



Quantification of Lead Fractions in Contaminated Soil Pedons of Coimbatore Industrial Belts, Tamil Nadu, India

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ABSTRACT

The risk to the environment from contaminated soil can not be assessed by simply considering the total amount of potentially toxic metals within the soil because these metals are not necessarily completely mobile or bio-available. Hence, it is necessary to reduce the fraction of toxic elements that is potentially mobile or bio-available. Total lead varied from traces to 250.0 ppm. The amounts of other lead fractions were 0-1.31, 0-4.81, 0-85.81, 0-89.31, 0-63.52 and 0-50.81 ppm for water soluble, exchangeable and adsorbed, organically bound, carbonate bound, Fe-Mn oxide and residual fraction respectively. Bio-available form of lead is very dangerous and mostly seen in roadside profiles of Ganapathy and Ukkadam areas.

INTRODUCTION

Soil contamination can have dire consequences, such as loss of ecosystem and agricultural productivity, diminished food chain quality, tainted water resources, economic loss and human and animal illness. In extensive areas of eastern and central Europe, people suffer from illness associated with elevated levels of lead in the air. Soluble contaminants are subjected to migration with soil water, uptake by plants or aquatic organisms or loss due to volatilization into the atmosphere. Metals in soils may be associated with various phases that are reactive, semi-reactive or non-reactive. The risk to the environment from contaminated soil can not be assessed by simply considering the total amount of potentially toxic metals within the soil because these metals are not necessarily completely mobile or Bio-available. Hence, it is necessary to reduce the fraction of toxic elements that is potentially mobile or Bio-available. Environmental mobility is the capacity for toxic elements to move from contaminated materials to any compartment of the soil or ground water. Hence, the movement of contaminants through the soil profile is a legitimate concern of the society.

The concentration of Pb in soil ranges from traces to 250 ppm in Coimbatore district due to pesticides, mining industries and automobiles. In the vehicles using leaded gasoline, some lead in its way to the atmosphere is deposited in the engine and when washed it goes to the drainage water. All these ultimately increase the lead status of the soil which is harmful to man as well as animals.

MATERIALS AND METHODS

The profile study was carried out at Ganapathy, Peelamedu, Kurichi and Ukkadam industrial areas to see the mobile lead fractions at different horizons of soil profile in both contaminated and uncontaminated sites. The soil series seen in those places were Somayanur, Peelamedu and Pallathurai respectively. The general properties of various horizons of contaminated and uncontaminated profiles are given in Table 1. These profiles were dug out nearby road sides electroplating industries, as well as sewage water irrigated fields. Soil samples of various soil series of both contaminated and uncontaminated sites of Coimbatore district were collected from different depths and processed according to the need of analytical procedures. Total lead of the soil was determined by nitric and perchloric acid digestion method (Jackson 1974). The sequential extraction used in this study is as summarized by (McLaren & Clucas Lymne 2000).

Water soluble lead: Two gram of soil sample was shaken with 50 mL of distilled water for two hours, centrifuged at 800 rpm for 10 minutes, filtered through Whatman No. 42 filter paper and the supernatant was analysed for water soluble fractions. The procedure was repeated for two times.

Exchangeable and adsorbed lead: To the sample residue 50 mL of 0.5 M KNO_3 was added, shaken for 16 hours, centrifuged at 800 rpm for 10 minutes and filtered through Whatman No. 42 filter paper.

Organically bound lead: To the sample residue 50 mL of

0.5 M NaOH was added, shaken for 16 hours, centrifuged at 800 rpm for 10 minutes and filtered through Whatman No. 42 filter paper .

Carbonate bound lead: To the sample residue, 50 mL of 0.05 M Na₂EDTA was added, shaken for 16 hours, centrifuged at 800 rpm for 10 minutes and filtered through Whatman No. 42 filter paper .

Fe-Mn oxide lead: To the sample residue, 0.04 M NH₂OH.HCl in 25% acetic acid was shaken for 16 hours,

centrifuged at 800 rpm for 10 minutes and filtered through Whatman No. 42 filter paper.

Residual fraction: To the sample residue 50 mL of 4.0 M HNO₃ was added and digested at 70-80°C. The digested sample was analysed for residual fraction.

RESULTS AND DISCUSSION

The metal contaminated profiles are characterized by high pH, EC, organic carbon and CaCO₃ content. This might be

Table 1: General soil properties of different horizons of contaminated profiles.

