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Unpublished Reports.

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Locator # WQMS81-005
Contribution # 81-005

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ABSTRACT

There is ample evidence of the release of potentially toxic metals from the Sudbury region of Ontario. However, insufficient information is available concerning the distribution of arsenic from atmospheric inputs in northern Ontario. This element is associated with smelting activities in other parts of Canada especially northern Manitoba and Yellowknife, N.W.T. Bog vegetation was chosen as indicator of this chemical input, since bogs receive their chemical inputs solely from atmospheric fallout. This alleviates problems associated with monitoring lake sediments and soils which can receive elemental inputs from their watershed.

An increase in arsenic concentration was found in bog vegetation near smelters, both at Sudbury and in the Timmins/Kirkland Lake, Ontario/Rouyn, Quebec areas. A distinct decrease in concentration occurred with distance. A comparison of arsenic levels between species examined at the same location indicated that the moss and lichen species were more efficient scavengers of arsenic than low shrubs. Concentrations determined in this study were above background data from more remote areas, especially in the Sudbury area where a 20x increase was noted in lichens. This study further confirms the use of bog vegetation as a sensitive indicator of elemental fallout.

INTRODUCTION

The region of northern Ontario (Fig. 1) in this study is one of the richest in mineral deposits in Canada. Arsenic amongst other elements occurs in sulphide ores. When these ores are smelted, large amounts of sulphur dioxide (Hutchinson and Whitby, 1973) and heavy metals are emitted into the atmosphere during the process.

Several studies during the last decade have investigated the long-range transport of heavy metals measuring elemental contents of mosses and lichens (Ruhling and Tyler, 1971; Folkeson, 1979). Bog vegetation such as mosses, lichens, and low shrubs were used in this study to evaluate their arsenic contents with respect to possible sources of pollution. Bogs were chosen over other ecosystems because they are ombrotrophic receiving chemical inputs strictly by atmospheric deposition. Interception losses by trees are thus minimized due to the nature of bog vegetation. Previous studies on the monitoring of heavy metals emission using vegetation from Sudbury, Ontario, were done on lichens by Nieboer et al.(1972), Freedman and Hutchinson (1980), and Glooschenko et al. (1981). However, no evidence is available about arsenic in vegetation due to atmospheric fallout. This study was done to determine the content of arsenic in various species of vegetation with respect to possible sources. Thus it will also establish a base line value for future studies.

MATERIALS AND METHODS

Bog sites shown in Fig. 1 were sampled in September, 1979. Species sampled include the mosses Sphagnum fuscum and Sphagnum capillaceum, a lichen (Cladonia spp.) and leaves of the low shrubs Chamaedaphne calyculata and Ledum groenlandicum. These bogs were located on an approximate northwest line between Sudbury and Fraserdale, Ontario, some 380 km to the north. Major mining centers represented in Fig. 1 include Sudbury and Timmins, Ontario, and Rouyn, Quebec.

All samples were collected by hand and sampling was done at least 0.1 km from the road to avoid possible contamination from nearby traffic. Plant samples were handled with disposable plastic gloves and stored in plastic bags in a cooler. Upon return to the laboratory, samples were oven-dried for 48 hrs. at 90-95°C and subsequently milled in a Wiley mill to 60 mesh (250 uM).

Wet digestion was performed on a 1.0 g sample of milled vegetation by using a combination of HNO_3: H_2SO_4 and H_2O_2 (Arafat and Glooschenko, 1981). Arsenic was determined by the hydride generation method of Goulden and Brooksbank (1974); the detection limits of this method is 0.1 ug l^{-1}. in the extract. All vegetation analyses are reported on a dry weight basis.

RESULTS AND DISCUSSION

Data from the vegetation analyses is represented in Fig. 2. Results were plotted versus distance from Sudbury, Ontario, which was assumed to be a major source of arsenic.

The lowest arsenic levels were found in *Ledum groenlandicum* and *Chamaedaphne calyculata* with an exception in the latter species at site 14 near Sudbury with a value of 2.3 ug g^{-1}. The range of concentration varied in these two species between 0.03–0.10 ug g^{-1} arsenic. Highest values were found in lichen *Cladonia* and mosses *Sphagnum capillaceum* and *Sphagnum fuscum*, with a concentration range of 0.11–0.25 ug g^{-1} arsenic.

The trend indicates higher arsenic concentration in Sudbury, decreasing with distance north, with increases near other potential sources such as at Timmins. Here, concentrations suddenly increased indicating a contribution of mining and smelting operations in Timmins, Kirkland Lake and the Rouyn area. No clear trend could be established relating arsenic to a specific source in this area.

A comparison of the results of several species examined shows that mosses and lichens have a better scavenging capacity when compared to species of the low shrubs examined. Comparing our results with others, Furr et al. (1979) found arsenic levels in mosses varied between 0.0–0.2 ug g^{-1} in the Adirondack mountains of New York State. Our values of 0.03–2.3 ug g^{-1} are higher than found in that study and probably are the results of smelter operations.

