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Lead Particulate Analysis in Air and Soil of The City of Winnipeg 1982

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LEAD PARTICULATE ANALYSIS IN AIR AND SOIL OF THE CITY OF WINNIPEG 1982

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ABSTRACT

A lead research project was co-operatively implemented by the Canadian Bronze Company Limited, Atomic Energy of Canada (Pinawa) and the Environmental Management Division of the Province of Manitoba. The objectives were to investigate a procedure which would distinguish between the forms of lead originating from various sources in the City of Winnipeg in addition to carrying out follow-up soil surveys in the vicinity of smelters, school yards and areas of varying traffic volume. A procedure was developed by A.E.C.L. using scanning electron microscopy (SEM)/energy dispersive x-ray spectometry (EDX) to "fingerprint" lead emissions to source. Smelter and motor vehicle emissions were found to have unique physical and chemical characteristics. Secondary smelters may be significant contributors to very localized high lead concentrations and although elevated concentrations of lead were found in the Weston school yard, one year after clean-up, the major source is believed to be the exhaust of motor vehicle traffic.

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I SUMMARY

Lead is one of the oldest known toxins to man. The most common sources of lead are: industrial emissions such as smelters, the combustion of leaded gasoline from motor vehicles, and lead based products such as paints. Exposure to lead in man is by ingestion or inhalation. Of particular concern is the indirect effects of lead in soil in areas frequented by young children.

The Environmental Management Division adopted a 2600 $\mu g/g$ (micrograms per gram) guideline for maximum concentration of lead in soil and recommends removal and replacement of residential sod or soil having lead levels equal to or exceeding the guideline. In 1981 and 1982 remedial action was taken in the Weston area of Winnipeg when lead in soil was found to exceed the guideline. In the City of Winnipeg this is the only residential area where a secondary lead smelter is located (the Canadian Bronze Company Limited).

Analysis of lead in soil by conventional atomic absorption spectroscopy provided data on total lead concentrations ($\mu g/g$) exclusive of source. A lead research project was designed to characterize the lead species originating from known sources in the in the city. To facilitate the research a collective agreement was arranged between the Atomic Energy of Canada at Pinawa, the Canadian Bronze Company Limited and the Environmental Management Division.

Atomic Energy of Canada used automated electron beam microanalysis techniques to analyze 3389 respirable size particulates collected on 22 environmental air filters. X-ray spectral pattern recognition techniques were used to determine various lead species from automobile exhaust and secondary lead smelting operations. Auto exhaust emissions appear to be the primary source of lead around schools located near major traffic arteries in northwest and north-central Winnipeg. Lead in soil and particulate debris at Weston Elementary School had returned to elevated levels one year after clean-up. The significance of the contribution of lead smelter emissions to the total annual lead deposition in Winnipeg requires additional sampling and study.

II BACKGROUND

Lead (Pb) is a natural constituent of the earth's crust. Although lead has been used extensively by man since the early ages, levels in the environment increased substantially in recent times as a result of the industrialization of our society. The most common sources of lead are: industrial emissions such as smelters, the combustion of leaded gasoline in motor vehicles, and lead based products such as paints.

It is well known the more common forms of lead are toxic to man[1,4,5]. The human body acquires lead by ingestion or inhalation and it is generally accepted that lead burdens in the body are cumulative with time.[5,6,7,] On exposure to a given concentration in the environment, there is a greater risk of toxic lead symptoms in children than in adults. This is because children's habit of pica and of mouthing objects increases the chance of ingesting the lead and their lower body mass increases the effective body concentration.[1,3]

Lead in soil is relatively immobile and can persist for a long period of time. As a result there is concern for indirect effects which may arise from the following: (a) ingestion by small children; (b) the consumption of edible vegetables grown in high lead soils; and (c) the reentrainment of leaded particulate matter into the air[6,9].

The Environmental Management Division of the Province of Manitoba has been concerned about lead in soil of the City of Winnipeg since 1979. At that time soil surveys indicated elevated lead levels in sod and soil adjacent to major traffic arteries and in the vicinity of three secondary lead smelters[11]. There was particular concern for the residential area of Weston in which a secondary lead smelter, the Canadian Bronze Company Limited, is located. This is the only smelter located in a residential area in the city. During 1980 and 1981, the Environmental Management Division carried out extensive soil sampling surveys in the vicinity of this smelter.

In 1981 the Environmental Management Division adopted the recommended Ontario Ministry of the Environment guideline for lead in soil of 2600 μg/g. This guideline is an arbitrary criterion for unacceptable lead concentrations in sod and soil of residential areas or areas frequented by children.

The surveys identified two areas where lead concentrations in soil were above this accepted criterion. These areas were the north yard of Weston School adjacent to Logan Avenue and a residential area of approximately two city blocks between the school and the secondary smelter.

In 1981 the Environmental Management Division carried out a physical clean-up program of the north yard of Weston School. In 1982 a sod/soil removal and replacement program was carried out on

26 residential properties in the area[8]. At the same time the Canadian Bronze Company contracted out the removal and replacement of contaminated sod and soil on the picnic site of their property.

The clean-up of contaminated soil in the Weston School yard and the sod/soil removal and replacement program were implemented as preventative actions by the Environmental Management Division to remove potential risk to the health of children. The criteria used to define unacceptable levels were based on the best available information about the relationship between human health and lead levels in the soil.

The levels of lead in soil are representative of historical deposition and accumulation. Conventional atomic absorption spectroscopy was used to analyse soils, the results being reported as micrograms of lead per gram of soil. These data represent total lead, not distinguishable by source.

In July 1982 a lead research project was implemented to investigate a procedure which would distinquish between the forms of lead originating from various sources in the City of Winnipeg. This is also technically known as "speciation" or "fingerprinting". The research was a co-operative endeavour between Atomic Energy of Canada, the Canadian Bronze Company Limited, and the Environmental Management Division.

III RESEARCH SCOPE

The research project was undertaken as a follow-up to the remedial actions of soil removal and replacement carried out in the Weston area in 1981 and 1982. It was designed to provide a better understanding of lead deposition by "fingerprinting" lead particles, thus providing a means of tracing the lead to its source.

The research was divided into several component parts. The first was the development of a procedure to sample air emissions from the exhaust of a motor vehicle burning leaded gasoline and from the stack of a secondary lead smelter. The second component was to test the hypothesis that lead particles could be identified, and characterized by morphology or elemental association. This procedure would provide a mechanism of fingerprinting or speciating lead particles to identify their source.

Following the development of these procedures, a sampling design was developed to provide representative coverage of the areas of concern for lead deposition or accumulation in the City of Winnipeg. Twenty samples were collected from eighteen locations throughout the city. Included were the three secondary lead smelters with particular emphasis on the Weston area, National Air Pollution Surveillance (N.A.P.S.) sites, Weston Elementary School and three other schools in north-central Winnipeg.

Because the initial microanalysis phase identified a close association between lead and zinc in samples from the Canadian Bronze smelter stack, soil samples were taken from all sites and analyzed by conventional procedures for lead and zinc. It was anticipated that if a similar association of lead and zinc in the soil was found, it could implicate the Canadian Bronze stack as a possible source. Follow-up surveys of soil and particulate debris were also carried out at Weston Elementary School in the north yard adjacent to Logan Avenue which was thoroughly cleaned up in 1981 following the discovery of elevated lead levels.

The research effort was divided into two distinct phases:

(I) Under contract, Atomic Energy of Canada was to undertake research and development of scanning electron microscopy (SEM)/energy dispersive x-ray spectrometry (EDX) analysis to characterize lead species from air samples at various locations.

(II) The Environmental Management Division undertook to develop air sampling procedures for the collection of SEM samples, to develop a sampling network to provide representative coverage of the areas under investigation and to carry out the soil sampling and analysis at all sites in addition to the re-sampling at Weston Elementary School.

These two phases of the research program are presented separately as Section 1 and Section 2.

IV SECTION 1

MICROANALYSIS OF LEAD PARTICULATES FROM THE CITY OF WINNIPEG

1.1 INTRODUCTION

Canadian Bronze Co. Ltd. (purchase order C-5783) authorized the scanning electron microscopy (SEM)/energy dispersive x-ray spectrometry (EDX) analysis of twenty filter samples collected under the direction of the Province of Manitoba, Environmental Management Division. Two reference specimens had been analyzed at an earlier date courtesy of AECL.

The main objectives of the contract were:

(1) to characterize the lead species originating from automobile exhaust and various secondary lead smelters in northwest Winnipeg,

(2) to identify the primary sources of lead contamination around the Weston school area.

Figure 1 is a map of the individual sampling locations.

1.2 EXPERIMENTAL

1.2.1 Sample Preparation Each of the air samples listed in Table 1 was collected on a 47 mm diameter polycarbonate (Nucleopore) membrane filter having a 0.4 μm pore size. A 10 mm wide strip was cut from the centre of each of the 22 sample filters, mounted on a glass slide, and coated with a thin carbon film (15 - 20 mm thick) using a vacuum evaporator. The carbon film was necessary to render the specimens electrically conductive for examination in the SEM.

Representative areas (approximately 10 mm x 10 mm) from each of the carbon-coated filters were subsequently mounted on carbon stubs and examined in an ISI DS-130 scanning electron microscope equipped with a Tracor Northern TN-2000 energy dispersive x-ray spectrometer.

X-ray microanalysis of each sample was conducted on the bottom stage of the SEM under the control of the Particle Recognition and Characterization (PRC) computer program using backscattered electron imaging. High resolution secondary electron images were collected on the top stage of the SEM.

1.2.2 "PRC" Operation The Particle Recognition and Characterization (PRC) software used to collect x-ray microanalysis data is a proprietary program developed by Tracor Northern and U.S. Steel Corp. A brief description of the principles of program operation and experimental limitations is attached as Appendix 1.

The main experimental parameters of PRC were set to characterize particulates with an equivalent spherical diameter of 0.25 - 10 μm. A maximum x-ray analysis time of 20 seconds/particle was used. The 0.25 μm minimum particle diameter was chosen based on signal/noise characteristics of the EDX spectra, and the 10 μm maximum particle diameter was selected to restrict analysis to particules of respirable dimensions.

All EDX analyses were performed using a 25 keV electron beam to facilitate Pb L-xray and Pb M-xray identifications, and at an optimum specimen geometry (20^{o} tilt, 22 - 24 mm working distance) to maximize minor element x-ray intensities.

1.3 RESULTS AND DISCUSSION

For the 22 samples submitted, 3389 particles were analyzed. All particles observed were of respirable dimensions (less than 6 μm equivalent spherical diameter).

Relevant EDX data are summarized in Tables 1 and 2. As a basis for discussion, the 22 samples can be divided into three major groups:

(1) reference samples collected from the exhaust of an automobile burning leaded gasoline, and stack samples from the three secondary lead smelters, designated by code leters A, B, and C.

(2) control samples collected from the Weston area during the summer months while Smelter A was not operating,

(3) experimental samples collected throughout Winnipeg during autumn while all smelters were operating.

Comparison of Figures 2, 3, 4 and 5 indicates that each reference sample exhibits a relatively distinct particle morphology, but more importantly, carries a distinctive EDX spectral pattern or "fingerprint". The one exception is the stack sample from Smelter C which is nearly electron transparent and devoid of characteristic x-ray emissions (the crystals are suspected to be sulphur). The "fingerprint" pattern for auto exhaust is lead with bromine and/or chlorine; for Smelter A, lead with zinc; for Smelter

B, strong lead x-ray signals with possibly a minor nickel presence (the nickel may be an artifact from secondary x-ray fluorescence within the SEM). These differences in EDX spectra form the basis for assignment of lead species in Table 1. In addition, a strong lead plus tin and/or tin-antimony incidence was observed near Smelter C (at 1476 Wellington Ave.) and may be characteristic of that specific smelting operation. The absence of lead in the Smelter C stack sample may be the result of a small population of lead particles being lost in a sea of sulphur crystals collected on the filter.

Because of potential spectral overlaps between lead or sulphur, and bromine or aluminum, Table 1 distinguishes between Pb-confirmed (both sets of Pb spectral lines observed) and Pb-suspected (potential for Pb or S) particulates. In many cases, the Pb-suspected data was confirmed to have Pb present by visual examination of the individual particle spectra, but the peak intensities needed to satisfy the counting statistics of the computer algorithm were not exceeded and a positive confirmation was not reported.

The incidence of zinc suspected as opposed to zinc confirmed usually meant that the zinc was present along with other metallic elements such as iron (characteristic of galvanized metal), and was not in the form of the zinc oxide or zinc oxy-hydroxide which was the distinctive crystalline structure observed in the stack emissions from Smelter A.

A very high population of calcium rich (calcium x-rays $\geq$50% of total x-ray emissions) particles was associated with cement and/or construction materials.

Some abnormalities noted in Table 1 are considered in greater detail in Appendix 2 which gives a single page profile of each sample.

Table 2 normalizes the discrete particle counts from Table 1 on a percentage basis, and attempts to derive a possible lead accumulation rate (arbitrary units) for each sample location. This calculation is based on:

(1) normalizing the percent total area covered by particles to a 60 minute accumulation time - assuming a linear deposition rate,

(2) multiplying the normalized particle area deposition rate calculated above, with the percentage of confirmed lead particulates in the total particle population to yield a lead accumulation rate.

This calculated lead accumulation/deposition rate must be considered as a very rough estimate (i.e. order of magnitude calculation) and may only be useful to suggest trends and avenues for further study.

Table 3 displays the same information as Table 2, but the samples are arranged in decreasing rank from highest to average values.

The most noteworthy observation from Table 3 is that the highest lead accumulation rates were calculated to be near Lord Nelson School, Dufferin School, and Weston School - all located alongside major traffic arteries.

It should be noted that in many instances particles overlap or form agglomerates and the particle size information tabulated in Appendix 2 must be considered as an overestimation of particle size. In addition, as illustrated in Figure 6, many particles smaller than 0.25 μm are not visible when imaging with the Robinson backscattered electron detector, and consequently would neither be sized nor analyzed. It is believed that many of these very small particles are of auto exhaust origin, and consequently the value for confirmed lead as auto-exhaust must be considered as a minimum value.

Finally, throughout this analytical report, no effort has been made to correlate variations between experimental and control samples as a result of changes in meteorological conditions. To aid in this aspect of interpretation by the Environmental Management Division, the wind velocity and direction is included with the Table 2 data.

1.4 CONCLUSIONS

(1) SEM-EDX analysis is an extremely useful technique to "fingerprint" smelter emissions.

(2) All particulates analyzed by this experimental technique were of a respirable size ($\leq$6 μm spherical diameter).

(3) The major source of lead deposition around Weston School is probably motor vehicle exhaust rather than Smelter A (Canadian Bronze Company Ltd.).

(4) Other Winnipeg schools may also be developing high lead levels from auto exhaust due to their proximity to major traffic arteries.

(5) Isolated sample locations (2126 Logan near Smelter B and 1476 Wellington near Smelter C) suggest smelters may be significant contributors to the very localized, high lead concentrations.

V SECTION 2

AIR SAMPLING PROCEDURES AND SOIL SURVEYS FOR LEAD DEPOSITION FROM THE CITY OF WINNIPEG

2.1 INTRODUCTION

The Environmental Management Division developed air sampling procedures for microanalysis of lead particulate by Atomic Energy of Canada, Pinawa. Twenty air samples were collected and analyzed from eighteen locations in north-central and northwest Winnipeg. In addition, soil sampling for conventional chemical analysis was carried out at all locations. A follow up survey of the north yard of Weston Elementary School was included.

The Weston area received particular emphasis as it is the only residential area of the City of Winnipeg in which a secondary lead smelter, the Canadian Bronze Company Limited is located . Previous investigations of lead in soil resulted in remedial action being taken by the province in the north yard of Weston Elementary School in 1981 and in the residential area between the school and the smelter in 1982. Microanalysis results of the smelter emissions from this smelter indicated a close association of lead and zinc; zinc appears to be a useful tracer.

The main objectives of Environmental Management's participation in the lead research were:

(1) To develop a procedure to collect air samples for microanalysis by Atomic Energy of Canada.

(2) To investigate lead and zinc in soils which may assist in the identification of potential sources of lead.

(3) To further knowledge of lead deposition in the Weston area in the vicinity of the secondary lead smelter.

2.2 EXPERIMENTAL

2.2.1 SAMPLING PROCEDURES

Air sampling procedures were developed in co-operation with the Air Pollution Control Section of the Environmental Control Services Branch, Environmental Management Division. Air was drawn by a vacuum pump across a 47 mm diameter polycarbonate (Nucleopore) membrane filter having a 0.4 μm pore size. Because of the nature of the microanalysis procedure the population of particles on each filter had to be small enough to insure good separation but large enough to provide a reasonable sample. It was found that an optimum sample was collected when the filter was slightly discoloured. Since different particle densities were present in the air at each site, the sampling time was varied from site to site.

