ALBERTA OIL SANDS
ENVIRONMENTAL
RESEARCH PROGRAM

Symptomology and Threshold Levels of Air Pollutant injury to Vegetation, 1979-80

Project LS 3.1

December 1980

Alberta
ENVIRONMENT
15th Floor, Oxbridge Place
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Edmonton, Alberta, Canada
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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program. This program was designed to direct and co-ordinate research projects concerned with the environmental effects of development of the Athabasca Oil Sands in Alberta.

A list of research reports published to date is included at the end of this report.

Enquiries pertaining to the reports in the series should be directed to:

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Symptomology and Threshold Levels of Air Pollutant Injury to Vegetation, 1979-80

Project LS 3.1

AOSERP Report 109

This report may be cited as:

Malhotra, S.S., P.A. Addison, and A.A. Khan. 1980. Symptomology and threshold levels of air pollutant injury to vegetation, 1979-80. Prep. for the Alberta Oil Sands Environmental Research Program by Northern Forest Research Centre, Canadian Forestry Service. AOSERP Report 109. 17 pp.

The Hon. J.W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

Sir:

Enclosed is the report "Symptomology and Threshold Levels of Air Pollutant Injury to Vegetation, 1979-80".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Land System, under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

SYMPTOMOLOGY AND THRESHOLD LEVELS OF AIR POLLUTANT INJURY TO VEGETATION 1979-80

DESCRIPTIVE SUMMARY

Forest vegetation near oil sands operations in northeast Alberta has been subjected to varying levels of airborne-pollutants for approximately 13 years. There is as yet no apparent damage to the forest ecosystem because of emissions characteristic of oil sands operations; however, the long-term effects of increasing emissions from industrial developments in this area are not thoroughly understood.

The objectives of this study were to screen the plant species collected from the Suncor tailings sand dike for SO_2 tolerance and to compare the ability of the native species to survive on undisturbed soils, both under adverse atmospheric pollution conditions.

Several plant species, such as white spruce [*Picea glauca* (Moench) Voss], black spruce [*Picea mariana* (Mill) BSP] jack pine (*Pinus banksiana* Lamb.), basford willow (*Salix fragilis* var. *basfordiana* Redham), and trembling aspen (*Populus tremuloides* Michx.), were collected from the Suncor tailings sand dike, which is located in the zone of maximum air pollution impingement, and studied further under controlled environmental conditions. These species were selected for SO_2 tolerance experiments because they had successfully established on the tailings sand dike.

The results indicated that the coniferous trees (jack pine and white and black spruce) grown in tailing sands were much more sensitive to SO_2 injury than those grown in native soils.

This report has been reviewed and accepted by the Alberta Oil Sands Environmental Research Program.

W.R. MacDonald
Director

SYMPTOMOLOGY AND THRESHOLD LEVELS OF AIR POLLUTANT INJURY TO VEGETATION, 1979-80

by

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ALBERTA OIL SANDS

ENVIRONMENTAL RESEARCH PROGRAM

Project LS 3.1

December 1980

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ABSTRACT

A number of coniferous and deciduous species that had been growing on the Suncor tailings sand dike for five to seven years were fumigated with 0.34 ppm SO_2 under controlled environmental conditions. The results obtained were compared with those from similar fumigations of the same species grown in "uncontaminated" native soils. The coniferous species (*Pinus banksiana, Picea glauca,* and *Piecea mariana*) grown in tailings sand were much more sensitive to SO_2 injury than those grown in native soils (Dystric Brunisol). They required approximately half as much fumigation time to exhibit physiological and visual injury even though they were collected less than 30 km apart. The woody angiosperms (*Populus tremuloides, Caragana arborescens,* and *Salix* sp.) were not ranked due to a pollution chamber breakdown during the experiment. No additional plant material was available to repeat this experiment.

ACKNOWLEDGEMENTS

This research project LS 3.1 was funded by the Alberta Oil Sands Environmental Research Program that was established to fund, direct, and co-ordinate environmental research in the Athabasca Oil Sands area of northeastern Alberta. The authors thank P.A. Hurdle, R. Blundon, and F. Theriault for technical assistance.

