INTERIM REPORT ON SYMPTOMOLOGY AND THRESHOLD LEVELS OF AIR POLLUTANT INJURY TO VEGETATION, 1975 to 1978

by

S.S. MALHOTRA and P.A. ADDISON
Northern Forest Research Centre
Canadian Forestry Service

for

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ABSTRACT

Six boreal forest plant species were fumigated in a newly developed environmental growth chamber with SO_2 control capability, for up to 40 days at 0.34 ppm SO_2. All species showed a gradual decline in CO_2 gas exchange which was related to symptom development characteristic of SO_2 toxicity. Paper birch was the most sensitive species to SO_2 injury followed by green alder, jack pine, Labrador tea, and white and black spruce.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Ranking of species in the order of their sensitivity to air pollutants is a prerequisite for interpreting air pollution injury to vegetation and changes in species composition in the field. In view of the industrial development in the Athabasca Oil Sands area and the potential impact of emissions therefrom on forest vegetation, an attempt must be made to rank the dominant species of this region in order of their sensitivity to SO_2 fumigation. This is necessary in selecting species for revegetation purposes.

The objectives of this study were to: (1) describe visible and microscopic effects of air pollutants on selected species from the Athabasca Oil Sands area in order to develop techniques to identify and assess the impact of air pollutants on vegetation; (2) determine in quantitative terms, the threshold levels of air pollutant injury to species native to the Athabasca Oil Sands region; and (3) screen candidate revegetation species for tolerance to air-borne pollutants.

The use of threshold levels requires some definition. Visual threshold level of SO_2 is defined as that time and concentration where foliar damage is first detected. Initial visible response to SO_2 of each plant species was determined in preliminary studies. Physiological threshold level of SO_2 is defined in this case as that time and concentration which reduces net CO_2 assimilation by 10%.

Because of the interim nature of this report the statements made herein are subject to revision upon completion of the project and release of the final report.

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.), green alder (*Alnus crispa* (Ait.) Pursh), paper birch (*Betula papyrifera* Marsh.), and common Labrador tea (*Ledum groenlandicum* Oeder), were collected from the Athabasca Oil Sands area in the Alberta Oil Sands Environmental Research Program study area (Figure 1). These species were selected as they predominate in the Boreal Forest in general and in the Athabasca Oil Sands area in particular. Collections were made in an area that had no visible signs of air pollution injury, 26 km north of Great Canadian Oil Sands Ltd. (GCOS). In addition, sulphation plate data indicated that ambient SO_2 concentrations at this site were not significantly different from the background levels greater than 75 km from the source.

Plants were grown under greenhouse conditions (*ca.* 20°C and 50% RH) with supplemental light (photoperiod of 16 h) for 3 months before being placed in the controlled environment chamber. Experimental environmental conditions are described below.

2.2 FUMIGATION CHAMBER

A specially constructed controlled environment chamber (Figure 2) was used to fumigate forest species collected in the AOSERP study area. This chamber is equipped with 4,000 W each of high pressure sodium and metal halide lamps in addition to 1,200 W of incandescent lamps in a 2.88 m^2 growing area. Light intensity at plant height is controlled by using a combination of turning lights on and off and adjusting the height of the plant bed (Figure 3). It has the capability to produce light intensities from 0 to 1,500 $\mu E\ m^{-2}\ s^{-1}$. Air flow into the chamber is 5.7 $m^3\ min^{-1}$ and replaces the chamber air every 70 seconds. Approximately 56.6 $m^3\ min^{-1}$ of air is recirculated within the chamber to maintain a

