A Survey of Lead Accumulation in Tree Foliage and Surface Soil of the Winnipeg Area

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A SURVEY OF LEAD ACCUMULATION IN TREE FOLIAGE AND SURFACE SOIL OF THE WINNIPEG AREA

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ABSTRACT

During the 1979 growing season, a survey of urban tree foliage and surface soil was conducted to determine lead concentrations in areas of varying traffic density, in areas adjacent to secondary lead smelters and in the immediate area of Lord Nelson and Weston Elementary Schools within the City of Winnipeg. It was found that variability among tree species in the absorption and accumulation of lead in leaf tissue exists. Lead accumulation from urban traffic in the Winnipeg area resulted in lead concentrations which ranged from 43.4 ug/gm to 17.6 ug/gm in tree foliage and 1085.0 ug/gm to 132.5 ug/gm in surface soils for areas of high and low traffic volume respectively. Levels of lead concentration around both elementary schools was high and a gradient of decreasing concentration was found as distance increased from major emission sources. Lead concentrations in tree foliage and surface soil from sampling locations in close proximity to the secondary lead smelters was frequently tenfold the values found to accumulate from normal motor vehicle emissions in the Winnipeg area. It can be anticipated that lead will accumulate to the same degree in other plant tissues and soils such as those found in vegetable gardens.

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INTRODUCTION

It has been well documented that airborne lead emissions induced from motor vehicles can accumulate in excessive amounts along major traffic thoroughfares and adjacent to major highways (Lioy et al. 1979, Vik 1979). The heavy metal content of various plant materials and soils has been related to sources of air pollution and their ability to accumulate these metals demonstrated throughout the literature. Lead, in particular, has been found to readily accumulate in lichens, mosses, tree bark, tree foliage and surface soils. Chemical analysis of soil and the aforementioned vegetative tissues has been used to determine lead concentrations in relation to major transportation networks (Darley 1963, Laaksovirta 1976, Martinez 1971, Reinbold and Rolfe 1976).

In the recent past, high levels of lead in the blood of school children living in high volume traffic areas has been detected in the Winnipeg area. In addition, elevated lead levels have been found in neighbourhood children and employees of secondary lead smelters within the city and much concern has been raised. In the early spring of 1979, the Air Pollution Control Branch of the Environmental Management Division initiated an intensive lead sampling program in the Winnipeg area. The program monitored air emissions from high and low volume traffic areas in addition to the three major secondary lead smelters within the city. To supplement this information, the Environmental Research and Development Branch initiated a survey of lead accumulation in urban vegetation and soils in the areas of principal concern within the city.

OBJECTIVES

To conduct a survey of tree foliage and surface soil to determine lead concentrations in areas of high and low traffic density, in areas adjacent to secondary lead smelters, and in the immediate area of Lord Nelson and Weston Elementary Schools within the City of Winnipeg.

METHODS

The survey was directed toward two principal target sources of lead emissions, non-industrial where the major emission source was identified to be that of motor vehicles and industrial where emission levels derive principally from the operation of secondary lead smelters.

In consideration of non-industrial sources of lead emissions, the following five areas were surveyed:

(i) Motor Vehicle Traffic
 (a) NAPS station 70118 located at Scotia Street and Jefferson Avenue, an area of low traffic volume;
 (b) NAPS station 70102, at 2120 Portage Avenue, representative of an area of high traffic volume;
 (c) Weston Park, Logan Avenue at Lock Street, representing medium traffic flow;

(ii) Lord Nelson School, 820 McPhillips Street, and

(iii) Weston School, 1410 Logan Avenue.

The industrial emission sources surveyed consisted of the following three major secondary lead smelting complexes in the Winnipeg area:

(i) Canadian Bronze Co., Ltd., 15 Bury Street

(ii) Canada Metal, 1221 St. James Street, and

(iii) Northwest Smelting and Refining Ltd., 2185 Logan Avenue.

At each sampling location, natural trees or well established street plantings were used as primary receptors and tree foliage was selected as the principal vegetative tissue for analysis of lead concentration. It was recognized that in any urban environment, the natural vegetative cover is non-existent and environmental stress is ever present on existing cover, both surviving remnants and established landscape components. The survey could not limit itself to specific species and therefore species selection was based on presence and condition. In most sampling areas, selection included more than one species which was not only necessary due to presence, but also beneficial in that variance in lead accumulation between species could be investigated from areas of equal loading. Although the survey design attempted to provide sampling from all aspects of each emission source, this was not always possible especially in the areas surrounding the industrial emission sources. Once again, species presence and condition were primary selection criteria at each sampling location.

Once sampling sites were established for each of the principal locations, then samples were taken in an identical fashion in early July and in late August. Selected trees were identified and a random composite sample of foliage was taken from the crown. At each major sampling site, a composite surface soil sample was collected by combining five soil cores each consisting of the upper 3 cm of soil taken in close proximity to each tree selected for foliage sampling. Both foliage and soil samples were sealed in plastic bags and submitted to the Technical Services Laboratory for lead analysis.

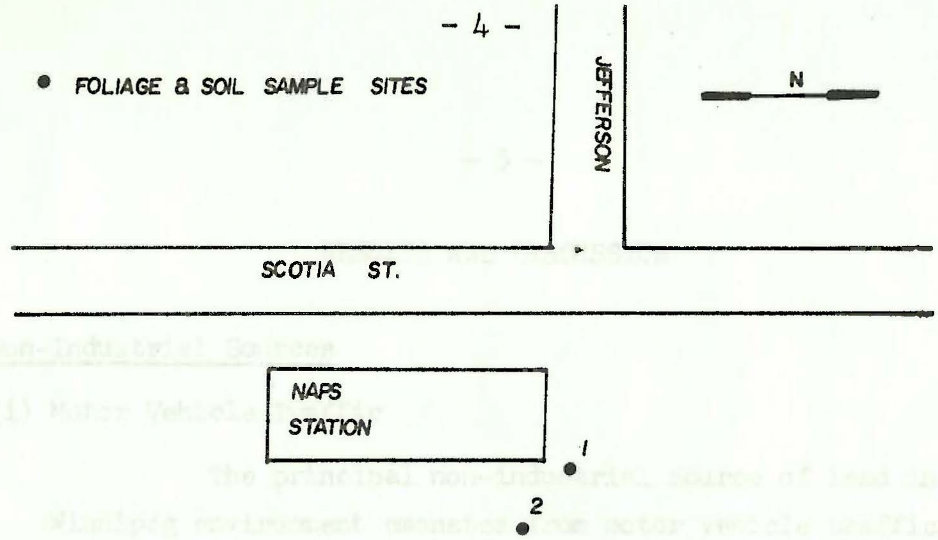

FIGURE 1(a): SAMPLE SITE LOCATIONS FOR NAPS STATION 70118.

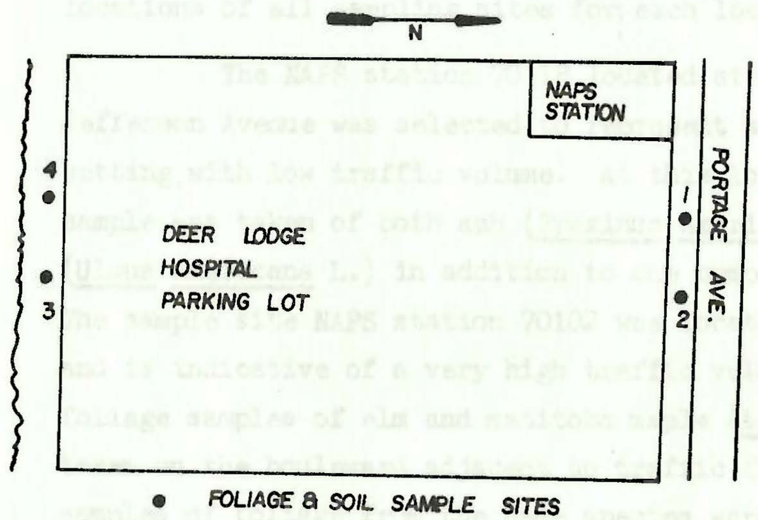

FIGURE 1(b): SAMPLE SITE LOCATION FOR NAPS STATION 70102.