Source specific reference samples were collected from Smelter A and from the exhaust of a vehicle using leaded gasoline. These two samples were analyzed courtesy of Atomic Energy of Canada as part of their procedure development and testing program. Twenty samples were subsequently collected from eighteen locations in the north-central and northwest part of the city. These samples included stack emissions from the three secondary smelters, four elementary school locations including Weston Elementary School, and areas of varying traffic volume (Figure 1). Three of the samples

(No. 2, 6, 7) were obtained as controls during the summer shut down of the Weston Smelter. All other samples were collected in September and October when all smelters were operating. Simultaneous sampling of soil and sod was carried out at all locations with the exception of smelter stacks.

The sod and soil samples were air dried at room temperature, ground, sieved (No. 80 sieve), and analyzed for lead and zinc by the Provincial Technical Services Laboratory using conventional atomic absorption spectrophotometry.

Soil and particulate debris for lead analysis was also collected from the north yard of Weston Elementary School. After the school grounds cleanup in 1981, three follow-up surveys were carried out at sixteen locations, (Figure 7) in 1982. The first set of follow-up samples was collected on April 7, 1982 prior to the City of Winnipeg's spring cleanup program, the second was on May 19, 1982 immediately following the spring cleanup and the third survey was on September 16, 1982.

2.3 RESULTS AND DISCUSSION

2.3.1 AIR SAMPLING

Air sampling procedures to collect samples suitable for the microanalysis, were developed. Exposure time was critical, in that optimal loading had occurred when a very slight discolouration was evident on the face of the nucleopore filter.

A summary of the sampling data, exposure time and meteorological data is found in Table 4. It is noted that exposure time varied from 4 minutes to 3 hours 35 minutes. Although meteorological conditions were documented at the time of sampling, no attempt was made to use that information in the data interpretation. Also it should be noted that sampling was not replicated.

2.3.2 SOIL SAMPLING - LEAD AND ZINC

Lead and zinc concentration in soil and particulate debris from each of the fifteen ground locations is presented in Table 5. As stated in Section A, the results of microanalysis found distinctive EDX spectral patterns or "fingerprints" for auto exhaust and the different smelters. For Smelter A, zinc was associated with the lead while zinc is not in close association with auto exhaust or particulates from the other secondary lead smelters.

The first six sites referred to in Table 5 are located in the Weston area, from the parking lot of Smelter A to the corner of Pacific and Quelch i.e. four blocks south of the smelter. Lead and zinc levels are highest at those sites closest to the smelter and decrease as distance increases. The levels of lead and zinc found at 2193 Gallagher is representative of uncontaminated soil replaced

as part of the remedial action program in June, 1982. The concentrations found at the N.A.P.S. site on Ellen Street (no. 17) are considered to be representative of the downtown core area of Winnipeg.

The amount of zinc found in the boulevard soil at Weston School and the corner of Pacific and Quelch is higher than at other sites but still within reasonable background variability. The Weston School sample is substantially higher in both lead and zinc than the Dufferin School sample although both schools are located on the same major traffic route (Logan Avenue). Dufferin School and Lord Nelson School results are similar and are representative of lead deposition near high volume traffic arteries. Tyndall Park School is located in a new subdivision and is not near a major traffic artery; levels of both lead and zinc are lower.

The results from samples taken at 2126 Logan Avenue and 1476 Wellington Avenue are of interest as the sites are adjacent to smelter B and C respectively. In both cases lead levels are elevated while zinc levels are not. The higher lead levels found in the soil have resulted from deposition and accumulation over time. The relatively low lead concentration in the sod at site 13 is thought to be the result of recent sodding of the site.

The levels of lead and zinc found at the N.A.P.S. locations are representative of the downtown core (Ellen Street), a quiet residential area (Scotia at Jefferson), and a site adjacent to a

major traffic artery (2120 Portage Avenue). Lead levels range from 80 to 1100 µg/g and zinc levels from 100 to 360 µg/g.

The elevated levels of both lead and zinc, 7200 and 3200 µg/g respectively, found in the Smelter A parking lot probably derive from the deposition of stack emissions which have been concentrated by runoff at the edge of the pavement. The sample from Weston School was taken from the boulevard and represents the historical accumulation from both Logan Avenue traffic and smelter emissions.

2.3.3 SOIL SAMPLING - WESTON SCHOOL

The results of the three surveys from Weston Elementary School are presented in Table 6. The original material removed in the 1981 cleanup program contained lead concentrations in the 4,000 to 5,000 µg/g range.

The results of the follow-up surveys indicate clearly that within one year the lead concentrations became elevated again. The concentrations found in each survey exceeded the level of 2600 µg/g in 77 to 79% of the sites sampled. The lead concentrations ranged from 950 to 6,000 µg/g. In general, lead values were highest in those samples taken in April, prior to the spring cleanup of streets and sidewalks. However, the differences are slight between results of each of the surveys.

It should be noted that the material sampled on the paved playground and sidewalk was soil combined with particulate debris and thus had much higher concentrations than boulevard sod and soil. The provincial criterion of 2600 µg/g was intended for lead concentrations in urban sod and soil, however it was also used for the composite playground material for want of a specific standard. The level of lead found in the boulevard adjacent to the playground was 1800 µg/g in the sod, 620 µg/g in the upper 5 cm of soil. This is representative of an historical accumulation and not of recent depositions. It is believed that the large concentration of lead in the composite dust on the paved playground area is primarily derived from the vehicle traffic on Logan Avenue.

Evidence that vehicular exhaust is a major contributor to the lead burden in the Weston Area is contained in Table 3. The percentage of lead species confirmed in the samples from Weston School and the corner of Pacific and Quelch was substantially higher in the control period of July 1982 when Smelter A was shut down than in September when the smelter was in full operation. This plus the high association of bromine/chlorine in these samples (Table 1) is strong evidence that the source of the lead particles was vehicle exhaust.

2.4 CONCLUSIONS

(1) Air sampling using nucleopore filters is a useful technique for collecting particulates for microanalysis.

(2) Exposure time is critical in air sampling; an optimum sample was present on the filter when a very slight discolouration was observed.

(3) Lead and zinc were found in elevated concentrations and in close association at sites closest to Smelter A, (the Canadian Bronze Company Limited).

(4) Lead and zinc were not found in association with soil samples taken at other schools or smelters in North Central Winnipeg.

(5) Levels of lead and zinc were found to be higher in boulevards adjacent to Weston School than at in other school areas near major traffic arteries.

(6) Levels of lead found in the soil and particulate debris of the north yard of Weston School were again elevated one year after a complete clean up.

(7) Based on the data collected in these studies, the major source of elevated lead levels in the Weston School yard is believed to be the exhaust of vehicle traffic.

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LITERATURE CITED

1. Brunckreef, B. S. J. Veenstra, Klaas Biersteker, and Jan. 5 M. Boleij, 1981. The Arnhem Lead Study I, Lead uptake by 1 to 3 year old children living in the vicinity of a secondary lead smelter in Arnhem, The Netherlands. Environ. Res. 25: 441-448.

2. Budiansky, S. 1981. Lead: the debate goes on but not over science. Env. Sci. & Tech. Vol. 15, No. 3, 243-246.

3. Coodin, F. J., C. Danes, G. W. Dean, P. R. Desjardines, J. B. Sutherland, 1980. Riposte to "Environmental Lead and Young Children". C.M.A. Jour. Vol. 123, 469-471.

4. Diemel, J. A. L., B. Brunekreef, J. S. M. Boleij, K. Biersteker, and S. J. Veenstra, 1981. The Arnhem Lead Study II. Indoor pollution, and indoor/outdoor relationships. Environ. Res. 25, 449-456.

5. Drill, S. C., J. J. Konz, H. Mahar and M. E. Morse, 1979. The Environmental Lead Problem: An assessment of lead in drinking water from a multi-media perspective. U.S. E.P.A., Mitre Corp. Rep. -7802, 62 pp.

6. E. H. B. 1976. Public hearing on lead contamination in the Metropolitan Toronto area. Envirionmental Hearing Board Report. 193 pp.

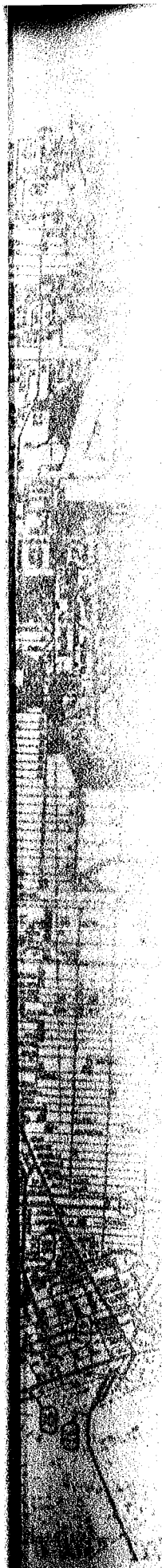
7. Jaworski, J. F. 1978. Effects of lead in the environment - 1978. Nat. Res. Council of Canada Publ. No. 16736, 779 pp.

8. Jones, D. C., and D. L. Wotton. 1982. Lead program report soil/sod removal and replacement in the Weston area of Winnipeg, 1982. Manitoba Environmental Management Division, Terrestrial Standards and Studies. Rep. #82-3, 8 pp.

9. Linzon, S. N., B. L. Chai, P. J. Temple, R. G. Pearson, and M. L. Smith, 1976. Lead contamination of urban soils and vegetation by emissions from secondary lead industries. APCA Jour., Vol. 26, No. 7, 650-654.

10. Temple, P. J., S. N. Linzon, and B. L. Chai. 1977. Contamination of vegetation and soil by arsenic emissions from secondary lead smelters. Environ. Pollut. (12), 311-320.

11. Wotton, D. L. 1980. A Survey of Lead Accumulation in Tree Foliage and Surface Soil of the Winnipeg area. Manitoba Dept. of Consumer and Corporate Affairs and Environment, Rep. 80-1, 31 pp.



FIGURES

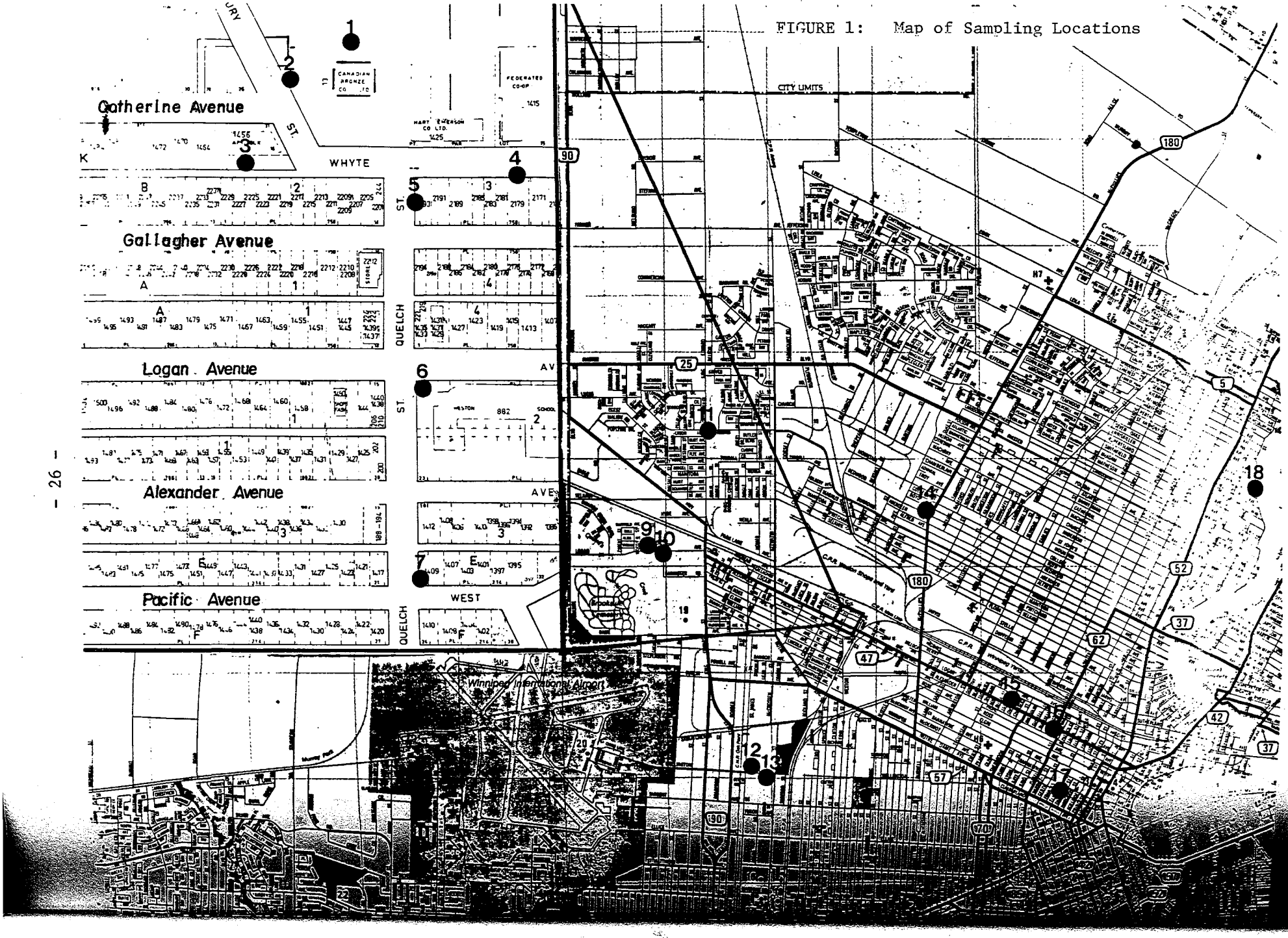


FIGURE 1: Map of Sampling Locations

FIGURE 1: KEY TO MAP LOCATIONS

MAP #	LOCATION
1	Smelter A Stack sample
2	Smelter A parking lot sample
3	#1 Bury St. (parking lot sample)
4	2179 Gallagher Ave. (backyard sample)
5	2193 Gallagher Ave. (west side sample)
6	Weston School (corner Quelch and Logan) sample
7	Pacific Ave. and Quelch St. sample
8	N.A.P.S. (2120 Portage Ave.) sample
9	Smelter B
10	2126 Logan Ave. sample
11	Tyndall Park School sample
12	Smelter C
13	1476 Wellington Ave. sample
14	Lord Nelson School sample (corner McPhilips and Redwood)
15	Technical Services Lab roof sample
16	Dufferin School sample (corner Logan and Isabel)
17	Ellen St. sample (#1 firehall)
18	N.A.P.S. Scotia St. and Jefferson Ave. sample