1. INTRODUCTION

Forest vegetation near oil sands operations in northeastern Alberta often has been subject to varying levels of airborne pollutants for 12 to 13 years. At present, there appears to be very little or no damage to the forest ecosystem that can be attributed to emissions characteristic of the oil sands operation. Increased emissions from the expanding industrial development in the area, however, eventually may have a serious impact on the forest system.

In previous years, a number of dominant species from undisturbed soils outside the "air pollution impingement zone" of oil sands operations were fumigated with SO_2 and ranked according to pollutant sensitivity (Malhotra and Addison 1979; Addison and Malhotra 1980). The ranking was done on the basis of visual and physiological responses to SO_2 fumigation at 0.34 ppm. Such ranking is a prerequisite for the interpretation of air pollution injury to vegetation and subsequent changes in species composition in the field.

The objectives of this study in 1979-80 were:

1. To screen plant species provided by Alberta Oil Sands Environmental Research Program (AOSERP) for their tolerance to SO_2; and
2. To rank the species according to their ability to survive in a combination of adverse soil and atmospheric pollution conditions.

Plant material was to be made available from the Suncor Inc. tailings dike and from those grown by various Alberta Government agencies on other disturbed soils.

2. MATERIALS AND METHODS

2.1 PLANT COLLECTION AND GROWING CONDITIONS

Several plant species such as white spruce [*Picea glauca* (*Moench*) Voss], black spruce [*Picea mariana* (Mill)], jack pine (*Pinus banksiana* Lamb.), caragana (*Caragana arborescens* Lam.), basford willow (*Salix* sp.), and trembling aspen (*Populus tremuloides* Michx.) were collected from the Suncor tailings sand dike (Figure 1). This dike is located in the zone of maximum air pollution impingement (Barrie and Whelpdale 1978). All of the above species had been made available to Suncor by the Alberta Forest Service for revegetation purposes about five to seven years previously. White spruce, black spruce, and jack pine seedlings were about one year old when transplanted on the dike in May 1975; aspen and basford willow were also about one year old when transplanted in July 1974 and June 1976, respectively; and caragana was about two years old at the time of transplanting in May 1972. A large number of woody species were tested on the dike. The above species, however, were selected for SO_2 tolerance experiments because they had proved to be the only species to establish successfully on the tailings sand dike.

These species were potted in dike soil and were grown under greenhouse conditions (ca. 20°C and 50% RH) with supplemental light (photoperiod of 18 h) for 7 to 8 mo before being transferred into a controlled environment chamber for experimentation.

Plants in native soils (Degraded Dystric Brunisol) were collected from the Fort MacKay area (Figure 1) and treated in a similar manner as those from the dike (Addison and Malhotra 1980).

Attempts were made to obtain through AOSERP more plant species grown on disturbed soils but none was available from the various provincial agencies involved in revegetation projects.

2.2 SO_2 FUMIGATION AND MEASUREMENT OF PHOTOSYNTHESIS AND RESPIRATION

The plants were held in the controlled environment chamber in clean air for 10 d for equilibration with chamber conditions and to determine the prefumigation net assimilation rates (NAR). After this

