

**Department of Consumer &  
Corporate Affairs & Environment**

**Environmental Management Division**

**Environmental Management Services**

AMBIENT FLUORIDE LEVELS AND THEIR EFFECTS  
ON VEGETATION AND SOIL IN THE VICINITY OF  
THE RED RIVER BRICK AND TILE COMPANY,  
LOCKPORT, MANITOBA

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**Environmental Standards and Studies**

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THE RED RIVER BRICK AND TILE COMPANY,  
LOCKPORT, MANITOBA

D. C. Jones, D. L. Wotton, and D. B. McEarchern  
Environmental Standards and Studies  
Environmental Management Division  
Department of Consumer & Corporate Affairs  
& Environment

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## EXECUTIVE SUMMARY

### ENVIRONMENTAL MANAGEMENT SERVICES BRANCH REPORT

#### Ambient Fluoride Levels and Their Effects on Vegetation and Soils in the Vicinity of the Red River Brick and Tile Company, Lockport

The Red River Brick and Tile Company operates a manufacturing plant at Lockport, Manitoba which emits fluoride to the atmosphere as a part of its process. The plant operates under Order No. 631 of the Clean Environment Commission, issued November 5, 1976. At present this order does not set limits for fluoride emissions and the survey was, therefore, requested by the Air Pollution Control Section, to establish whether any harmful effects on vegetation, soil and animals, in the vicinity of the plant, results from these fluoride emissions. This report focuses on the effects of fluoride emission on vegetation and soils.

During the months of June to September 1979, monitoring systems were maintained at selected study sites surrounding the plant. A system of fluoride plate traps was used to establish fluoridation rates within the study sites and a biological monitoring system used potted nursery seedlings as transplanted receptors to evaluate vegetation and soil effects.

Within the scope of this study, no detrimental effect to vegetation growth could be found from fluoride levels in the vicinity of the plant. It is therefore inferred that existing ambient levels of fluoride are not adversely affecting native vegetation.

This study provided further evidence to the hypothesis that by monitoring indicators of pollution it is possible to evaluate emission levels from a point source and to determine by their effect on the surrounding natural environment the need for further regulation or limitation.

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JONES, D.C., D.L. WOTTON and D.B. McEACHERN

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Manitoba Department of Consumer and Corporate Affairs and Environment Environmental  
Management Services Branch  
Environmental Standards and Studies Section

### ABSTRACT

The ambient levels of total fluorides in the vicinity of the Red River Brick and Tile plant at Lockport were monitored using a fluoride trap system established in six sampling sites selected in close vicinity of the plant. To determine if the existing ambient fluoride levels are causing any detrimental effect on vegetation and soil, a system of biological monitors using potted dogwood (Comus Stolonifera Michx), seedlings were established in each of the selected sampling sites and together with the fluoride traps were maintained from early June to September 1979. It was found that converting the fluoridation rate to ambient fluoride level, the level exceeded the recommended Canadian Air Quality Standards. The level of fluorides found in the foliage of the biological monitors were in excess of levels recommended for the protection of vegetation. However, no detrimental effects on vegetation could be related with the levels of fluorides found within the study area.

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## INTRODUCTION

The Red River Brick and Tile Division of I.XL Industries Ltd. operates a brick manufacturing plant located near P.T.H. No. 44 East in the unincorporated village of Lockport, Rural Municipality of St. Clements, Manitoba. Established in 1971, the plant utilizes different blends of clay from as many as six different quarries to produce brick products in a variety of colours and sizes. It has been established that the normal operation of a high temperature kiln used in the manufacturing of bricks results in the aerial emission of fluorides which are generally in the form of gaseous hydrogen fluoride and/or silicon fluoride and particulate calcium fluoride (Suttie 1980, Rose and Marier 1977, Anonymous 1975).

In 1976 the Environmental Control Branch sampled clays used by the plant, the results of which indicated an average total fluoride content of 634 ppm with a range of 203 to 1066 ppm. The finished brick product when analyzed for total fluorides was found to have an average of 237 ppm per brick with a range of 44 to 2060 ppm. Thus it can be anticipated that the majority of these fluorides, whether gaseous or particulate form, are being released to the atmosphere during the manufacturing process.

