A Study of the Lead Profile of Soil and Vegetation Along Taft/España Avenue, Manila, Philippines

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Abstract

Soils and plants sampled along Taft/España Avenue were found to contain high levels of lead. The lead contents tend to decrease with soil depth ; increase with proximity to the avenue and traffic density ; and increase with increased obstruction to air circulation.

Much of the lead in the leaves of plants can be removed by washing. This removable lead is exceedingly high in leaves of plants growing in the street islands and within the 0 to 3 m from the sidewalk of Taft/España Avenue . These values are very much higher than the reported literature value of about 5 ppm for natural lead content of plant leaf and even above the critical limit of 50 ppm .

The level of lead in soils was found exceedingly high in the 0-2 cm surface soil in the street islands and in soils alongside Taft/España Avenue. This level of lead is maintained high during the dry and rainy season. The 2-5 cm and 5-10 cm below the surface soils acquire as much lead as the 2-cm surface soil during the wet or rainy months. The lowest lead content of the 2-cm surface soil was collected in June at the Manila City Hall site (119 ppm) and the highest at the Quezon City Rotonda site in March (7596 ppm), values very much higher than the reported value of 25 ppm for virgin soil.

Introduction

The toxicity of lead has been known since antiquity. It is believed to exert ill effects on heme biosynthesis and accumulates in the body causing damage to the central nervous system. Lead is absorbed very slowly into the human body but this slow and chronic absorption is sufficient to cause lead poisoning because the rate of elimination is even slower, thus results in its accumulation. The seemingly harmless trace amounts absorbed by the body over a period of time can accumulate beyond the threshold level and thereby produce delayed toxic symptoms.

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WHO (1988) has given the threshold for interference with heme formation to be about 20 ug Pb/dl blood in adults and about 10-20 ugPb/dl blood in children. The kinetics of lead distribution and accumulation in man have not been well defined. However, from autopsy data, the general pattern of lead metabolism is discernible. It shows that lead has a strong tendency to localize and accumulate in bones and be distributed throughout the soft tissues with especially high concentrations in the liver and kidneys. The accumulation of lead in the body begins in fetal life. It is readily transferred across the placenta as shown in the concentration of lead in the blood of newborn children which is similar to that of their mothers, indicating mother-fetus equilibrium processes (WHO, 1977). Numerous animal studies have also demonstrated placental transfer of lead to the fetus (Carpenter, S., 1974).

Most of the lead in the environment arise from both the production and the use of this element and its compounds. The single largest source is from the use of alkyl lead as an anti-knock agent in gasoline (WHO, 1988).

In recognition of the health hazard posed by lead, virtually all industrialized nations, by the late 1970s had begun to phase down gasoline lead content and set emission limits for lead to meet ambient air quality standards. However, in developing countries, like the Philippines, a move in this direction has just begun. According to WHO (1988), the guideline range of 0.5 - 1.0 ug/m^3 lead in air is considered to be the maximum recommended value for maintaining blood lead levels below 20 ug/dl.

Researchers have established that atmospheric pollution of lead resulting from combustion of leaded gasoline has increased Pb content in water, in plants, and in soils [Bashirova, 1966; Cannon & Boules (1962); Marten & Hammond (1966); Page and Ganje (1970) ; Ward, Brooks & Roberts (1977) ; Smith (1972); Chow & Patterson (1962); Lagerwerff and Specht (1970); Koji (1981); Chino (1981)].

To determine the extent of lead pollution from vehicle emissions, the lead profile of Taft/España Avenue was taken. The lead content of soil samples taken at specified areas along the avenue at depths of 0-2 cm, 2-5cm, and 5-10cm were measured.

Likewise, samples of plant leaves obtained from plants growing in specified areas perpendicular to the avenue within the 0-3 m, 3-8 m, and 8-15 m away were analyzed for their lead content.

Experimental

1. Sample Collection

1.1. Soil

Soil samples were collected on specified sites (Figure. 1) along Taft/ España Avenue. At one site, the Rotonda, samples were taken at the center island of the avenue. On each area A, B, and C, about 1/2kg samples were taken from the upper 2 cm surface soil, from about 2- 5 cm and 5-10 cm below the surface. Collection of samples were done on March 17, 1989 and June 18, 1989 from the Rotonda and on June 18, 1989 from all the other sampling sites.

1.2. Vegetation

Samples of plant leaves from 3 to 5 unidentified plants were gathered from within the 0-3 m, 3-8 m, and 8-15 m away from the avenue at specific sites indicated in Figure 1.

Collection of samples were done on March 17, 1989 from the center islands on Quezon Boulevard - Lerma sampling site and on June 18, 1989 from all the other sampling sites.

