 ± 0.02[b]	0.27 ± 0.30[a]	0.08 ± 0.01[ab]	0.08+0.02[ab]	0.05+0.01[b]
Mg (ppt)	5.56 ± 1.81[a]	4.54 ± 2.39[a]	1.53 ± 0.46[b]	2.69 ± 0.62[b]	1.04+0.33[b]	0.78+0.13[b]
Mn	56.1 ± 14.1[b]	92.7 ± 50.6[b]	37.2 ± 12.3[b]	23.5 ± 4.3[b]	233+85[a]	79+13[bc]
Na (ppt)	0.44 ± 0.48[a]	0.02 ± 0.01[b]	0.01 ± 0.01[b]	0.01 ± 0.01[b]	0.04+0.03[b]	0.01+0.01[b]
Ni	1.6 ± 0.4[ab]	3.9 ± 1.1[a]	1.3 ± 0.6[b]	1.2 ± 0.2[b]	0.7+0.6[b]	0.9+1.5[b]
Rb	13.3 ± 6.1[a]	3.0 ± 0.8[b]	4.4 ± 1.1[b]	3.2 ± 1.7[b]	2.1+1.1[b]	2.3+1.1[b]
Ru	5.5 ± 1.8[a]	3.7 ± 1.5[b]	1.6 ± 0.5[c]	3.4 ± 1.3[b]	0.0+0.0[c]	0.4+0.3[c]
Ti	6.0 ± 1.5[a]	4.4 ± 0.9[b]	5.0 ± 2.0[b]	4.0 ± 1.2[b]	2.5+0.4[b]	1.7+0.3[b]
V	4.8 ± 2.9[a]	1.9 ± 0.7[b]	1.7 ± 0.8[bc]	1.8 ± 0.3[bc]	0.3+0.4[bc]	0.4+0.1[d]
Zn	55.7 ± 15.8[c]	480 ± 158[a]	74.3 ± 33.3[c]	245 ± 43[b]	17.8+4.2[c]	52.1+22.3[c]

[1] Elements are presented in µg/g dry weight unless otherwise stated (abbreviation: ppt, parts per thousand).

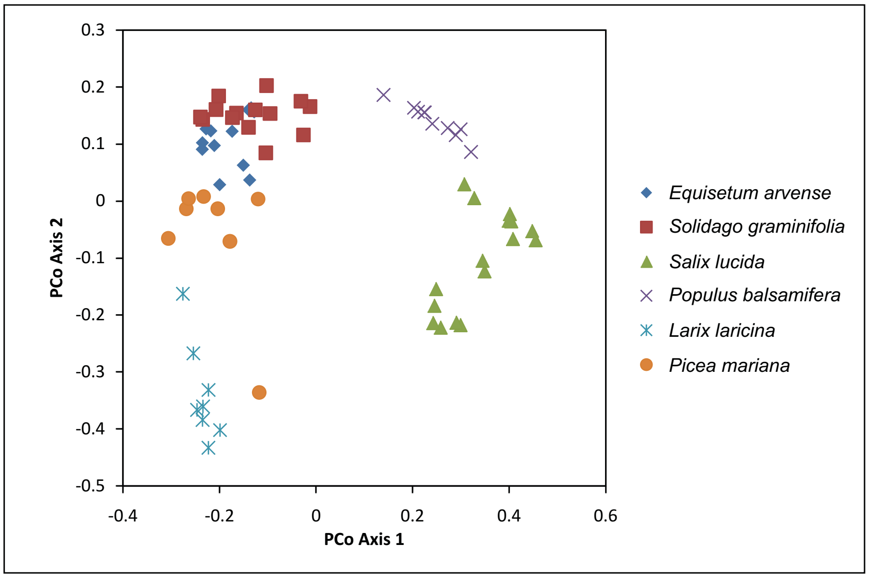

Figure GS-18-1: *Comparison of concentrations of multiple elements in plant tissues using principle co-ordinate (PCo) analysis.*

tool for tracking the movement of plant residues through ecosystems. Overall, these results suggest that the selected plants growing in the tailings do not seem to accumulate large quantities of heavy metals in their tissues. However, based on the literature, the possibility that some of these elements could have limited growth, at least in some of the species, cannot be ruled out.

Economic considerations

With more and more anthropogenically impacted lands (including those impacted by mine waste) being returned to functional land use, the potential for economic gain derived from their ecological function can be high. Reclamation of boreal forest can allow for silviculture practices, encourage native wildlife invasion, and thereby raise aesthetic and recreational value of the land. When considering a site-specific reclamation plan, if possible, it is valuable to observe and understand how native plants will interact with the present contaminants. Knowledge concerning how common plant species interact with remnant soil contaminants will allow one to confidently select native plant species compatible with the given soil situation, ultimately increasing the likelihood of a successful reclamation effort. The results of this study highlight the difficulty in doing this since each species accumulates different levels of an element. This study adds to the pool of data from which a reclamation specialist can draw when considering the plant selection aspects of a similar boreal forest reclamation project.

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