FIGURE 2 Automobile Exhaust

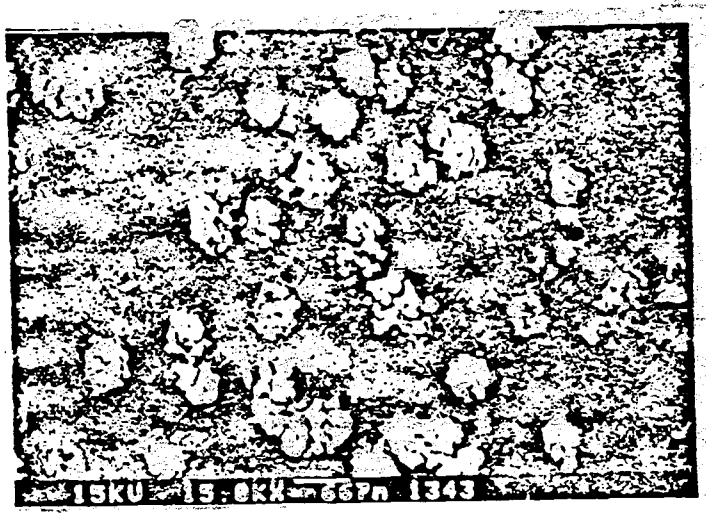


FIGURE 3 Smelter A

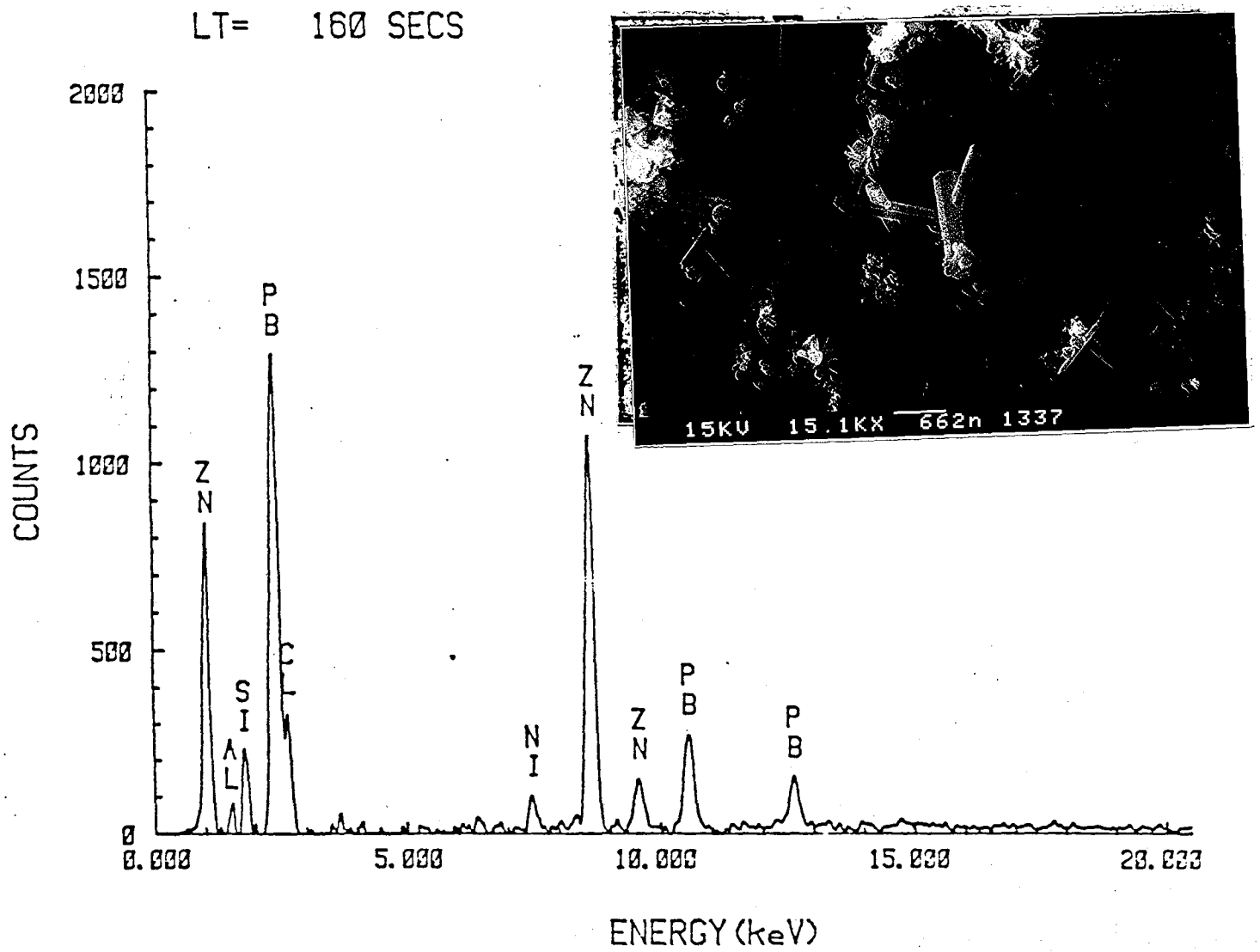


FIGURE 4 Smelter B

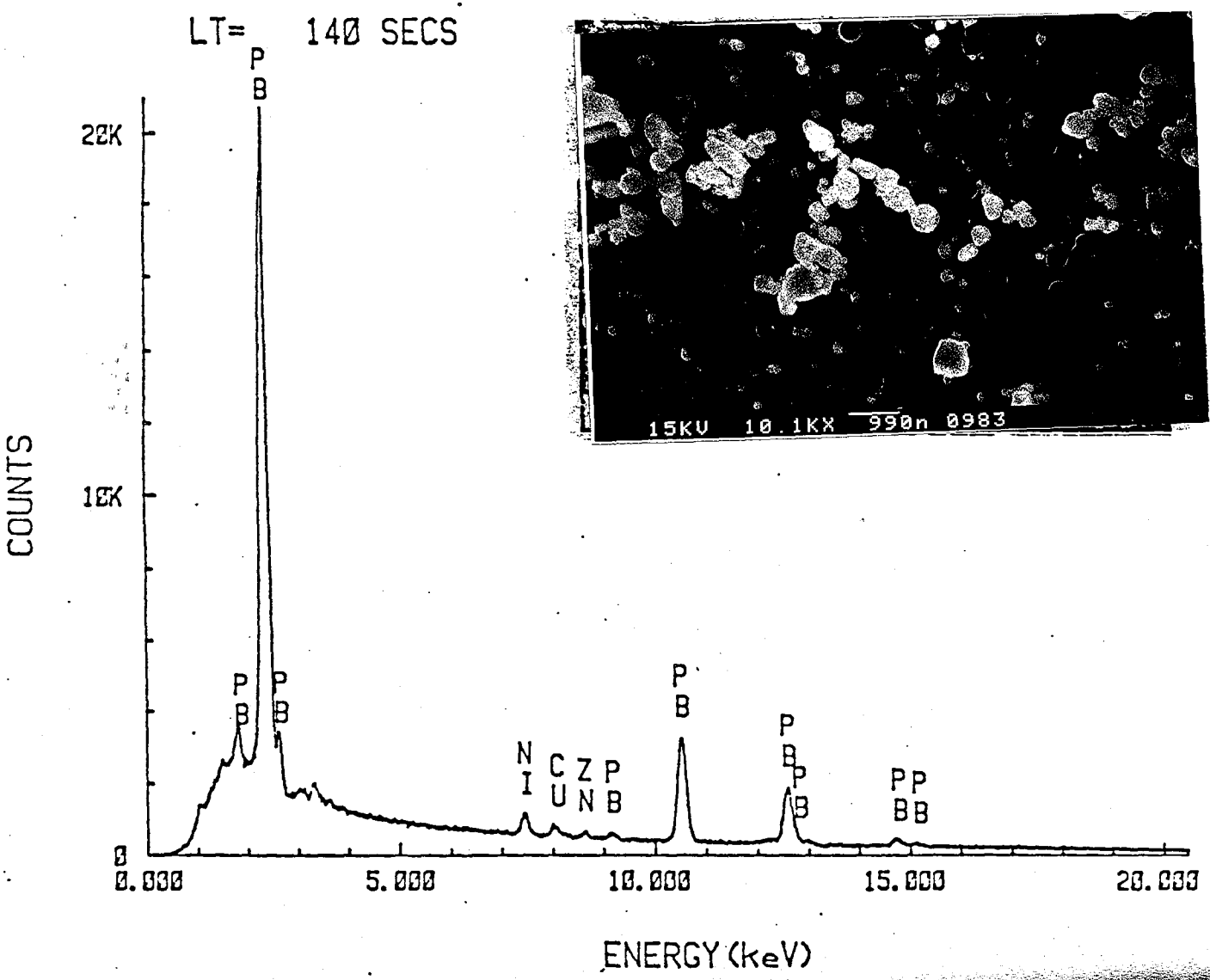


FIGURE 5 Smelter C

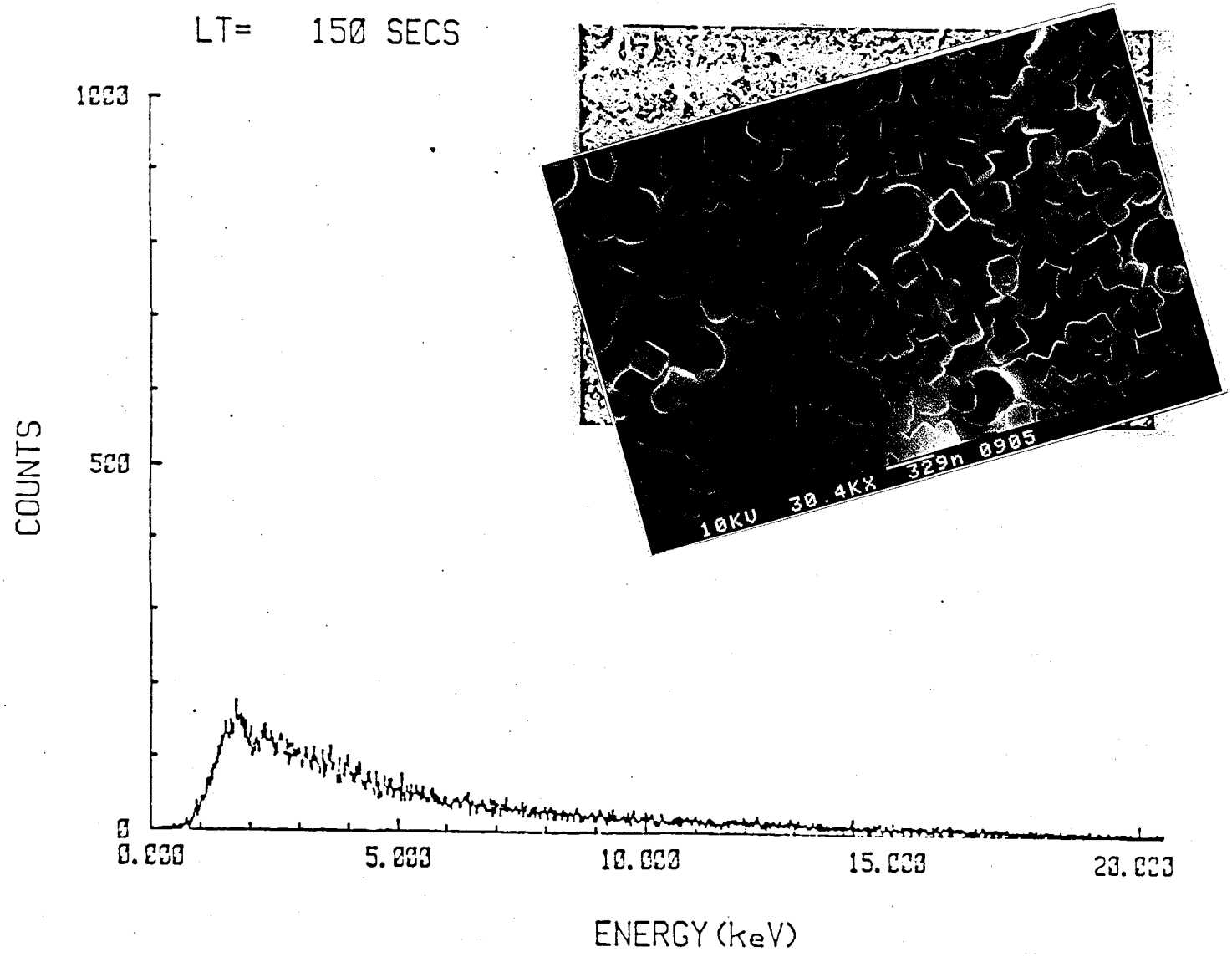


FIGURE 6 S.E. vs. B.S.E. Imaging Modes ("PRC" utilizes BSE Imaging for Adjust Contrast Threshold Values)

Secondary Electron Image of Particles on Nucleopore Filter

Backscattered Electron Image of Particles on Nucleopore Filter

TABLES

TABLE 1: Pb SPECIATION EXPERIMENTAL DATA

MAP LOCAT.	SAMPLE LOCATION	SEM REF. STUB	Total Popula	Confirmed Pb Particles								Suspected Pb Particles								Ca rich	Sulphu suspec	K & S .or K + S/Pb	Zn susp/ conf.	Comment
				Pb Only	+Zn	+Sn or Sn/Sb	+Other Metals (Cu, Fe Ba, Ti or Al	+Sili-cates No Br	+Br or Br/Cl	Exhaust + Silicates	Exhaust + Cemen	Pb Only	+Zn	+Sn or Sn/Sb	+Other Metals Cu, Fe Ba, Ti or Al	+Sili-cates No Br	+Br or Br/Cl	Exhaust + Silicat	Exhaust + Cemen					
	Auto. Exhaust	4	40						40															Ref.
1	Smelter A	3	124		64								46										0/124	Ref.
9	Smelter B	10	63	63*		Typically +2% Ni or Si/Cu																		Ref.
12	Smelter C	11		NO QUALITY CONTROL DATA AVAILABLE VIA "PRC"																				Ref.
2	Smelter A Lot (C)	5	201	2					14			4			6		5	23	6	48	9	2	1/0	Control
6	Weston School (C)	8	151	2					25			6			7		8	7	4	20	4		1/0	Control
7	Pacific & Quelch	7	167		2				26			5			1		5	14	5	17	1	5	2/2	Control
2	SmelterA Parking I	9	174	1					4			2			2	2	2	5	3	24	2	5	1/-	
6	Weston School	12	161	2	2			1	8		1	1	2		8	2		5	3	31	3		5/1	
7	Pacific & Quelch	13	162	1			1		13		1				1		1	8	27	117	4		0/1	High Ca
5	2193 Gallagher	14	151				1		11						6		2	47	32	49	3		0/3	
4	2179 Gallagher	16	108			1	1		1			1			4		1	29	13	14	3			
3	Bury St. Park Lot	22/31	212	4	2				13			4	2		8	3	3	7	2	30	3		6/3	High Fe, Mg
16	Dufferin School	17	161						25						5	1	6	14	1	20	2		8/0	
14	Lord Nelson School	18	122		1				21	1		2			1		6	10		6	4		4/2	
11	Tyndall Park Schoo	19	155		1				5	1							1	8	6	29			2/-	
10	2126 Logan	20	292	1			1	5		1					2			14	9	93	2		-/-	High Clay
13	1476 Wellington	21	173	6		4		8 + 3?		1		1		5	2	1	3		4	96	1			
15	Tech. Services Lab	24	137						13			3			6	2		13	5	28	4	5		
17	N.A.P.S. Ellen St.	26	252						1			1			11**	2		19	18	69	2		4/-	70 Part Fe>50
18	N.A.P.S. Scotia	23	200						4				1		3	37		9	11	30	8	16		K + S
8	2120 Portage	25	183	1	1				13			5			4	1	6	4	3	31	26		3/-	
			3389 PARTICLES																					

* Pb + Ca (No Br or Br/Cl)
** Mostly Fe

TABLE 2

MAP LOCAT.	SAMPLE LOCATION	Total Popul.	DISTRIBUTION OF CONFIRMED LEAD SPECIES: Exhaust	Non-Exhaust	Exhaust Non-Exh	PB Tot.Pop (%)	Exhaust Tot.Pop (%)	Non-Exh Tot.Pop (%)	Prtcle Area Coverage (%)	Smplg Time (Min)	Area* Norm to 60 min Time (%)	Lead Accumul Rate	Wind Direc-tion	Wind Velo-city (KMH)
	Automobile Exhaust	40	40			100	100		38.0	0.5	4560			
1	Smelter A	124		64		51.6		51.6	8.08	5	97			
9	Smelter B	63		63		100		100	7.73	0.03	15,500			
12	Smelter C		NO "PRC" DATA											
2	SmelterA Park. Lot (C)	201	14	2	7.0	8.0	7.0	1.0	~1.3	90	0.87	7.0	WSW	20
6	Weston School (C)	151	25	2	12.5	17.9	16.6	1.3	~1.0	60	1.0	18	WSW	20
7	Pacific & Quelch (C)	167	26	2	13.0	16.8	15.6	1.2	0.95	120	0.48	8.1	WSW	20
2	SmelterA Park. Lot	174	4	1	4.0	2.9	2.3	0.6	~1.3	75	1.0	2.9	S	8
6	Weston School	161	9	5	1.8	8.7	5.6	3.1	1.14	15	4.6	40	NNE	20
7	Pacific & Quelch	162	14	2	7.0	9.8	8.6	1.2	~1.4	75	1.1	11	WNW	20
5	2193 Gallagher	151	11	1	11.0	8.0	7.3	0.7	2.27	50	1.5	12	WNW	20
4	2179 Gallagher	108	1	2	0.5	2.8	0.9	1.9	~1.5	60	1.5	4.2	E	7
3	Bury St. Park. Lot	212	13	6	2.2	8.9	6.1	2.8	0.5	90	0.3	3.0	E	7
16	Dufferin School	161	25	0		15.5	15.5	0	3.4	40	5.1	79	NNE	17
14	Lord Nelson School	122	22	1	22.0	18.8	18.0	0.8	1.76	15	7.0	132	NNE	26
11	Tyndall Park School	155	6	1	6.0	4.5	3.9	0.6	0.8	90	0.53	2.3	WNW	21
10	2126 Logan	292	1	7	0.14	2.7	0.3	2.4	~2.0	30	4.0	11	WNW	21
13	1476 Wellington	173	0	21	0	12.1	0	12.1	2.0	45	2.7	32	WNW	21
15	Tech. Services Lab	137	16	0		11.7	11.7	0	0.84	90	0.56	6.6	N	20
17	N.A.P.S. Ellen Street	252	1	0		0.4	0.4	0	8.2	60	8.2	3.2	WNW	11
18	N.A.P.S. Scotia	200	4	0		2.0	2.0	0	3.05	145	1.3	2.6	S	20
8	2120 Portage	183	13	2	6.5	8.2	7.1	1.1	1.16	60	1.2	9.8	NNE	10

TABLE 3: LEAD AS A PERCENTAGE OF AIR SAMPLE POPULATION BASED ON CONFIRMED SPECIES

Total Pb (%) Population[1]		Exhaust Emissions (% Tot. Pop.)	
1) Lord Nelson School	18.8	1) Lord Nelson School	18.0
2) Weston School (control)	17.9	2) Weston School (control)	16.6
3) Pacific & Quelch (control)	16.8	3) Pacific & Quelch (control)	15.6
4) Dufferin School	15.5	4) Dufferin School	15.5
5) 1476 Wellington Avenue	12.1	5) Technical Services Lab	11.7
6) Technical Services Lab	11.7	6) Pacific & Quelch	8.6
7) Pacific & Quelch	9.8	7) 2193 Gallagher	7.3
8) Bury St. Parking Lot	8.9	8) 2120 Portage Avenue	7.1

Non-Exhaust Emissions (% Tot. Pop.)		Pb Accumulation Rate (arbitrary units)	
1) 1476 Wellington Avenue	12.1	1) Lord Nelson School	132
2) Weston School	3.1	2) Dufferin School	79
3) Bury Street Parking Lot	2.8	3) Weston School	40
4) 2126 Logan Avenue	2.4	4) 1476 Wellington Avenue	32
5) 2179 Gallagher	1.9	5) Weston School (control)	18
		6) 2193 Gallagher	12
		(7/8) 2126 Logan Avenue	11
		(7/8) Pacific & Quelch	11

[1]Percentage of particles containing total lead from the population of particles analyzed.