2. **Determination of Lead**

2.1. Soil

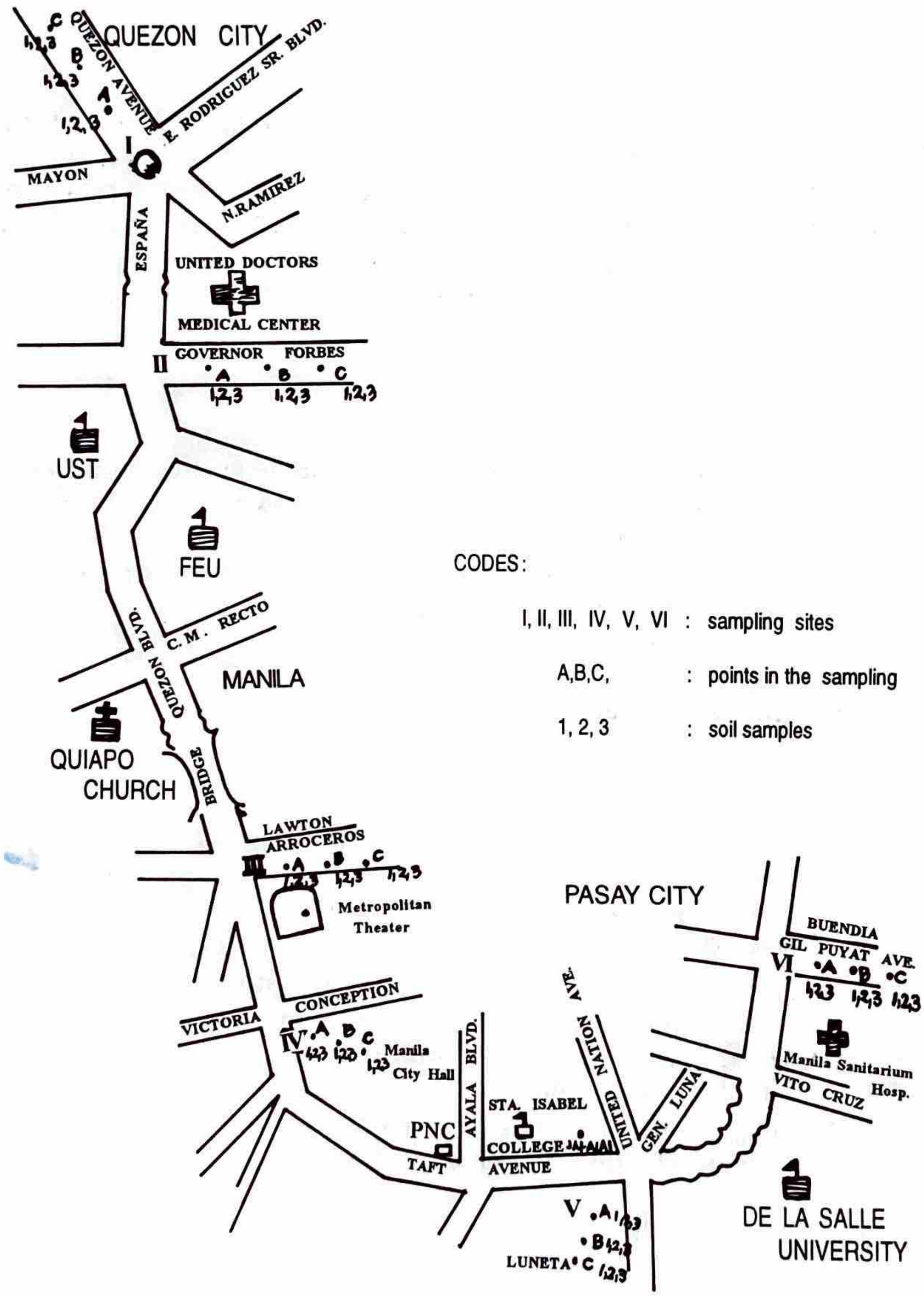
Soil samples were oven dried at 100-105°C. A representative sample was then taken (by the quartering technique) and ground to pass a 60-mesh sieve. About 0.5 gram of the sample was accurately weighed into a porcelain crucible and ignited at 450°C in a furnace to destroy the organic matter. It was then decomposed with 10 ml (twice) of a 1:1 mixtureof conc. HNO_3 and HF in a 100 ml polypropylene beaker and evaporated to dryness over a water bath. The residue was dissolved in 20 ml of 2M HNO_3 and diluted to mark in a 100-ml volumetric flask.

Aliquots of the solution were taken and analyzed by AAS using standard addition technique on a Varian AA-275.

2.2 Vegetation

Leaf samples of the same plant were apportioned into two. One

Figure 1. Diagram of the Sampling Sites.



portion was dried in the oven at 150ºC then ashed in the furnace at 450ºC. The other portion was washed well with detergent and water then rinsed with distilled water. This was oven dried at 150º then ashed at 450ºC.