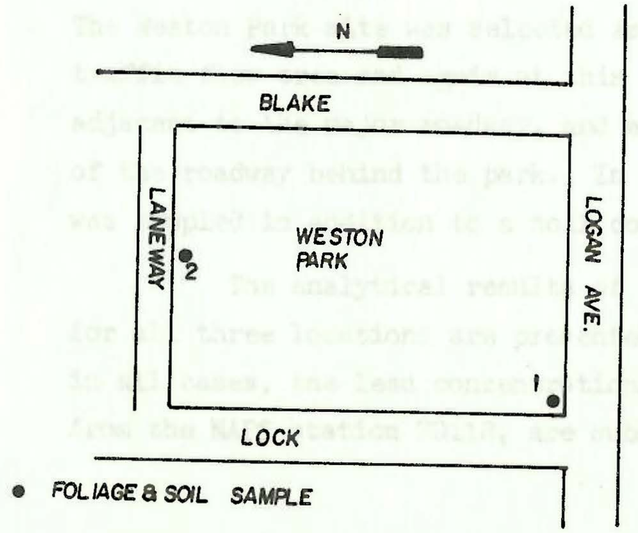

FIGURE 1(c): SAMPLE SITE LOCATIONS FOR WESTON PARK

RESULTS AND DISCUSSION

I. Non-Industrial Sources

(i) Motor Vehicle Traffic

The principal non-industrial source of lead in the Winnipeg environment emanates from motor vehicle traffic. To determine levels of lead from this source, sampling from three locations was carried out. Figure 1 (a) (b) (c) delineates the locations of all sampling sites for each location.

The NAPS station 70118 located at Scotia Street and Jefferson Avenue was selected to represent a quiet residential setting with low traffic volume. At this location, a foliage sample was taken of both ash (*Fraxinus americana* L.) and elm (*Ulmus americana* L.) in addition to one composite soil sample. The sample site NAPS station 70102 was located at 2120 Portage Avenue and is indicative of a very high traffic volume. At this site, foliage samples of elm and manitoba maple (*Acer negundo* L.) were taken on the boulevard adjacent to traffic flow and additional samples of foliage from the same species were taken approximately 50 metres south of the roadway at the rear of the Deer Lodge Hospital parking lot. In addition, one soil sample was taken from each location, adjacent to the roadway and some 50 metres south. The Weston Park site was selected as representative of a medium traffic flow area and again at this site, samples were taken adjacent to the major roadway, and approximately 50 metres north of the roadway behind the park. In both locations, foliage of ash was sampled in addition to a soil composite.

The analytical results of tree foliage and surface soil for all three locations are presented in Table I. As anticipated, in all cases, the lead concentrations found in foliage and soils from the NAPS station 70118, are substantially less than those

Site	Species	Tree Foliage (ug/gm)			Surface Soils (ug/gm)		
		July	August	Mean	July	August	Mean
(a) NAPS 70118							
1	Ash	6.61	10.0	8.31	150.0	115.0	132.5
2	Elm	12.7	22.5	17.6			
(b) NAPS 70102							
1	Elm	30.8	56.0	43.4	1200.0	970.0	1085.0
2	Maple	37.0	67.5	52.3			
3	Maple	8.88	27.5	18.2	255.0	160.0	207.5
4	Elm	11.2	40.0	25.6			
(c) Weston Park							
1	Ash	27.9	29.0	28.45	530.0	420.0	475.0
2	Ash	14.2	19.0	16.6	-	290.0	290.0

Table I: Summary of Lead Concentrations from Motor Vehicle Traffic reported for the high and medium traffic flow areas. For example, lead content of elm foliage in the low traffic area is 17.6 ug/gm and adjacent to Portage Avenue, the mean value of elm foliage is 43.4. Also, in the residential area, foliage samples of ash are 8.31 and in the medium traffic area 28.45. Similarly, a gradient of lead concentration in the surface soils between low, medium and high traffic volume areas is readily apparent (i.e. 132.5, 475.0 and 1085.0 ug/gm respectively).

Analytical results from the Portage Avenue station when comparing sites 1 and 2, and 3 and 4 are also as anticipated. A dramatic decrease of lead concentration in the surface soil is evident as distance increases away from the major roadway (i.e. soil close to road 1085.0 ug/gm and 50 metres south 207.5). The lead concentration found in the foliage of the same species of trees but located adjacent and away from the roadway indicates the same relationship (i.e. elm foliage adjacent to road 43.4 ug/gm and 50 metres south 25.6; maple foliage adjacent to road 52.3 ug/gm and 50 metres south 18.2). It is also noted from Table I that considerable variability appears to exist between species of trees sampled. For example, the maple adjacent to the road contained more lead than the elm, yet the samples taken 50 metres south of the road indicate that the elm accumulated higher lead levels.

The samples selected at the Weston Park location indicated similar relationships as those of the Portage Avenue sites. Tree foliage adjacent to the roadway contained higher levels of lead than those 50 metres away (i.e. 28.45 ug/gm to 16.6). Similarly soil samples taken adjacent to the major road were higher at 475.0 ug/gm than those taken well away at 290.0.

In evaluating results of foliage analysis in Table I, it is readily seen that all values reported in the August sample are higher than those of July. However, in the soil analysis, levels are not consistently higher in August than in July. If this had

