IMPACT OF SO_2 ON THE SOILS AND VEGETATION NEAR THE GIANT MINE, YELLOWKNIFE, NWT

by

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The effect of air pollution on the forest is a major concern in Canada. Serious ecological and economic consequences could result if forest decline as a result of pollutants were to occur. In North America, the influence of air pollutants has been shown to affect forest growth and survival in specific cases (ie point sources); however, with such large unmanaged areas, the evidence for regional air pollutant effects on forests is not that clear (Addison 1989).

Within the Northwest Region (Alberta, Saskatchewan, Manitoba, and Northwest Territories), Forestry Canada has done studies near the largest point source emitters of SO_2 including: the oil sands operations (Addison et al. 1986), sour gas processing plants in west-central Alberta (Addison et al. 1984; Maynard 1990) and the mining smelters in Flin Flon and Thompson, Manitoba (Hogan and Wotton 1984). Chronic effects of SO_2 on the forests near these point sources have been limited to elevated S concentrations in the foliage and soil within 5 km of the emission sources. Damage to trees has occurred as a result of acute fumigation of SO_2 such as gas well blowouts, elemental S block fires and excessive emissions due to plant malfunctions. There has been no evidence that soil acidity has increased as a result of the point source emissions at sites located > 4 to 5 km from any sources. In the oil sands area, lichens and mosses showed a response to SO_2 but changes in vascular plant communities could not be related to SO_2 deposition (Addison et al. 1986). Severe impact from point sources has been primarily related to other pollutants such as elemental S within 2 km of sour gas processing plants (Maynard 1990) and heavy metal accumulations within 10 km of mine smelters (Hogan and Wotton 1984).

In late July, early August 1989 the NWT Department of Renewable Resources received numerous calls from the public concerning discolored trees and premature leaf drop in areas north of the Giant Yellowknife Mine site. Yellowing of the older needles was observed again in June and early July of 1990 and by early August yellowing and premature senescence were observed in larch and deciduous trees north of the Giant mine site. Forestry Canada, Northwest region, Edmonton, was asked by the NWT Department of Renewable Resources to visit the area and collect vegetation and soil samples in order to determine if the visual symptoms reported north of the Giant Mine site could be the result of SO_2 emissions from the mine.

Materials and Methods

We visited the area suspected of SO_2 damage, July 12 and 13, 1990. Foliage samples were collected from 4 areas, 3 north of the Giant Mine (Vee Lake, Ranney Hill and Vee Lake road intersection) and one site west of Yellowknife as a control (Figure 1). Soil samples were collected at all but the Vee Lake location. Visual observations were made at these sites and a helicopter flight was taken to have a overview of the area north of the mine site. Additional soil and vegetation samples were collected at Ryan Lake as well as a site south of the Giant mine in late July (Sites 5 and 6, Figure 1). Towards the end of July visual symptoms began to appear on white birch, willow and larch along the Vee Lake road between the mine and Vee Lake. Foliage samples were collected at two new locations and additional samples were taken at Vee Lake.

The foliage and soil samples were brought to the laboratory and analyzed for various parameters using standard procedures of our analytical services laboratory. Foliar analysis included S, N, P, Ca, Mg, K, Mn, Al, and Fe. Several analyses were done on the soils including total and extractable S, pH, cation exchange capacity and exchangeable Ca, Mg, Na, and K. Total analysis of the soil was also done.

Results and Discussion

Yellowing of older black spruce needles was observed on July 12 and 13, 1990 at most sites including the control area west of Yellowknife. Little or no yellowing was observed on jack pine except at site 3, (Vee Lake Road intersection) about 1 km from the stack. These symptoms were not highly specific and could have been the result of either air pollution damage or abnormal climatic conditions, such as drought (Malhotra and Blauel 1980). Drought conditions have persisted in the Yellowknife area for the growing seasons of 1989 and 1990. The moisture content of the soil collected during 1990 was very low (Table 1) and would also suggest that drought conditions were widespread.

No widespread foliar symptoms were seen on the deciduous species or larch on July 12 or 13. Aerial observations indicated a low lying area near Ryan Lake containing larch appeared to be stressed and yellowing of the leaves in deciduous trees was also observed at the Vee Lake road intersection 1 km from the stack. Widespread yellowing and leaf fall in deciduous trees and larch, however, were observed later in July and early August by NWT Department of Renewable Resources personnel along the Vee Lake Road between the lake and the mine site. Again yellowing and premature leaf fall is not specific to air pollution injury and could have resulted from drought conditions.