A 0.1 to 0.5 g sample of the ash was accurately weighed into a beaker and digested with 10 ml of 1:1 mixture of concentrated HNO_3 and $HClO_4$ and evaporated almost to dryness.

The residue was dissolved in 2 ml of 10 M HNO_3, transferred to a 50-ml volumetric flask and diluted to mark with distilled water.

Aliquots of the solution were analyzed by AAS using standard addition technique on a Varian AA-275.

Results and Discussion

1. Lead Content of Soil

In view of the difficulty in controlling the effects of sample matrix and the variations in absorbance readings, analysis was done by standard addition method. Results are expressed as ppm (ug Pb per gram of soil).

1.1. Site I - Rotonda, Q.C. (RQC)

Results obtained from this sampling site are given in Table 1. Since collection of samples were done at different times, those collected in March are indicated as March A, B, C and those collected in June are indicated as June A, B, C, respectively.

As shown in this table, surface soils A1, B1 and C1 collected in March have higher lead contents than the soil samples taken 2-5 cm below the surface, i.e. A2, B2, C2. Still a further decrease in lead content is noted for samples taken 5-10 cm below the surface (A3, B3 and C3). In this area the ratio of the lead content of A1 to A2 to A3 is 33 to 1.3 to 1.0; B1 to B2 to B3 is 10 to 1.6 to 1.0 ; and C1 to C2 to C3 is 3.1 to 2.4 to 1.0. Samples collected in June which was the start of the rainy season still revealed that the surface soil have higher lead contents than soils below the surface. A comparison of the lead content of the top soil with those taken below the surface showed the ratio of A1 to A2 to A3 od 1.7 to 1.5 to 1.0 ; B1 to B2 to B3 of 2.9 to 1.8 to 1.0 ; and C1 to C2 to C3 of 4.9 to 2.0 to 1.0. A comparison of the Pb contents of the March and June samples taken from the same sampling area showed that the March samples are higher by a factor of 1.2 to 1.4 than their June counterpart. However, for soil samples below the surface, the June samples are higher than their March counterpart by as much as 2.4 to 19 times except for C2 and C3 samples wherein the March samples are higher by 2.0 to

Table 1. Lead Content of Soil Samples Along Taft/España Avenue

Samples/Area		Lead Content of Soil Samples, ppm			
		Trials			
		I	II	III	Average
March	RQC A1	4854	4337	3541	4244
	RQC A2	172	150	171	164
	RQC A3	138	124	123	128
	RQC B1	7399	7596	7499	7498
	RQC B2	1424	1065	1158	1216
	RQC B3	790	767	778	778
	RQC C1	4879	3872	4174	4308
	RQC C2	3543	3543	2964	3355
	RQC C3	1461	1301	1421	1394
JUNE	RQC A1	3566	3349	3649	3521
	RQC A2	3243	2704	3367	3105
	RQC A3	2058	2426	1787	2090
	RQC B1	5173	5322	5193	5229
	RQC B2	3346	3270	3317	3311
	RQC B3	1912	1767	1813	1831
	RQC C1	3049	3917	3084	3350
	RQC C2	1321	1376	1365	1354
	RQC C3	662	691	705	686
June	GF A1	924	1132	908	988
	GF A2	825	827	786	813
	GF A3	689	760	706	718
	GF B1	1372	891	999	1087
	GF B2	897	753	768	806
	GF B3	700	631	648	660

Table 1 continued

	GF C1	1221	1377	1399	1332
	GF C2	973	935	971	960
	GF C3	671	757	708	712
JUNE	L A1	868	763	707	779
	L A2	450	411	396	419
	L A3	244	324	303	290
June	L B1	374	424	347	282
	L B2	223	317	262	267
	L B3	128	147	155	143
	L C1	208	191	181	193
	L C2	177	172	177	175
	L C3	175	149	167	164
June	MCH A1	683	780	782	748
	MCH A2	734	665	723	707
	MCH A3	670	606	586	621
	MCH B1	461	435	381	426
	MCH B2	83	62	73	73
	MCH B3	59	34	60	51
	MCH C1	157	147	119	141
	MCH C2	124	78	80	94
	MCH C3	104	63	34	67
June	RP A1	460	503	549	504
	RP A2	442	502	411	452
	RP A3	327	333	322	327
	RP B1	339	296	332	332
	RP B2	158	170	215	181
	RP B3	171	108	119	133
	RP C1	246	248	228	241
	RP C2	185	234	247	222
	RP C3	111	101	155	122
June B	A1	991	1021	1121	1044
	B A2	351	303	222	292
	B A3	84	86	114	95

Table 1 continued

	B	B1	709	666	727	699
	B	B2	458	480	498	479
	B	B3	502	443	441	462
	B	C1	569	532	519	540
	B	C2	344	403	373	373
	B	C3	275	340	453	356

2.5 times their June counterpart.