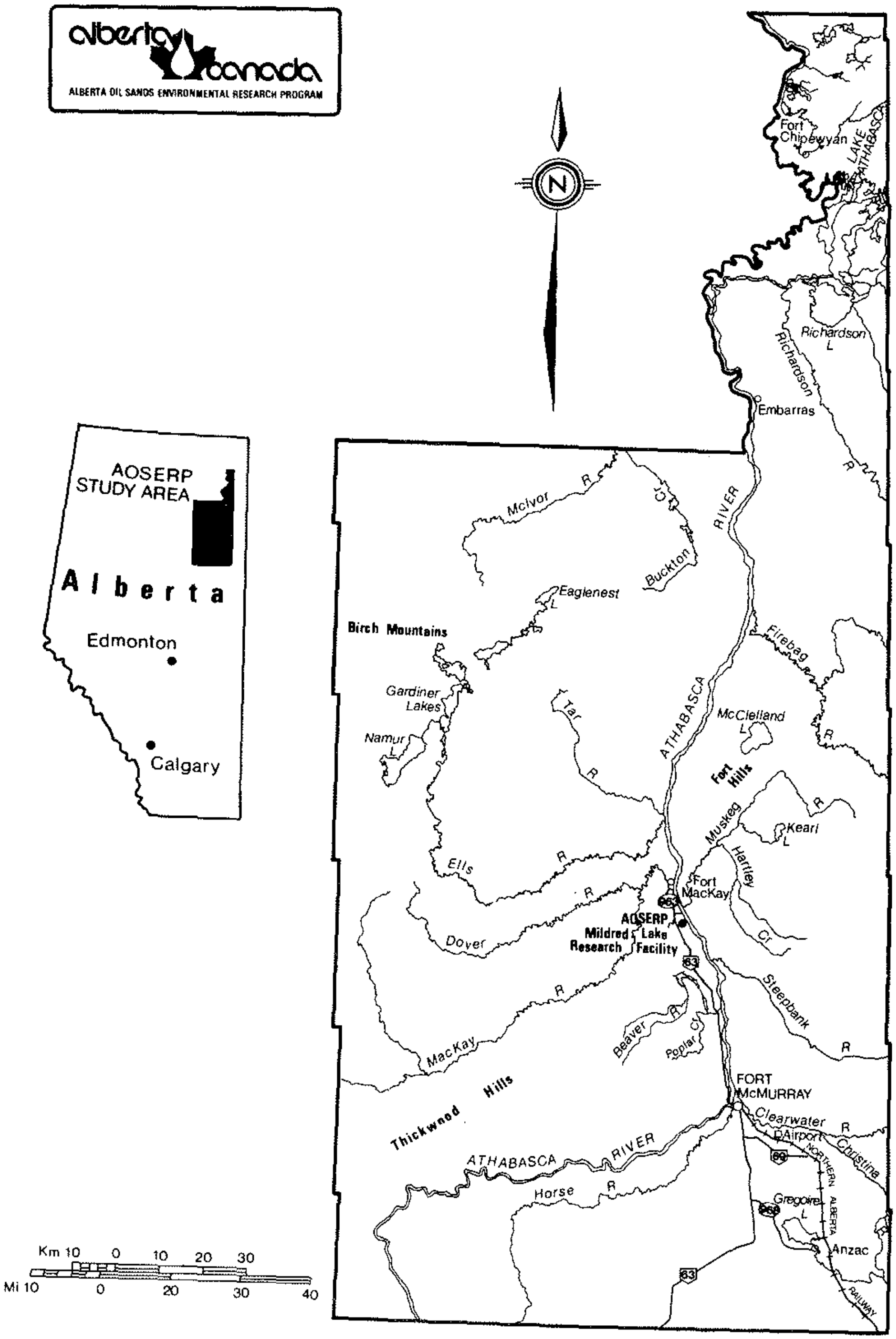

Figure 1. The AOSERP study area.