The Red River Brick and Tile Co. operates under C.E.C. Order No. 631 which sets no standards for fluoride emissions. Fluorides at elevated levels have been documented as being phytotoxic (Hendrickson 1970, Semrau 1977, Sinclair 1969, Hepting 1966, 1964, Heck 1965, Middleton and Paulus 1956). The Environmental Management Division initiated a research study in 1979 to determine the effects of ambient fluoride emissions from the brick manufacturing operation on vegetation and soil in the immediate vicinity of the plant.

## STUDY OBJECTIVES

To investigate the ambient level of total fluorides in the vicinity of the Red River Brick and Tile plant at Lockport and to determine if the existing ambient level of fluorides has any detrimental effect on vegetation and soil.

## STUDY DESIGN

To satisfy the objectives, two independent research components were incorporated within

the scope of the study. Each component was designed to function within a network of six selected sample sites as illustrated in Figure 1. Five sites were located in close proximity to the plant with a concentration of sites in those areas most frequently exposed to air flow patterns. One site, site 6, was located well away from the plant in the direction of least wind activity to provide background information.

To investigate the ambient level of fluoride in the vicinity of the plant a monitoring system of fluoride plate traps using an accepted procedure of impregnated filter papers was established at each of the six sampling sites. To determine if existing ambient fluoride levels are affecting vegetation and soil a system of biological monitors using transplanted indigenous tree seedlings and potting soil as primary receptors were also established at each sampling site. Both sampling components were maintained from June 12 to September 5, 1979.