The high Pb contents of surface soils seem to indicate that the source of Pb is the surrounding air which could mean from emissions. During the rainy season, part of this lead deposited on the surface soil is leached, hence a high Pb content in the soil below the surface.

1.2. Site II - Governor Forbes (GF)

Only June samples were analyzed from this site. Results also shown in Table 1 gave the ratio of their Pb contents are as follows :

A1	to	A2	to	A3	is	1.4	to	1.1	to	1.0
B1	to	B2	to	B3	is	1.6	to	1.2	to	1.0
C1	to	C2	to	C3	is	1.9	to	1.3	to	1.0

As shown the Pb contents of surface soils are 1.4 to 1.9 times higher than soils below the surface.

1.3. Site III - Lawton (L)

As shown in Table 1, surface soils A1, B1, & C1 contained higher levels of Pb compared to soils collected below the surface in the ratio of:

A1	to	A2	to	A3	is	2.7	to	1.4	to	1.0
B1	to	B2	to	B3	is	2.7	to	1.9	to	1.0
C1	to	C2	to	C3	is	1.2	to	1.1	to	1.0

Likewise, soils taken further away from the Taft/España Avenue and away from any street used by motor vehicles such as B & C areas have lead contents very much less than samples from area closest to the avenue. The ratios of their Pb contents are :

A1 to B1 to C1	is	4.0 to 2.0 to 1.0
A2 to B2 to C2	is	2.4 to 1.5 to 1.0
A3 to B3 to C3	is	2.0 to 1.0 to 1.0

1.4. Site IV - Manila City Hall (MCH)

Results obtained for this sampling site are also presented in Table 1. Samples analyzed were collected in June. The Pb content of the surface soil samples are also higher than of soil samples below the surface in the ratios of:

A1	to	A2	to	A3	is	1.2	to	1.1	to	1.0
B1	to	B2	to	B3	is	8.0	to	1.4	to	1.0
C1	to	C2	to	C3	is	2.1	to	1.4	to	1.0

The Pb contents of soils closest to the Taft/Espana Avenue are much higher than from soils further away from this motor vehicle dense street. The ratios of their lead contents are :

A1	to	B1	to	C1	is	5.3	to	3.0	to	1.0
A2	to	B2	to	C2	is	9.7	to	1.0	to	1.3
A3	to	B3	to	C3	is	12.1	to	1.0	to	1.3

1.5. Site V - Luneta or Rizal Park (RP)

The transect as shown in Figure 2 was drawn inward the park area away from Taft Avenue.

Results presented in Table 1 show decreasing Pb content away from Taft Avenue. The ratio of Pb contents of samples from the different areas on the transect are:

A1	to	B1	to	C1	is	2.1	to	1.4	to	1.0
A2	to	B2	to	C2	is	2.5	to	1.0	to	1.2
A3	to	B3	to	C3	is	2.7	to	1.1	to	1.0

Surface soils contained higher Pb than soils taken below the surface on the same sampling area. The ratios of their Pb contents are :

A1	to	A2	to	A3	is	1.5	to	1.4	to	1.0
B1	to	B2	to	B3	is	2.5	to	1.4	to	1.0
C1	to	C2	to	C3	is	2.0	to	1.8	to	1.0

Figure 2. Sample Collection Sites for Vegetation.