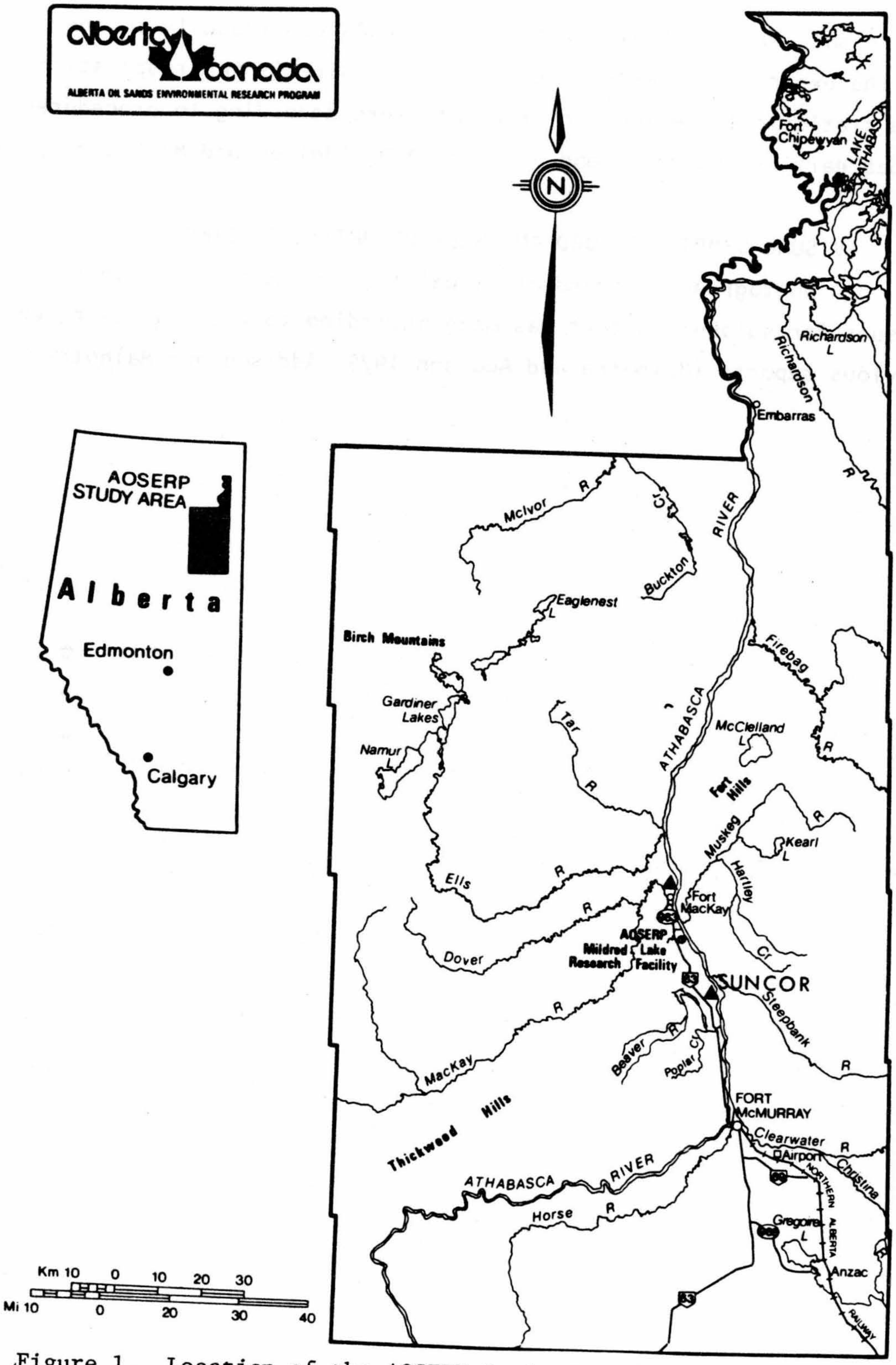

Figure 1. Location of the AOSERP Study Area showing collection locations for plant material. ▲s indicate sampling points for plant material.

period, plants were fumigated with 0.34 ppm SO_2 continuously to the end of the experiment. Measurement of photosynthesis and respiration and the statistical treatment of the data were according to procedures described earlier (Malhotra and Addison 1979; Addison and Malhotra 1980).

2.3 VISUAL SYMPTOM RECORD AND SULPHUR UPTAKE STUDIES

A photographic record of visual injury symptoms and analyses of tissues for sulphur content was made according to methods described in previous reports (Malhotra and Addison 1979; Addison and Malhotra 1980).