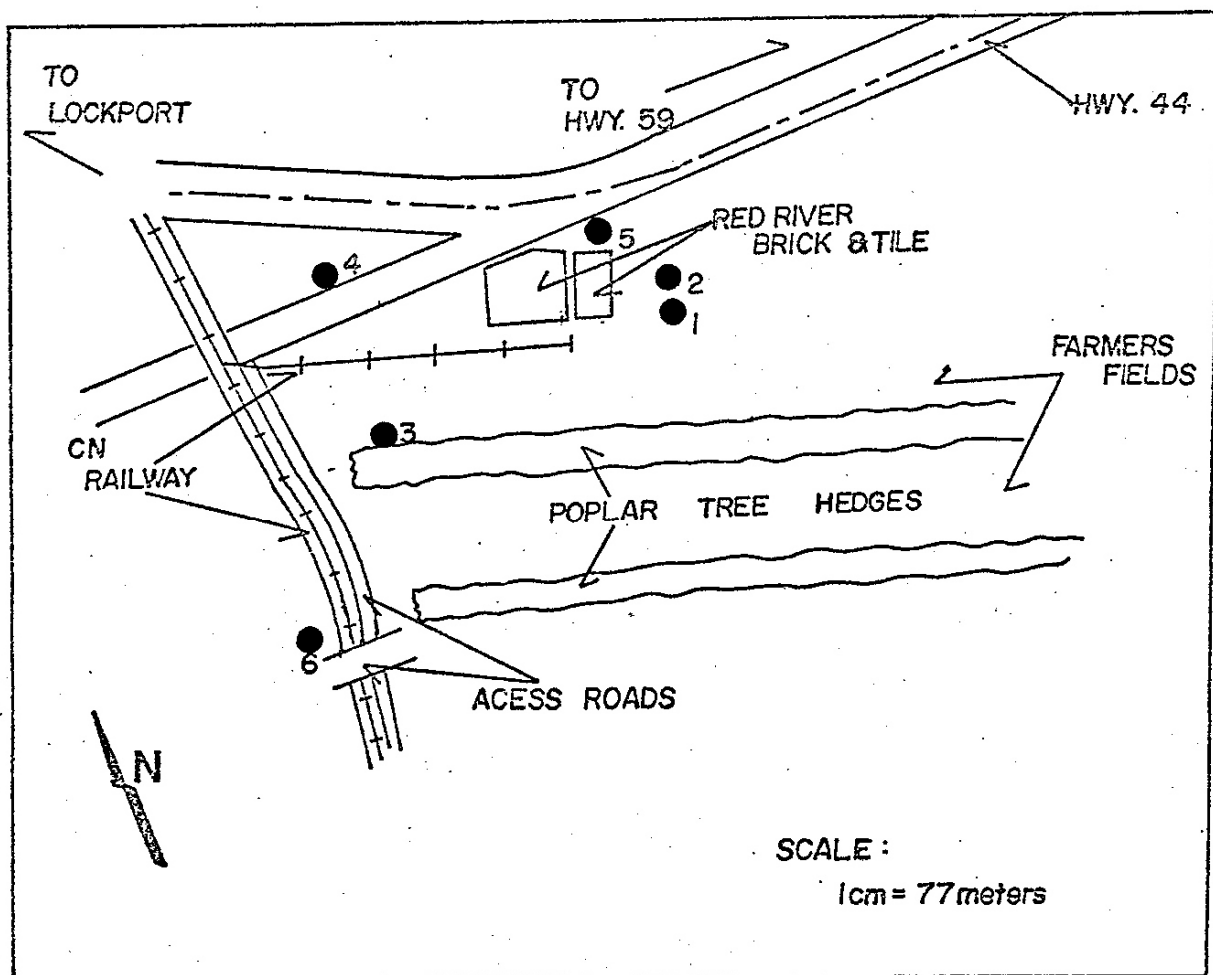


FIGURE 1: SAMPLE SITE LOCATIONS.

## STUDY PROCEDURES

### 1. FLUORIDE TRAPS

A system of fluoride plate traps designed to monitor weekly ambient levels of fluoride were established according to a procedure developed by Sidhu (1977, 1978, 1979). Ten replicate plates were set out at each sample site, each plate consisting of a Whatman 40, circular 9 cm filter paper. The papers were impregnated with a solution of 10 g sodium formate mixed with a 1:1 100 ml solution of ethyl alcohol and distilled water, air dried and refrigerated in plastic bags prior to placement. Each fluoride plate was suspended with elastic bands in a bank of 10 inverted petri dishes at an approximate height of 1.5 meters above ground level at each site. The exposed plates were then submitted to the Technical Services Laboratory where each plate was analyzed for total fluorides (Appendix II).

### 2. BIOLOGICAL MONITORS

A system of biological monitors composed of seedling transplants and potting soil was designed to evaluate ambient fluoride effects on vegetation and soil. The indigenous tree species Red Osier Dogwood (Cornus stolonifera Michx.) was selected and seeds from mature trees were collected in the fall of 1978 from the Brandon area. Following a 16 week stratification period, seeds were planted in styrobloc 20's filled with a standard nursery potting soil mix and greenhouse reared<sup>1</sup> from February to the last week of May 1979. All environmental conditions including watering and fertilizing were consistently maintained for all seedlings. During the last week of May, seedlings were scrutinized for height and growth characteristics and selected individuals were transplanted to 15 cm pots which were placed in the lath house for hardening off.

On June 12, a total of 330 selected seedlings were transported to the study area and 55 individuals were randomly selected and placed within a fenced enclosure approximately 3 metres square at each sample site (Figure 1). The condition of each seedling was evaluated and

<sup>1</sup>Seedlings reared in the Provincial Forest Research Greenhouse, Pineland Nursery, Hadashville, Manitoba.

documented by a Foliar Condition Index (Appendix i), in addition to measurements of height and number of stems. A subsample of 11 individuals from each site was selected and photographed to provide a permanent record of condition and for comparison among sites. Seedlings were watered and maintained Monday, Wednesday and Friday of each week, depending on rainfall experienced throughout the project. Water for the project was consistently taken from Building 3, 139 Tuxedo Avenue, Winnipeg and weeding of plots was conducted to prevent excessive competition where required.

Seedling height, foliar condition and photographic records were remeasured on July 18. On September 3, transplants in site 6 and site 4 were damaged by vandals. The project was terminated on September 5, height was remeasured on sites 1,2,3 and 5 and a composite sample of the seedling tissues and soil was taken from all sites for chemical analysis. At each site 5 replicate sets of 11 seedlings were randomly selected and subdivided into the following component samples: leaves, stems, roots, and surface soil. All leaves were stripped from seedlings, stems separated from roots, loose soil removed from roots, and a composite of the upper 2.5 cm of potting soil removed.