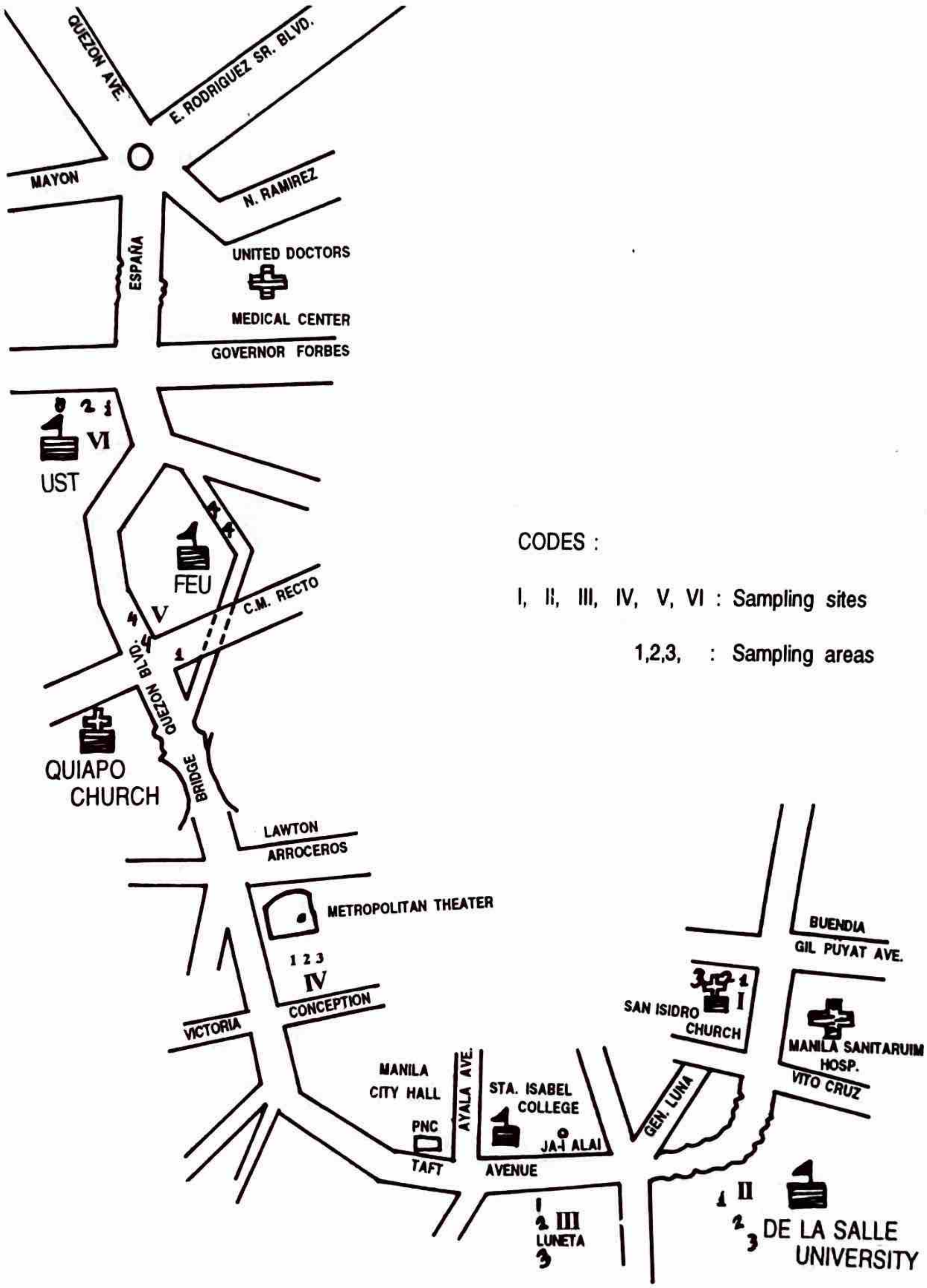


Table 2. Summary of the Lead Content of Soil Samples Along Taft/España Avenue

Samples/ Area	Average Lead Content of Soil Samples at The Different Sampling Sites, ppm						
	Rotonda	Gov Forbes	Lawton	Manila CityHall	Luneta/ RizalPark	Buendia	Ave.
1. Surface Soil (0-2 cm) , June Samples							
A	3521	988	779	748	504	1044	1264
B	5229	1087	382	426	332	699	1359
C	3350	1332	193	141	241	540	966
2. Soil 2-5 cm Below , June Samples							
A	3105	813	419	707	452	292	965
B	3311	806	267	73	181	479	853
C	1354	960	175	94	222	373	530
3. Soil 5-10 cm Below, June Samples							
A	2090	718	290	621	327	95	690
B	1831	660	143	51	133	462	547
C	686	712	164	67	122	356	351
1. Surface Soil (0-2cm), March Samples							
A	4244						
B	7498						
C	4309						
2. Soil 2-5 cm Below , March Samples							
A	164						
B	1216						
C	3355						
3. Soil 5-10 cm Below , March Samples							
A	128						
B	778						
C	1394						

1.6. Site 6 - Buendia (B)

Results from this sampling site are given in Table 2. As in the other sites the Pb contents of surface soils are higher than in soils taken below the surface. The ratios of their lead contents are:

A1	to	A2	to	A3	is	11.3	to	3.2	to	1.0
B1	to	B2	to	B3	is	1.5	to	1.0	to	1.0
C1	to	C2	to	C3	is	1.5	to	1.0	to	1.0

2. **Lead Content of Vegetation**

The leaves of plants growing along major thoroughfares may acquire lead from emissions through deposition. The particles deposited on the surfaces may totally or partially be removed by washing.

In this study, leaves of the same plant were apportioned into two. One portion was washed well with detergent and water and rinsed with distilled water before drying and ashing. The other portion was dried, then ashed without washing. The difference in lead content is taken as removable lead, the amount of lead collected on the surfaces of the leaves.

To minimize matrix effects and the variations in the day to day absorbance readings, standard addition method was used. The lead content of the sample was calculated in ug per gram of ash and expressed as ppm.