The visual observations were not conclusive. Two general observations point to drought as being the primary cause of the widespread symptoms observed while specific observations at the Vee Lake road intersection, 1 km from the stack would indicate that SO_2 injury might be the primary cause. Deciduous species generally develop air pollutant symptoms more rapidly than conifers (Malhotra and Blauel 1980). If SO_2 was the primary cause of the visual symptoms it would be expected to appear first or at least at the same time as symptoms on the black spruce. In addition, jack pine is generally more drought tolerant than black spruce. Yellowing on black spruce and not on jack pine, suggests the widespread symptoms were primarily drought related. In contrast, at the Vee Lake Road intersection discoloration was evident on all tree species in the area including jack pine and trembling aspen. In addition, the yellowing of the older black spruce needles at this site appeared to be greatest on the side of the tree facing the stack. These two observations would suggest, that at least at the Vee Lake Road intersection, SO_2 was involved.

The results of the soil and foliar analysis are given in Tables 1 and 2. Since the visual symptoms were not specific to air pollution damage it was hoped that the foliar analysis, in particular, could verify if S deposition had occurred at these sites. The soil chemistry was determined to assess the ability of the soil to buffer S additions and possibly to determine if there was any accumulation of S.

All the surface organic (LFH) samples had moisture contents of 20 to 30 % moisture except one subsurface organic horizon from the low area of Ryan Lake (Table 1). Organic soils in general have high water holding capacity with moisture contents often exceeding 200% moisture. The low moisture content of the soils indicates the trees were likely under moisture stress and had been for some time.

The cation exchange capacity (CEC) and exchangeable bases of the mineral soils were low (< 6 cmol(+) kg^{-1}; Table 1). The soils were shallow and discontinuous with the underlying bedrock in the area being noncarbonate. The surface organic horizons had higher CEC and exchangeable bases but were not very deep. With two exceptions, the soils sampled had low potential to reduce acidity of atmospheric deposition (Environment Canada 1986), even though the soils presently contain typical amounts of exchangeable Ca, Mg, and K.

The soils at the Vee Lake road intersection and in the low Ryan Lake site were the exceptions with pH > 6.0 and high concentrations of Ca. The soils at the Vee Lake road intersection could either be an anomaly (there are carbonate bearing parent material in the NWT; Environment Canada 1986) or the result of contamination either from mine activity or road dust. The Ryan Lake site was located in a low area and was likely accumulating Ca even though the surrounding soils are generally low in base cations.

The S concentrations of the soils at the sites north of the Giant mine were higher than either site south and west of the mine. This could have been a result of S deposition to the soil. This seems surprising when compared to S deposition rates from larger S sources and the lack of S accumulation in the soils near them (eg Addison et al. 1986); however, the gas temperature and the low height of the Giant mine stack has probably resulted in less dispersion than would be typical from the taller heated stacks of the mining smelters and sour gas processing plants. The results of Alberta Environment modelling exercise using the STACK2 model indicated ground level SO_2 concentrations (hourly basis) would exceed the maximum permissible levels (0.17 ppm) for Alberta by 7 times at 1.3 km from the Giant mine stack. In comparison, the same model predicted tree top levels of SO_2 concentrations (hourly average) < 0.17 ppm for the Ram River sour gas processing plant, with emissions of 53.5 t/d of SO_2, almost double that of the Giant mine (Concord Scientific Corp 1990). Aside from the differences in terrain, the stack height (91.4 vs 45.7 m) and gas temperature (440 vs 82 ^{o}C) from the Ram River incinerator stack would disperse the SO_2 over a larger area. Therefore, it is possible that in areas within 5 to 10 km of the Giant mine stack SO_2 deposition could be higher than in the vicinity of point sources with higher annual SO_2 emission rates.

It is also possible the high soil S concentrations found at the Vee Lake Road intersection, Ranney Hill and Ryan Lake sites were characteristic for this area. If S deposition was responsible for the high soil S concentrations at these sites above normal concentrations would have been expected in the foliage. The foliar S concentrations at these sites, however, were similar to those found at other non-polluted areas. Further sampling of the soils in the area, would be needed to assess whether the apparently high soil S levels north of the Giant mine were directly related to S deposition.