A survey of tree foliage from native species found in windbreaks and residual clusters of natural ecosystems was made within the sampling area. A composite sample of foliage was removed from trees within close proximity to each of the 6 sampling sites. A windbreak of white spruce *Picea glauca* (Moench) Voss, was sampled adjacent to site 5 and all other samples were taken from trembling aspen, *Populus tremuloides* Michx.

All samples were sealed in plastic bags and submitted to the Technical Services Laboratory for analysis of total fluorides (Appendix II). In addition, to supplement analysis and to verify control levels for site 6, a separate sample of transplant material from the original greenhouse stock which was maintained in a similar experiment in Brandon, (Wotton 1979), was submitted for analysis to increase background confidence.

The chemical analysis results were subjected to statistical analysis for tests of significance. The analysis of variance was used to determine any significant difference between sample plots. Duncan's Multiple Range Test was then used to determine significant differences among means for each sample component with a significant difference between plots.

## STUDY RESULTS

### 1. FLUORIDE TRAPS

The mean weekly concentration of total fluoride per plate, ( $\mu\text{gF}/\text{plate}/7$  days), based on a 10 replicate analysis per week for each of the six sites are found in Table 1. The mean concentration of total fluorides in air per week ( $\mu\text{gF}/\text{m}^3/7$ ) was then calculated using Adam's Formula, (Sidhu 1977, 1978, 1979); values are presented in Table II.

The total fluoride concentrations expressed as  $\mu\text{gF}/\text{fluoride plate}/7$  days were converted to  $\mu\text{gF}/\text{m}^3$  of air/7 days by first converting the mean  $\mu\text{gF}/\text{plate}/7$  days to  $\mu\text{gF}/\text{dm}^2/7$  days and then substituting in the formula:  $\mathbf{H \times Y - 4.36 \times \mu\text{gF}/\text{dm}^2/7 \text{ days}}$  where:

1.  $\mathbf{H}$  = hours of exposure - 24 hrs/day x 7 days = 168
2.  $\mathbf{Y}$  = mean  $\mu\text{gF}/\text{m}^3/7$  days
3.  $\mu\text{gF}/\text{dm}^2/7$  days = the conversion of the concentration of fluorides on a filter paper area of  $63.61 \text{ cm}^2$  to  $\text{dm}^2$  by the formula:  
 $\mu\text{gF}/\text{dm}^2/7 \text{ days} = \mu\text{gF}/\text{plate}/7 \text{ days} \times 1.57$ , where  $63.61 \text{ cm}^2 \times 1.57 = 100 \text{ cm}^2 = 1 \text{ dm}^2$

Values for concentrations of fluorides in plates were quite variable from week to week at the same site and between sites. However, the total accumulated level of fluorides in each site had the same ranking (except for sites 1 and 2 being reversed, which could be anticipated due to their close proximity) as the ranking of accumulated fluoride levels found in the seedling foliage. A regression of total accumulated  $\mu\text{gF}/\text{site}$  over the study duration versus total concentration of fluorides in foliage by site is shown in Figure II. The correlation coefficient obtained was  $r = 0.93$ , significant at  $p = 0.05$ , and represented by the power curve equation  $y = (0.14) (x)^{1.09}$  where  $y$  = foliage fluoride level and  $x$  = plate fluoride level

Collection	Mean of-Total Fluorides per site ( $\mu\text{gF}/\text{plate}/7\text{days}$ )					
Date	1	2	3	4	5	6
June 20	34	65	15	223	82	8
June 27	239	289	21	52	56	11
July 4	55	71	69	75	33	5
July 11	41	56	10	26	26	0.1
July 18	168	110	16	14	444	3
July 25	63	62	20	25	73	1
Aug. 1	224	226	21	50	105	5
Aug. 8	77	99	7	5	220	5
Aug. 15	14	15	26	78	6	5
Aug. 22	523	501	11	23	27	8
<b>Total</b>	<b>1438</b>	<b>1494</b>	<b>216</b>	<b>571</b>	<b>1072</b>	<b>66</b>