3. RESULTS AND DISCUSSION

3.1 PHYSIOLOGICAL RESPONSES

3.1.1 Coniferous Species

Maximum, minimum, and average CO_2 assimilation rate (NAR) changes of jack pine, white spruce, and black spruce caused by 0.34 ppm SO_2 fumigation are shown in Figure 2. NAR is defined as the difference between gross photosynthesis and dark respiration. The solid line represents the average response and was determined through regression analysis against time (three replicates for each of the five sampling times). Maximum and minimum responses, on the other hand, are actual case histories.

All three coniferous species responded very rapidly and sharply to SO_2 exposure. It took only 15 to 20 d of fumigation to almost completely inhibit net photosynthesis of all three species grown on tailings sand (Figures 2 and 3). The same species grown on uncontaminated native soils under virtually identical conditions had a much slower response (Addison and Malhotra 1980).

The regression coefficient of NAR versus time for each species grown on tailings sand during SO_2 fumigation was significantly different from zero ($p<0.05$) and was negative, indicating that NAR decreased with time (Table 1). These slopes, however, were not significantly different from one another ($p<0.05$), suggesting that all three species grown on tailings sand responded in a similar way to SO_2 fumigation.

The differences among the three species in the maximum and minimum NAR responses during fumigation were variable (Figure 2). The largest difference was observed in jack pine followed by much smaller differences in white and black spruce, which were about the same. Jack pine grown on "uncontaminated" native soils produced a more uniform NAR response to SO_2 than the ones grown on tailings sand. Tailings sand appears to cause a more variable NAR response to SO_2 fumigation in jack pine than the other two coniferous species. This difference may be due to the influence of toxic materials in the tailings sand.