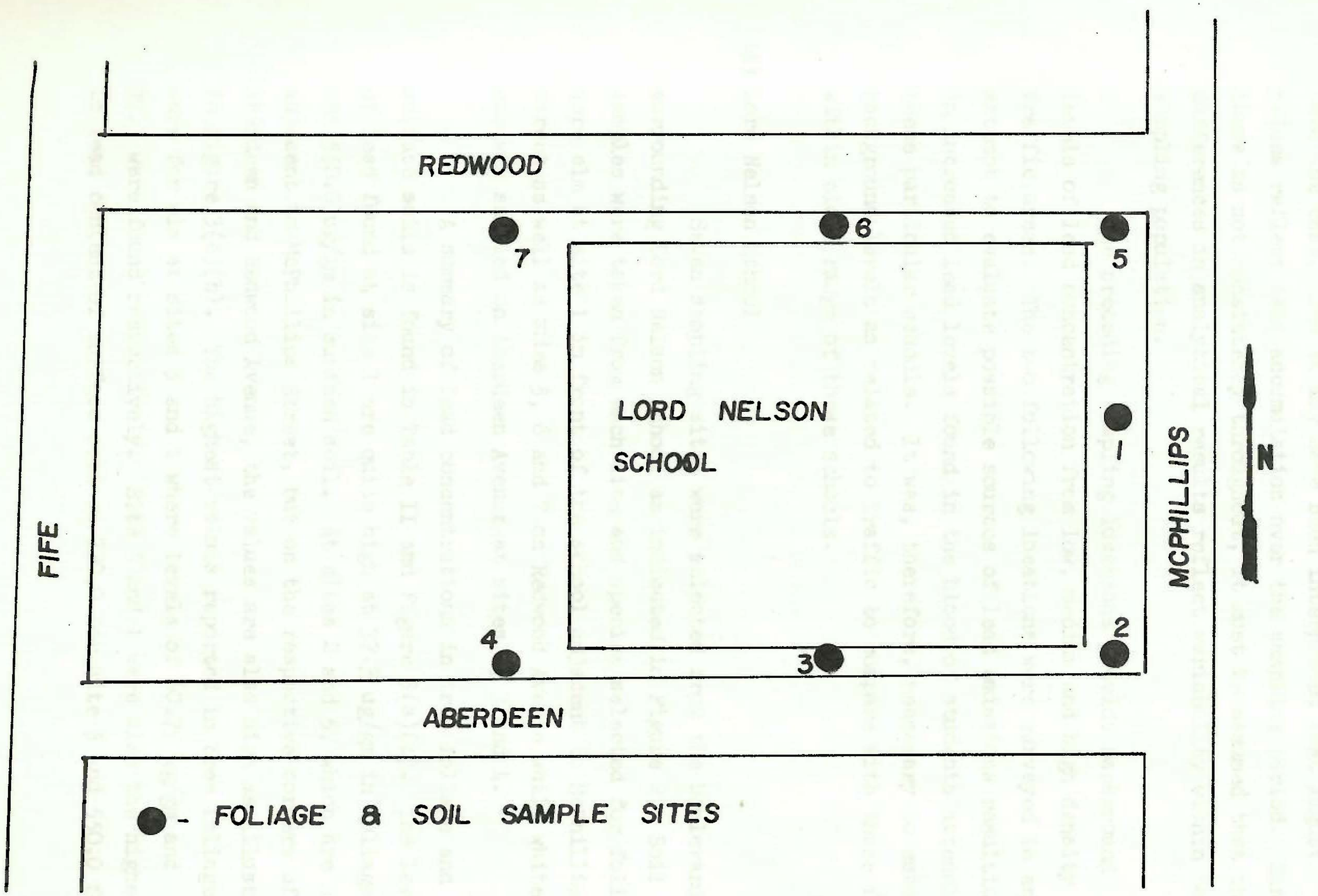

FIGURE 2: SAMPLE SITE LOCATIONS FOR LORD NELSON SCHOOL

been the case, then it may have been interpreted that August values reflect lead accumulation over the sampling period. Since there is not consistency throughout, it must be assumed that the differences in analytical results reflect variability within the sampling population.

The preceding sampling locations provide background levels of lead concentration from low, medium and high density traffic areas. The two following locations were surveyed in an attempt to evaluate possible sources of lead emissions resulting in increased lead levels found in the blood of students attending these particular schools. It was, therefore, necessary to establish background levels as related to traffic to compare with those found within close range of these schools.

(ii) Lord Nelson School

Seven sampling sites were selected from the boulevards surrounding Lord Nelson School as indicated in Figure 2. Soil samples were taken from each site and species selected for foliage were elm at site 1 in front of the school adjacent to McPhillips Street as well as sites 5, 6 and 7 on Redwood Avenue while white ash was sampled on Aberdeen Avenue at sites 2, 3 and 4.

A summary of lead concentrations in tree foliage and surface soils is found in Table II and Figure 3(a)(b). The levels of lead found at site 1 are quite high at 37.3 ug/gm in foliage and 550.0 ug/gm in surface soil. At sites 2 and 5, which are also adjacent to McPhillips Street, but on the respective corners of Aberdeen and Redwood Avenue, the values are also high as illustrated in Figure 3(a)(b). The highest values reported in tree foliage were for elm at sites 5 and 1 where levels of 60.75 ug/gm and 37.3 were found respectively. Site 5 and 1 were also the highest in lead content of surface soil at 720.0 for site 5 and 550.0 for

Site	Species	Tree Foliage (ug/gm)			Surface Soil (ug/gm)		
		July	August	Mean	July	August	Mean
1	Elm	39.1	35.5	37.3	820.0	280.0	550.0
2	Ash	30.8	37.5	34.15	370.0	280.0	325.0
3	Ash	11.2	12.5	11.85	210.0	140.0	175.0
4	Ash	15.0	19.0	17.0	220.0	120.0	170.0
5	Elm	51.5	70.0	60.75	540.0	900.0	720.0
6	Elm	24.2	39.0	31.6	340.0	540.0	440.0
7	Elm	17.0	25.0	21.0	420.0	290.0	355.0

Table II: Summary of Lead Concentrations at Lord Nelson School

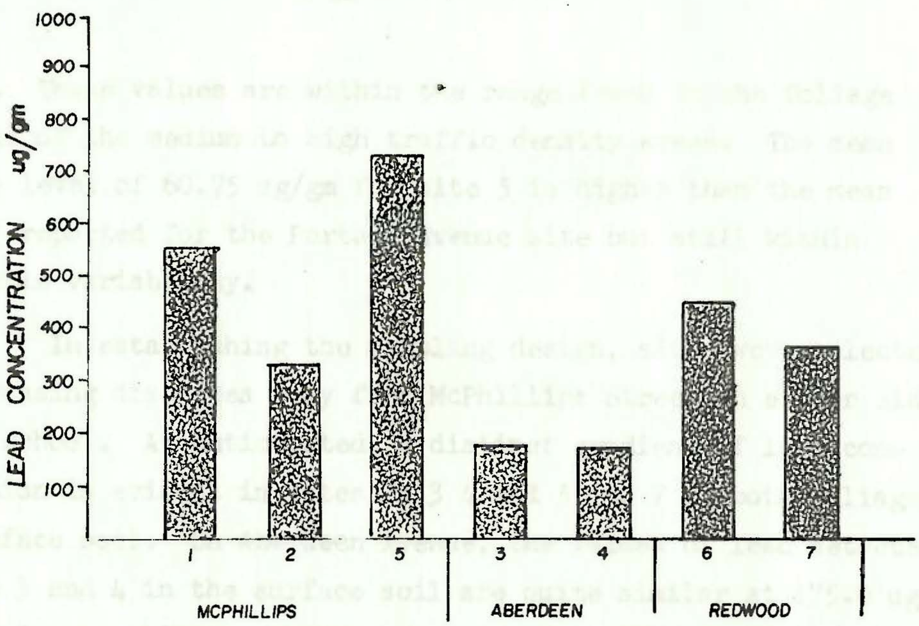

FIGURE 3(a): SUMMARY OF LEAD CONCENTRATIONS IN SURFACE SOIL: LORD NELSON SCHOOL.

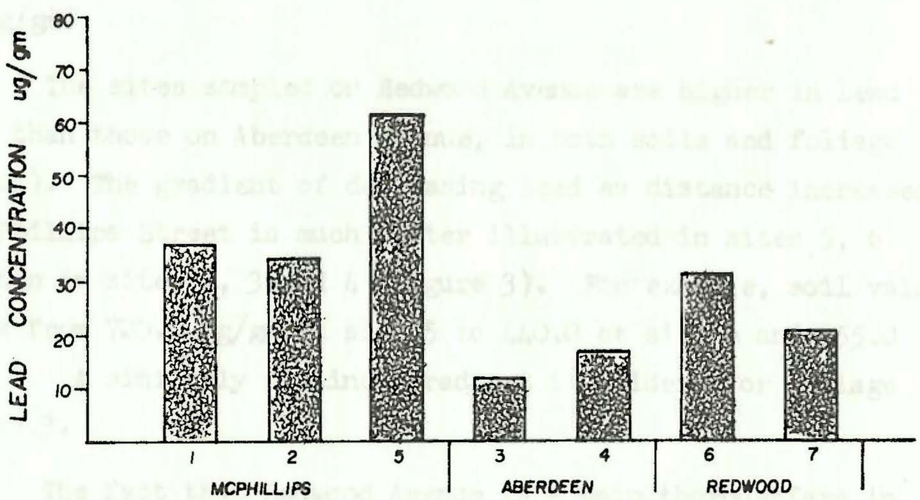

FIGURE 3(b): SUMMARY OF LEAD CONCENTRATIONS IN TREE FOLIAGE: LORD NELSON SCHOOL.

site 1. These values are within the range found in the foliage and soil of the medium to high traffic density areas. The mean foliage level of 60.75 ug/gm for site 5 is higher than the mean of 52.3 reported for the Portage Avenue site but still within reasonable variability.