TABLE I. MEAN CONCENTRATION OF TOTAL FLUORIDES PER PLATE

Collection	Mean of Total Fluorides ( $\mu\text{gF}/\text{m}^3/7\text{ days}$ ) per site					
Date	1	2	3	4	5	6
June 20	1.39	2.65	0.61	9.09	3-34	0.33
June 27	9.74	11.78	0.86	2.12	2.28	0.45
July 4	2.24	2.89	2.81	3.06	1.34	0.20
July 11	1.67	2.28	0.41	1.06	1.06	0.0
July 18	6.85	4.48	0.65	0.57	18.09	0.12
July 25	2.57	2.53	0.81	1.02	2.97	0.65
Aug. 1	9.13	9.21	0.86	2.04	4.28	0.20
Aug. 8	3.14	4.03	0.29	0.20	8.96	0.20
Aug. 15	0.57	0.61	1.06	3.18	0.24	0.20
Aug. 22	21.31	20.41	0.45	0.94	1.10	0.33
Aug. 29	9.49	-	0.29	-	1.87	-
<b>Mean</b>	<b>6.19</b>	<b>6.09</b>	<b>0.83</b>	<b>2.33</b>	<b>4.14</b>	<b>0.27</b>

TABLE II. MEAN CONCENTRATION OF TOTAL FLUORIDES IN AIR

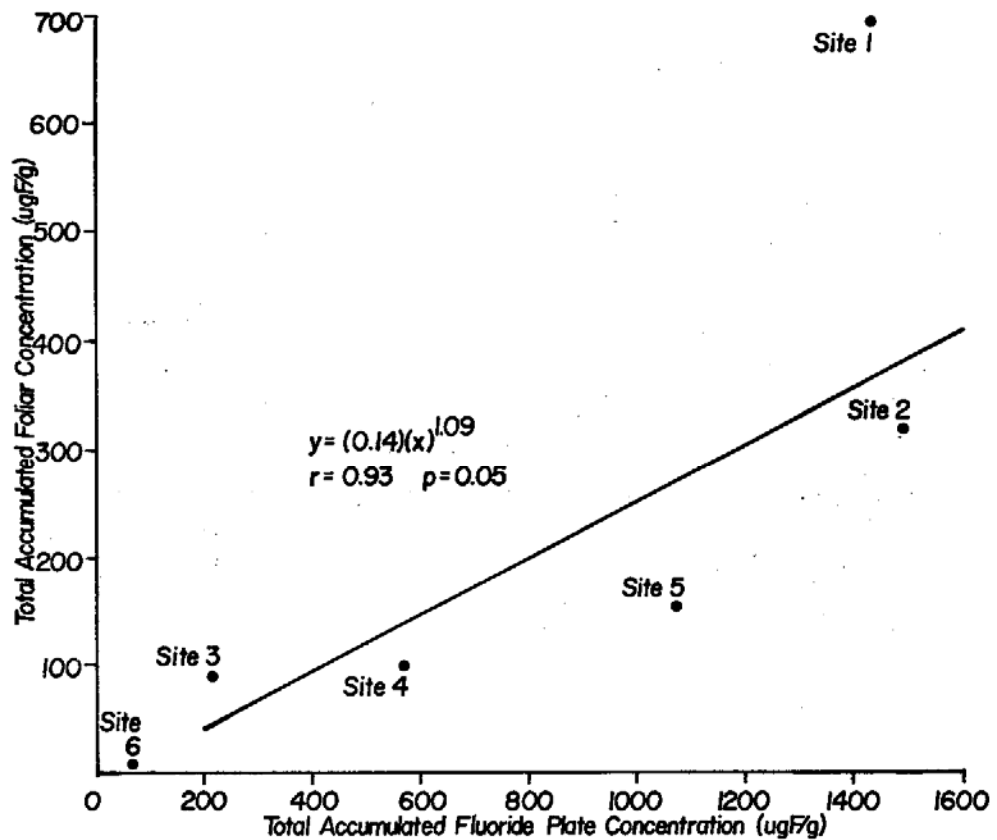


FIGURE II: REGRESSION OF TOTAL FLUORIDE PLATE CONCENTRATION VS. TOTAL FOLIAR CONCENTRATION.