The foliar S concentration of the white birch samples provide the best evidence for S deposition north of the Giant mine. The S concentrations of the white birch follow a gradient with the highest concentrations closest to the stack (site 8, 2.2 km) and the lowest concentrations at Ryan Lake (10.8 km)(Table 2). Typical concentrations of S in white birch have been reported to range from 1.0 - 1.6 g kg^{-1} at background sites near Sudbury, Ont. (Lozano and Morrison 1981) to 2590 $\pm$ 300 g kg^{-1} at background sites in Norman's Cove, Nfld (Sidhu, 1983; unpublished data). Sulfur concentrations in white birch showing SO_2 damage near a SO_2 source in Newfoundland ranged from 2.4 to 4.6 g kg^{-1} (Sidhu and Singh 1977). Using these values as guidelines, sites 7 and 8 (within 4 km of the stack) would have S concentrations in the white birch where SO_2 damage to the foliage be expected. Sulfur concentrations in larch and willow at these two sites were also above what would be expected. The S concentrations in white birch at Vee Lake were borderline and concentrations at Ryan Lake were similar to background levels in birch reported elsewhere.

Conclusions

The results of the visual survey and chemical analysis indicate that there are at least two factors contributing to the symptoms observed on the trees north of the Giant mine. There is no question that drought conditions have contributed to the widespread yellowing of the black spruce needles and premature yellowing and leaf fall in larch and deciduous species. The soil moisture content and the extent of area affected would eliminate SO_2 as the sole cause; however, in areas within 5 km of the Giant mine stack, along the Vee Lake Road, SO_2 may be contributing to the symptoms being reported. The increasing S concentration in the white birch from Ryan Lake (10.8 km) to site 8 (2.2 km) is a fairly convincing argument that S deposition is occurring in these areas. The difficulty is in trying to separate the symptoms caused by natural stresses from those caused by SO_2. In addition to drought and SO_2, the poor nutrient (Mg and K) status of these sites because of shallow soils derived from noncalcareous bedrock could also be contributing to the premature yellowing and leaf (needle) fall.

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Table 1: Soil chemical characteristics from five locations near the Giant Mine, Yellowknife NWT.

SITE	pH	MOISTURE %	TOTAL S g kg^{-1}	EXTRACTABLE SO_4 mg kg^{-1}	CEC[1]	EXCHANGEABLE Ca	Mg	K
					------cmol(+) kg^{-1}	--------		
Site 4 -Control								
LFH[2]	4.4	17	0.46	14.2	16.7	7.1	2.3	0.9
MIN	5.3	7	0.15	2.6	4.1	1.8	0.4	0.1
Site 6 - South								
LFH	5.0	8	0.83	35.0	36.3	26.6	5.0	0.6
MIN	4.8	3	0.25	11.6	7.7	2.9	0.7	0.2
Site 5 - Ryan Lake								
LFH - High	4.6	18	1.81	56.5	54.4	43.8	3.8	1.4
MIN - High	4.4	15	0.98	27.6	33.6	19.0	1.3	0.6
LFH - Low	4.8	28	1.37	40.3	63.6	49.0	8.1	9.3
LFH - Low[3]	6.6	94	7.37	64.7	160	140	7.6	0.2

[1]CEC - Cation exchange capacity

[2]LFH - Surface organic soil horizon

[3]This sample was taken below the LFH low sample and was originally designated a mineral soil

Table 1 (Cont.): Soil chemical characteristics from five sites near the Giant Mine, Yellowknife, NWT.

SITE	pH	MOISTURE %	TOTAL S g kg^{-1}	EXTRACTABLE SO_4 mg kg^{-1}	CEC[4]	EXCHANGEABLE Ca	Mg	K
					------cmol(+) kg^{-1}	--------		
Site 2 - Ranney Hill								
LFH - JP[5]	4.1	26	2.93	146	42.7	13.4	3.2	1.6
MIN - JP	5.0	30	5.21	36.0	14.0	1.9	0.6	0.3
LFH - BS[6]	4.3	24	1.68	66.7	39.4	15.6	2.1	0.8
Site 3 - Vee Lake Road Intersection								
LFH	6.2	15	1.82	90.9	92.2	91.2	12.5	1.0
LFH	5.8	23	3.31	172	103	92.2	10.2	0.7
MIN	6.6	3	0.20	6.2	48.9	10.0	0.8	0.1

[4]CEC - Cation exchange capacity

[5]JP - Sample taken under jack pine tree

[6]BS - Sample taken under black spruce tree

Table 2: Total S concentration ($g\ kg^{-1}$) in the vegetation at 8 sites near the Giant Mine, Yellowknife, NWT.

