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THE EFFECT OF ARSENIC TRIOXIDE ON THE GROWTH OF WHITE SPRUCE SEEDLINGS

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Abstract. In the smelting of arsenopyrite ores during the gold extraction process, substantial amounts of As_2O_3 are released into the environment. The work described in this paper demonstrates the potential effect of this fallout on the growth of white spruce trees. Several small trees were planted in soil containing various amounts of As_2O_3 and their growth was studied over an 11 mo period. Substantial retardation of the growth of the trees with As containing soil was observed.

1. Introduction

Initial aspects of this research program involved a detailed analysis of the operation of an 800 metric ton day^{-1} gold extraction plant located in Canada. The name and location of the mine is proprietary information. The As pollution problem at this particular site was discovered by an abnormally high As content in the receiving waters.

Table I gives a summary of a basic mine As balance. Two points of special interest are:

(a) The majority of the As is lost in the form of emissions during the roasting operation. This is primarily in the As_2O_3 form (Lodeishcahikov and Zhuchkov, 1968) and for the mine under study amounted to over 1400 metric tons yr^{-1} of lost As.

(b) Even though the discharge of soluble As to the receiving waters was a small fraction of the total As lost, this still amounted to several metric tons yr^{-1} at this particular site.

The problem of dissolved As removal from the water streams has been treated in

TABLE I

Mine As balance

Stream	Units (ton As ton^{-1} As in ore)
As Input	1.0
As Output	
i) Back Fill	0.026
ii) Flue Dust	0.018
iii) Solids to Lake	0.148
iv) Liquid to Lake	0.003
v) Stack Losses	0.805
Total	1.0

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9165

detail in the literature (Rosehart and Lee, 1972) and the topic of this paper is to examine the potential effects of As_2O_3 on the growth rate of white spruce trees and also to examine the accumulation rate of arsenic in various parts of the trees.

Sandi and Farmalo (1969) have reported an analytical assessment of As pollution in a gold mining community but no control study has been reported and the separate effects of SO_2 and As have not been reported. O'Toole *et al.* (1971) reported another survey of As in a mining area but again the work was strictly reporting in nature. The State of California (1963) has reported reduced yield and destruction of chlorophyll in the foliage of plants in areas with soil of high As content.

2. Experimental Procedure

A. PREPARATION OF WHITE SPRUCE

Small white spruce trees were transplanted into the prepared beds containing controlled amounts of As_2O_3 as shown in Table II. The trees were obtained after 3yr in the seed bed and were typical of trees ready for transplant in the forest. The soil containing 6.04% Fe and 4.12% Al was prepared by mixing reagent grade As_2O_3 as

TABLE II

As content in soil (initial mixing)

Samples	As (ppm)	Remarks
#1, #2	1000	in
#3, #4	2000	same water
#5, #6	0	bed
#7, #8	0	in different water bed from samples #1–#6

required. In addition to the six trees planted in the contaminated beds, two control samples were planted in separate beds. All trees were watered three times a week and fertilized every other month and then kept in a controlled atmosphere greenhouse. After an 11 mo period, one tree of each condition was removed from its bed for As analysis.

B. ARSENIC ANALYSIS

For the As determination, the silver diethyldithiocarbonate colorimetric method (APHA, AWWA, WPCF, 1971) was used after employing the standard HNO_3/H_2SO_4 digestion of oven dried tree samples and soil. The trees were cut into 4 parts: the root, trunk, branch and leaves for the above analysis. All results are quoted in ppm weight.

3. Results

Figure 1 shows the remarkable effect of the As on the growth of white spruce after applying a dosage of arsenic for approximately 11 mo. (Dose level determined by soil sampling in mine area.) Samples #7 and #8, which were in an As free bed, grew almost twice the rate as trees (#1–6) in the contaminated beds. Expert examination of the trees also indicated that in addition to the stunted growth severe damage had been done to the foliage and bud system.

The result of soil analysis shown in Table III indicates that even small amounts of dissolved As were enough to affect the growth of the trees. A water sample from the contaminated bed taken on 30 October 1973 had a 1.5 ppm As content. Also it was found that #5 soil which was not mixed with As originally, but was on purpose kept in the same water bed with the other arsenic containing soil samples, picked up 44 ppm of As through water circulation.