2.1. Site I - San Isidro Church Compound (SIC).

Results of the analysis of the SIC samples are presented in Table 3. Leaf samples from different plants (A, B, C, ... etc.) contained varying amounts of lead. On the average, leaves of plants growing closest to Taft Avenue contained about twice the lead content of plants about 3 to 8 meters away and about seven times the lead content of those growing 8 to 15 meters away. On the average unwashed samples contained about 118% more lead than the washed samples for plants growing close to Taft Avenue, 52% and 98% for plants growing 3 to 8 meters and 8 to 15 meters away from the avenue, respectively. This seems to indicate that a major portion of this lead is just suspended on the leaves and may be blown by the wind or washed off by the rain.

Also it shows that this deposited lead must have come from the surrounding air, hence must have originated from emissions.

2.2. Site II - Dela Salle University Campus (DLSU)

Table 3. Lead Content of Plants Along Taft-España Avenue

Sample	Lead Content, ppm Washed	Unwashed	Removable Lead %
SIC 1 A	490	1423	190
SIC 1 B	303	686	126
SIC 1 C	161	580	260
SIC 1 D	491	620	26
SIC 1 E	222	318	43
Average	333	725	118
SIC 2 A	154	433	181
SIC 2 B	269	324	20
SIC 2 C	130	140	8
SIC 2 D	135	152	13
Average	172	262	52
SIC 3 A	45	75	67
SIC 3 B	44	79	80
SIC 3 C	54	125	131
SIC 3 D	51	108	112
Average	49	97	98
DLSU 1 A	130	188	45
DLSU 1 B	95	147	55
DLSU 1 C	121	202	67
DLSU 1 D	87	90	3
Average	108	157	45
DLSU 2 A	114	159	39
DLSU 2 B	67	165	146
DLSU 2 C	100	101	1
DLSU 2 D	63	95	51
Average	86	123	43
DLSU 3 A	70	100	43
DLSU 3 B	57	97	70
DLSU 3 C	50	89	78
DLSU 3 D	73	95	30
Average	63	95	51

Table 3 continued

RP 1 A	333	439	32
RP 1 B	338	519	54
RP 1 C	243	429	77
RP 1 D	269	792	194
Average	296	545	84
RP 2 A	245	258	5
RP 2 B	280	507	81
RP 2 C	261	305	17
RP 2 D	188	212	13
Average	244	321	32
RP 3 A	140	157	12
RP 3 B	102	100	-
RP 3 C	59	68	15
RP 3 D	70	139	99
Average	93	116	25
AR 1 A	408	694	70
AR 1 B	371	714	92
AR 1 C	369	430	17
AR 1 D	270	578	114
Average	366	604	65
AR 2 A	180	255	42
AR 2 B	132	206	56
AR 2 C	121	279	131
AR 2 D	158	200	27
Average	144	235	63
AR 3 A	98	116	18
AR 3 B	156	146	-
AR 3 C	105	117	11
AR 3 D	87	115	32
Average	112	124	11
QBL 4 A	394	1548	293
QBL 4 B	158	3646	2208
QBL 4 C	744	3047	310
QBL 4 D	731	927	27
QBL 4 E	263	1470	459
Average	458	2128	364

Table 3 continued

UST 1 A	112	205	83
UST 1 B	98	187	91
UST 1 C	193	268	39
UST 1 D	122	173	42
Average	131	208	59
UST 2 A	105	99	-
UST 2 B	73	125	71
UST 2 C	89	93	4
UST 2 D	75	76	1
Average	86	98	14
UST 3 A	71	98	38
UST 3 B	87	91	5
UST 3 C	97	150	55
UST 3 D	130	138	6
Average	96	119	24

Also presented in Table 3 are the results of the analysis of the DLSU samples. On the average, leaf samples from plants growing closest to Taft Avenue contained about 1.3 times the lead content of leaves of plants growing 3 to 8 meters away and 1.7 times the lead content of those growing 8 to 15 meters away for both washed and unwashed samples. The removable lead for the plants in Area 1 (closest to Taft Avenue), Area 2 (within 3 to 8 m) and Area 3 (within 8 to 15 m) away from Taft, are 45%, 43%, and 51%, respectively. The lower % removable lead in these samples maybe the result of the movement of a stronger breeze that comes from the athletic field behind the campus blowing towards Taft. The small variation in lead contents of plants in all three sampling areas within the campus may be due to this strong breeze and the watering of the plants in this site.

2.3. Site III - Luneta or Rizal Park (RP)

Results of the analyses of samples from this site are given in Table 3. The ratio of the lead content of the RP1 to the RP2 to the RP3 samples is 3 to 2.6 to 1.0 for the washed samples and 4.7 to 2.8 to 1.0 for the unwashed samples. The average removable lead in Area I was about 84% while in Area 2 and 3 the values were 32% and 25%, respectively. The large removable lead in plants growing in Area 1 (closest to Taft Avenue) seems to point to a high lead content of the air in this area. The large difference in removable lead between Area 1 and Area 2 or 3 may be caused by a good circulation of air due to the open space, the wind or strong breeze that blows from the sea towards Taft, and the continuous watering of plants in this area.