TABLE 4: AIR SAMPLING DATA - EXPOSURE TIMES AND METEOROLOGICAL CONDITIONS, 1982

Sample Location	Date d/m/yr.	Start Time	End Time	Exposure Time (hrs:min)	Mean Wind Spd (kph)	Wind Direction	Humidity % Max	Humidity % Min
Smelter A	06/07/82	9:15 A.M.	10:30 A.M.	1:15	20	WSW	90	47
(west side	06/07/82	10:35 A.M.	12:05 P.M.	1:30	20	WSW	90	47
parking lot)	15/09/82	1.15 P.M.	2:30 P.M.	1:15	8	S	89	27
	16/09/82	8:40 A.M.	10:10 A.M.	1:30	20	S	88	39
Weston School	06/07/82	12:30 P.M.	1:30 P.M.	1:00	20	WSW	90	47
(corner Logan &	06/07/82	1:35 P.M.	2:00 P.M.	1:25	20	WSW	90	47
Quelch)	05/10/82	8:50 A.M.	9:35 A.M.	0:45	17	NNE	97	79
	05/10/82	9:40 A.M.	10:10 A.M.	0.30	20	NNE	97	79
Northeast Corner	06/07/82	2:25 P.M.	3:55 P.M.	1:30	20	WSW	90	47
Quelch St. and	06/07/82	4:00 P.M.	6:00 P.M.	2:00	20	WSW	90	47
Pacific Avenue	30/09/82	9:45 A.M.	11:00 A.M.	1:15	20	WNW	93	54
	30/09/82	1:35 P.M.	2:05 P.M.	0:30	20	WNW	93	54
N.A.P.S. - 2120	14/09/82	8:32 A.M.	9:32 A.M.	1:00	21	NNE	79	46
Portage Avenue	14/09/82	8:32 A.M.	10:02 A.M.	1:30	21	NNE	79	46
N.A.P.S. - Ellen	20/09/82	9:00 A.M.	11:00 A.M.	2:00	11	WNW	96	44
Street	20/09/82	1:10 P.M.	2:15 P.M.	1:05	11	WNW	96	44
N.A.P.S. - Scotia	16/09/82	10:55 A.M.	1:20 P.M.	2:25	20	S	88	39
Street	16/09/82	10:55 A.M.	2:30 P.M.	3:35	20	S	88	39
T.S.L. - roof -	13/09/82	8:20 A.M.	9:50 A.M.	1:30	20	N	90	49
745 Logan Ave.	13/09/82	8:20 A.M.	10:20 A.M.	2:00	20	N	90	49
#1 Bury Street	01/10/82	8:55 A.M.	10:25 A.M.	1:30	7	E	97	69
(parking lot)	01/10/82	10:30 A.M.	12:05 P.M.	1:35	7	E	97	69
2193 Gallagher	30/09/82	11:30 A.M.	1:00 P.M.	1:30	20	WNW	93	54
Ave. (back yard)	30/09/82	11:30 A.M.	1:15 P.M.	1:45	20	WNW	93	54
2179 Gallagher	01/10/82	1:40 P.M.	2:40 P.M.	1:00	7	E	97	69
Ave. (back yard)	01/10/82	1:40 P.M.	2:55 P.M.	1:30	7	E	97	69
Dufferin School	05/10/82	2:30 P.M.	2:55 P.M.	0:25	17	NNE	92	65
(NW corner)	05/10/82	2:30 P.M.	3:10 P.M.	0:40	17	NNE	92	65
Lord Nelson School	06/10/82	9:22 A.M.	9:37 A.M.	0:15	26	NNE	97	79
(NE corner)	06/10/82	9:22 A.M.	9:52 A.M.	0:30	26	NNE	97	79
Tyndall Park	14/10/82	10:25 A.M.	11:40 A.M.	0:15	21	WNW	92	47
School (west side)	14/10/82	10:25 A.M.	11:55 A.M.	0:30	21	WNW	92	47
2126 Logan (Thermo	14/10/82	1:30 P.M.	2:00 P.M.	0:30	21	WNW	92	47
King parking lot)	14/10/82	1:30 P.M.	2:15 P.M.	0:45	21	WNW	92	47
1476 Wellington	14/10/82	2:40 P.M.	3:10 P.M.	0:30	21	WNW	92	47
Ave. (Koerbel	14/10/82	2:40 P.M.	3:25 P.M.	0:45	21	WNW	92	47
Industries parking lot								
Smelter A	12/07/82	A.M.	-	0:15	12	WSW	90	34
Stack		A.M.	-	0:10	12	WSW	90	34
Smelter B	27/10/82	9:20 A.M.	9:24 A.M.	0:04	22	SSE	81	47
Stack		9:30 A.M.	9:40 A.M.	0:10	22	SSE	81	47
		9:43 A.M.	9:58 A.M.	0.15	22	SSE	81	47
Smelter C	27/10/82	10:30 A.M.	multi samples taken - sample times were a matter of 2 or 3 seconds because of heavy particulate loading visible on filters		22	SSE	81	47
Refinery Stack								

TABLE 5: LEAD AND ZINC CONCENTRATION IN SOD AND SOIL, 1982

Map #	SITE	LEAD (µg/g)		ZINC (µg/g)	
		SOD	SOIL	SOD	SOIL
2	Smelter A Parking Lot	-	7200	-	3200
3	Bury Street (parking lot)	2400	680	1400	840
4	2179 Gallagher (back yard)	860	960	600	720
5	2195 Gallagher (west yard)	120	40	110	90
6	Weston School	1800	1400	620	500
7	Pacific and Quelch	1140	860	400	420
15	Technical Services Laboratory	120	40	180	100
16	Dufferin School	480	400	220	190
14	Lord Nelson School	480	180	320	170
11	Tyndall Park School	60	40	60	50
10	2126 Logan Avenue	800	1040	90	100
13	1476 Wellington Avenue	300	2600	90	240
8	N.A.P.S.-2120 Portage Avenue	1100	720	240	170
17	N.A.P.S. - Ellen Street	640	760	280	360
18	N.A.P.S.-Scotia at Jefferson	80	80	200	100

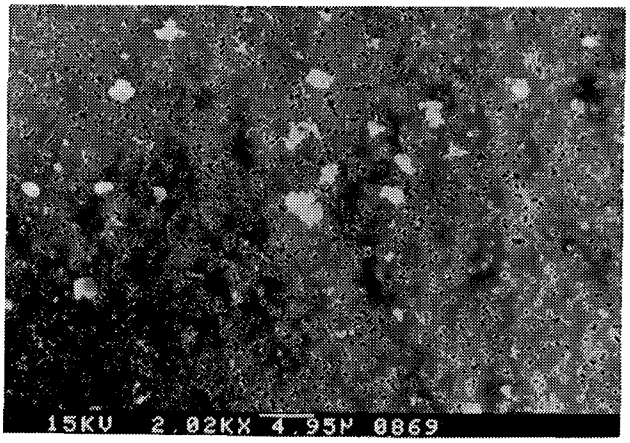
TABLE 6: LEAD IN SOIL AND PARTICULATE DEBRIS FROM WESTON SCHOOL, 1982

Sample Site #	Lead Concentration in Soil Material (µg/g) April 7,	May 19,	Sept. 16,
1	3,000	2,800	2,400
3	4,600	4,400	3,000
4	3,600	4,300	3,200
5	5,500	5,400	3,800
6	4.700	3.800	3,800
7	3,000	6,000	2.700
8	950	2,300	3,300
9	4,800	2,900	2,400
10	2,200	-	1,900
12	4,000	3,200	3,500
13	1,800	3,800	3,600
14	4,000	2,000	3,300
15	3,100	2,000	2,400
16	4,000	3,000	5,600
Mean Level	3,518	3,530	3,207
% samples >2600 µg/g	79%	77%	77%

APPENDICIES

SAMPLE IDENTIFICATION:

2193 Gallagher Avenue

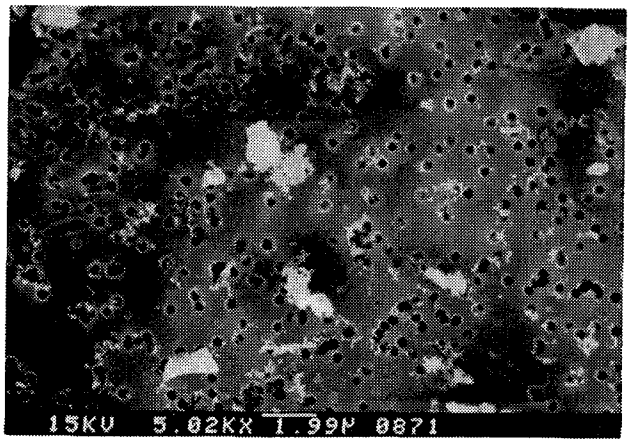


WIND DIRECTION/VELOCITY: WNW/20 kmh

COLLECTION TIME: 90 minutes

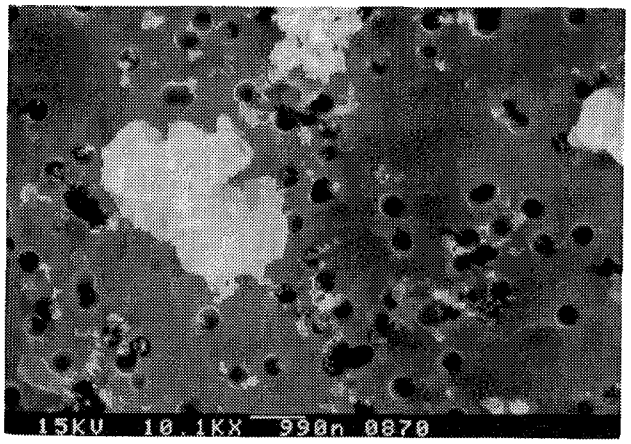
"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.77 µm
- TOTAL PARTICLE POPULATION 151
- % TOTAL AREA COVERED BY PARTICLES 2.3 %



COMMENTS:

Very high incidence of exhaust particulates.



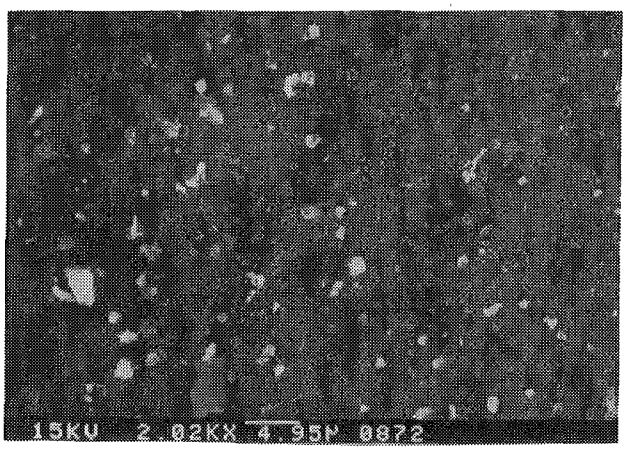
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	ØØ---1Ø---2Ø---3Ø---4Ø---5Ø---6Ø
Ø.33	12	7.9	[****
Ø.67	59	39.Ø	[**********
1.ØØ	41	27.1	[**********
1.33	24	15.8	[********
1.67	12	7.9	[****
2.ØØ	2	1.3	[*
2.33	1	Ø.6	[*
2.67	Ø	Ø.Ø	[

SAMPLE IDENTIFICATION:

2179 Gallagher Avenue

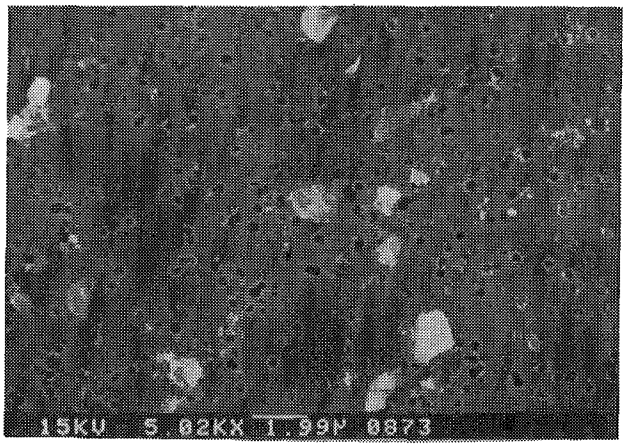


WIND DIRECTION/VELOCITY: E/7 kmh

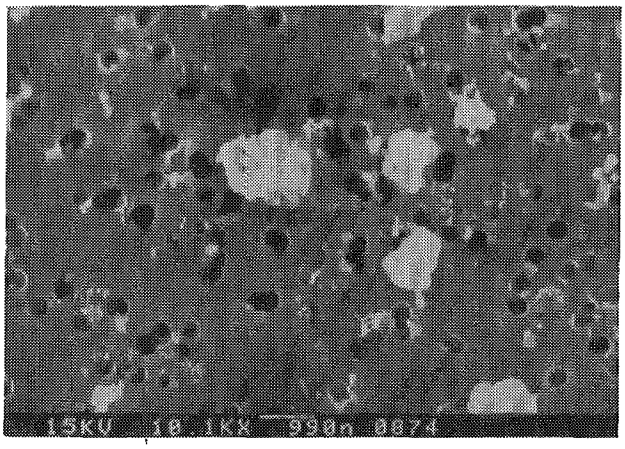
COLLECTION TIME: 60 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.0 µm
- TOTAL PARTICLE POPULATION 108
- % TOTAL AREA COVERED BY PARTICLES 1.5 %



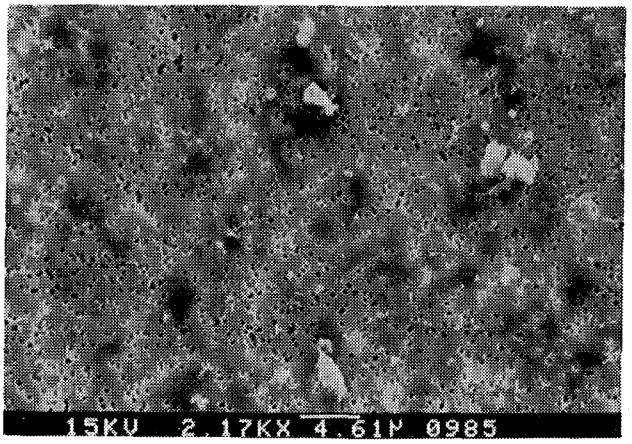
COMMENTS:

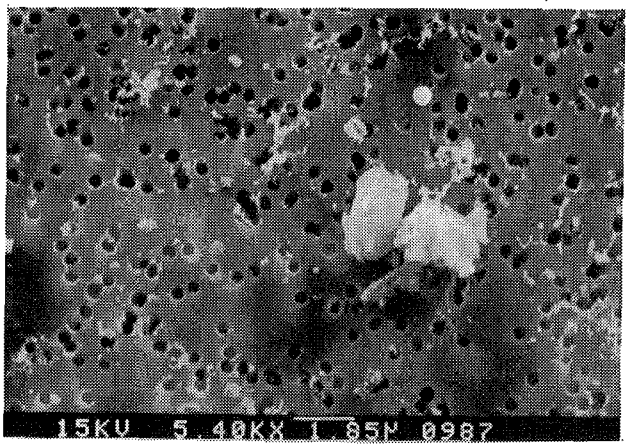


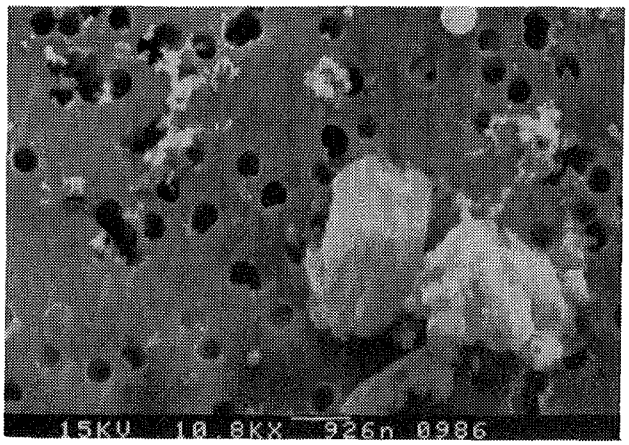
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	1	1.8	[*
0.67	12	21.8	[**********
1.00	16	29.0	[***********
1.33	19	34.5	[**************
1.67	6	10.9	[******
2.00	1	1.8	[*
2.33	0	0.0	[







SAMPLE IDENTIFICATION:

Bury St. Parking Lot

WIND DIRECTION/VELOCITY: E/7 kmh

COLLECTION TIME: 90 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.90 µm
- TOTAL PARTICLE POPULATION 212
- % TOTAL AREA COVERED BY PARTICLES 0.5 %

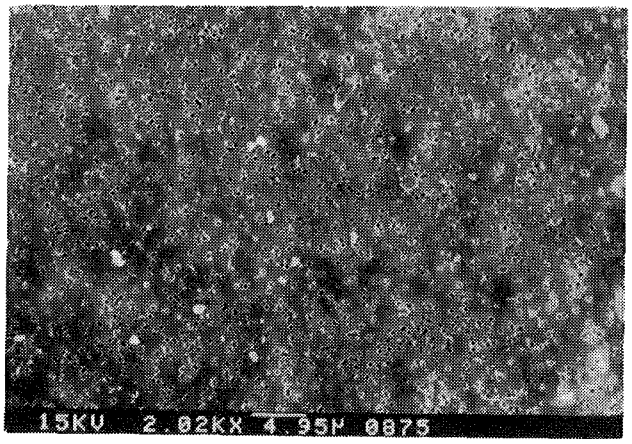
COMMENTS:

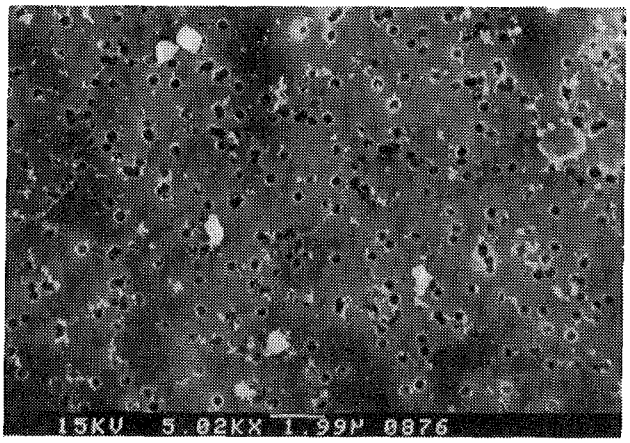
Very high incidence of iron with manganese particles.