In establishing the sampling design, sites were selected at increasing distances away from McPhillips Street on either side of the school. As anticipated, a distinct gradient of lead concentration is evident in sites 2, 3 4 and 5, 6, 7 in both foliage and surface soil. On Aberdeen Avenue, the values of lead detected at site 3 and 4 in the surface soil are quite similar at 175.0 ug/gm and 170.0 respectively, whereas site 2, close to McPhillips Street is 325 ug/gm. In the foliage, site 4 has higher lead levels than 3 (17.0 to 11.85) but both are substantially less than site 2 at 34.15 ug/gm.

The sites sampled on Redwood Avenue are higher in lead content than those on Aberdeen Avenue, in both soils and foliage (Table II). The gradient of decreasing lead as distance increases from McPhillips Street is much better illustrated in sites 5, 6 and 7 than in sites 2, 3 and 4 (Figure 3). For example, soil values decrease from 720.0 ug/gm at site 5 to 440.0 at site 6 and 355.0 at site 7. A similarly distinct gradient is evident for foliage in figure 3.

The fact that Redwood Avenue is a main thoroughfare in the east and west direction may provide an explanation of the higher lead concentrations in sites 5, 6 and 7. Site 5, located on the corner of Redwood and McPhillips, may be receiving an even heavier loading than site 1, located adjacent to McPhillips Street in the centre of the block. Sites 2, 3 and 4 being located on Aberdeen Avenue would experience less traffic than those sites on Redwood as Aberdeen is not a main thoroughfare. Subsequently, levels of lead in foliage and soil of sites 3 and 4 approach those of the

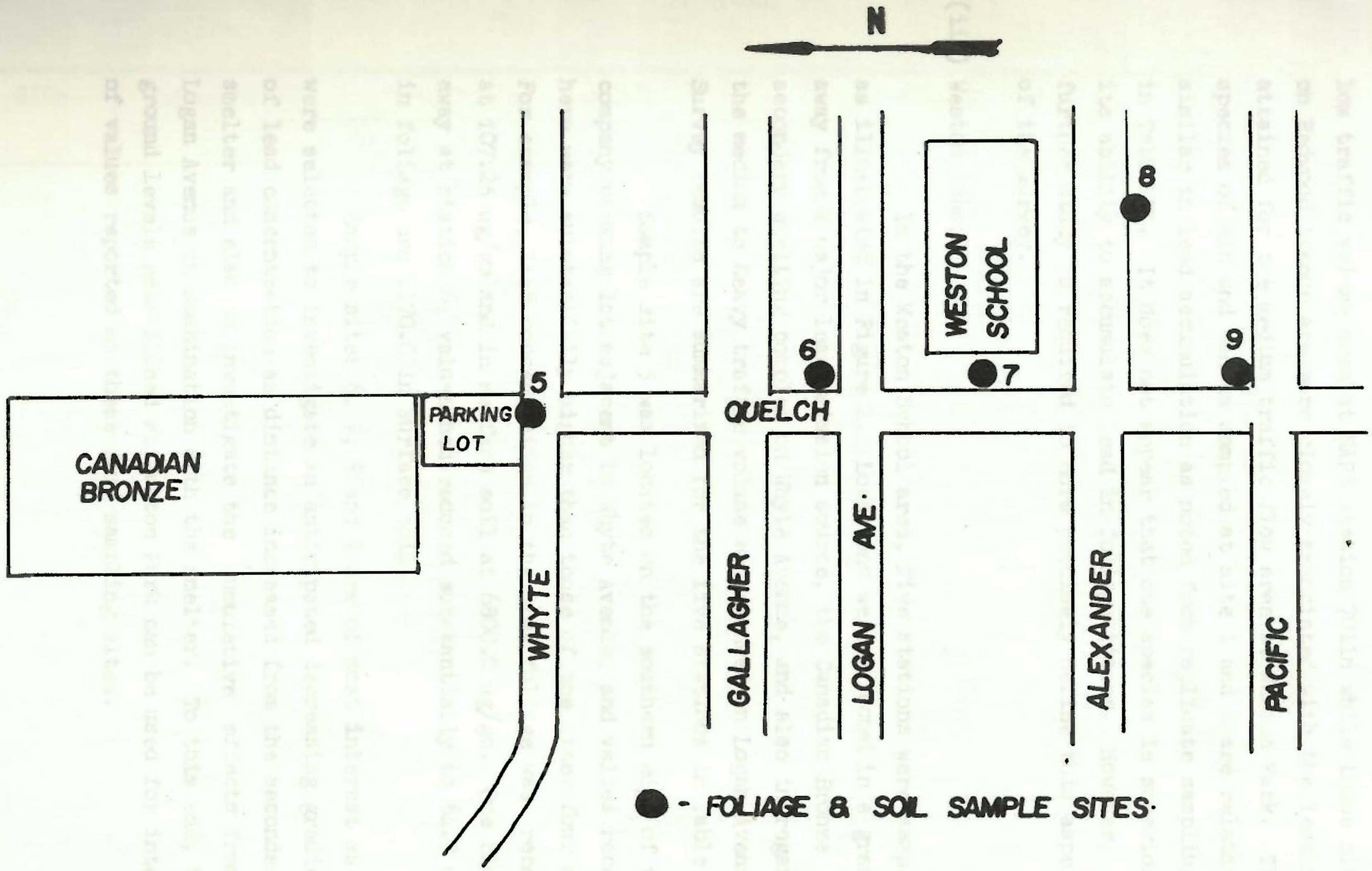

FIGURE 4: SAMPLE SITE LOCATIONS FOR WESTON SCHOOL.

low traffic volume area at NAPS station 70118 while those sites on Redwood Avenue are more closely associated with the levels attained for the medium traffic flow area at Weston Park. The species of elm and ash as sampled at site 1 and 2 are relatively similar in lead accumulation as noted from replicate sampling in Table II. It does not appear that one species is superior in its ability to accumulate lead in foliage tissue. However, further study is required to more precisely define this aspect of the survey.

(iii) Weston School

In the Weston School area, five stations were sampled as illustrated in Figure 4. Locations were selected in a gradient away from a major lead emission source, the Canadian Bronze secondary smelting complex on Whyte Avenue, and also in regard to the medium to heavy traffic volume experienced on Logan Avenue. Survey results are summarized for the five stations in Table III.

Sample site 5 was located on the southern edge of the company parking lot adjacent to Whyte Avenue, and values recorded here were substantially higher than those of the other four stations. For example, lead concentration in the tree foliage was recorded at 107.25 ug/gm and in surface soil at 6800.0 ug/gm. One block away at station 6, values had reduced substantially to 64.9 ug/gm in foliage and 1170.0 in surface soil.

Sample sites 6, 7, 8 and 9 are of most interest as they were selected to investigate an anticipated decreasing gradient of lead concentration as distance increased from the secondary smelter and also to investigate the cumulative effects from Logan Avenue in combination with the smelter. To this end, background levels established at Weston Park can be used for interpretation of values reported at these four sampling sites.