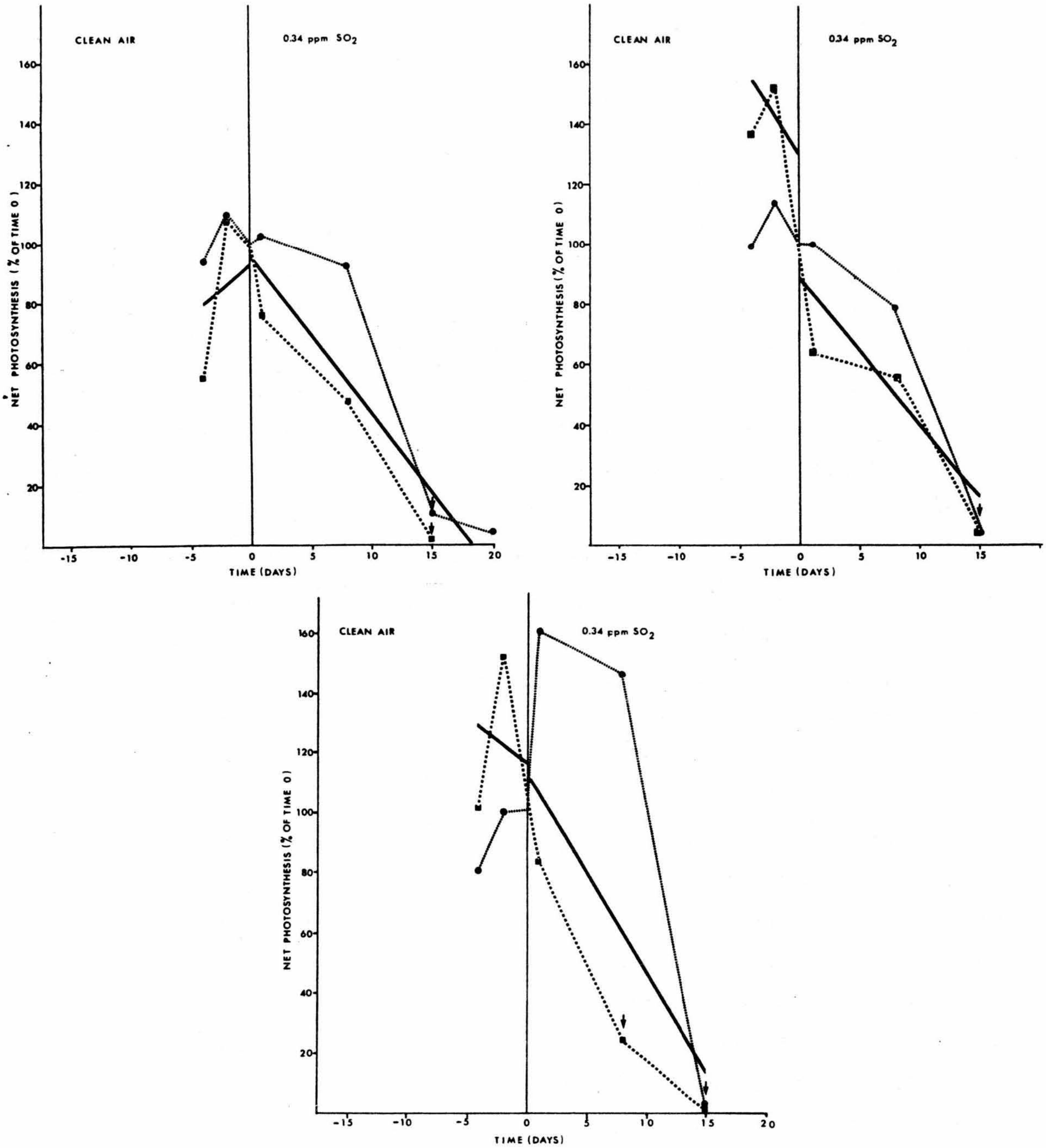

Figure 2. Maximum (••••••), minimum (··········), and average (▬▬) responses of relative net CO_2 assimilation rates of white spruce (a), black spruce (b) and jack pine (c) in tailings sand both before and during fumigation with 0.34 ppm SO_2 under controlled conditions. Arrows mark the time of first visual symptom observation.