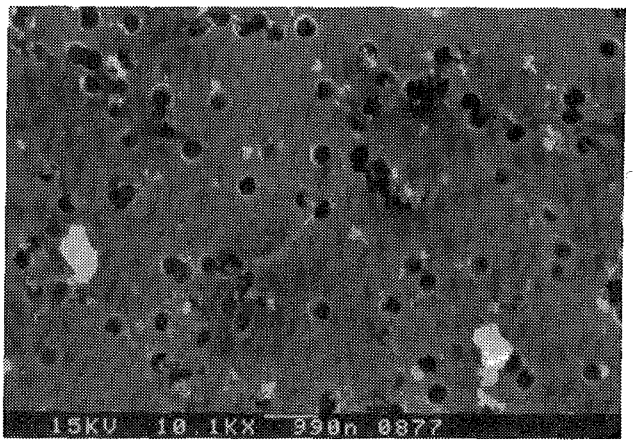
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø0---10---20---30---40---50---6%
Ø.33	23	14.9	[********
Ø.67	49	31.8	[**********
1.ØØ	34	22.Ø	[**********
1.33	19	12.3	[*******
1.67	17	11.Ø	[******
2.ØØ	6	3.8	[**
2.33	4	2.5	[**
2.67	2	1.2	[*
3.ØØ	Ø	Ø.Ø	[







SAMPLE IDENTIFICATION:

Dufferin School

WIND DIRECTION/VELOCITY: NNE/17 kmh

COLLECTION TIME: 40 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.93 µm
- TOTAL PARTICLE POPULATION 161
- % TOTAL AREA COVERED BY PARTICLES 3.4 %

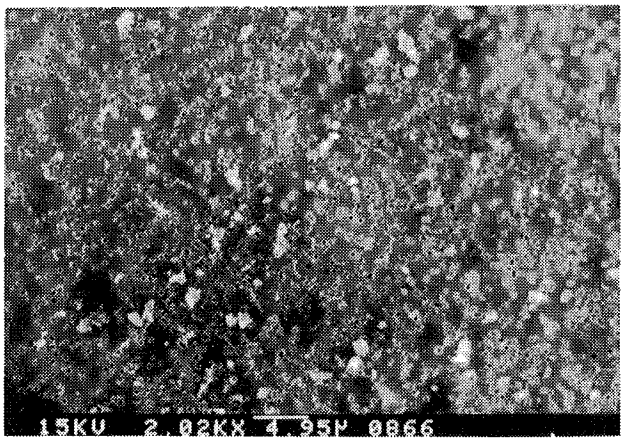
COMMENTS:

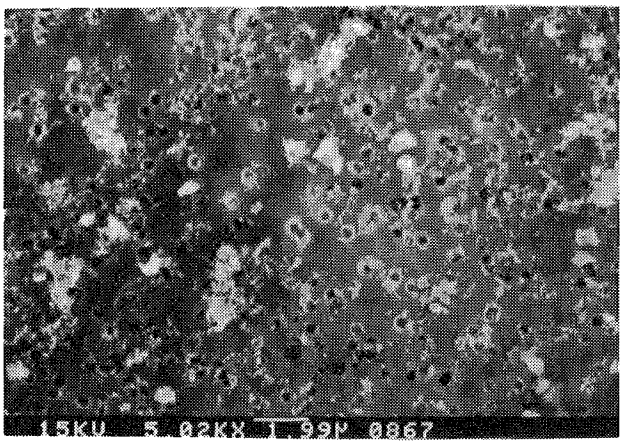
Note high incidence of exhaust particulates.

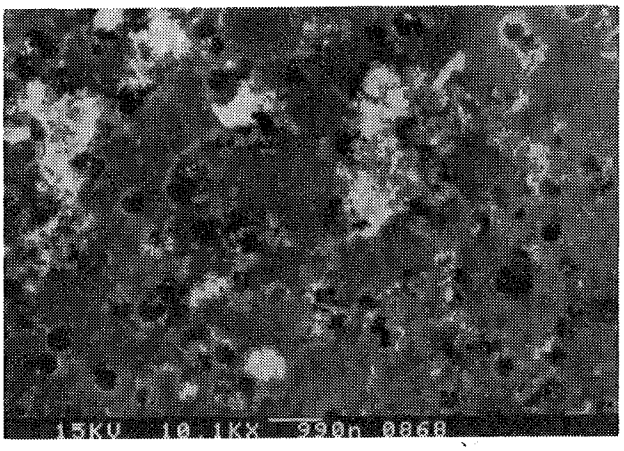
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	10	5.4	[***
0.67	61	33.1	[******************
1.00	44	23.9	[************
1.33	38	20.6	[**********
1.67	14	7.6	[****
2.00	7	3.8	[**
2.33	3	1.6	[*
2.67	4	2.1	[**
3.00	0	0.0	[
3.33	1	0.5	[*
3.67	1	0.5	[*
4.00	0	0.0	[
4.33	0	0.0	[
4.67	0	0.0	[
5.00	0	0.0	[
5.33	0	0.0	[
5.67	1	0.5	[*
6.00	0	0.0	[







SAMPLE IDENTIFICATION:

Lord Nelson School

WIND DIRECTION/VELOCITY: NNE/26 kmh

COLLECTION TIME: 15 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.98 µm
- TOTAL PARTICLE POPULATION 122
- % TOTAL AREA COVERED BY PARTICLES 1.76 %

COMMENTS:

High incidence of exhaust particles/agglomerates.

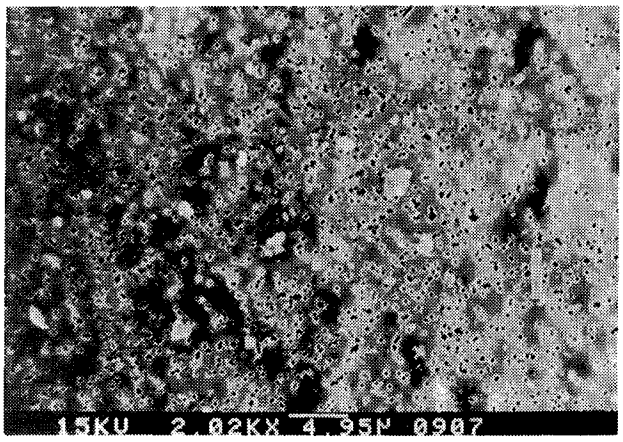
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	ØØ---1Ø---2Ø---3Ø---4Ø---5Ø---6Ø
Ø.33	8	6.5	[****
Ø.67	42	34.4	[******************
1.ØØ	24	19.6	[**********
1.33	21	17.2	[*********
1.67	8	6.5	[****
2.ØØ	9	7.3	[****
2.33	4	3.2	[**
2.67	2	1.6	[*
3.ØØ	3	2.4	[**
3.33	Ø	Ø.Ø	[
3.67	1	Ø.8	[*
4.ØØ	Ø	Ø.Ø	[

SAMPLE IDENTIFICATION:

Tyndall Park School

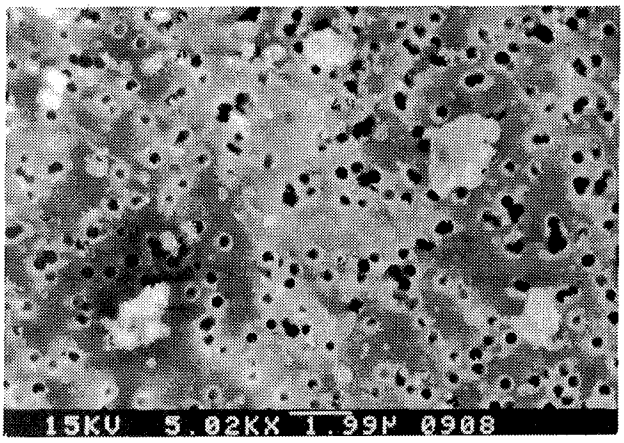


WIND DIRECTION/VELOCITY: WNW/21 kmh

COLLECTION TIME: 90 minutes

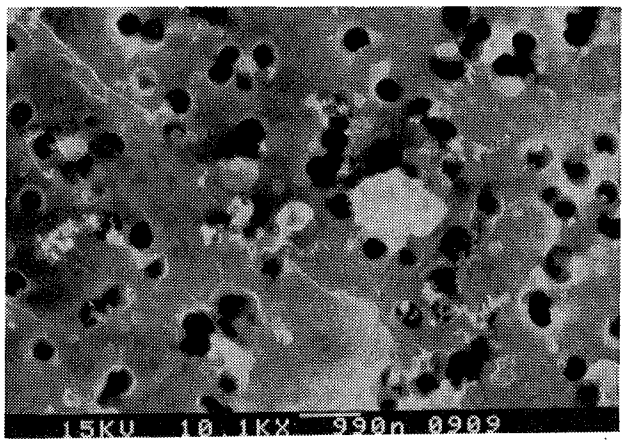
"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.4 µm
- TOTAL PARTICLE POPULATION 155
- % TOTAL AREA COVERED BY PARTICLES 0.8 %



COMMENTS:

Very low particle loading observed by "PRC" when normalized to 60 minute accumulation. Larger average particle diameter.

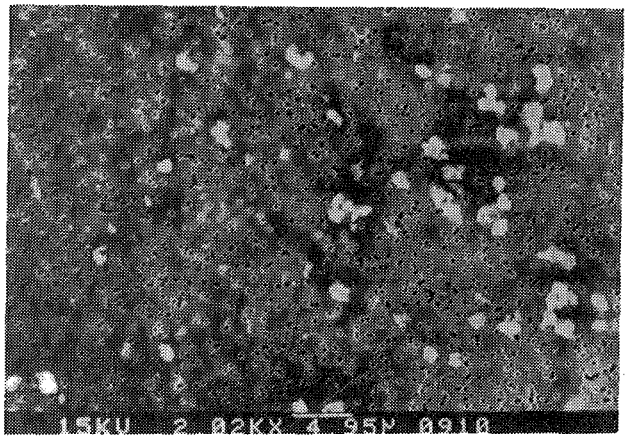


PARTICLE SIZE HISTOGRAM:

```
AVERAGE DIAMETER HISTOGRAM FOR TYPE:  0  ALL TYPES
BIN MAX    NO.   %    00---10---20---30---40---50---6
   0.33     0   0.0 [
   0.67     1   4.1 [***
   1.00     4  16.6 [*********
   1.33     2   8.3 [*****
   1.67     7  29.1 [***************
   2.00     3  12.5 [*******
   2.33     2   8.3 [*****
   2.67     5  20.8 [***********
   3.00     0   0.0 [
```

SAMPLE IDENTIFICATION:

2126 Logan Avenue

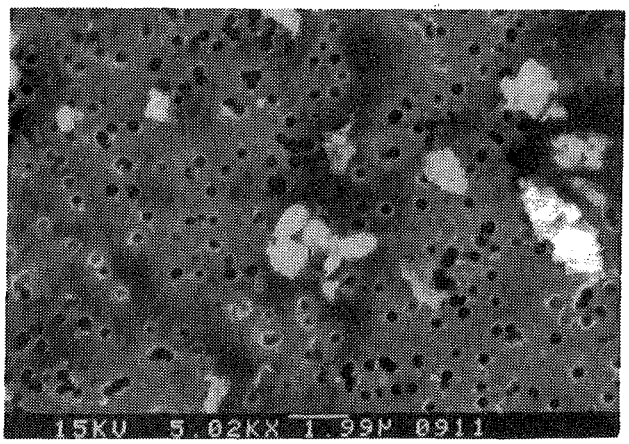


WIND DIRECTION/VELOCITY: WNW/21 kmh

COLLECTION TIME: 30 minutes

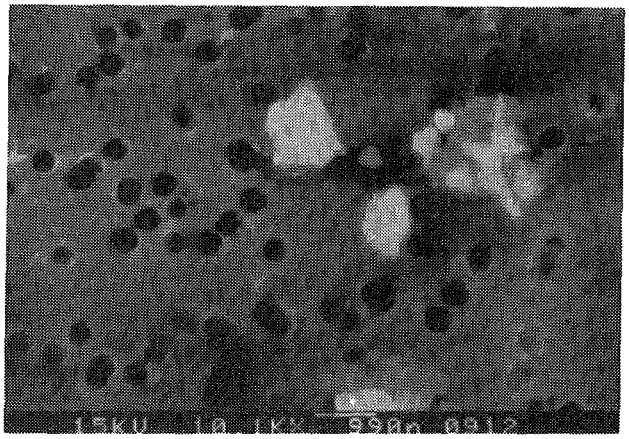
"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.97 μm
- TOTAL PARTICLE POPULATION 292
- % TOTAL AREA COVERED BY PARTICLES ≃2.0 %



COMMENTS:

Very high incidence of clay minerals.