Site	Species	Tree Foliage (ug/gm)			Surface Soil (ug/gm)		
		July	August	Mean	July	August	Mean
5	Ash	49.5	165.0	107.25	5800.0	7800.0	6800.0
6	Ash	37.8	92.0	64.9	1400.0	940.0	1170.0
7	Ash	37.6	88.0	62.8	1420.0	1270.0	1345.0
8	Ash	17.6	59.0	38.3	640.0	350.0	495.0
9	Ash	14.4	28.0	21.2	440.0	290.0	365.0

Table III: Summary of Lead Concentrations at Weston School

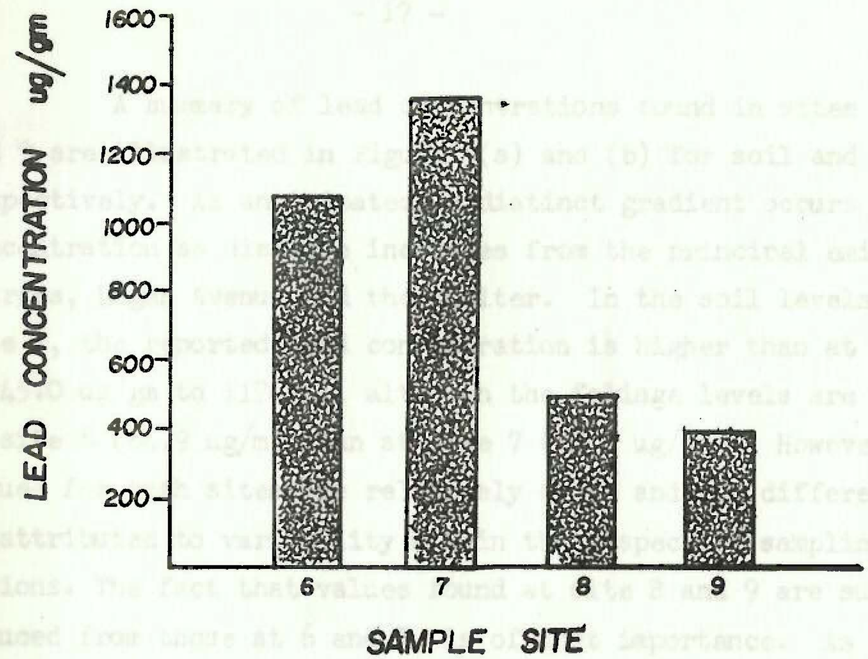

FIGURE 5(a): SUMMARY OF LEAD CONCENTRATIONS IN SURFACE SOIL : WESTON SCHOOL.

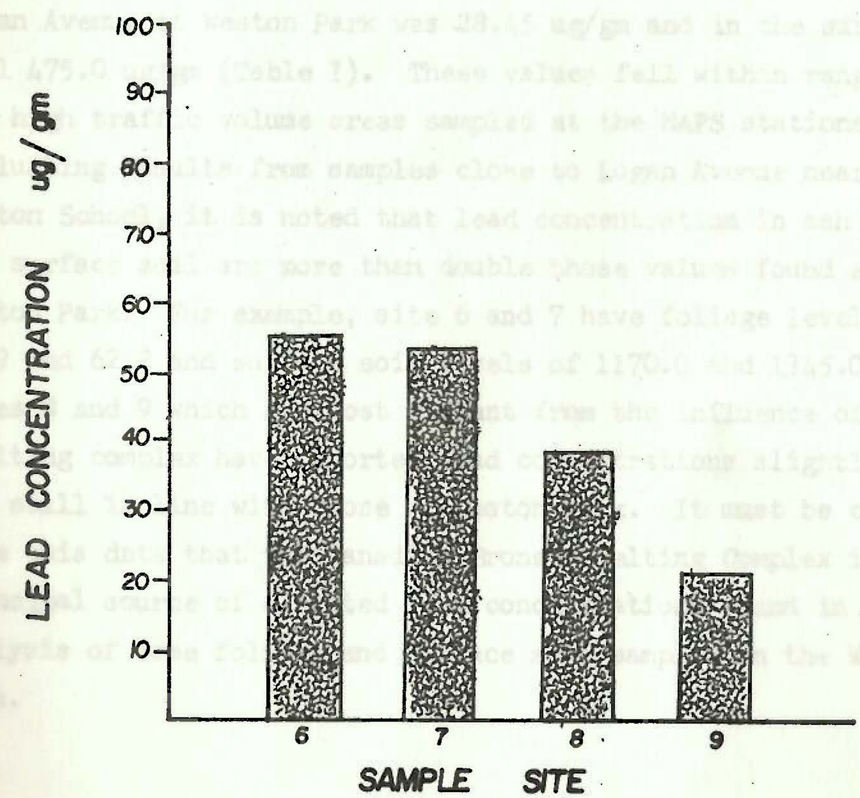

FIGURE 5(b): SUMMARY OF LEAD CONCENTRATIONS IN TREE FOLIAGE : WESTON SCHOOL.

A summary of lead concentrations found in sites 6, 7, 8 and 9 are illustrated in Figure 5(a) and (b) for soil and foliage respectively. As anticipated, a distinct gradient occurs in lead concentration as distance increases from the principal emission sources, Logan Avenue and the smelter. In the soil levels at site 7, the reported lead concentration is higher than at site 6 (1345.0 ug/gm to 1170.0), although the foliage levels are higher at site 6 (64.9 ug/m) than at site 7 (62.8 ug/gm). However, values for both sites are relatively close and the difference can be attributed to variability within the respective sampling populations. The fact that values found at site 8 and 9 are substantially reduced from those at 6 and 7, is of most importance. As clearly indicated in Figure 5, the level of lead concentration found in surface soils and tree foliage decreases as distance increases from the Canadian Bronze Smelting complex and Logan Avenue.

The lead concentration found on ash foliage adjacent to Logan Avenue at Weston Park was 28.45 ug/gm and in the surface soil 475.0 ug/gm (Table I). These values fell within range of low and high traffic volume areas sampled at the NAPS stations. In evaluating results from samples close to Logan Avenue near the Weston School, it is noted that lead concentration in ash foliage and surface soil are more than double those values found at Weston Park. For example, site 6 and 7 have foliage levels of 64.9 and 62.8 and surface soil levels of 1170.0 and 1345.0 respectively. Sites 8 and 9 which are most distant from the influence of the smelting complex have reported lead concentrations slightly higher yet still in line with those of Weston Park. It must be concluded from this data that the Canadian Bronze Smelting Complex is a principal source of elevated lead concentrations found in the analysis of tree foliage and surface soil sampled in the Weston School area.