## 2. BIOLOGICAL MONITORS

At the time of initial seedling placement on site the foliage of each seedling was assessed for condition and an index value assigned (Appendix I). It was anticipated that any change in foliage condition could be quantitatively evaluated through reassessment using the foliar condition index at regular intervals throughout the growing season. However, as the season progressed it became apparent that air pollution symptomatology could not be precisely distinguished from natural environmental influences on foliar appearance. Thus the major thrust of the study was directed toward the comparison of seedling growth and the chemical analysis of transplant components.

In each of the 6 sampling sites, 11 seedlings were randomly selected for height

measurements which were taken at the initiation of the study, after 5 weeks growth and at study termination. The results of the mean seedling height measurements are summarized in Table III. A comparison of the percentage increase in mean seedling height between sites is found in Table IV. Height growth appeared random throughout the sample sites with no distinct pattern or gradient of variance with distance from the plant. Seedlings from site 5 exhibited the least amount of height growth, 30.99 cm, however, these seedlings experienced a much greater percentage growth increase than others, 134.1%. No significant correlations between seedling height growth and levels of fluorides in vegetative tissues or soil could be found.

Site	Mean Seedling Height (cm)		
	June 12/79	July 19/79	Sept. 5/79
1	27.01	32.13	33.75
2	28.0	28.77	37.27
3	23.41	30.34	36.02
4	17.88	25.0	-
5	13.24	27.3	30.99
6	19.94	25.4	-

TABLE III. SUMMARY OF MEAN SEEDLING HEIGHT INCREASE

Site	Percent Growth Increase (%)		
	June 12-July 19/79	July 19-Sept. 5/79	June 12-Sept. 5/79
1	19.0	5.0	25.0
2	2.0	29.0	33.1
3	29.0	19.0	53.9
4	39.0	-	0
5	106.0	13.0	134.1
6	27.0	-	-

TABLE IV. PERCENTAGE INCREASE IN MEAN SEEDLING HEIGHT

The concentration of total fluorides found in the foliage, stems, roots and potted surface soil of the dogwood transplants are summarized in Table V. Figures presented are mean values based on 5 replicates of 11 seedlings per site and include the analysis results of identical transplant stock from the Brandon control. The statistical analysis of these results found that foliage and stem tissues were the only transplant components where a significant difference between sampling sites,  $p = 0.005$ , could be demonstrated.

Site	Mean Total Fluorides in $\mu\text{gF/g}$			
	Foliage	Stems	Roots	Soil
1	698	85	224	154
2	320	18	182	131
3	90	10	220	168
4	101	10	244	155
5	154	10	232	174
6	<10	<10	238	154
Brandon Control	<10	<10	222	142

TABLE V. . SUMMARY OF FLUORIDE CONCENTRATION IN SEEDLING TISSUE AND SOIL

Foliage analyses indicated 5 groups of sites significantly different from one another. Plot 1 at 698  $\mu\text{F/g}$  is the highest level and stands by itself as does plot 2 at 320  $\mu\text{g/g}$  and plot 5 at 154  $\mu\text{g/g}$ . Plots 3 and 4 at 90  $\mu\text{gF/g}$  and 101  $\mu\text{g/g}$ , respectively, are the fourth group significantly different from the other groups but not between themselves. The fifth and final group is the two control sites at 10  $\mu\text{gF/g}$ . In the stem material the mean fluoride levels found at site 1, 85  $\mu\text{gF/g}$  and at site 2, 18  $\mu\text{gF/g}$  were significantly different from each other and from all other sites where values were consistently at 10  $\mu\text{g/g}$ .

The results of root analysis were not significantly different between sites. The fluoride concentration ranged from a high of 244  $\mu\text{gF/g}$  at plot 4 to a low of 182  $\mu\text{gF/g}$  at plot 2. The

values of the site 6 and Brandon controls were found to fall in between at 238 and 222  $\mu\text{gF/g}$ , respectively.

Soil values were found to range from 174  $\mu\text{gF/g}$  at site 5 to 131  $\mu\text{gF/g}$  at site 2 and again the site 6 and Brandon control values fell in between at 154 and 142  $\mu\text{gF/g}$ , respectively. No significant differences between sites were found.

