NUTRIENT AND METAL LEVELS AND DYNAMICS ON A 30-YEAR REVEGETATED COPPER-NICKEL TAILINGS SITE AT COPPER CLIFF, ONTARIO[1]

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INTRODUCTION

On the western edge of the city of Sudbury, Ontario, exists the largest sulphide tailings compound in Canada. This compound, which is operated by Inco Ltd., has a total area of 5,500 acres (2225 ha) and began operation in the 1930s. Oxidation of the 5-10% of residual sulphide originally present in the tailings, combined with trace amounts of nickel and copper, make the tailings acid-generating and phytotoxic. Since the mid-1940s, attempts have been made to revegetate the tailings, the main goal being to stabilize the surface and prevent wind erosion. Today, most of the inactive tailings surfaces have been revegetated to some degree, with the older sites showing a relatively well established tree cover. The oldest of the revegetated sections in this complex is the so-called CD area, on which a vegetation cover has been established for up to thirty years.

The CD area is dominated by stands of white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), red pine (*Pinus resinosa*), and jack pine (*Pinus banksiana*). The deciduous species have invaded the area from the hilltops which protrude from the tailings surface, while the conifers were planted from the mid-1970s on. The other main plant assemblage on the CD area is herbaceous, predominantly of grasses and legumes, and is referred to here as the field community. This community has essentially developed from the grass-legume seeding carried out in the late 1950's. The present study examines the edaphic and vegetative properties of representative samples of the three main communities of the CD area - the field community, the jack pine community, and the white birch community.

METHODS

During the summer of 1995, soil properties, vegetative structure, and foliar metal and nutrient levels of the three selected CD area plant communities were examined. Soil samples were collected in two different ways, in order to establish both general properties and localized trends beneath the trees. Generalized soil properties were examined by collecting samples along a 100m transect in each of the three communities, at the following three depths: 0-5 cm, 5-10 cm, and 10-20 cm. These samples were then analyzed for pH, organic matter, particle size distribution, percent moisture, and total metal/cation content. For the more localized properties, six samples were collected from beneath each of the trees that had foliage sampled. The six soil samples were combined, then analyzed for pH and total metal/cation levels. All total metal/cation analysis was carried on an ICP spectrophotometer at the Inco Limited laboratory.

Vegetation was described in three layers, along the same transects used for the soil samples in the field, birch, and jack pine communities. The layers were: (a) the ground layer, which included all species less than one metre in height; (b) the shrub layer, which included all woody vegetation greater than one metre in height and having a diameter at breast height (dbh) of less than five centimetres, and (c) the tree layer, which included all vegetation greater than one metre in height and having a dbh greater than five centimetres. Percent cover, frequency and, for the ground cover, diversity indices were compared for the three different sites.

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The metal and nutrient levels of the foliage were examined in jack pine needles and white birch leaves only. In the case of the jack pine foliage, needles from two consecutive years (1994-1995) were collected and analyzed separately. The birch leaves were only collected from the 1995 growing season. In each case, approximately 0.1g of plant material was analyzed for total metal and cation content. Leaves from similar vegetative stands on sandy soil at an uncontaminated control site near Sudbury were also collected and analyzed for comparison.

RESULTS

Soil Analysis

The pH values for all three plant communities on the tailings showed the same general trend, with the lowest values occurring at the surface and the highest values found at greater depth. The range of pH values in the birch community was from 3.65 to 6.13, with a mean of 4.58. For the field community the values ranged from 4.27 to 6.49, with a mean of 5.17, and the conifer community had a range of 5.4 to 7.71, with an overall mean of 6.71.

Values for mean percent organic matter were highest at the surface for all three communities. The overall highest surface soil values were observed in the jack pine community, with the average value being 10.2% organic matter. The lowest values were in the field community, where the average value was 6.5%.

Significantly higher mean copper and nickel concentrations were found in the surface soils of the field community (approximately 1,000 µg/g of each element), than in those of the birch and pine communities (approximately 400 to 800 µg/g). There were no significant differences between the surface soil metal levels in the birch and pine communities, although there was a trend in which copper tended to be higher in the birch community and nickel in the pine community.

Calcium values in the surface soils were significantly higher in the jack pine and field communities than in the birch community. The calcium values ranged from approximately 1.6% to 2.4%. Magnesium values were significantly higher in the surface soils of the field community than in those of the jack pine and birch communities. The magnesium values ranged from 1.4% to 1.9% for all sample depths and sites.

In the case of surface soil sulphur concentrations, the highest mean values were observed in the birch community (3938 µg/g) and the field community (3504 µg/g). Lowest mean values were seen in the jack pine stand (1046 ppm). In the birch and field communities, the sulphur level was slightly lower in the deeper soil, whereas under pines it was slightly higher.

Phosphorus levels were higher in surface soil than subsurface soil, and significantly higher under grasses than under birch at both depths

Vegetative Structure

The total percent ground cover was found to be highest in the field community at approximately 98%, and lowest, 68%, in the birch community. The percent litter cover for each of the three communities differed in that the birch site had an accumulation (38% litter cover), whereas the other sites had very little cover in the way of litter (2.5-5.5%). However, when comparing the species diversity of the ground cover between the three sites, the birch community had a higher diversity than the other communities.

With respect to the shrub layer, the jack pine community had no species which fitted this criterion, all woody species being members of the tree layer. The birch community had 122 shrub-sized individuals, which were represented by five different species, and the field community had 3 shrub-sized trembling aspens.

Foliage Nutrient and Metal Levels

Foliar copper and nickel were higher on tailings than at the control sites. Copper levels were higher in jack pine, while nickel was higher in white birch. Sulphur levels in birch were typical for the Sudbury region, whereas those in jack pine were four times those in birch. In both species, manganese levels were 2 to 5 times higher in control leaves than in tailings leaves, despite the well-drained soil and the comparable soil levels at the control site

Foliar calcium and magnesium levels in birch were not significantly different on tailings and at the control site, but in jack pine both elements are significantly higher on the tailings. Despite the elevated level of some potentially toxic metals on the tailings, there were no visible signs of stress.

DISCUSSION

Although Inco Ltd.'s revegetation program has been successful in establishing an aesthetically pleasing vegetative cover on the CD tailings area, questions could be raised about the biodiversity and sustainability of the cover. In the jack pine community, no regeneration has occurred over the twenty-plus years since the trees were planted. However, in the birch community, the trees are actively regenerating, but a deep pad of leaf litter has developed, suggesting poor decomposition. Experiments are currently under way to investigate means of increasing both biodiversity and litter decomposition rate.

It is encouraging that, although there is evidence of elevated foliar metal levels, there are no visible signs of metal toxicity or stress.

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