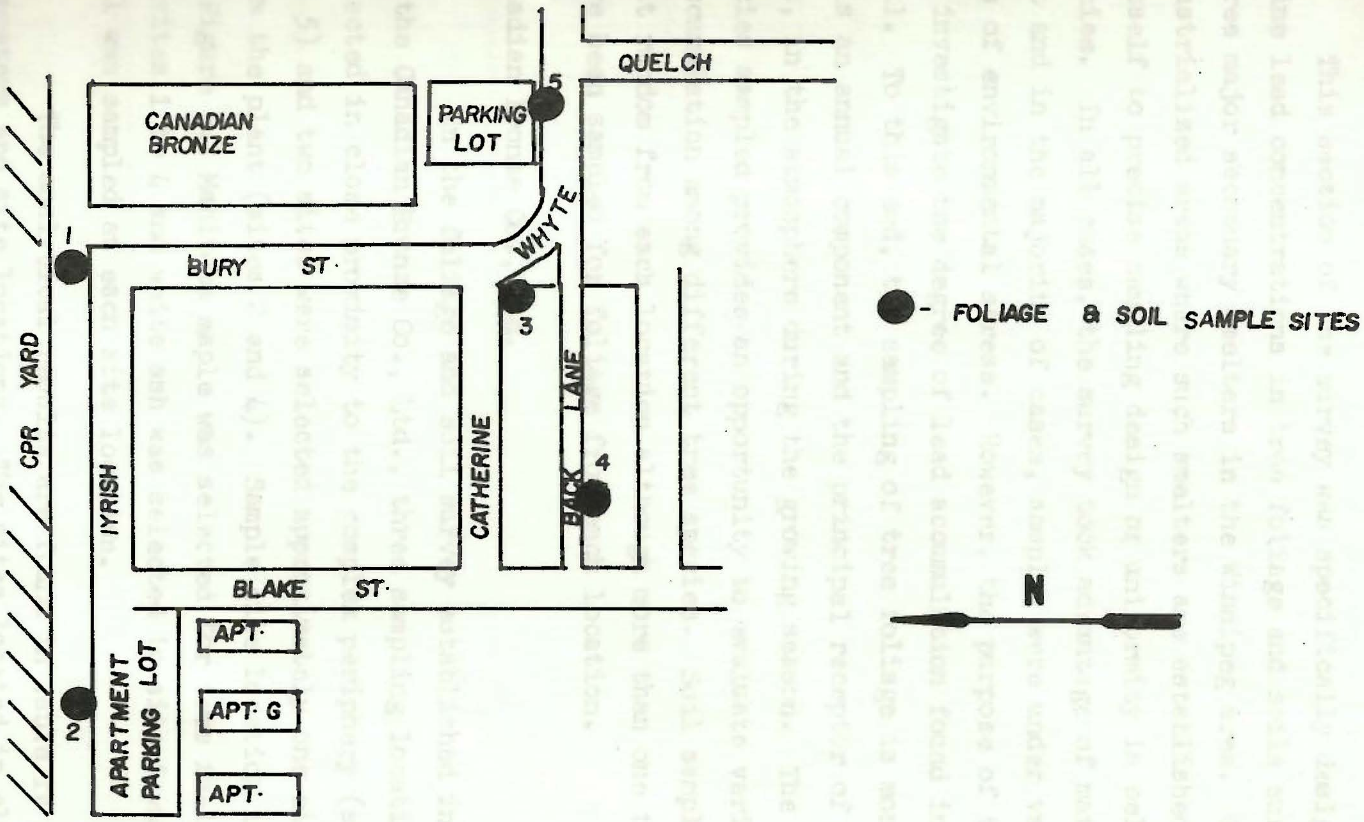

FIGURE 6: SAMPLE SITE LOCATIONS FOR CANADIAN BRONZE CO. LTD.

II. Industrial Sources

This section of the survey was specifically designed to determine lead concentrations in tree foliage and soils surrounding the three major secondary smelters in the Winnipeg area. The nature of industrialized areas where such smelters are established does not lend itself to precise sampling design or uniformity in selection of species. In all cases, the survey took advantage of material present and in the majority of cases, samples were under various degrees of environmental stress. However, the purpose of the survey was to investigate the degree of lead accumulation found in vegetation and soil. To this end, the sampling of tree foliage is most useful as it is an annual component and the principal receptor of lead, if present, in the atmosphere during the growing season. The variation of species sampled provides an opportunity to evaluate variance in lead accumulation among different tree species. Soil samples were taken at random from each location although more than one tree species may have been sampled for foliage from each location.

(i) Canadian Bronze Co., Ltd.

In the foliage and soil survey established in relation to the Canadian Bronze Co., Ltd., three sampling locations were selected in close proximity to the complex periphery (sites 1, 3 and 5) and two sites were selected approximately one city block from the plant (sites 2 and 4). Sample site location is indicated in Figure 6. Manitoba maple was selected for tree foliage sampling in sites 1 to 4 and white ash was selected in site 5 while surface soil was sampled at each site location.

The analytical results are found in Table IV for all parameters and site locations. The sites located in closest proximity to the complex reflect lead concentrations in both foliage and soil that are considerably higher than those from the sites one block away. For example, sites 1, 3 and 5 were found to be

Site	Species	Tree Foliage (ug/gm)			Surface Soil (ug/gm)		
		July	August	Mean	July	August	Mean
1	Maple	109.0	118.0	113.5	3300.0	3050.0	3175.0
2	Maple	38.9	26.0	32.45	880.0	930.0	905.0
3	Maple	79.3	94.0	86.65	3500.0	3800.0	3650.0
4	Maple	35.8	30.0	32.9	1070.0	670.0	870.0
5	Ash	49.5	165.0	107.25	5800.0	7800.0	6800.0

Table IV: Summary of Lead Concentrations of Canadian Bronze Company Limited respectively 113.5 ug/gm, 86.65 and 107.25 in the foliage and 3175.0, 3650.0 and 6800.0 in the surface soil. This is opposed to sites 2 and 4 where foliage values were 32.45 and 32.9 and surface soil values were 905.0 and 870.0 respectively.

Samples taken from sites 1 and 5 are closer to the complex than those of site 3 and as anticipated, the concentration of lead found was higher than that of site 3 in foliage. Site 3 soil values are higher than site 1 and this may be attributed to site 3 being located on a street corner which may receive more traffic than that of site 1, or it may be simply due to site variability. The lead values reported for site 5 are nearly double those of the other two close-in sites. The location of site 5 adjacent to the principal parking lot of the complex may have caused these excessive levels. However, all three close-in sites have considerably higher levels of lead in foliage and soils than the sites one block away.

The more distant sites, 2 and 4, are still considerably higher than those found for samples from a low volume traffic area and in fact approach those of a high volume traffic area (Table I). For example, foliage values at sites 2 and 4 are 32.45 and 32.9 ug/gm while soil values were 905.0 and 870.0 respectively. In comparison at the high volume traffic area, the foliage analysis values for elm were 43.4 and for maple 52.3, while at the low traffic volume area they were 17.6 for elm and 8.31 for ash. Soil values at the Portage Avenue site were 1085.0 and at Scotia and Jefferson they were 132.5. A good comparison of the levels found at this location to normal values found adjacent to Logan Avenue and within relatively the same area of the city is also of value. I refer to the analysis of samples from Weston Park where levels adjacent to Logan Avenue were slightly less (28.45) in the foliage than those at one block distance from the smelting complex, while those away from Logan Avenue were almost half at 16.6. Similarly soil values at Weston Park