Depth (cm)	Horizon	pH	EC	Organic C(g/kg)	CaCO ₃ (g/kg)	Texture	CEC (C mol/kg)	Clay (%)
1. Ganapathy-C								
0-33	Ap	8.15	0.27	1.13	3.1	scl	25.5	34.3
33-59	B1	8.50	0.21	1.00	3.7	scl	28.2	31.8
59-94	B ₂ 1	8.64	0.97	0.38	5.9	sl	29.6	13.8
94-135	B ₂ 2	8.72	1.05	0.17	4.7	cl	29.2	35.7
135-180	B ₂ 3	8.88	0.33	0.06	5.7	scl	25.0	23.7
2. Ganapathy-UC								
0-30	Ap	7.70	0.10	0.52	2.2	scl	21.10	28.9
30-62	B1	7.72	0.12	0.50	2.8	scl	25.0	27.2
62-90	B ₂ 1	7.81	0.12	0.45	3.0	sl	25.0	8.9
90-132	B ₂ 2	8.00	0.13	0.42	4.3	cl	20.0	18.5
132-170	B ₂ 3	8.05	0.13	0.32	4.7	scl	20.0	10.5
3. Peelamedu-C								
0-12	Ap	8.43	0.48	2.75	10.5	sc	53.2	35.9
12-27	B1	8.97	0.69	2.56	10.7	sc	55.2	29.8
27-43	B ₂ ss	9.09	0.89	2.44	10.7	sc	50.2	25.9
43-58	C	8.24	0.91	2.31	10.2	sc	49.2	21.2
4. Peelamedu-UC								
0-12	Ap	7.74	0.29	0.41	5.7	Sc	43.2	23.2
14-27	B1	8.24	0.13	0.35	5.3	Sc	44.1	22.9
27-45	B ₂ ss	8.45	0.17	0.30	4.5	sc	40.0	21.4
45-58	C	7.91	0.12	0.10	4.1	sc	27.3	18.3
5. Kurichi-C								
0.20	Ap	8.08	0.32	2.95	7.3	scl	35.5	23.4
20-50	B ₂	8.13	1.12	2.08	2.6	scl	37.2	19.9
50-63	B ₂ 1	8.28	1.55	2.05	3.5	scl	37.0	10.8
63-85	C	8.74	1.47	1.95	4.5	scl	33.0	8.8
6. Kurichi-UC								
0.20	Ap	7.51	0.20	0.32	1.46	scl	32.9	13.1
20-48	B ₂	7.88	0.20	1.12	1.60	scl	33.4	9.8
48-69	B ₂ 1	8.01	0.18	1.55	2.0	gscl	33.2	9.7
69-86	C	8.05	0.18	1.47	2.5	vgsc1	28.0	6.2
7. Ukkadam-C								
0-20	Ap	8.84	1.84	4.37	10.5	Sc	53.2	25.9
20-54	B ₁	8.87	1.64	4.30	10.7	Sc	55.5	28.4
54-79	B ₂ ss ₁	8.89	1.71	3.52	10.7	Sc	56.0	30.3
79-115	B ₂ ss ₂	8.39	2.08	3.10	10.8	Sc	50.0	13.5
115-142	B ₃	7.98	1.10	2.91	10.8	sc	45.0	10.2
8. Ukkadam-UC								
0-20	Ap	7.31	0.48	0.40	8.3	sc	42.5	8.8
20-54	B ₁	7.52	0.69	0.35	8.3	sc	45.2	8.1
54-80	B ₂ ss ₁	8.11	0.89	0.30	8.4	sc	45.6	8.3
80-116	B ₂ ss ₂	8.22	1.28	0.23	8.7	sc	42.0	7.5
116-150	B ₃	8.20	1.20	0.20	9.0	gsc	40.0	7.3

due to the increase in soluble salt concentration in the effluent, the richness of organic materials in the sludge, and also the translocation of organic acids produced during the degradation of organic matter in the tilled layer leads to increase in pH from upper horizon to lower in contaminated soil profiles, when compared to uncontaminated profiles. Though texture plays a major role in metal retention, there is not as much as textural variation noticed between contaminated and uncontaminated soil profiles. Even then, a few changes like changing of gravelly sandy clay loam into sandy clay loam have been noticed in contaminated soil profiles. The CEC and clay content for all the horizons of contaminated profiles were high which again depends upon the textural make up of the soil.

The total Pb content ranges from 123-250 ppm in contaminated soil profile and between 21-47 mg/kg in uncontaminated soil profiles in Coimbatore district. The total content of lead decreased with increase in depth. The highest concentration of lead occurred on surface, with lesser amounts in deeper layers as reported by Kabala & Szerzen (1999). The high lead in the surface may be due to the fact that lead originating from contamination or from decayed plant materials if immobilized in the top soil due to fixation or due to low mobility from surface to lower depths in the soil.