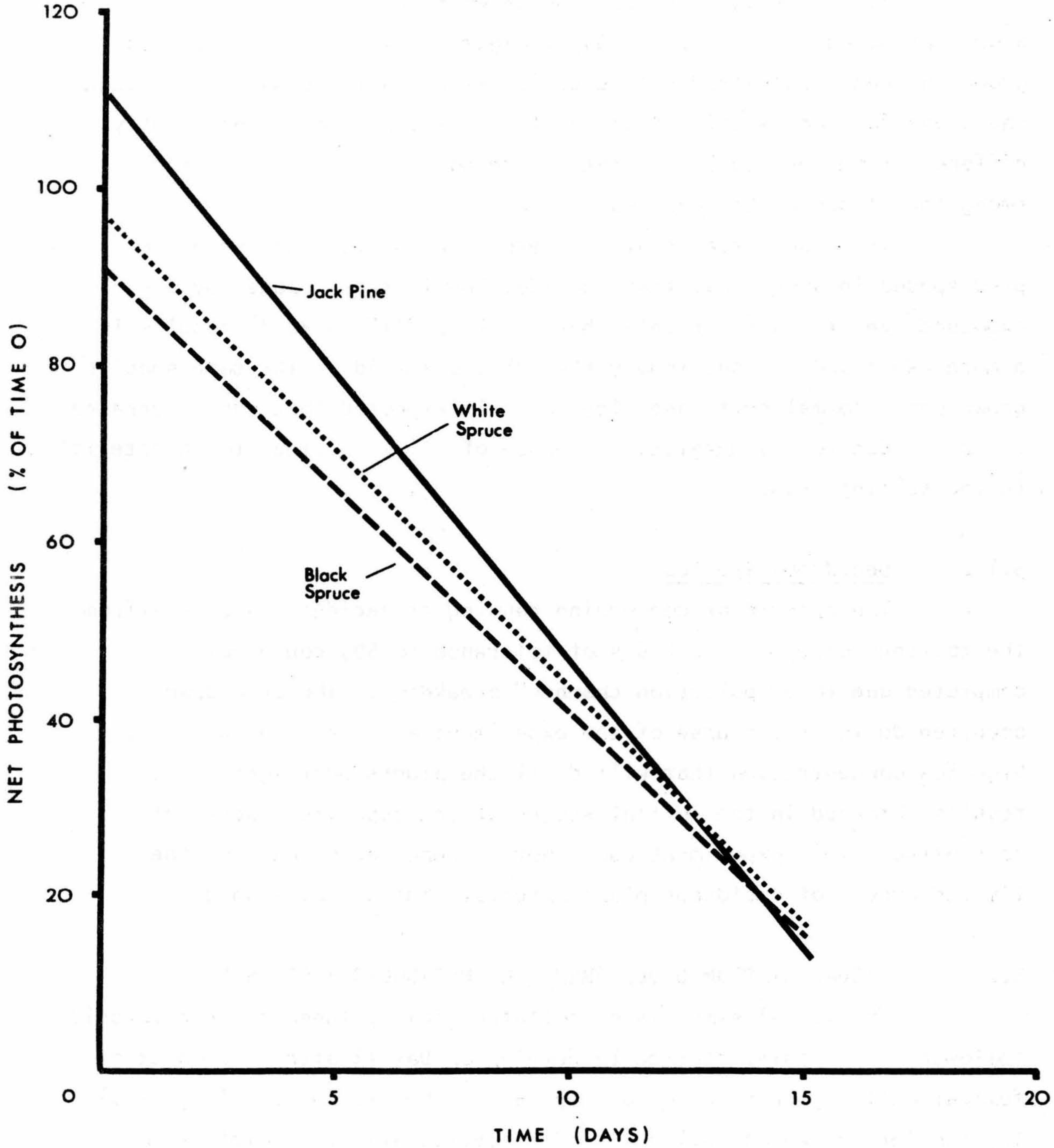

Figure 3. Regression lines of relative net CO_2 assimilation rate versus time for three boreal forest coniferous species during fumigation with 0.34 ppm SO_2 under controlled conditions.

Table 1 shows a comparison between regression coefficient slopes produced in response to SO_2 fumigation by coniferous species grown on "uncontaminated" native soils versus tailings sand. Although the slope for each species from the two soil types was significantly different from Zero ($p<0.05$), there were no significant differences among the slopes within each soil type.

It is suggested that conifers grown on tailings sand are predisposed in such a way that the additional stress caused by SO_2 exposure even for a relatively short duration (15 to 20 d) results in a more rapid and serious innury than that observed in the same species grown under normal soil conditions. It is expected that such increased injury is due to a synergistic response of SO_2 with other toxic materials in the tailings sand.

3.1.2 Deciduous Species

The experiment concerning ranking of deciduous species (from the tailings dike) on the basis of tolerance to SO_2 could not be completed due to a "pollution chamber" breakdown. The breakdown occurred during the course of the experiment and resulted in a very high SO_2 concentration that killed all the plants overnight. The results obtained in the initial stages of the experiment were not conclusive. This experiment could not be repeated because of the limited amount of deciduous plant material that was available.

3.2 VISUAL SYMPTOM DEVELOPMENT AND METABOLIC RESPONSES

The visual symptoms of pollutant injury (needle tip chlorosis followed by necrosis) started to develop on Day 13 after the onset of fumigation for jack pine and on Day 15 for the two spruces (Figure 2). The conifers grown on tailings sand exhibited almost a complete loss of NAR prior to visual symptom development of SO_2 injury. In plants grown in native soils, the reduction in NAR in response to SO_2 was much less before visual symptom development (Addison and Malhotra 1980).

Table 1. Slope (regression coefficient) of the change in net CO_2 assimilation rate (NAR) with time during fumigation with 0.34 ppm SO_2. Negative signs indicate a reduction in NAR with time. Units are percentage of maximum NAR decrease per day. Group 1 conifers were grown on "uncontaminated" native soils, whereas Group 2 conifers were grown on tailings sand.

Group	Species	Fumigation Slope	
1	Jack pine	-1.30[a]	[b]
	White Spruce	-2.02[a]	
	Black Spruce	-1.69[a]	
2	Jack pine	-6.53[a]	[b]
	White spruce	-5.22[a]	
	Black spruce	-4.96[a]	

[a] Slope is significantly different from zero ($p<0.05$).