2.4. Site IV - Aroceros Area (AR)

Table 3 shows the results of the analysis of the AR samples. The lead content of plants growing in Area 1 is comparable to the lead content of plants in Area 1 of Rizal Park. However, the average removable lead of the RP samples (84%) is higher than the AR samples (65%).

The lead content of washed samples in Area 1 is 2.5 times that of Area 2 and about 3.3 times that Area 3. However, the removable lead of Area 1 is 65% and Area 2 is 63 % while Area 3 is 11% only. This sampling site is opposite an open area (without buildings) and strong breeze coming from this open space moves the air away from Taft towards Area 1, 2, and 3, probably causing the removable lead of Area 1 and 2 to be almost the same. However, the particles of lead seem unable to travel far and thus settle on the leaves of plants in Area 1 & 2, hence resulting to low removable lead in Area 3 (11%).

2.5. Site V - Quezon Boulevard - Lerma Site (QBL)

The samples in this area were taken from the center islands of Quezon Boulevard in front of Far Eastern University and on España just before the intersection with Lerma Street. Samples were gathered in March 1989. Unlike the usual month of March in Manila, this March was still cool and not yet very dry. It rains every now and then and the plants in this area, although collecting black deposits (oily soot) from motor vehicle emissions, were still alive and green.

The results of the analysis of the plants from these islands are presented in Table 3. Although the lead contents are different for different plants, ranging from 158 to 744 ppm for washed and 927 to 3646 ppm for unwashed, the levels are appreciably high. The removable lead is exceeding high, an average of 364% pointing to vehicle emissions as the source of the lead. The lead content of washed samples, an average of 458 ppm, is also high in comparison with the other sites.

2.6. Site VI - University of Santo Tomas Campus (UST)

Lead contents of UST samples are likewise given in Table 3. The lead levels of samples closest to España Avenue is higher (average of 131 ppm for washed and 208 for unwashed) compared to the lead level of plants 3 to 8 meters away (86 ppm for washed and 98 ppm for unwashed). Although the levels of lead in these plants varied with kind, the levels generally are low. The removable lead is 59% closest to España Avenue and decreases away from the Avenue (14% and 24% for Area 2 and 3, respectively).

The low lead levels of samples in this site maybe due to the open space in which there is free circulation of air and may also be due to the watering of the plants in the campus.

Summary and Conclusion

In a summary presented in Table 2 the following trends in the lead contents and lead distribution in soils along Taft-España Avenue were observed:

1. In all the sampling sites the surface 2 cm soil contained from 1.3 to 2.0 times the lead content of soils 2-5 cm below the surface and from 1.6 to 2.6 times the lead content of soils 5-10 cm below the surface. Based on the average of all the sampling sites, the surface 2-cm soil contained 1.5 times the lead content of soils 2-5 cm below and 2.3 times the lead content of soil 5-10 cm below the surface.

2. The 2-cm surface soil of Rizal Park had the lowest lead content while the Rotonda had the highest. The order according to decreasing lead level is Rotonda, 4033 ppm > Gov. Forbes, 1136 ppm > Buendia, 761 ppm > Lawton >, 451 ppm >Manila City Hall, 438 ppm > Rizal Park, 359 ppm.

3. The 2-cm surface soils at the Rotonda contained from 1000 to 2000 ppm more lead during the month of March than in June.

4. Soil 2-5 cm below the surface gave lower lead contents than the 2-cm surface soil but about 1.2 to 1.7 times higher than the lead content of soil 5-10 cm below the surface. The order according to decreasing lead contentis Rotonda, 5590 ppm > Gov. Forbes, 860 ppm> Buendia, 381 ppm > Manila City Hall, 291 ppm >Lawton, 287 ppm > Rizal Park, 285 ppm.

5. On the average, the lead contents of soil 2-5 cm below the surface are higher during the month of June than in March unlike the surface 2-cm soil in which the lead contents of samples gathered in March were higher than the June samples.

Table 4. Summary of the Lead Content of Vegetation Along Taft-España Avenue

Samples/Area	ppm (ug Pb/g ash) Lead Content of Vegetation per Site						
	SIC	DLSU	RP	AR	QBL	UST	Ave-rage
1. Area 1 (1-3 m away)							
Washed	333	108	296	366		131	247
Unwashed	725	157	545	604		208	448
Removable Lead	392	49	249	238		77	201
2. Area 2 (3-8 m away)							
Washed	172	86	244	144		86	146
Unwashed	262	123	321	235		98	208
Removable Lead	90	37	77	91		12	61
3. Area 3 (8-15 m away)							
Washed	49	63	93	112		96	83
Unwashed	97	95	116	124		119	110
Removable Lead	48	32	23	12		23	28
3. Area 4 (Center Islands)							
Washed					458		458
Unwashed					2128		2128
Removable Lead					1670		1670

6. The 5-10 cm below the surface soil gave a lead level lower than the lead levels of soil above it. The sites arranged in the order of decreasing lead content is Rotonda, 1536 ppm > Gov. Forbes, 697 ppm > Buendia, 304 ppm> Manila City Hall, 246 ppm > Lawton, 199ppm > Rizal Park, 194 ppm.