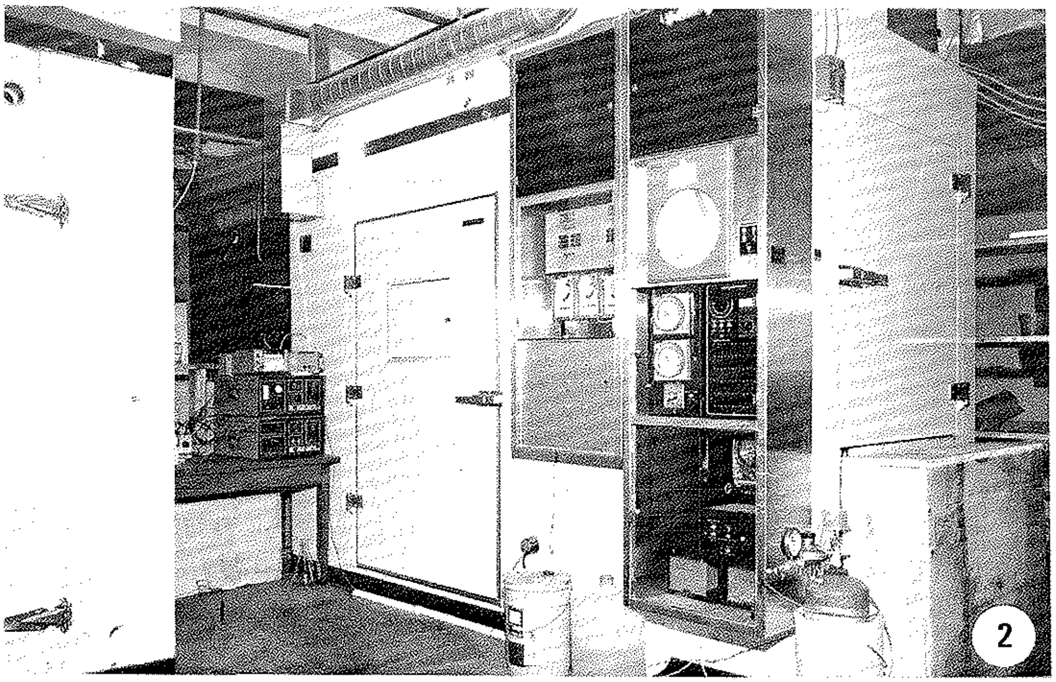

Figure 2. Air pollution fumigation chamber with control panel for light, temperature, humidity, and SO_2.

Figure 3. Interior of environmental growth chamber showing field collected boreal forest species on a movable platform.

homogeneous environment. Temperature is programmable on an hourly basis and can range from 5 to 35°C. Dew point can be controlled if less than 5°C below air temperature. In general, this chamber permits simulation of almost all conditions that may occur during the growing season in the boreal forest.

2.3 SO_2 FUMIGATION

SO_2 fumigations were carried out at a constant 18°C with a 15°C dewpoint and 18 h photoperiod. Light regime was programmed to simulate diurnal variations with a maximum light intensity of 500 $\mu E\ m^{-2}\ s^{-1}$. Pure SO_2 was injected into the intake duct via a motor-driven needle valve, and SO_2 flow was automatically adjusted by a feedback control mechanism to give the desired concentration within the chamber. SO_2 concentration was continuously monitored by a Monitor Labs SO_2 analyzer. A photographic record of visual symptoms of SO_2 toxicity on different species was maintained for the duration of the experiments.

2.4 DETERMINATION OF CO_2 ASSIMILATION AND RESPIRATION

Net CO_2 assimilation and dark respiration were measured in a controlled environment microchamber (Siemens Canada Ltd.) at 18°C and a 15°C dewpoint. Ambient air from outside was mixed in two 200 L drums to provide uniform CO_2 concentration. An open gas flow system involving a Beckman model 865 infrared CO_2 analyzer was used to differentially measure the CO_2 concentration of the chamber air stream against the reference stream.

During CO_2 assimilation measurements, plants were maintained under a 600 $\mu E\ m^{-2}\ s^{-1}$ light source (high pressure sodium and metal halide lamps). Dark respiration was measured under reduced air flow with the microchamber completely covered with black plastic. The CO_2 analyzer was calibrated twice daily using standard CO_2 concentrations from precalibrated gas cylinders.

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3. RESULTS AND DISCUSSION

3.1 FUMIGATION OF FOREST SPECIES

Preliminary long-term fumigations of about 45 days were conducted at 0.34 ppm SO_2. The responses measured were visual injury symptoms, CO_2 gas exchange rate, and sulphur uptake.

In general, 5- to 7-year-old jack pine and 7- to 10-year-old white spruce saplings showed an increase in CO_2 gas exchange for the first 20-35 days in a SO_2-free environment of the growth chamber (Figures 4 and 5). The initial low rates of gas exchange were probably due to plant response to previous greenhouse conditions that were not as favourable for growth as the growth chamber. It appeares to take about 15 days for the plant to acclimate to growth chamber conditions but budbreak and the subsequent increase in metabolically active tissue was partially responsible for the variability seen before day 35 in Figures 4 and 5. In spite of the increase in tissue, CO_2 gas exchange declined rapidly in both conifer species after SO_2 was added to the environment on day 38. One of the two white spruce saplings responded more slowly than the others (Figure 5) and appeared to require about 15 rather than 3 days at 0.34 ppm of SO_2 before its CO_2 gas exchange rate was affected. This may be a result of partially closed stomata since clean air CO_2 exchanges rates were also lower.