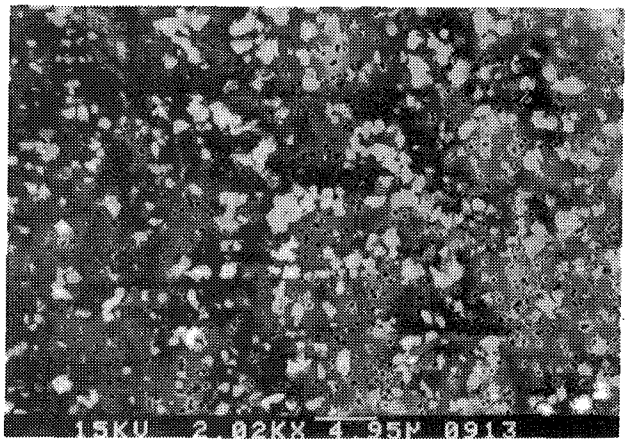
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---6
0.33	3	1.9	[*
0.67	25	16.1	[*********
1.00	38	24.5	[**************
1.33	33	21.2	[************
1.67	34	21.9	[************
2.00	12	7.7	[****
2.33	6	3.8	[**
2.67	3	1.9	[*
3.00	0	0.0	[
3.33	1	0.6	[*
3.67	0	0.0	[

SAMPLE IDENTIFICATION:

1476 Wellington Avenue

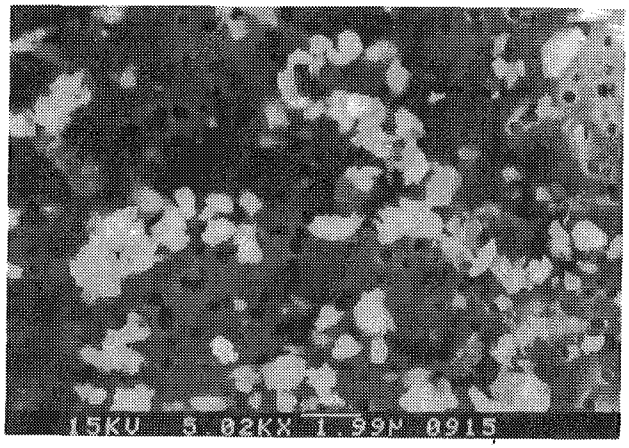


WIND DIRECTION/VELOCITY: WNW/21 kmh

COLLECTION TIME: 45 minutes

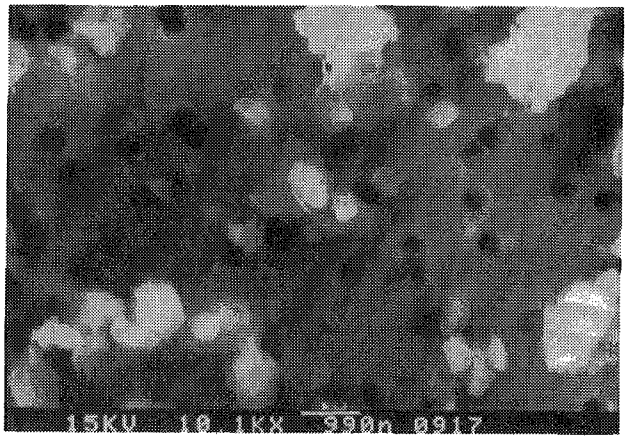
"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.72 μm
- TOTAL PARTICLE POPULATION 173
- % TOTAL AREA COVERED BY PARTICLES ≃ 2.0 %



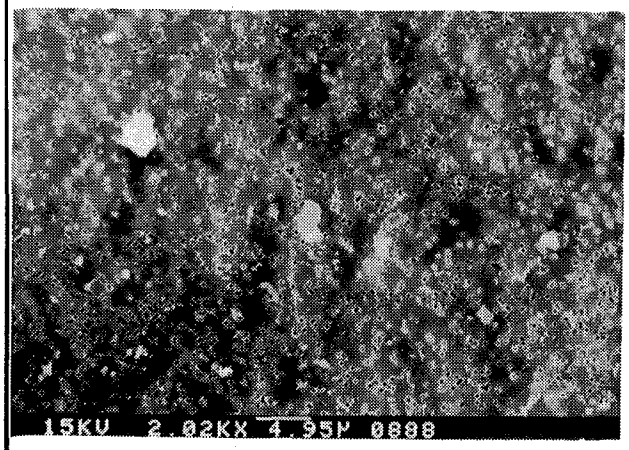
COMMENTS:

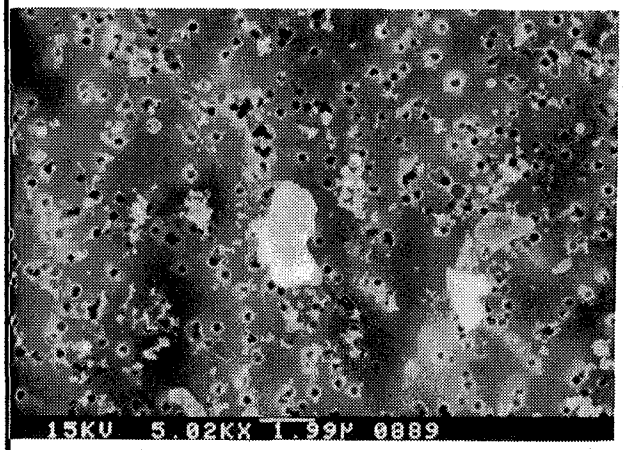
Very high incidence of silicate and clay minerals. PRC data indicates strong Pb + Sn or Pb + Sn/Sb correlations.

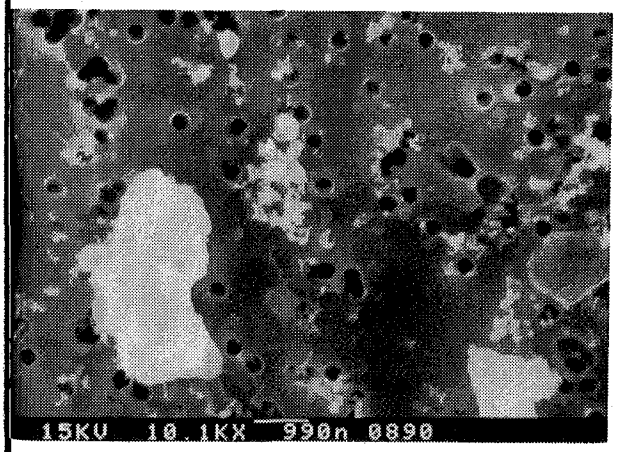


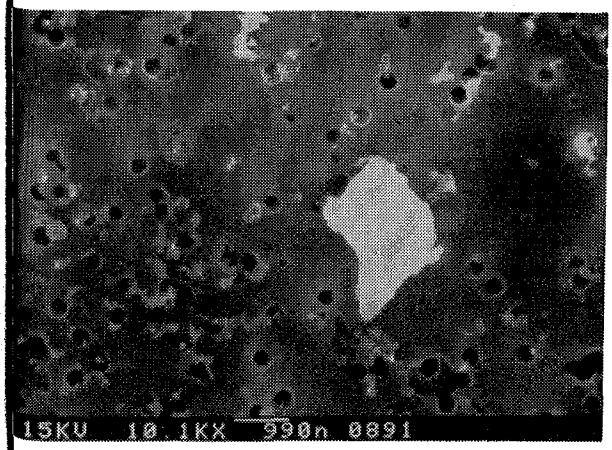
PARTICLE SIZE HISTOGRAM:

Not available.









SAMPLE IDENTIFICATION:

Technical Service Lab (roof)

WIND DIRECTION/VELOCITY: N/20 kmh

COLLECTION TIME: 90 minutes

"PRC" DATA:

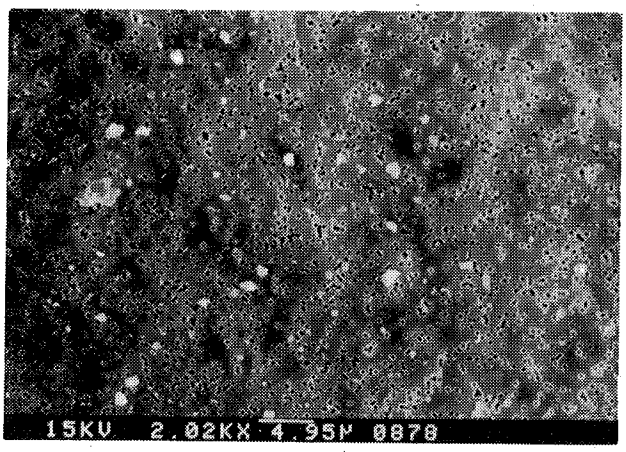
- AVERAGE PARTICLE DIAMETER = 1.05 µm
- TOTAL PARTICLE POPULATION 137
- % TOTAL AREA COVERED BY PARTICLES 0.84 %

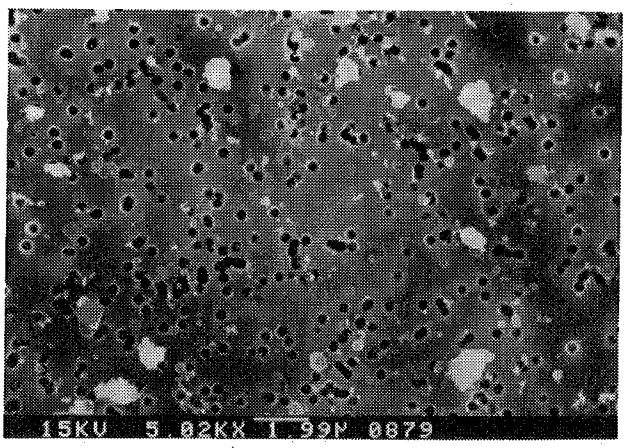
COMMENTS:

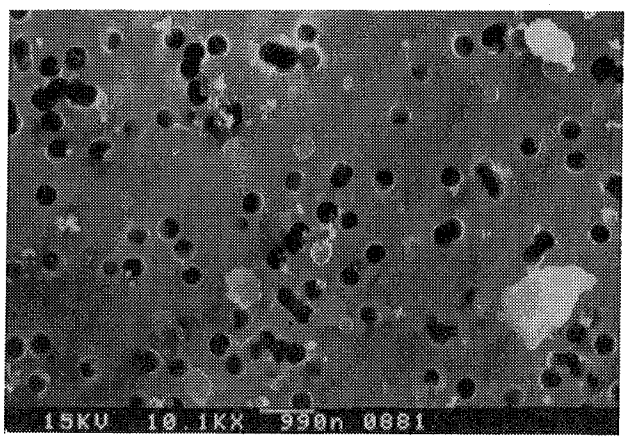
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø0---10---20---30---40---50---60
Ø.33	10	7.2	[****
Ø.67	41	29.9	[**********
1.00	21	15.3	[********
1.33	19	13.8	[*******
1.67	19	13.8	[*******
2.00	19	13.8	[*******
2.33	6	4.3	[***
2.67	2	1.4	[*
3.00	Ø	Ø.Ø	[







SAMPLE IDENTIFICATION:

N.A.P.S. Ellen Street

WIND DIRECTION/VELOCITY: WNW/11 kmh

COLLECTION TIME: 60 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.79 µm
- TOTAL PARTICLE POPULATION 252
- % TOTAL AREA COVERED BY PARTICLES 8.2 %

COMMENTS:

Relatively high particle loading. 70 particles (28%) had iron x-ray intensities greater than 50% of total x-ray emissions!

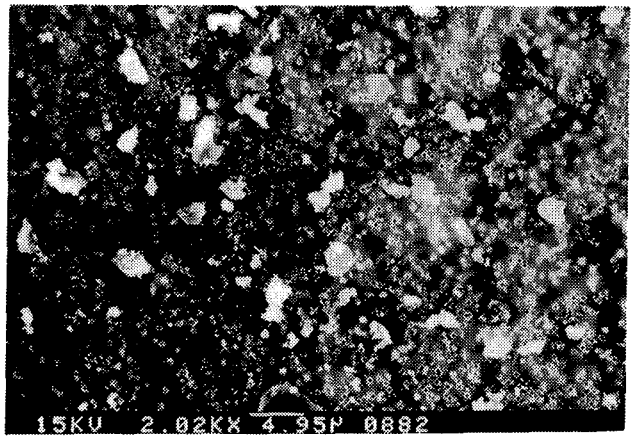
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	20	7.9	[****
0.67	111	44.0	[**********
1.00	55	21.8	[**********
1.33	30	11.9	[******
1.67	25	9.9	[*****
2.00	5	1.9	[*
2.33	3	1.1	[*
2.67	0	0.0	[
3.00	2	0.7	[*
3.33	1	0.3	[*
3.67	0	0.0	[

SAMPLE IDENTIFICATION:

N.A.P.S. Scotia Street

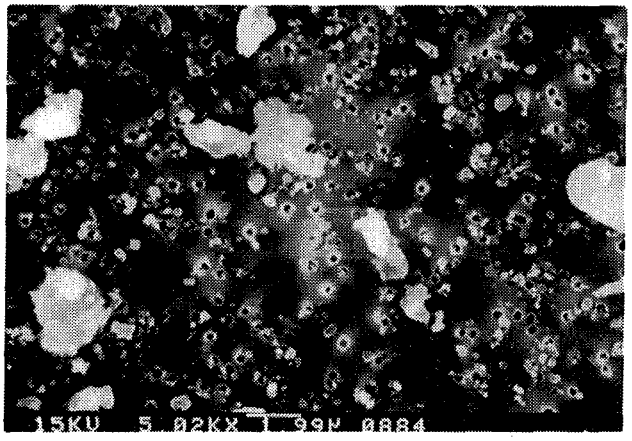


WIND DIRECTION/VELOCITY: S/20 kmh

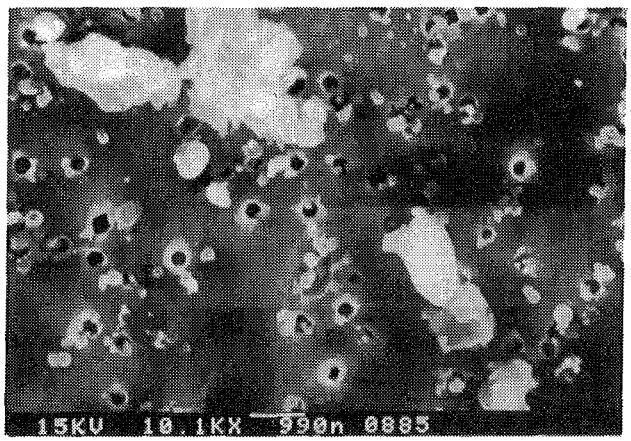
COLLECTION TIME: 145 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.01 µm
- TOTAL PARTICLE POPULATION 200
- % TOTAL AREA COVERED BY PARTICLES 3.05 %



COMMENTS:



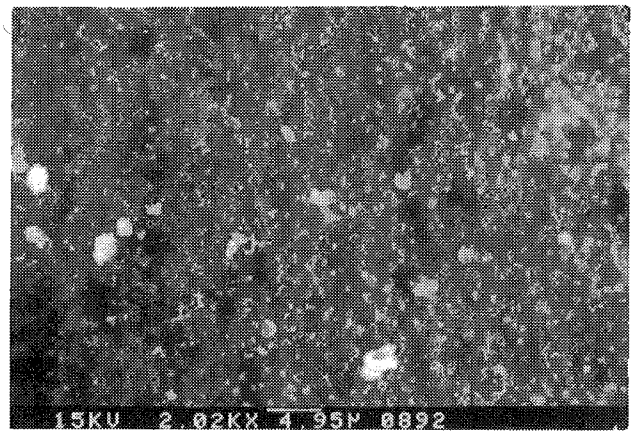
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	25	12.5	[*******
0.67	63	31.5	[****************
1.00	32	16.0	[*********
1.33	26	13.0	[*******
1.67	16	8.0	[*****
2.00	13	6.5	[****
2.33	10	5.0	[***
2.67	5	2.5	[**
3.00	5	2.5	[**
3.33	5	2.5	[**
3.67	0	0.0	[

SAMPLE IDENTIFICATION:

2120 Portage Avenue

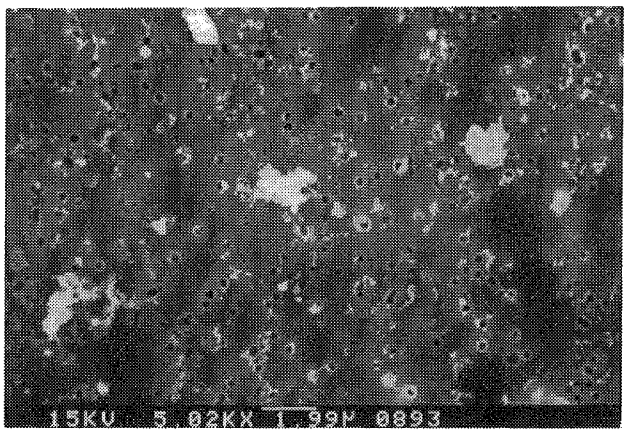


WIND DIRECTION/VELOCITY: NNE/10 kmh

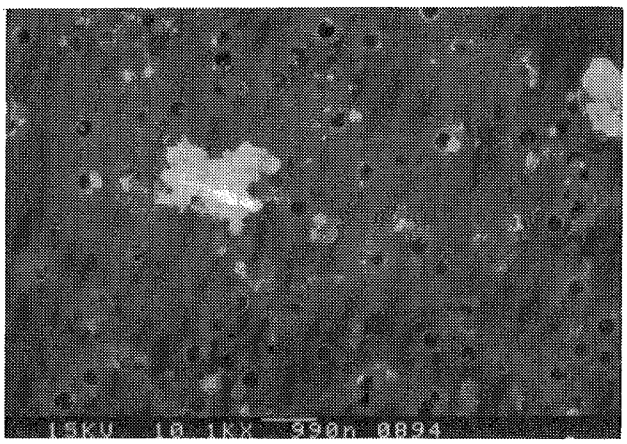
COLLECTION TIME: 60 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.7 µm
- TOTAL PARTICLE POPULATION 183
- % TOTAL AREA COVERED BY PARTICLES 1.16 %



COMMENTS:



PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

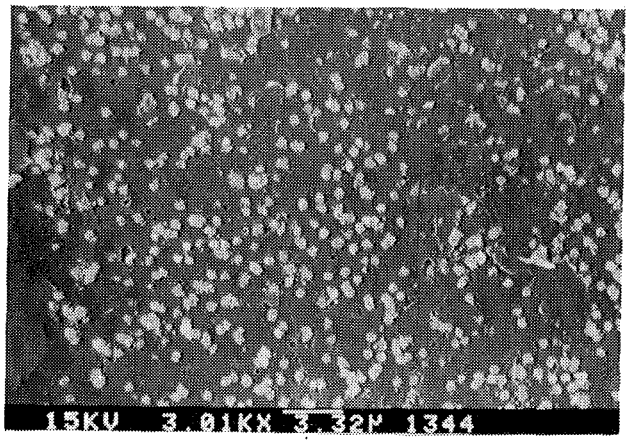
BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	43	23.4	[**********
0.67	80	43.7	[**********
1.00	25	13.6	[*******
1.33	12	6.5	[****
1.67	10	5.4	[***
2.00	6	3.2	[**
2.33	5	2.7	[**
2.67	1	0.5	[*
3.00	1	0.5	[*
3.33	0	0.0	[

APPENDIX 2

SAMPLE PROFILES

SAMPLE IDENTIFICATION:

Automobile Exhaust

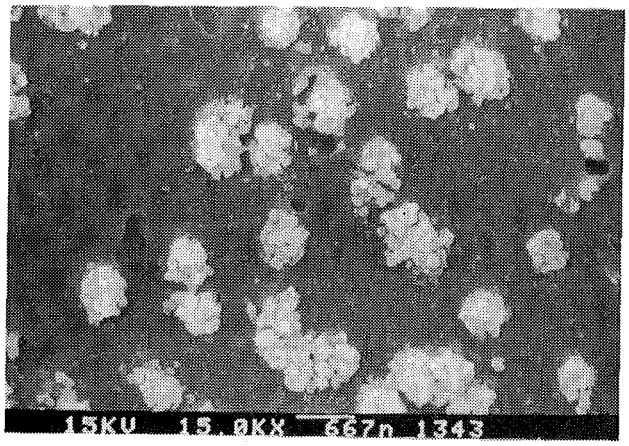


WIND DIRECTION/VELOCITY: N/A kmh

COLLECTION TIME: 0.5 minutes

"PRC" DATA:

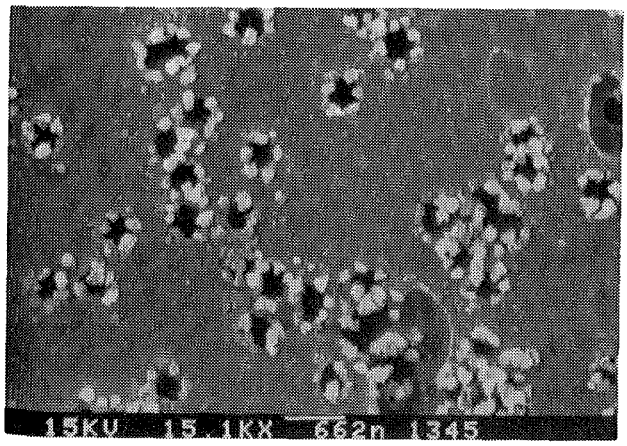
- AVERAGE PARTICLE DIAMETER = <0.2 μm*
- TOTAL PARTICLE POPULATION 40
- % TOTAL AREA COVERED BY PARTICLES 38 %



COMMENTS:

* Average particle diameter is that of individual crystallites which have clumped together to form conglomerates of approx. 1.0 μm.