7. On the average, the lead content of soil 5-10 cm below the surface is higher during the month of June than in March similar to the soil samples 5-cm below the surface.

From the results wherein the surface 2-cm soil in all sampled sites showed very much higher lead content than below surface soil; the higher lead content in surface 2-cm soil than the soil below it during the month of March and June; the increase in the lead content of soils 2-5 cm and 5-10 cm below the surface during the month of June than in March, all point to aerial source of lead. Since the higher lead contents are in sites with higher vehicular traffic, Rotonda, Gov. Forbes & Buendia; lower lead content in sites of a stronger breeze blowing away from it like the Rizal Park and Lawton; and the lower lead content of soils in open areas where air can circulate freely or air current are more mobile, point to vehicle emission as the source of the lead in soil.

As shown in the summary presented in Table 4, the following trends in the lead levels and distribution in vegetation along Taft-Espana Avenue were observed:

1. Using washed samples as basis, the levels of lead in plants closer to the Avenue are higher in the range of 1.2 to 2.5 times the level of lead in plants growing 3 to 8 m away from the avenue and in the range of 1.4 to 6.8 times the level of lead in plants 8 to 15 m away. On the average the ratio of lead content in washed samples within 0-3 m from the avenue to 3 to 8 m away to 8 to 15 m away is 3.0 to 1.8 to 1.0. The order of decreasing lead content in washed samples is Aroceros, 366 ppm > San Isidro Church Compound, 333 ppm >Rizal Park, 296 ppm > UST, 131 ppm > DLSU, 108 ppm for area I (closest to Taft-España Avenue) ; Rizal Park, 244 ppm > San Isidro Church Compound, 172 ppm > Aroceros,144 ppm > DLSU, UST, 86 ppm for area 2 (3 to 8 maway);and Aroceros, 112 ppm > UST, 96 ppm > Rizal Park, 93 ppm > DLSU, 63 ppm > San Isidro Church Compound, 49 ppm for area 3 (8 to 15 m away).

2. For the unwashed samples, the order according to decreasing lead content is San Isidro Church Compound, 725 ppm > Aroceros, 604

ppm > Rizal Park, 545 ppm> UST, 208 ppm > DLSU, 157 ppm for Area 1; RP, 321 ppm> SIC, 262 ppm > AR, 235 ppm > DLSU, 123 ppm > UST, 98 ppm for Area 2 ; and AR, 124 ppm > UST, 119 ppm > RP, 116 ppm > SIC, 97 ppm > DLSU, 95 ppm for Area 3.

3. The lead content of unwashed samples from the center islands is 4.6 times the lead content of washed samples.

4. The level of removable lead is highest in the center islands and decreases with decrease in traffic density and increases with decrease in air circulation or increased obstructions to free movement of air. The level of removal lead arranged in a descending order is QBL, 1670 ppm >> SIC, 392 ppm > RP, 249 ppm > AR, 238 ppm > UST, 77ppm > DLSU, 49 ppm taking into consideration only the level of lead in the center islands and the area closest to Taft-Espana Avenue.

5. The level of lead in plants during the summer month of March is higher than during the rainy month of June.

The higher lead content suspended on the leaves of plants closest to the traffic dense street and on the center islands and indicated by the large amount of removable lead points to vehicle emission as the source of lead. This conclusion is supported by the trend of decreasing amount of removable lead with increasing distance from the high density traffic area. But these particles of lead do not travel far from the source, hence lead pollution in some areas in Metro Manila will not cause appreciable lead pollution in areas outside Metro Manila with low vehicle traffic density.

In areas of high traffic density such as the Quezon Boulevard underpass, the lead content of unwashed plants of 2128 ppm (2.1 mg Pb per gram of ash) is exceedingly high compared to the 5 ppm natural lead content of plant leaves (Daines, *et al*, 1970) indicating that lead in the ambient air in this area may be greater than the recommended 0.5 - 1.0 ug Pb/m^3 air necessary to maintain the blood lead level below 20 ug/dl, hence may be hazardous to children and the weak.

In view of the high lead content in the surface soil of Rotonda, Gov. Forbes and Buendia and the high removable lead content of plants in the Quezon Boulevard- Lerma area, policy makers should look into possible strategies to lessen traffic in these areas to decrease the amount of vehicle emissions to safeguard the riding public and the people living in the vicinity of these areas. Likewise, since vehicle emissions is the source of lead, policy makers should look into the possibility of a phase down in the lead content of gasoline.

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