SITE	Black Spruce	Jack Pine	White Birch	Other[7]
Site 4 - Control				
Deep Soil	1.04	0.49	---	---[8]
Outcrop	1.38	1.01	---	---
Site 6 - South	1.21	---	---	---
Site 2 - Ranney Hill	0.88	0.95	---	---
Site 5 - Ryan Lake				
High Site	1.26	---	1.08	---
Low Site	1.17	---	---	---
Site 1 - Vee Lake				
July 12	1.51	---	---	---
Aug. 2	1.73	---	2.84	---
Site 7 - 3.2 km	---	---	3.46	4.37
Site 8 - 2.2 km	---	---	4.16	5.36
Site 3 - Vee Lake Rd. Intersection				
Tree 1 - Facing[9]	1.37	1.13	---	---
Tree 1 - Opposite	1.09	---	---	---
Tree 2 - Facing	0.91	---	---	---
Tree 2 - Opposite	0.94	---	---	---

[7]Site 7 - Larch and Site 8 - Willow

[8]No sample

[9]Samples were taken on two sides of two black spruce trees. One sample was taken on the side facing the stack and the other on the side opposite the stack.

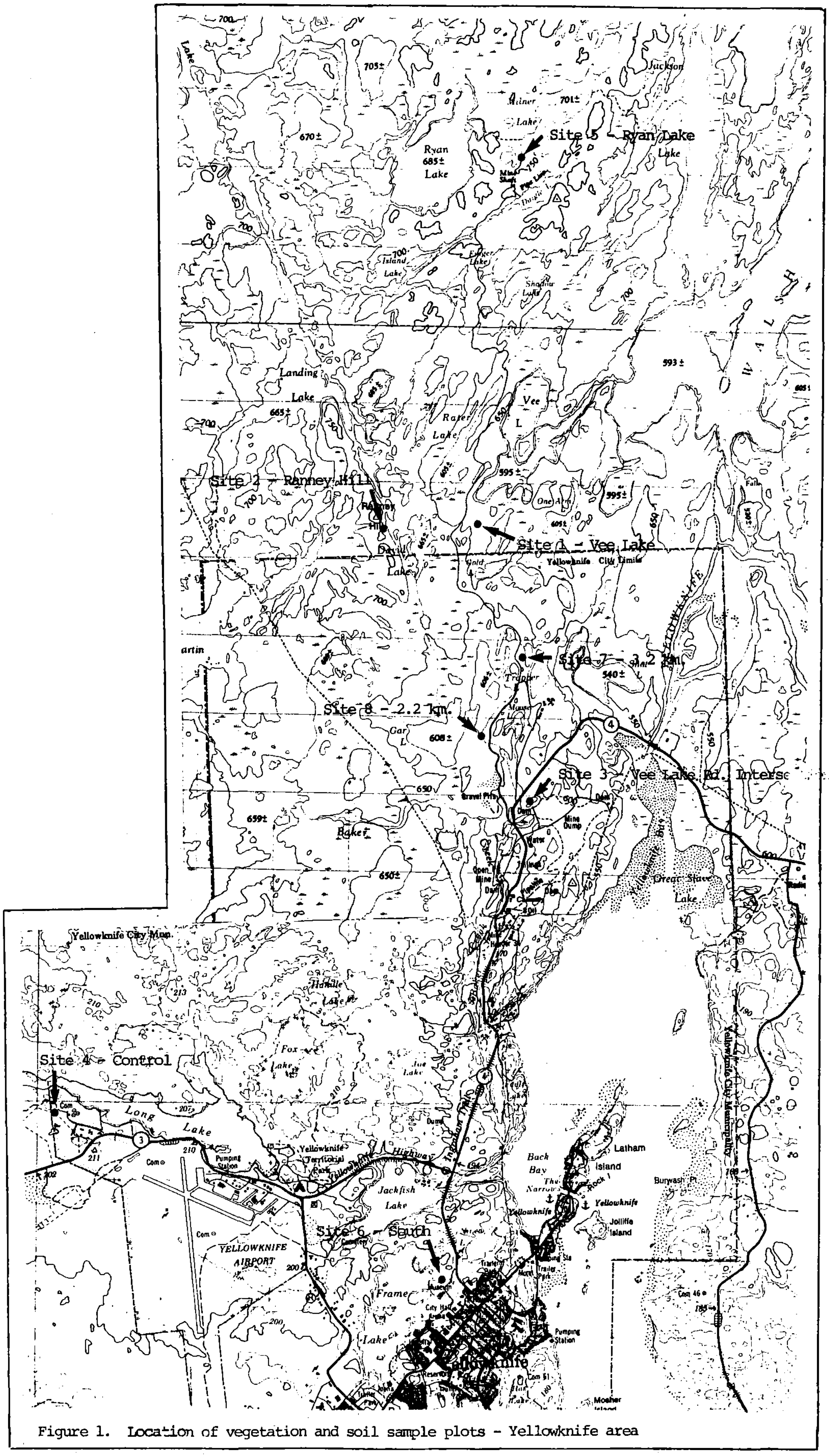

Figure 1. Location of vegetation and soil sample plots - Yellowknife area