Table IV gives the As accumulation of various parts of the white spruce. Most of the As seems to accumulate in the root structure and this would affect the growth.

The remaining trees from the study are being transplanted to the university forest and will be allowed to grow several years before analysis.

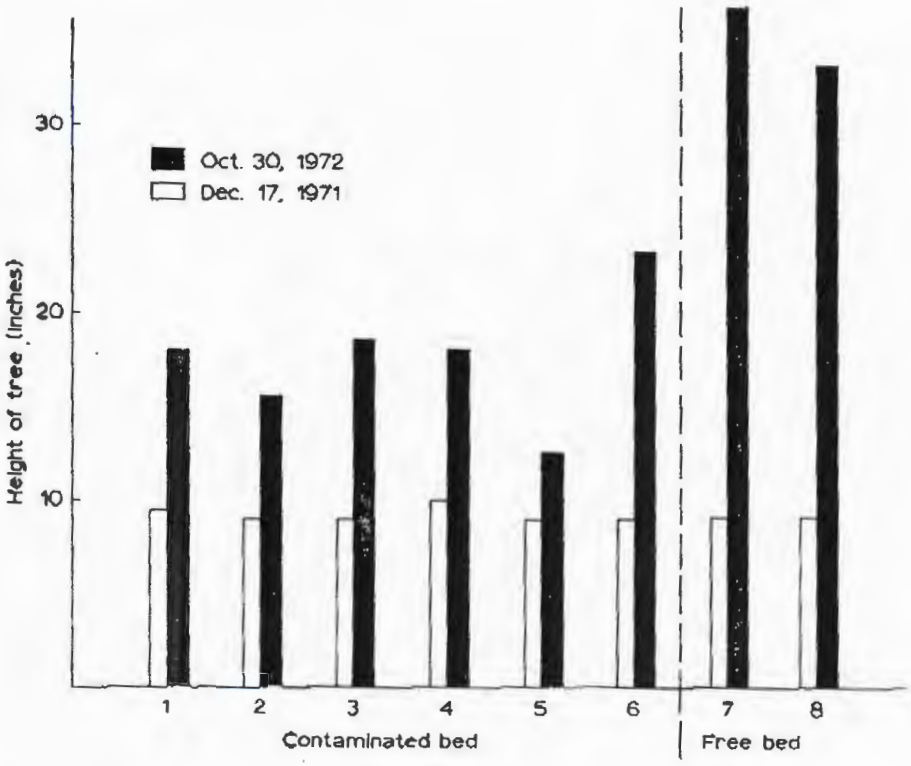

Fig. 1

TABLE III

As content in soil after 11 months

Samples		Initial As (ppm)	After 11 months (ppm)
In As contaminated bed	#2	1000	700
	#3	2000	1780
	#5	0	44
In As uncontaminated bed	#7	0	0

TABLE IV

As accumulation in various parts of tree after 11 months exposure to As

Bed Sample	As contents (ppm)		Part of Tree	
	Root	Trunk	Branch	Leaf
#2	59.5	0.3	14.3	2.9
#3	130	55	3.0	2.08
#5	45	6.4	2.8	9.5
#7	1.0	2.4	2.1	2.1

4. Conclusions

It is very difficult to analyze the effects observed in terms of As without knowing the growth mechanisms of white spruce. The level of As in the various parts of the tree relates to the level in the soil as noted in Table IV. Regardless of the As level in the soil (range 44 to 1780 ppm), the effect on the growth of the tree is dramatic (Figure 1). This indicates that even a small amount of contamination may be significant to the growth cycle. Reported As contents in gold mine area vegetation (Saidi and Farmalo, 1969) are markedly higher than those in Table IV indicating the long term cumulative nature of As. Based then on preliminary results, one can conclude that forests in such areas are influenced very much by the emission of As. Through processing of the pulp wood, this As could ultimately contaminate food stored in paper or box containers.

The background levels of As in the control trees (#7–#8) range from 1 to 2.4 ppm which agrees favorably with the work of Chattopadhyay (1971). The distribution of As in the various parts of the tree seems quite sporadic and is probably a dynamic process. As far as an environmental problem is concerned, it would be desirable that the As content to the usable parts of the tree (trunk) be low.