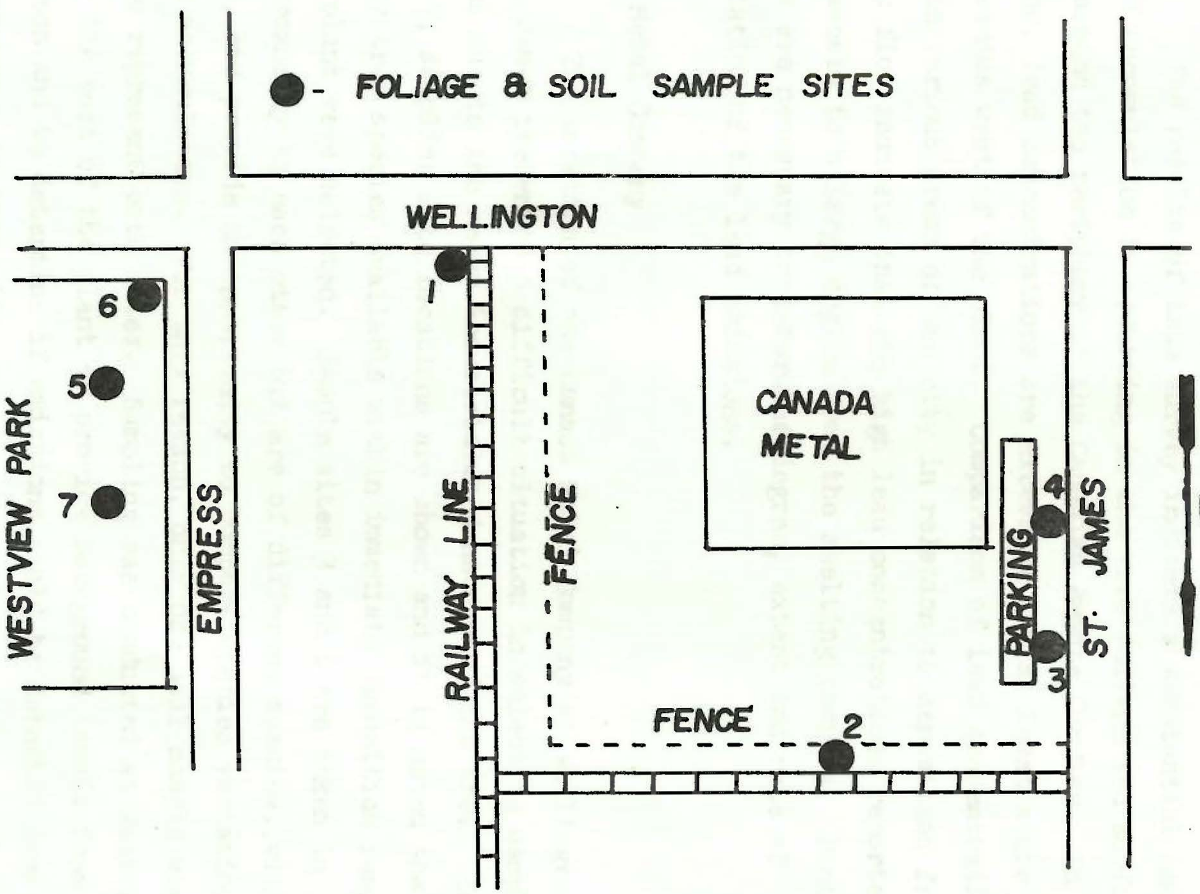

FIGURE 7: SAMPLE SITE LOCATIONS FOR CANADA METAL COMPANY.

were considerably less (475.0 adjacent to Logan Avenue and 290.0 one block north) than the lowest values found around the smelting complex (870.0 one block west).

The results of this survey indicate a substantial amount of lead accumulation is occurring in the tree foliage and surface soils around the periphery of the Canadian Bronze Complex. In addition, lead concentrations are excessive for at least a one block radius west of the plant. Comparison of lead concentrations found in various areas of the city in relation to deposition from traffic flow indicate that the high lead concentrations reported here emanate to a large degree from the smelting complex. Further studies are necessary to determine degree, extent and rate of accumulation of the lead emissions.

(ii) Canada Metal Company

The location of the Canada Metal Company at Wellington and St. James presented a difficult situation in selecting sampling material due to the heavy industrialized nature of the area. In Figure 7, sampling site locations are shown and it is noted that the only tree species available within immediate deposition range of the plant were selected. Sample sites 3 and 4 are taken in close proximity to each other but are of different species, willow and elm, and provide an opportunity to compare species variation in lead accumulation. For this reason, only one soil sample was taken to represent both sites. Sampling was conducted at Westview Park to the east of the plant to provide background levels from Wellington and to determine if emissions could be detected from this distance. At this site, species selection was also restricted, however, both elm and willow were located and sampled for comparison with sites 1 to 4.

Site	Species	Tree Foliage (ug/gm)			Surface Soil (ug/gm)		
		July	August	Mean	July	August	Mean
1	Willow	258.0	488.0	373.0	2000.0	3000.0	2500.0
2	Willow	161.0	131.0	146.0	2540.0	2200.0	2370.0
3	Willow	391.0	450.0	420.5	4800.0	5900.0	5350.0
4	Elm	1796.0	900.0	1348.0	—	—	—
5	Elm	147.0	185.0	166.0	760.0	940.0	850.0
6	Elm	118.0	192.0	155.0	600.0	520.0	560.0
7	Willow	219.0	150.0	185.95	1800.0	730.0	1265.0

Table V: Summary of Lead Concentrations at Canada Metal Company

Analytical results for all sampling sites are found in Table V. It is quickly noted that foliage values found for the elm sampled at site 4 are extremely high (1348 ug/gm) and do not coincide with those for willow at sites 1, 2 and 3 which are 373.0, 146.0 and 420.0. It is also noted that values found for the elm and willow foliage from sites 5, 6 and 7, although higher in the willow are much more in line with each other. The excessively high values at site 4 were replicated in July and August sampling as shown in Table I and these values reflect a wide variance (i.e. 1796.0 to 900.0). However, they are consistently higher than the analysis of sites 1 and 2. Similarly, the values found for soil in the area of site 3 and 4 is consistently almost double the values found in the other close-in sites at 5350.0 ug/gm.

This excessive level may be slightly exaggerated due to the fact that the site is located between the plant's parking lot and the heavy volume of traffic experienced on St. James Street. However, it is most certain that traffic alone cannot account for such excessively high levels of lead concentration as found in the foliage and soil around the plant and direct deposition from the plant must be largely responsible. For example, the values found in surface soil range from 2370.0 at site 2 to 5350.0 at site 3, and those found adjacent to Portage Avenue were the highest of any roadway at 1085 ug/gm which is less than half of any sample analyzed close to the plant. In a similar way, foliage samples close to the plant are completely out of line with those from a major traffic area. For example, elm and maple adjacent to Portage Avenue were 43.4 and 52.3 ug/gm respectively while willow samples from sites 1, 2 and 3 were found to be 373.0, 146.0 and 420.5 respectively. These excessive levels must be attributed to aerial deposition from the Canada Metal Plant.