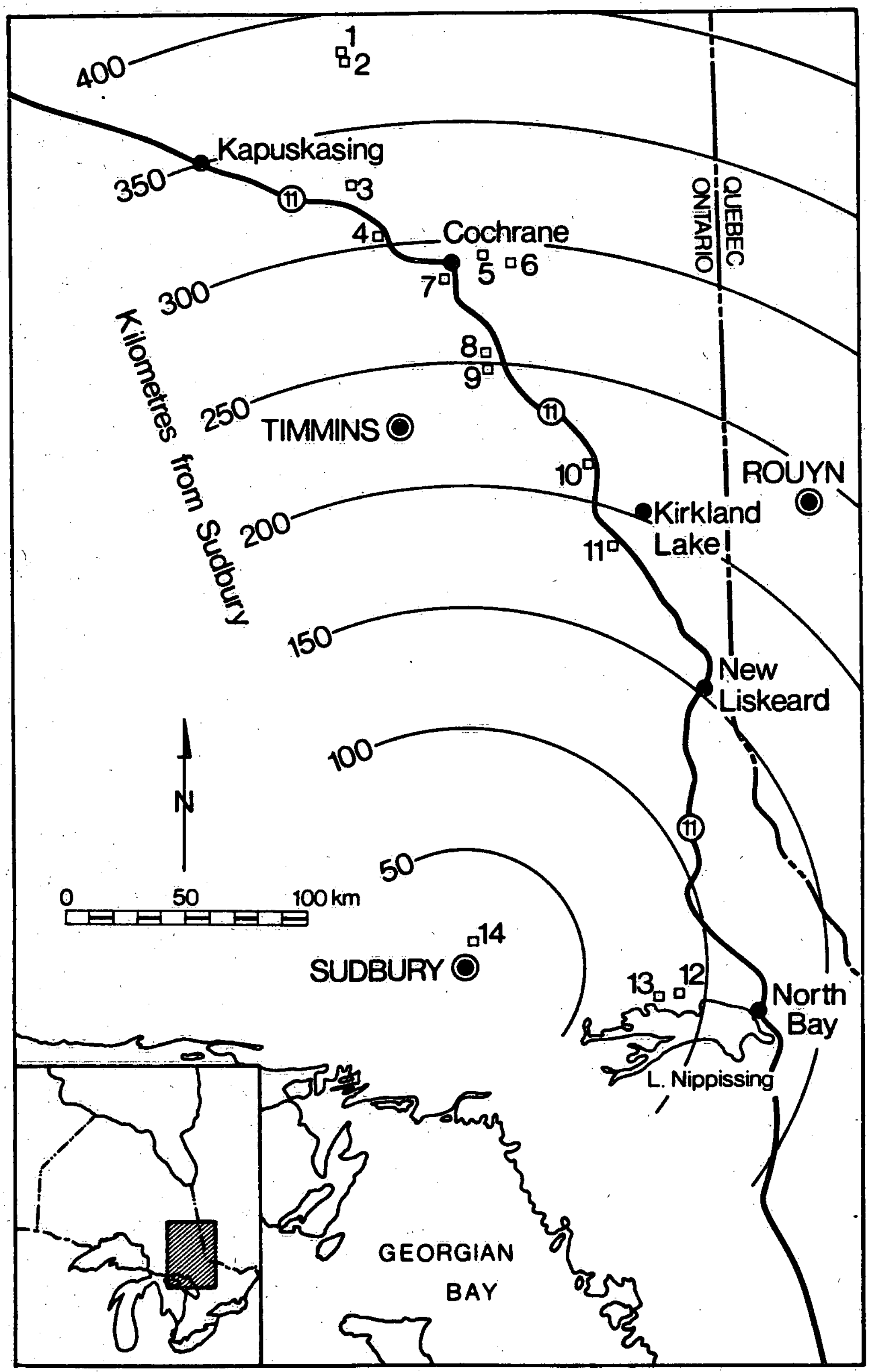
Three species of lichens collected in the Northwest Territories of Canada were analyzed for arsenic by Puckett and Finegan (1980). They found mean values of 0.26, 0.28, and 0.24 ug g^{-1} which are quite similar to background levels found in this study, except near sources.

In a study of arsenic contamination of lichens from the Yellowknife, N.W.T. area, Hocking et al (1978) analyzed lichens. Levels of arsenic as high as 11,438 ug g^{-1} were determined at a distance of 0.28 km from the smelter; concentrations were above 100 ug g^{-1} at 8.42 km, while at 45.23 km, levels were 38 ug g^{-1}. These levels are considerably higher than measured in the area of the present study.

In conclusion, our study indicates a major source of arsenic emissions in the Sudbury, Ontario, area with another source in the Timmins/Kirkland Lake/Rouyn, Quebec area. Levels of arsenic in vegetation were low however except in the Sudbury area. There, lichens analyzed were found to be at least 20 times the background concentrtion of arsenic found in more remote locations.

ACKNOWLEDGEMENT

The authors would like to express their appreciation to the Water Quality Branch in Burlington for their analysis; and Ms. Norma Snelling for typing the manuscript.