Coniferous foliage collected near the northeast corner of the brick plant, adjacent to site 5, contained foliage F-concentrations as high as 118  $\mu\text{g/g}$ . Poplar foliage collected along wind breaks and isolated clumps of bush had concentrations: 320  $\mu\text{gF/g}$  at site 1; 210  $\mu\text{g/g}$  at site 2; 50  $\mu\text{gF/g}$  at site 3; 170  $\mu\text{g/g}$  at site 4; 190  $\mu\text{g/g}$  at site 5, and only 10  $\mu\text{gF/g}$  at the control site.

## DISCUSSION

Proposed Canadian national air quality objectives for HF, to protect vegetation, recommend the maximum desirable limit of HF emissions be  $0.20 \mu\text{gHF/m}^3/7$  days and the maximum acceptable limit be  $0.55 \mu\text{gHF/m}^3/7$  days (Sidhu 1977). Sidhu in a 1977 study of levels of fluorides in vegetation surrounding a phosphorus plant in Newfoundland concluded that the safe level of fluoride in air for forest species is  $0.23 \mu\text{gHF/m}^3$ . The same author in 1978 concluded from a study of a number of coniferous and broadleaf trees that threshold levels of F-concentration in air were  $0.20 \mu\text{gF/m}^3$  for conifers and  $0.40 \mu\text{gF/m}^3$  for deciduous species.

A comparison of fluoride concentrations in air as calculated from Na-formate plate data,  $\mu\text{gF/dm}^2/7$  days, with the proposed national 7 days standard, indicated that boreal vegetation did not experience any serious danger to foliage in areas where fluoride concentrations were  $0.55 \mu\text{gHF/m}^3$  for 20% of the time and  $0.20 \mu\text{gHF/m}^3$  for 60% of the time during the growing season (Sidhu 1979).

Sidhu in 1980 examined long term exposure of boreal forest species to fluorides in air and found that accumulation of fluoride in most boreal conifers reached a maximum at the end of the second year of exposure and stabilized thereafter. He calculated that an air concentration of  $0.29 \mu\text{g/m}^3$  would result in 20  $\mu\text{g/g}$  as a F-level in foliage, which is reported to be a safe level for plants. He also noted that this F-level in air compares well with the recommended Canadian

Standard of  $0.20 \mu\text{gHF}/\text{m}^3$  average for a 70 day exposure period and  $0.30 \mu\text{gHF}/\text{m}^3$  average recommended by the International Union of Forest Research Organizations for a one year period.

Coniferous foliage collected near the northeast corner of the brick plant, adjacent to site 5, contained F-concentrations as high as  $118 \mu\text{gF}/\text{g}$ . Poplar foliage collected along wind breaks and isolated clumps of bush ranged from  $320 \mu\text{gF}/\text{g}$  at site 1, to  $10 \mu\text{gF}/\text{g}$  at the site 6 control. Levels of fluoride found in the potted dogwood species were within a similar range at each site. Sidhu in 1979 found that damage symptoms first appeared on white birch (*Betula papyrifera* Marsh.), at foliar fluoride concentrations of 1437 ppm. However, during the same time he also found visible damage to the same species when the foliage level was only 12 ppm at a different site. A study of tomato plants by Daines *et al.* (1975) indicated moderate plant injury at foliar F-concentrations as high as 1010 ppm and no plant injury at 170 ppm. Garrec and Vauasseur (1978) noted no visible damage symptoms in poplar foliage containing 600 ppm of fluoride. Sidhu in 1979 noted leaf fall in broadleaf species set in after 35 ppm F-accumulation in the foliage. He also concluded that threshold levels of F-accumulation were different among species at different air concentrations.

A comparison of the conversion of the fluoridation rate into  $\mu\text{gF}/\text{m}^3/7$  day values determined at each sampling site by the fluoride traps was made with the proposed national air quality objectives for HF which were determined for the protection of vegetation. The results of this comparison are presented in Table VI, and values indicate the percentage of time that the proposed maximum desirable and the maximum acceptable limits for  $\mu\text{gHF}/\text{m}^3/7$  days are exceeded. It is found that only at the control site 6 do levels not reflect a hazard to vegetation. Levels found at all other sites exceed the proposed recommended air quality criteria nearly 100% of the time.