Jack pine saplings started to show visual symptoms of SO_2 toxicity (needle tip yellowing or chlorosis) on day 46, 8 days after the onset of fumigation (Figure 4; first 38 days in clean air). White spruce, on the other hand, showed such symptoms on day 74, or 36 days after the start of fumigation (Figure 5). Severe necrotic symptoms (tissue death) on jack pine started to develop on day 81 and on white spruce on day 86 (Figures 4 and 5). In general, black spruce showed a SO_2 response pattern very similar to the one produced by white spruce. However, black spruce response to SO_2 was somewhat slower than that of white spruce.

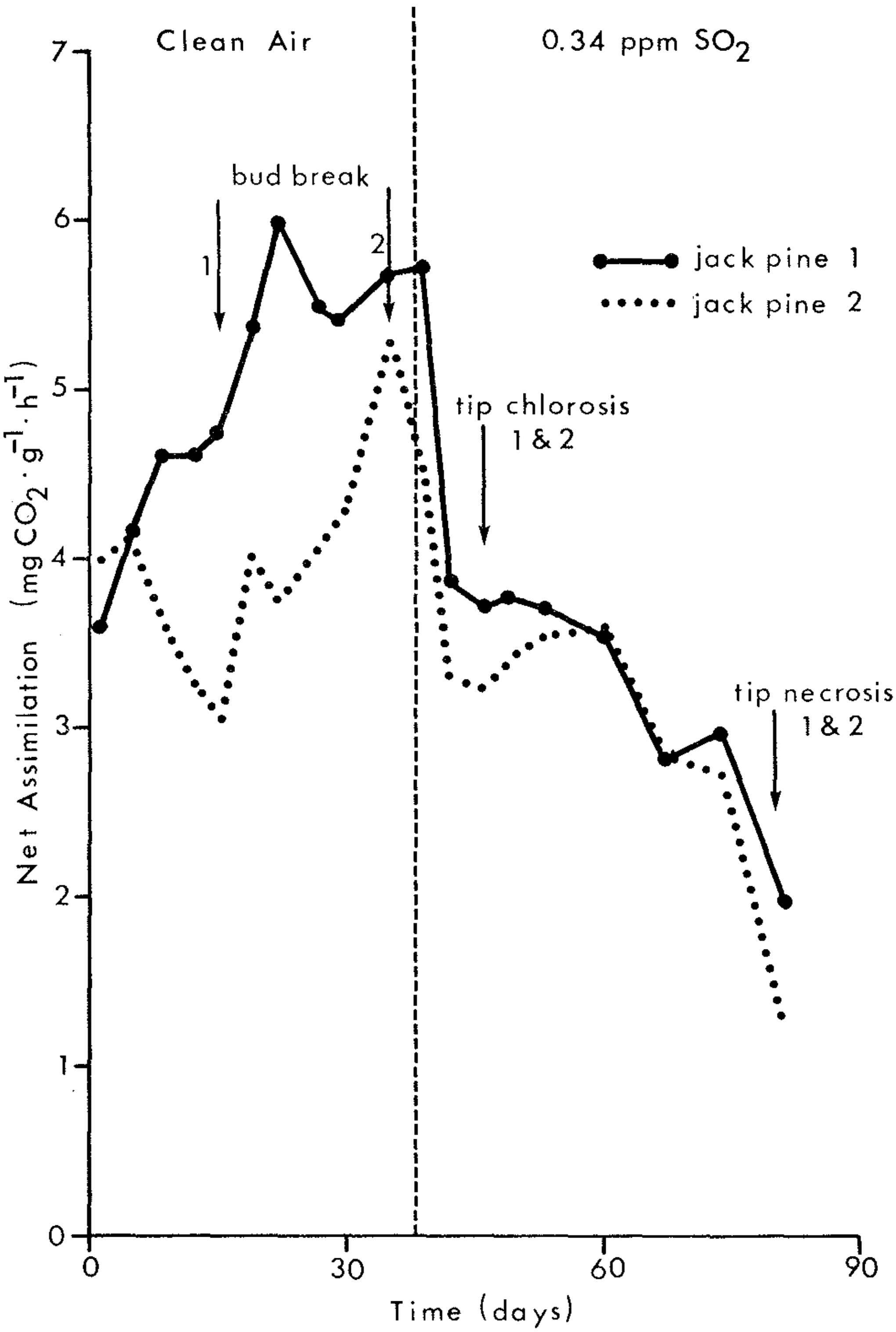

Figure 4. Net CO_2 assimilation rate of two jack pine saplings from the Athabasca Oil Sands area during exposure to SO_2. Plants are in early spring condition and measurements were taken at 600 µE m^{-2} s^{-1} at $18^{o}C$.