[b] Vertical lines join slopes that are not significantly different from each other ($p<0.05$) by the Simultaneous Test Procedure.

These results suggest that, in terms of physiological activity, the plants grown on "uncontaminated" native soil can withstand SO_2 exposure more effectively than the ones grown on tailings sand. The physiological response and visual symptom development of plants grown on tailings sand was similar to list of plants grown on uncontaminated soils and these responses appeared to be related to tissue sulphur content.

4. CONCLUSIONS AND RECOMMENDATIONS

The results obtained from previous studies indicated that, when plants are grown under normal soil conditions, deciduous species are more sensitive to SO_2 (0.34 ppm) injury than the coniferous ones (Addison and Malhotra 1980). All deciduous species were similar with respect to both physiological and visual sensitivities. Among conifers, jack pine is more sensitive than either white or black spruce.

Coniferous species grown on tailings sand, however, exhibit remarkably different sensitivities to SO_2 exposures as compared with the same species grown on "uncontaminated" native soils. It took less than half the fumigation time to almost completely inhibit photosynthesis and cause severe injury to conifers grown in tailings sand as compared with those grown in native soils.

It is suggested that the plants grown on tailings sand, which may contain toxic materials and possibly lack balanced nutrition, may be predisposed in such a manner that they display decreased resistance to SO_2 even after relatively short exposures (15 to 20 d). It is quite likely that exposures of plants to a combination of SO_2 and certain toxic substances in the tailings sand may have caused a synergistic response. Since pollutants exist as mixtures in industrial aerial emissions, a study of the combined effects of various gaseous and particulate pollutants would be the most logical extension of this work. The SO_2 dose (concentration X exposure time) required to produce a significant injury to tailings-dike-grown coniferous species was considerably higher than that normally experienced in the oil sands area. It is anticipated, therefore, that significant injury to such plant species on the tailings sand may not occur under normal conditions. In view of dramatic differences in the response to SO_2 fumigation of coniferous species grown on two different types of soils, it is strongly recommended that any future screening of oil sands revegetation species for their tolerance to air pollutants be carried out on plants grown on disturbed soils (tailings sand).

5. REFERENCES CITED

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6. LIST OF AOSERP RESEARCH REPORTS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
3.	HE 1.1.1	Structure of a Traditional Baseline Data System
4.	VE 2.2	A Preliminary Vegetation Survey of the Alberta Oil Sands Environmental Research Program Study Area
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15.	ME 3.4	A Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area
16.	ME 1.6	The Feasibility of a Weather Radar near Fort McMurray, Alberta
17.	AF 2.1.1	A Survey of Baseline Levels of Contaminants in Aquatic Biota of the AOSERP Study Area
18.	HY 1.1	Interim Compilation of Stream Gauging Data to December 1976 for the Alberta Oil Sands Environmental Research Program
19.	ME 4.1	Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area
20.	HY 3.1.1	Characterization of Organic Constituents in Waters and Wastewaters of the Athabasca Oil Sands Mining Area
21.		AOSERP Second Annual Report, 1976-77
22.		Alberta Oil Sands Environmental Research Program Interim Report to 1978 covering the period April 1975 to November 1978
23.	AF 1.1.2	Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout
24.	ME 1.5.2	Air System Winter Field Study in the AOSERP Study Area, February 1977.
25.	ME 3.5.1	Review of Pollutant Transformation Processes Relevant to the Alberta Oil Sands Area