Note the strong EDX fingerprint of Pb associated with Br or Br and Cl.

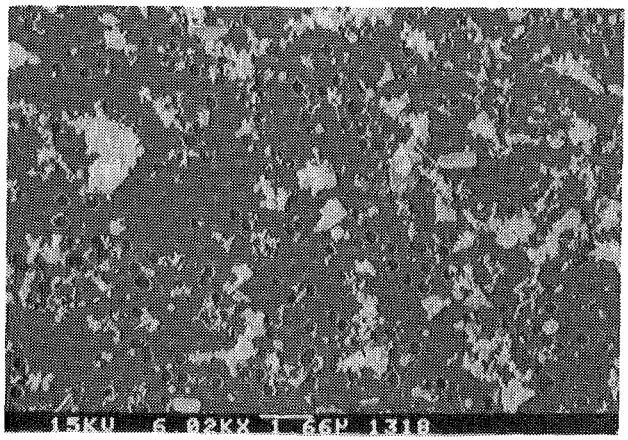


PARTICLE SIZE HISTOGRAM:

Particle size histogram calculated by PRC is invalid because of high degree of agglomeration. This level of agglomeration was not usually achieved in the confirmation of exhaust particulates in the other samples.

SAMPLE IDENTIFICATION:

Canadian Bronze Stack (12/07/82)

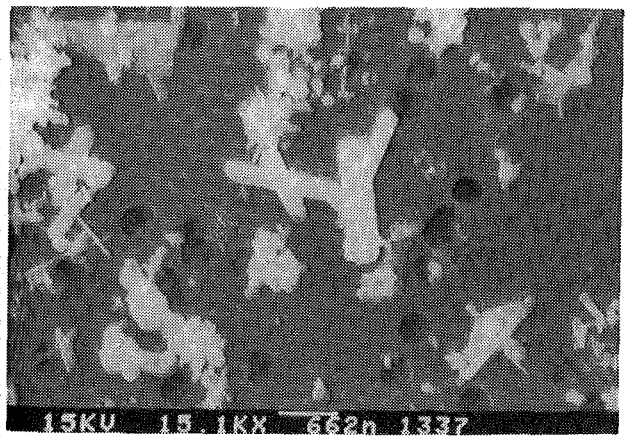


WIND DIRECTION/VELOCITY: N/A kmh

COLLECTION TIME: 5 minutes

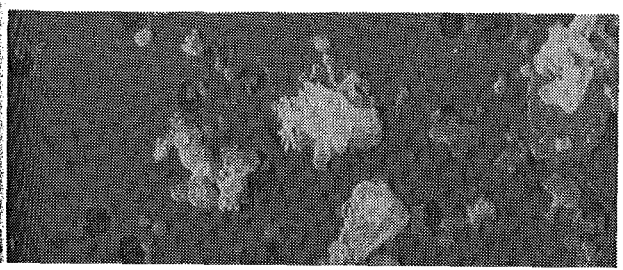
"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.8 µm
- TOTAL PARTICLE POPULATION 124
- % TOTAL AREA COVERED BY PARTICLES 8.08 %



COMMENTS:

Zinc was observed in 100% of particles analyzed, lead was associated with approx. 52% of the particles analyzed. The distinctive crystal habit observed in the attached SEM images is associated with the high Zn levels. Electron diffraction identified the zinc species as a zinc oxide or zinc oxyhydroxide.



PARTICLE SIZE HISTOGRAM:

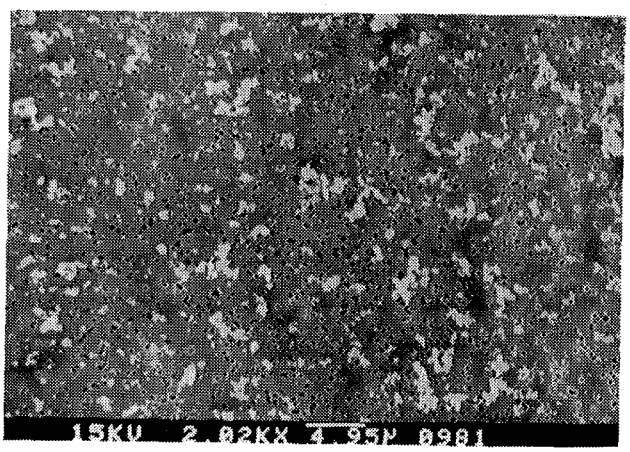
AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	6	4.8	[***
0.67	54	43.5	[**********
1.00	37	29.8	[**********
1.33	13	10.4	[******

2-3

SAMPLE IDENTIFICATION:

Northwest Smelter (27/10/82)

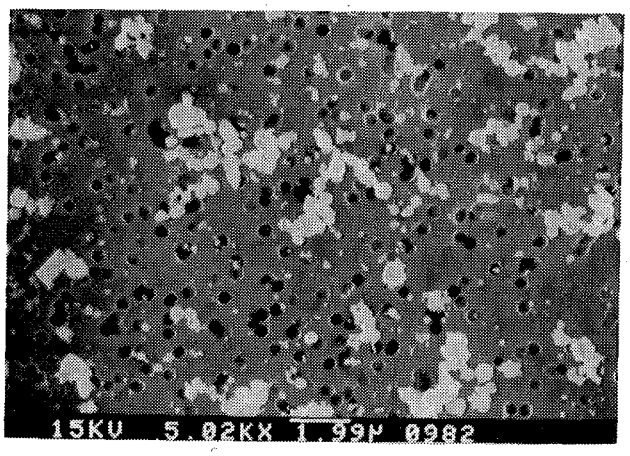


WIND DIRECTION/VELOCITY: N/A kmh

COLLECTION TIME: ~~0.03~~ 0.05 minutes

"PRC" DATA:

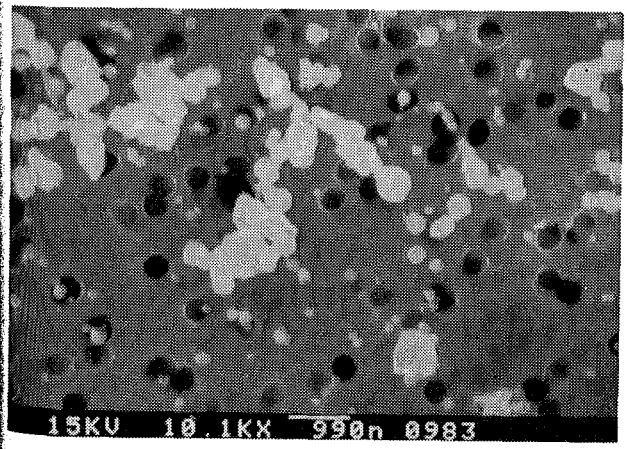
- AVERAGE PARTICLE DIAMETER = 1.5 µm
- TOTAL PARTICLE POPULATION 63
- % TOTAL AREA COVERED BY PARTICLES 7.7 %



COMMENTS:

Very strong Pb x-ray intensities were observed for every particle analyzed.

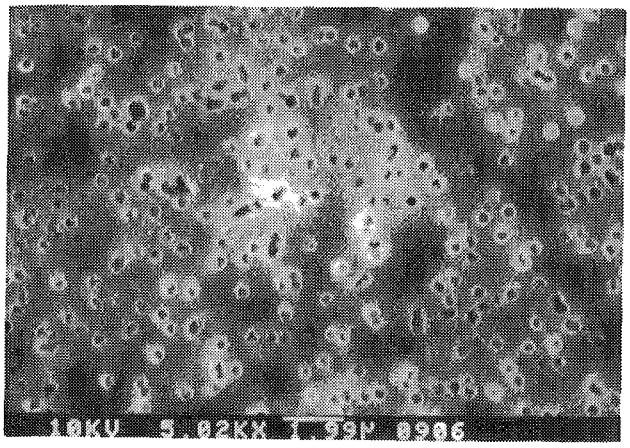
The minor EDX peaks for Ni and Cu may be artefacts from the SEM sample chamber

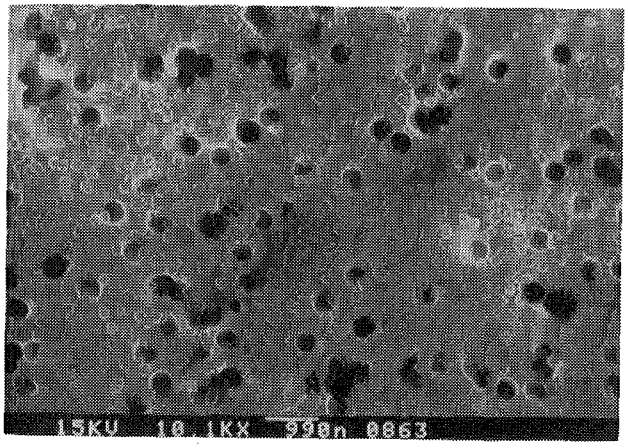


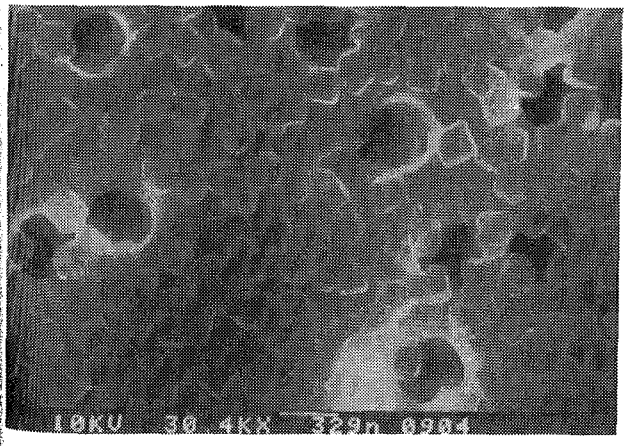
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	0	0.0	[
0.67	4	6.3	[****
1.00	9	14.2	[********
1.33	18	28.5	[**********
1.67	10	15.8	[********
2.00	9	14.2	[********
2.33	6	9.5	[*****
2.67	2	3.1	[**
3.00	2	3.1	[**
3.33	3	4.7	[***
3.67	0	0.0	[







SAMPLE IDENTIFICATION:

Canada Metal Stack (27/10/82)

WIND DIRECTION/VELOCITY: N/A kmh

COLLECTION TIME: 10 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.2 µm *
- TOTAL PARTICLE POPULATION Not known
- % TOTAL AREA COVERED BY PARTICLES Not known %

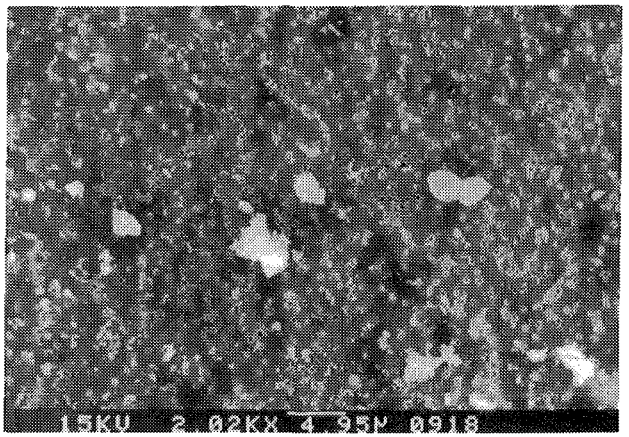
COMMENTS:

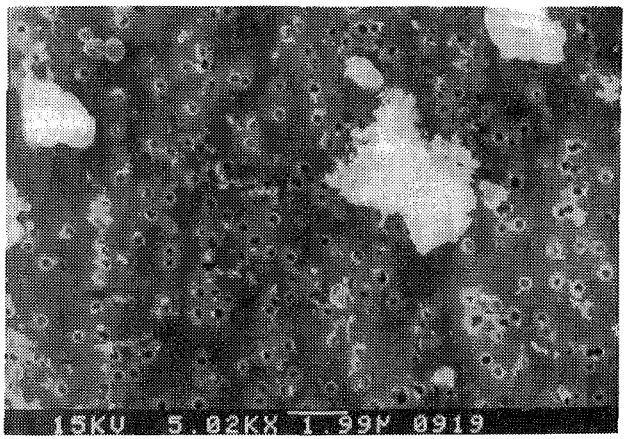
Note the very high electron transparency of crystals. The low density and small particle size prohibited successful microanalysis by PRC.

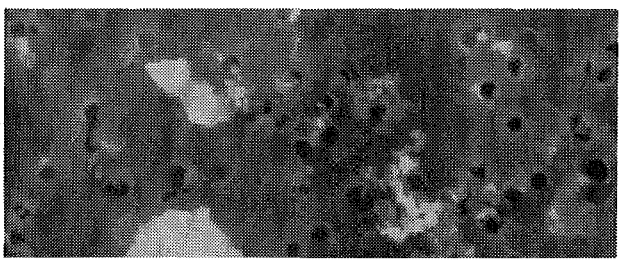
Based on the filter colour, crystal morphology, and low particle density, the particles are suspected to be sulfur.

PARTICLE SIZE HISTOGRAM:

Not Available.







SAMPLE IDENTIFICATION:

Canada Bronze Parking Lot (control)
West Side - 06/07/82.

WIND DIRECTION/VELOCITY: WSW/20 kmh

COLLECTION TIME: 90 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.1 μm
- TOTAL PARTICLE POPULATION 201
- % TOTAL AREA COVERED BY PARTICLES ≃1.3 %

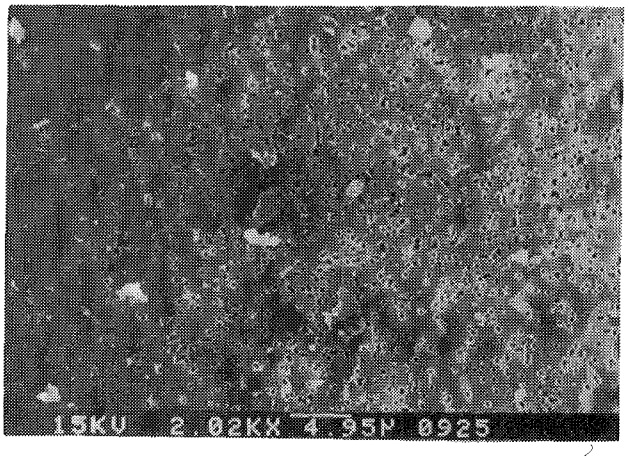
COMMENTS:

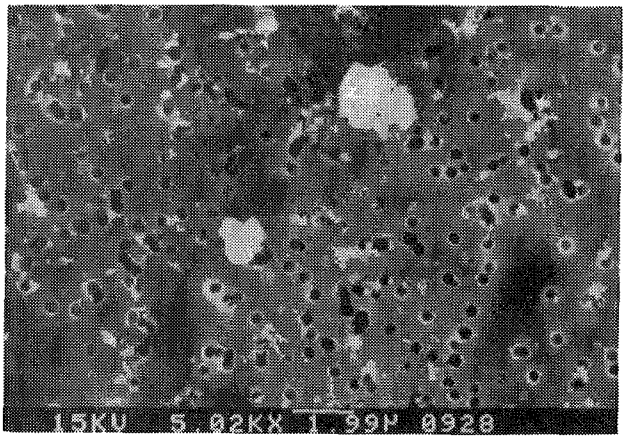
Note very low levels of zinc found by EDX. (A good control sample.)