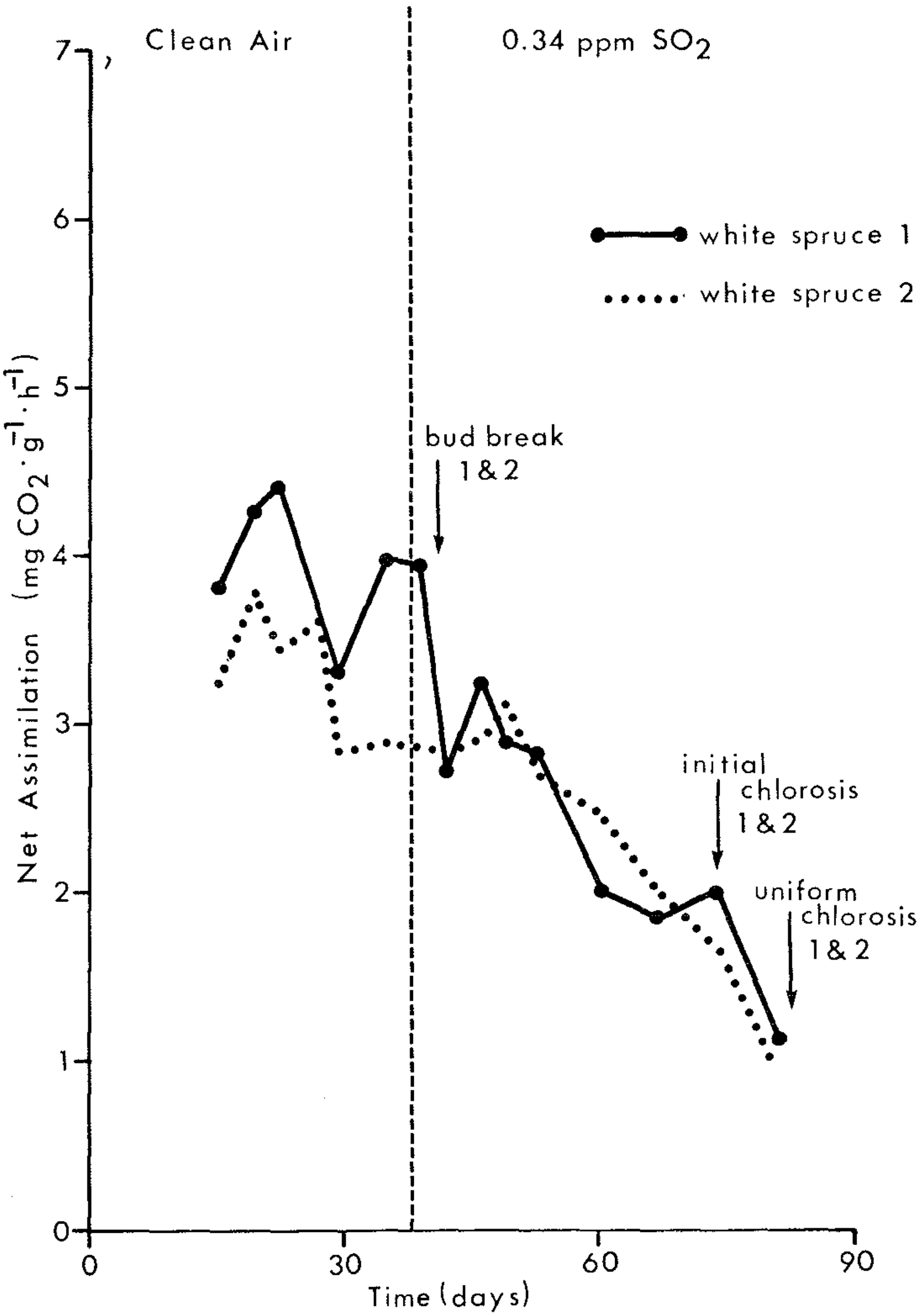

Figure 5. Net CO_2 assimilation rate of two white spruce saplings from the Athabasca Oil Sands area during exposure to SO_2. Plants are in early spring condition and measurements were taken at 600 $\mu E\ m^{-2}\ s^{-1}$ at 18^oC.

Dark respiration rates of both conifer species remained unaltered until the later stages of fumigation, when they increased considerably, probably as a result of the onset of tissue senescence. The analysis of total sulphur content of the experimental material is currently underway to determine the relationship between the extent of physiological or visual injury and SO_2 uptake.

The only response studied on paper birch, green alder, and Labrador tea was the development of visual injury symptoms of SO_2 toxicity. These symptoms first appeared on paper birch 2-3 days after the start of fumigation and were followed by green alder (5-6 days) and Labrador tea (10-12 days). Ranking of all six species in the order of SO_2 sensitivity showed paper birch to be the most sensitive species followed by green alder, jack pine, Labrador tea, and white and black spruce.

4. CONCLUSIONS

Although the results are preliminary, several conclusions can be drawn. The use of CO_2 gas exchange clearly indicated that physiological threshold level of SO_2 toxicity was much lower or shorter than visual threshold level. Biochemical threshold level is expected to be even more sensitive. These biochemical and physiological threshold levels should aid substantially in detecting previsual injury which is essential if existing forest environments are to be maintained. In addition, deciduous species were much more sensitive to SO_2 than coniferous ones. Work is currently underway that will quantify the physical and biochemical components of SO_2 tolerance that will help in assessing the potential ability of revegetation species to survive in a contaminated environment.

5. 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
5. HY 3.1 The Evaluation of Wastewaters from an Oil Sand Extraction Plant
6. Housing for the North--The Stackwall System
7. AF 3.1.1 A Synopsis of the Physical and Biological Limnology and Fisheries Programs within the Alberta Oil Sands Area