26.	AF 4.5.1	Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
27.	ME 1.5.1	Meteorology and Air Quality Winter Field Study in the AOSERP Study Area, March 1976
28.	VE 2.1	Interim Report on a Soils Inventory in the Athabasca Oil Sands Area
29.	ME 2.2	An Inventory System for Atmospheric Emissions in the AOSERP Study Area
30.	ME 2.1	Ambient Air Quality in the AOSERP Study Area, 1977
31.	VE 2.3	Ecological Habitat Mapping of the AOSERP Study Area: Phase I
32.		AOSERP Third Annual Report, 1977-78
33.	TF 1.2	Relationships Between Habitats, Forages, and Carrying Capacity of Moose Range in northern Alberta. Part I: Moose Preferences for Habitat Strata and Forages.
34.	HY 2.4	Heavy Metals in Bottom Sediments of the Mainstem Athabasca River System in the AOSERP Study Area
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43.	TF 6.1	A Socioeconomic Evaluation of the Recreational Fish and Wildlife Resources in Alberta, with Particular Reference to the AOSERP Study Area. Volume I: Summary and Conclusions
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45.	VE 3.3	Interim Report on Physiology and Mechanisms of Air-Borne Pollutant Injury to Vegetation, 1975 to 1978
46.	VE 3.4	Interim Report on Ecological Benchmarking and Biomonitoring for Detection of Air-Borne Pollutant Effects on Vegetation and Soils, 1975 to 1978.
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48.	HG 1.1	Interim Report on a Hydrogeological Investigation of the Muskeg River Basin, Alberta
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50.	ME 3.6	Literature Review on Pollution Deposition Processes
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54.	WS 2.3	A Preliminary Study of Chemical and Microbial Characteristics of the Athabasca River in the Athabasca Oil Sands Area of Northeastern Alberta
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56.	AF 3.2.1	The Acute Toxicity of Saline Groundwater and of Vanadium to Fish and Aquatic Invertebrates
57.	LS 2.3.1	Ecological Habitat Mapping of the AOSERP Study Area (Supplement): Phase I
58.	AF 2.0.2	Interim Report on Ecological Studies on the Lower Trophic Levels of Muskeg Rivers Within the Alberta Oil Sands Environmental Research Program Study Area
59.	TF 3.1	Semi-Aquatic Mammals: Annotated Bibliography
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66.	AS 4.3.2	An Assessment of the Models LIRAQ and ADPIC for Application to the Athabasca Oil Sands Area
67.	WS 1.3.2	Aquatic Biological Investigations of the Muskeg River Watershed
68.	AS 1.5.3 AS 3.5.2	Air System Summer Field Study in the AOSERP Study Area, June 1977
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70.	LS 28.1.2	An Interim Report on the Insectivorous Animals in the AOSERP Study Area
71.	HY 2.2	Lake Acidification Potential in the Alberta Oil Sands Environmental Research Program Study Area
72.	LS 7.1.2	The Ecology of Five Major Species of Small Mammals in the AOSERP Study Area: A Review
73.	LS 23.2	Distribution, Abundance and Habitat Associations of Beavers, Muskrats, Mink and River Otters in the AOSERP Study Area, Northeastern Alberta
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93.	WS 1.3.1	Fisheries and Aquatic Habitat Investigations in the MacKay River Watershed of Northeastern Alberta
94.	WS 1.4.1	A Fisheries and Water Quality Survey of Ten Lakes in the Richardson Tower Area, Northeastern Alberta. Volume I: Methodology, Summary, and Discussion.
95.	AS 4.2.6	Evaluation of the Effects of Convection on Plume Behaviour in the AOSERP Study Area
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97.	LS 3.4.1	Differences in the Composition of Soils Under Open and Canopy Conditions at Two Sites Close-in to the Great Canadian Oil Sands Operation, Fort McMurray, Alberta
98.	LS 3.4.2	Baseline Condition of Jack Pine Biomonitoring Plots in the Athabasca Oil Sands Area; 1976 and 1977
99.	LS 10.1	Synecology and Autecology of Boreal Forest Vegetation in the AOSERP Study Area
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101.	LS 21.1.3	Woodland Caribou Population Dynamics in Northeastern Alberta
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103. HS 50.4 Analysis of the Leisure Delivery System 1972-1979, with Projections for Future Servicing Requirements
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105. LS 11.3 Approaches to the Design of a Biomaonitoring Program using Arthropods as Bioindicators for the AOSERP Study Area
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