1
2
400
Kapuskasing
350
11
3
4
Cochrane
5
6
7
300
Kilometres from Sudbury
8
9
250
TIMMINS
10
ROUYN
Kirkland Lake
11
200
150
New Liskeard
100
N
50
0
50
100 km
14
SUDBURY
13
12
North Bay
L. Nippissing
GEORGIAN BAY
ONTARIO
QUEBEC

FIGURE 1.

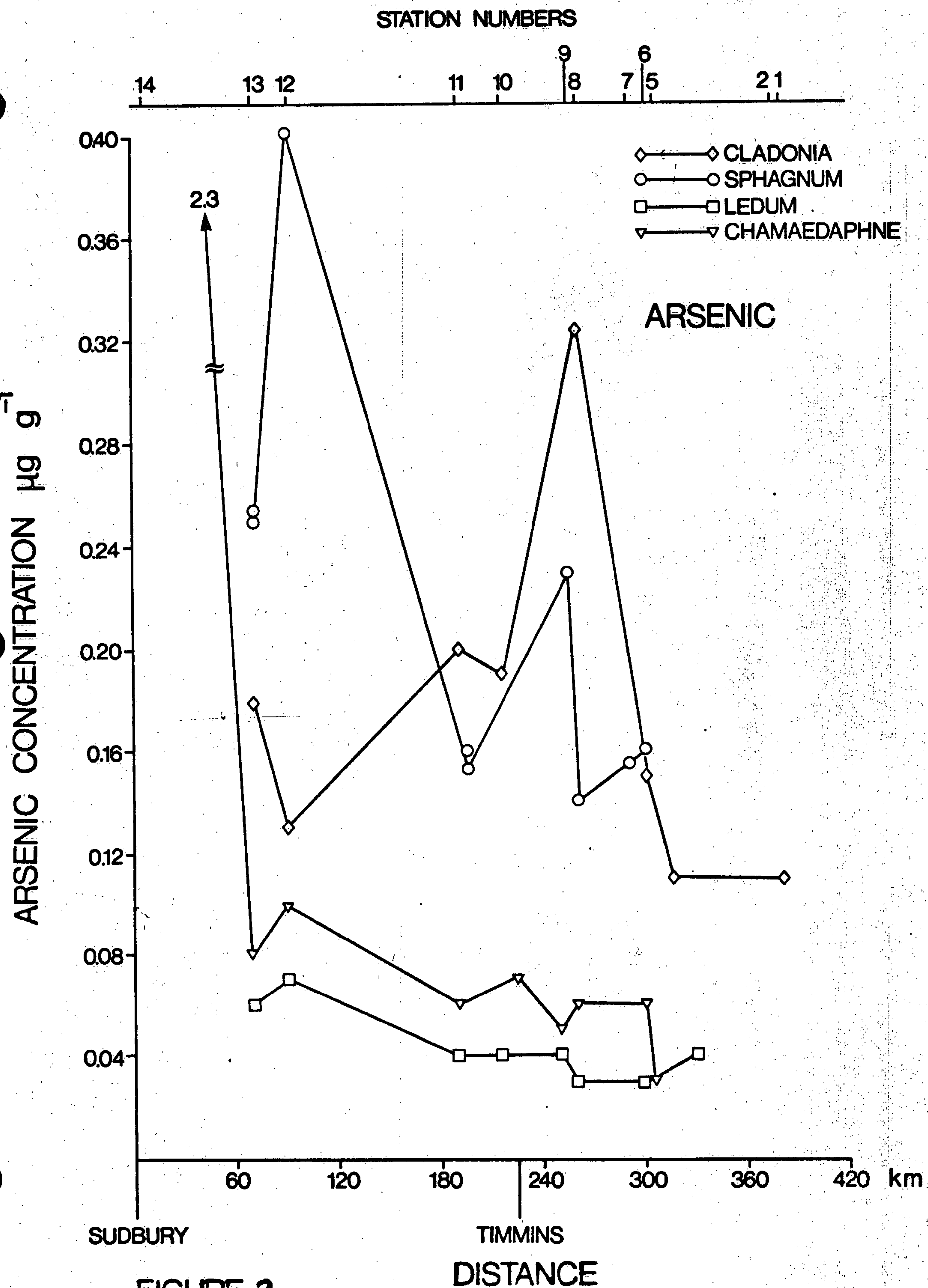

STATION NUMBERS
14
13 12
11
10
9
8
7
6
5
2 1
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
ARSENIC CONCENTRATION µg g-1
2.3
CLADONIA
SPHAGNUM
LEDUM
CHAMAEDAPHNE
ARSENIC
60
120
180
240
300
360
420
km
SUDBURY
TIMMINS
DISTANCE

FIGURE 2

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FIGURE CAPTIONS

Figure 1. Map of northern Ontario study area showing sampling sites 1-14.

Figure 2. Concentration of arsenic in various plant species as a function of distance from Sudbury, Ontario.