8. AF 1.2.1 The Impact of Saline Waters upon Freshwater Biota (A Literature Review and Bibliography)
9. ME 3.3 Preliminary Investigations into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10. HE 2.1 Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area
11. AF 2.2.1 Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12. ME 1.7 Very High Resolution Meteorological Satellite Study of Oil Sands Weather: "a Feasibility Study"
13. ME 2.3.1 Plume Dispersion Measurements from an Oil Sands Extraction Plant, March 1976
14. HE 2.4 Athabasca Oil Sands Historical Research Project. Volume I: Design
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.	HE 2.3	Maximization of Technical Training and Involvement of Area Manpower
23.	AF 1.1.2	Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout
24.	ME 4.2.1	Review of Dispersion Models and Possible Applications in the Alberta Oil Sands Area
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
35.	AF 4.9.1	The Effects of Sedimentation on the Aquatic Biota
36.	AF 4.8.1	Fall Fisheries Investigations in the Athabasca and Clearwater Rivers Upstream of Fort McMurray: Volume I
37.	HE 2.2.2	Community Studies: Fort McMurray, Anzac, Fort MacKay
38.	VE 7.1.1	Techniques for the Control of Small Mammals: A Review
39.	ME 1.0	The Climatology of the Alberta Oil Sands Environmental Research Program Study Area
40.	VE 7.1	Interim Report on Reclamation for Afforestation by Suitable Native and Introduced Tree and Shrub Species
41.	AF 3.5.1	Acute and Chronic Toxicity of Vanadium to Fish
42.	TF 1.1.4	Analysis of Fish Production Records for Registered Traplines in the AOSERP Study Area, 1970-75
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
44.	VE 3.1	Interim Report on Symptomology and Threshold Levels of Air Pollutant Injury to Vegetation, 1975 to 1978
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

These reports are not available upon request. For further information about availability and location of depositories, please contact:

Alberta Oil Sands Environmental Research Program
15th Floor, Oxbridge Place
9820-106 Street
Edmonton, Alberta T5K 2J6