The fluoride trap system used in this study provides a measure of total fluorides, including gaseous fluorides and water soluble particulate fluorides. It has been found that particulate fluoride is relatively non-phytotoxic (Anonymous 1975). Since this trap system provides no differentiation between gaseous and particulate fluorides, and the primary reason for complaint by local citizens has been the heavy dust condition, it can be hypothesized that the fluoride levels found in this study are due to particulate fluorides rather than gaseous fluorides. It then follows that the level of fluoride found in vegetation of the area is poorly related to visible plant injury.

	Percent of Time Limits are Exceeded	
Site	Maximum Desirable Limit (0.20 $\mu\text{gHF}/\text{m}^3/7$ days)	Maximum Acceptable Limit (0.55 $\mu\text{gHF}/\text{m}^3/7$ days)
1	100.00	100.00
2	100.00	100.00
3	100.00	64.0
4	90.0	90.0
5	100.0	91.0
6	40.0	10.0

TABLE VI. PERCENT TIME PROPOSED MAXIMUM DESIRABLE AND MAXIMUM ACCEPTABLE LEVELS OF  $\mu\text{gHF}/\text{m}^3/7$  days ARE EXCEEDED

The ambient levels of fluorides determined at the sampling sites located in closest proximity to the Red River Brick and Tile plant exceeded national air quality standards for the protection of vegetation. Fluoride concentrations found in foliage samples in some sampling sites located in closest proximity to the plant are above threshold foliage concentration levels tolerable in plant life as reported in literature. However, in spite of these quantitative statistics, there were no detrimental physiological effects found in vegetation of either the biological monitoring system or the native vegetation within the scope of this study.

### CONCLUSION

1. Rate of fluoridation was determined using a fluoride plate monitoring system. When conversion of fluoridation rates to fluorides in air was attempted it was noted that the calculated levels exceeded recommended Canadian maximum acceptable and maximum desirable air quality standards.
2. Levels of total fluorides found in foliage of transplanted dogwood seedlings located near the Red River Brick and Tile Co. exceeded the recommended tolerance level for vegetation.

3. Concentrations of total fluorides in transplant foliage and in the ambient air were found to exceed recommended limits in the vicinity of Red River Brick and Tile, however, no visual or measurable damage to vegetation growth or soil could be attributed to the fluoride levels found within this study.
4. On the basis of this investigation it was concluded that the present (1979/80) levels of fluoride emissions from the Red River Brick and Tile plant at Lockport have not affected the vegetation around the plant.
5. Air monitoring with fluoride traps is not recommended for future studies of a similar nature.

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## APPENDIX I: FOLIAR CONDITION INDEX

1. Vegetation vigorous with no visual foliage damage.
2. Minor evidence of necrotic spotting of broadleaf interveinal and veinal tissue or minor discoloration of broadleaf leaf margins. Minor evidence of necrotic spotting on coniferous foliage or minor needle tip discoloration.
3. Marked evidence of necrotic tissue spotting on broadleaf and coniferous vegetation and/or marked leaf margin discoloration with slight leaf cupping. Conifer needle tips show marked discoloration.
4. Extensive evidence of foliar tissue damage evident. Broadleaf foliage almost entirely discolored with some leaf drop initiated. Conifer foliage extensively damaged with entire branch tips :near death.
5. Vegetation near death. Broadleaf vegetation bears little remaining foliage with the remainder under maximum stress. Conifer foliage nearly entirely dead.
6. Vegetation dead.

## APPENDIX II: ANALYTICAL PROCEDURE FOR FLUORIDE ANALYSIS

The Technical Services Laboratory of the Environmental Management Division conducted the chemical analysis on filter papers from the fluoride traps and on all vegetation and soil samples involved in this research study.

The filter papers were analyzed according to the procedure outlined by S.S. Sidhu 1979, Canadian Forestry Service, Saint John's Newfoundland. Each filter was soaked in 50 ml TISAB in plastic beakers for 12 hours and subsequently analyzed for fluoride by an Orion specific-ion electrode.

The vegetation and soil samples were analyzed according to the procedure outlined by the British Columbia Water Resources Service, (M<sup>c</sup>Quaker 1976). Portions of the vegetation and soil were dried, ground and sieved. The prepared samples were fused with sodium hydroxide at 600°C, re-dissolved with hydrochloric acid and filtered prior to analysis. The fluoride concentration in the final solution was measured by an Orion fluoride specific-ion electrode.