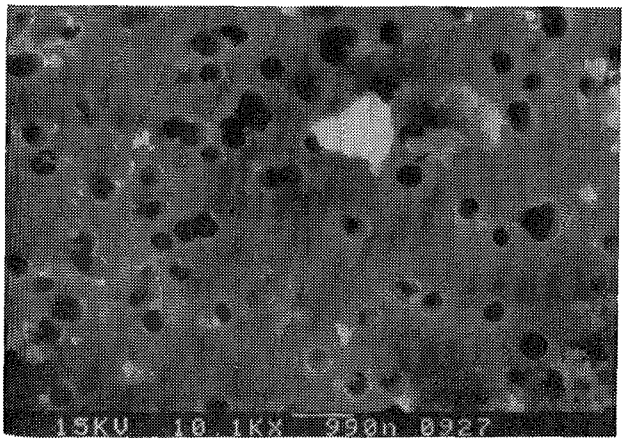
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø0---10---20---30---40---50---6Ø
Ø.33	24	17.Ø	[*********







SAMPLE IDENTIFICATION:

Weston School (control) 06/07/82

Corner Logan and Quelch

WIND DIRECTION/VELOCITY: WSW/20 kmh

COLLECTION TIME: 60 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.0 μm
- TOTAL PARTICLE POPULATION 151
- % TOTAL AREA COVERED BY PARTICLES ≃1.0 %

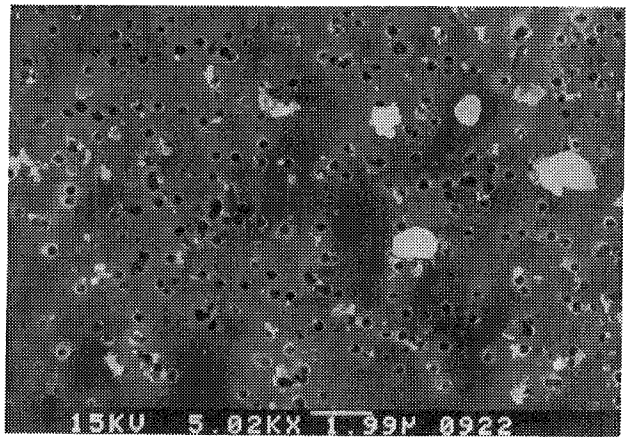
COMMENTS:

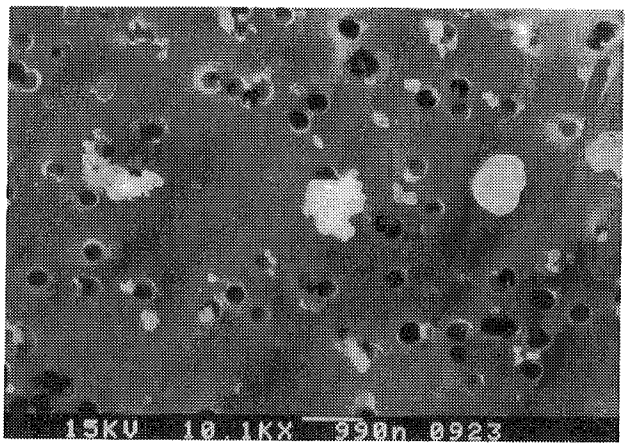
Note high incidence of exhaust particulates.

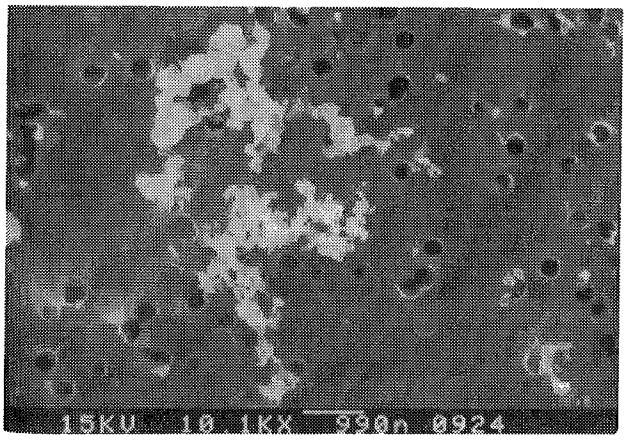
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø0---10---20---30---40---50---6
Ø.33	8	8.6	[*****
Ø.67	36	38.7	[**********
1.ØØ	24	25.8	[**********
1.33	8	8.6	[*****
1.67	7	7.5	[****
2.ØØ	3	3.2	[**
2.33	5	5.3	[***
2.67	1	1.Ø	[*
3.ØØ	Ø	Ø.Ø	[
3.33	Ø	Ø.Ø	[
3.67	1	1.Ø	[*
4.ØØ	Ø	Ø.Ø	[







SAMPLE IDENTIFICATION:

Pacific and Quelch (control)06/07/82

Northeast corner

WIND DIRECTION/VELOCITY: WSW/20 kmh

COLLECTION TIME: 120 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.2 μm
- TOTAL PARTICLE POPULATION 167
- % TOTAL AREA COVERED BY PARTICLES 0.95 %

COMMENTS:

Note high proportion of exhaust particulates.

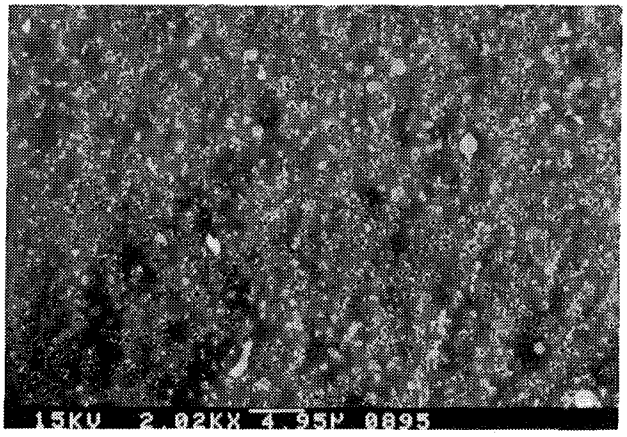
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø0---10---20---30---40---50---6
Ø.33	6	5.4	[***
Ø.67	32	29.Ø	[***************
1.ØØ	21	19.Ø	[**********
1.33	15	13.6	[*******
1.67	7	6.3	[****
2.ØØ	9	8.1	[*****
2.33	7	6.3	[****
2.67	3	2.7	[**
3.ØØ	4	3.6	[**
3.33	5	4.5	[***
3.67	1	Ø.9	[*
4.ØØ	Ø	Ø.Ø	[

SAMPLE IDENTIFICATION:

Canadian Bronze Parking Lot

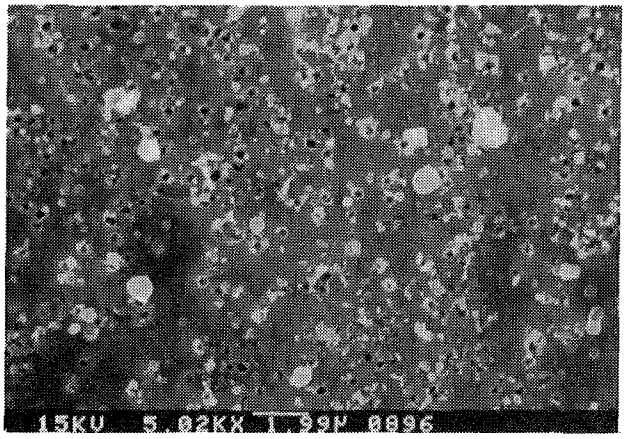


WIND DIRECTION/VELOCITY: S/8 kmh

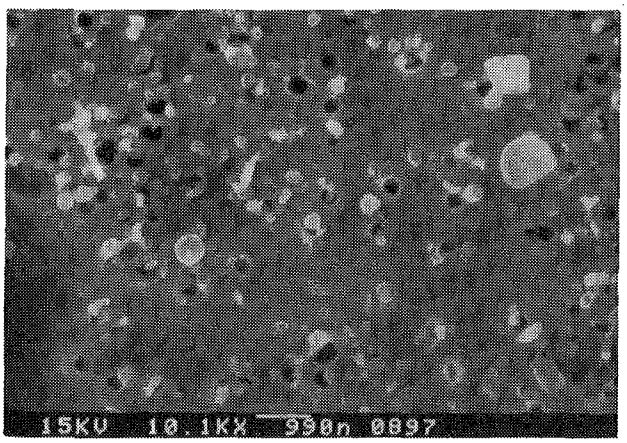
COLLECTION TIME: 75 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 0.95 µm
- TOTAL PARTICLE POPULATION 174
- % TOTAL AREA COVERED BY PARTICLES ≃ 1.3 %



COMMENTS:



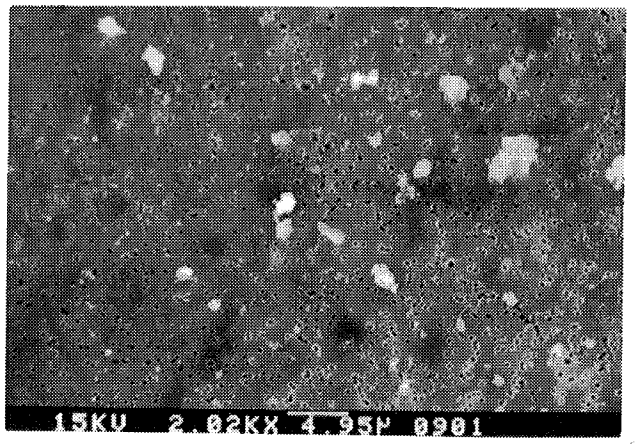
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: 0 ALL TYPES

BIN MAX	NO.	%	00---10---20---30---40---50---60
0.33	2	2.2	[**
0.67	31	35.6	[******************
1.00	23	26.4	[**************
1.33	10	11.4	[******
1.67	10	11.4	[******
2.00	6	6.8	[****
2.33	3	3.4	[**
2.67	2	2.2	[**
3.00	0	0.0	[

SAMPLE IDENTIFICATION:

Weston School

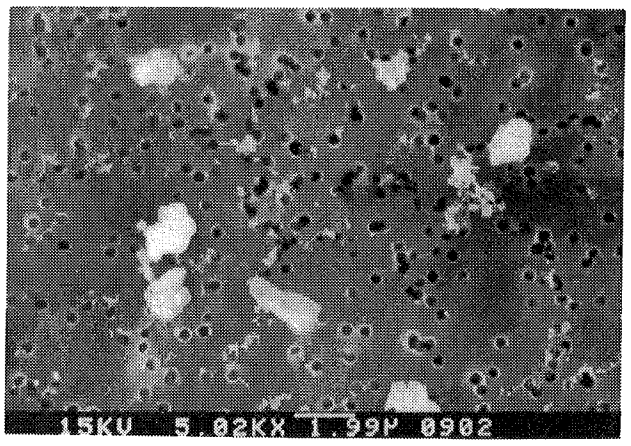


WIND DIRECTION/VELOCITY: NNE/20 kmh

COLLECTION TIME: 15 minutes

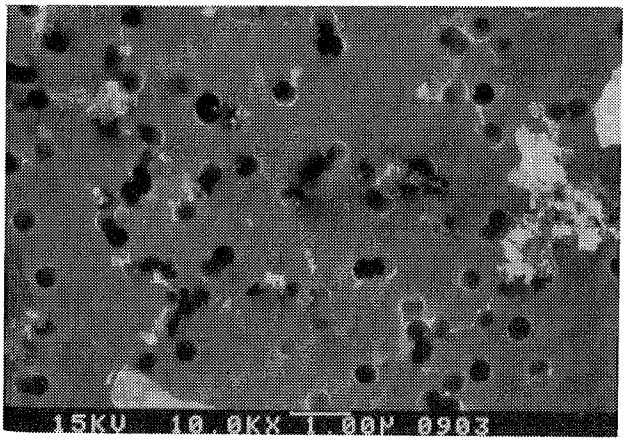
"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.0 µm
- TOTAL PARTICLE POPULATION 161
- % TOTAL AREA COVERED BY PARTICLES 1.14 %



COMMENTS:

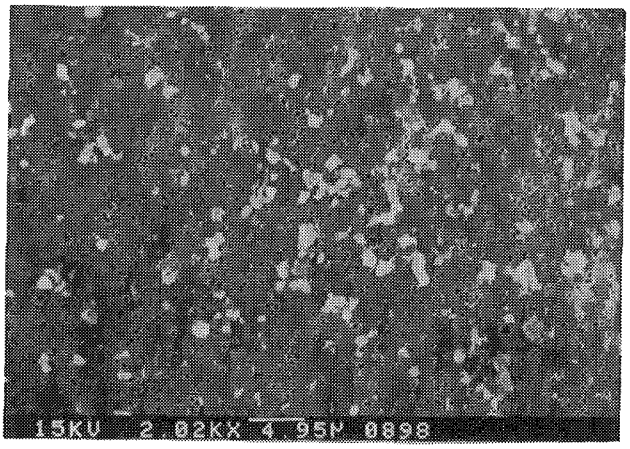
2 of 14 confirmed lead particles are of Pb-Zn origin. Canadian Bronze contribution to the total lead incidence may be approx. 14%, with the major source of lead being auto emissions.

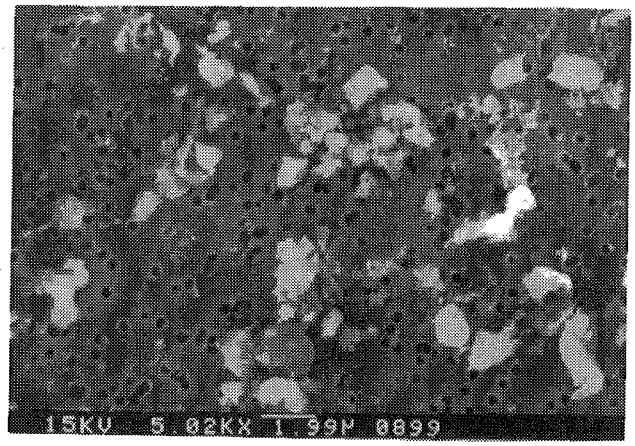


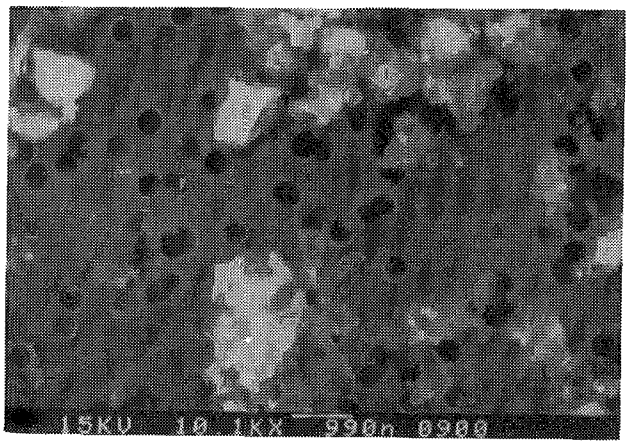
PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø---1---2---3---4---5---6
0.33	11	6.8	[****
0.67	40	24.8	[**********
1.00	37	22.9	[**********
1.33	31	19.2	[*********
1.67	18	11.1	[******
2.00	12	7.4	[****
2.33	8	4.9	[***
2.67	3	1.8	[*
3.00	1	0.6	[*
3.33	0	0.0	[







SAMPLE IDENTIFICATION:

Pacific and Quelch 30/09/82

Northeast Corner

WIND DIRECTION/VELOCITY: WNW/20 kmh

COLLECTION TIME: 75 minutes

"PRC" DATA:

- AVERAGE PARTICLE DIAMETER = 1.1 µm
- TOTAL PARTICLE POPULATION 162
- % TOTAL AREA COVERED BY PARTICLES 1.4 %

COMMENTS:

Note the extremely high incidence of Ca-rich particles suggesting large amount of cement and/or construction nearby.

**PRC data collected on less densely populated area of the filter.

PARTICLE SIZE HISTOGRAM:

AVERAGE DIAMETER HISTOGRAM FOR TYPE: Ø ALL TYPES

BIN MAX	NO.	%	Ø0---10---20---30---40---50---60
Ø.33	Ø	Ø.Ø	[
Ø.67	27	23.2	[**********
1.ØØ	27	23.2	[**********
1.33	28	24.1	[**********
1.67	23	19.8	[*********
2.ØØ	1Ø	8.6	[****
2.33	Ø	Ø.Ø	[
2.67	1	Ø.8	[*
3.ØØ	Ø	Ø.Ø	[