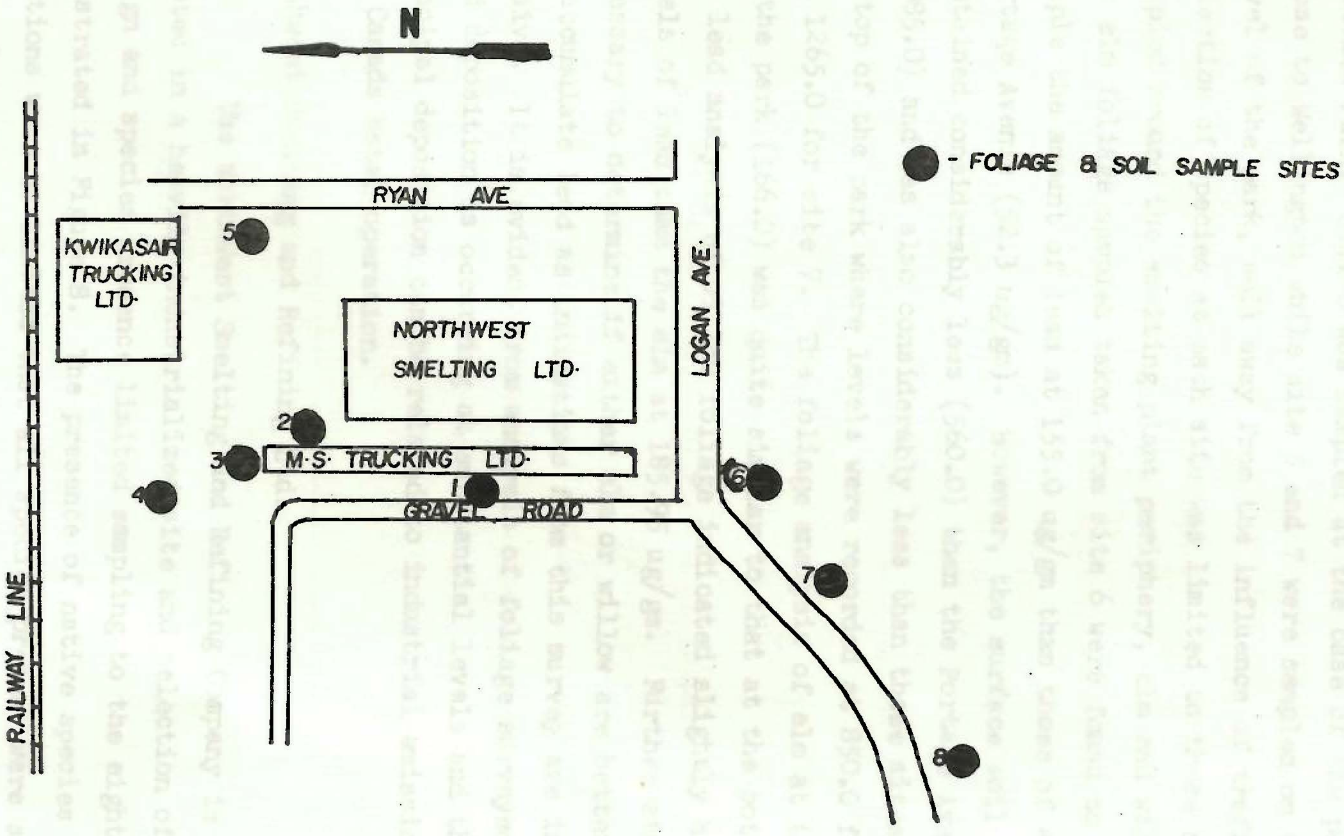

FIGURE 8: SAMPLE SITE LOCATIONS FOR NORTHWEST SMELTING AND REFINING LTD·

The sampling of sites 5, 6 and 7 was conducted in Westview Park. Site 6 was sampled at the base of the park and close to Wellington while site 5 and 7 were sampled on the upper level of the park, well away from the influence of traffic. The selection of species at each site was limited to those species sampled around the smelting plant periphery, elm and willow. The elm foliage samples taken from site 6 were found to contain triple the amount of lead at 155.0 ug/gm than those of elm from Portage Avenue (52.3 ug/gm). However, the surface soil sample contained considerably less (560.0) than the Portage Avenue site (1085.0) and was also considerably less than those sites sampled on top of the park where levels were recorded at 850.0 for site 5 and 1265.0 for site 7. The foliage analysis of elm at the top of the park (166.0) was quite similar to that at the bottom (155.0). The lead analysis of willow foliage indicated slightly higher levels of lead than the elm at 185.95 ug/gm. Further studies are necessary to determine if either elm or willow are better adapted to accumulate lead as indications from this survey are inconclusive. It is evident from analysis of foliage surveyed that lead deposition is occurring at substantial levels and that principal deposition can be related to industrial emissions from the Canada Metal operation.

(iii) Northwest Smelting and Refining Ltd.

The Northwest Smelting and Refining Company is also located in a heavily industrialized site and selection of sampling design and species presence limited sampling to the eight sites illustrated in Figure 8. The presence of native species and their locations were so limited that all species present were sampled to complete the survey, i.e. willow, poplar, manitoba maple and honeysuckle. In three site locations (2, 6 and 8), two tree species were sampled for foliage and as these samples were taken

Site	Species	Tree Foliage (ug/gm)			Surface Soil (ug/gm)		
		July	August	Mean	July	August	Mean
1	Willow	42.9	40.0	41.45	340.0	510.0	425.0
2	Willow	469.0	365.0	417.0	19000.0	18800.0	18900.0
	Poplar	195.0	100.0	147.5	—	—	—
3	Maple	346.0	305.0	325.5	1920.0	2570.0	2245.0
4	Poplar	73.7	105.0	89.35	2180.0	2800.0	2490.0
5	Honey-suckle	76.8	3150.0	1613.4	5200.0	2800.0	4000.0
6	Maple	208.0	285.0	246.5	890.0	930.0	910.0
	Poplar	130.0	209.0	169.5	—	—	—
7	Maple	122.0	149.0	135.5	890.0	530.0	710.0
8	Maple	63.2	60.0	61.6	720.0	700.0	710.0
	Willow	34.7	29.0	31.85	—	—	—

Table VI: Summary of Lead Concentrations at Northwest Smelting and Refining Limited from the same site, only one soil sample was required. As in other areas, the selection of different species was conducted to sample variance in lead accumulation of foliage between tree species.

To the west of the plant, sample site 1 is the only location surveyed. The willow foliage analyzed contained considerably less amounts of lead at 41.45 ug/gm than at any of the other locations (Table VII). Similarly, the level of lead in surface soil from site 1 is also much less at 425.0 than that of other sites sampled. The levels detected at site 1 are in line with those of a medium to heavy traffic area although the site was located on a gravel lane.

Sample sites 2, 3 and 4 were located along a transect northwest of the plant at increasing distances. As anticipated, a gradient of lead accumulation was found between foliage of willow, maple and poplar as distance increased from the smelter. For example, at site 2, foliage samples were found to have 417.0 ug/gm in willow, at site 3, levels of 325.5 in maple, and at site 4, the poplar were found to have 89.35. There was a considerably lower amount of lead found in poplar foliage at site 2 (147.5 ug/gm) than in the willow from the same site. However, this amount is still much higher than levels found at site 4 in the poplar foliage (Table VI). Lead levels in surface soil at site 2 were excessive at 18,900.0 ug/gm as compared to those at site 3 (2245.0) and site 4 (2490.0). However, at site 2, both July and August replicates indicated very consistent results (19,000.0 and 18,800.0 respectively) and therefore, this figure must be representative.

At sample site 5, the only available vegetation suitable for the survey purpose was honesuckle. The individuals located for sampling were adjacent to a landfill area in which the smelting complex was using discarded batteries for base fill. It is possible that for this reason, soil levels were found to be as high as

4,000.0 ug/gm during the survey. Although variation is substantial between July and August (5200.0 and 2800.0 respectively) still the mean value is within range in consideration of site 4 where 2490.0 ug/gm were recorded. Similar to soil, the lead concentrations in foliage were extemely high at site 5 with a mean value of 1613.4 ug/gm. In consideration of the variance between July and August (76.8 and 3150.0), the mean value found in foliage at site 5 cannot be accepted without further sampling for verification.

The location of sites 6, 7 and 8 was designed to investigate a possible gradient of deposition to the southwest of the smelter. As anticipated, a distinct gradient exists where lead concentration decreases as distance increases from the smelter. Maple foliage from the closest location at site 6 was 246.5 ug/gm, 135.5 in site 7 and 61.6 in site 8 while lead values reported in the soil were 910.0, 710.0 and 710.0 respectively. The furthest site contains lead levels which consistently reflect those of a heavy traffic area which is not normal for this section of Logan Avenue. The foliage values reported for sites 6 and 7 are much more in excess of those of site 8 and must be attributed to the deposition of lead emissions associated with Northwest Smelting and Refining Ltd. This situation is also true in the gradient of lead concentrations found in tree foliage and surface soils to the northwest of the smelting plant.

In three site locations, more than one species was selected for foliage sampling. The foliage of poplar and willow were found to accumulate considerably less lead than the Manitoba maple. Further studies will be required to precisely define variances between species, however, initial indications from this survey are that such variances do exist.

CONCLUSIONS .

1. The analytical results presented from this survey indicate that tree foliage and surface soil are useful indicators of the ambient deposition of lead emission in the urban environment.
2. It was found that variability among tree species in the absorption and accumulation of lead in leaf tissue exists, but further intensified study is needed to precisely define the difference between urban species.
3. It was determined that lead accumulation from urban traffic in the Winnipeg area resulted in lead concentrations which ranged from 43.4 ug/gm to 17.6 ug/gm in tree foliage and 1085.0 ug/gm to 132.5 ug/gm in surface soil for areas of high and low traffic volume respectively.
4. Levels of lead concentration in tree foliage and surface soils in the vicinity of Lord Nelson School were found to be highest adjacent to McPhillips Street and decreased substantially as distance increased away from this principal emission source.
5. Levels of lead concentration in tree foliage and surface soils in the vicinity of Weston School were substantially higher than normal levels associated with Logan Avenue and decreased as distance increased from the Canadian Bronze Complex.
6. Levels of lead concentration found in tree foliage and surface soils in the vincity of three secondary lead smelters was excessively high in the immediate periphery of each smelting complex and lead values decreased as distance increased away from each smelter.
7. Lead concentration in tree foliage and surface soil from sampling locations in close proximity to the secondary smelters was frequently tenfold the lead concentrations found to accumulate from normal motor vehicle emissions in the Winnipeg area.
8. It can be anticipated that levels of lead similar to those found in tree foliage and surface soils will also be present in other plant tissues and soils such as those found in vegetable gardens within range of the sampling network established in this study.

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