The distribution of various lead fractions at different horizons of contaminated and reference pedons of Coimbatore district are given in Table 2. The amount of water soluble, exchangeable and adsorbed lead ranges from below detection limit (BLD) to 1.31 mg/kg and BDL to 4.81 mg/kg respectively at various horizons of the contaminated soil profiles. The amount of water soluble, exchangeable and adsorbed lead was comparatively small which also decreased with increased depths. The low solubility and mobility of lead in the soil were main reasons for this. Also, most of the lead in the soil is strongly absorbed in non-exchangeable forms and undergoes solubilization reaction in the soil water system. It may be mentioned that the bulk of the compounds liberated to the environment by automobile exhaust are mainly lead halides (Gajghate & Saxena 1991).

Organic matter bound lead fractions range from BDL-85.81 mg/kg at various horizons of the contaminated soil profile. Organic matter bound lead was low in the soil as compared to carbonate and Fe-Mn oxide fractions in all the profiles except sewage farm which contains higher amount of organic carbon (4.37%), which leads to higher organic matter bound lead fractions (85.81 mg/kg) identified in the top soil. This indicated that there is formation of stable lead organic complexes due to the combination of lead with organic matter and by the strong affinity of lead with humic acid.

Fe-Mn oxide bounded fraction observed in soil indicated

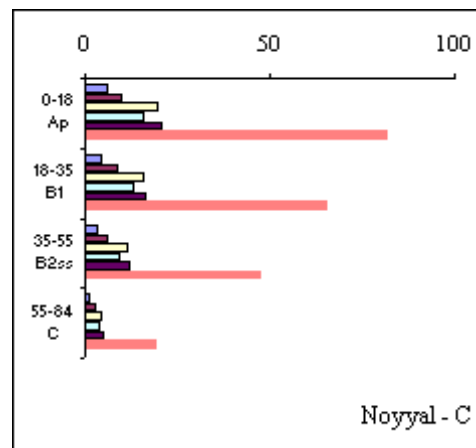


Fig. 1: The trend of lead fractions.

that the lead content decreased with the soil depth. The strong adsorption of lead by oxide minerals present in the soil can increase the amount of lead bound to Fe-Mn oxide in soil as reported by McLaren & Cameron (1990). Lead is occluded mainly in carbonate and oxide phases, with lesser amounts in residual and organic phases.

Carbonate bound lead content decreased with depth in all the profiles. The increase may be attributed to the increasing status of carbonates with increase in the soil depths. In Peelamedu and Kurichi, the increase in CaCO_3 content in B2ss and B21 horizons leads to increase in carbonate bound lead. Carbonate lead may have lesser mobility due to lesser solubility as the P-Ksp (-logarithm of solubility product) value of PbCO_3 is quite low (12.8) as compared to other lead compounds (Santilian 1986).

The experimental soil contained an unusual high amount of $\text{NH}_4\text{-NO}_3$ extractable Pb. The exact chemical nature of this Pb species is unknown. However, NH_4NO_3 -extractable heavy metal species are often supposed to be exchangeable cations, easily soluble organic complexes or salts such as chlorides (Zuiderveen 1994). The mobile forms of Pb were very important in deteriorating groundwater quality as well as food chains.

The lead present in the residual fraction probably resulted due to some sort of lead occlusion in soil silicates, because of solid-state diffusion of this metal into octahedral positions of layer silicates lattices. However, the trend observed with these fractions was similar to those obtained with total lead status (Fig. 1).

CONCLUSION

Total lead and its various fractions were estimated in contaminated and uncontaminated soil pedons of Coimbatore district. Total lead varied from traces to 250 ppm. The

Table 2: Distribution of various lead fractions at different horizons of contaminated and reference pedons of Coimbatore district (mg/kg).

Profile / Horizon	Horizon Name	Total Pb	DTPA-Pb	Water Soluble Pb	Exc+Ads. Pb	Org. bound Pb	Carbonate bound Pb	Fe-Mn oxide bound Pb	Residual fraction Pb
1. Peelamedu-C									
0-12	Ap	123.00	4.32	4.67	7.61	15.99	13.04	16.73	66.42
12-27	B1	109.00	1.91	4.14	7.63	14.17	11.55	14.82	58.86
27-43	B ₂ ss	85.00	ND	3.23	5.95	11.05	9.01	11.56	45.90
43-58	C	43.00	ND	1.63	3.01	5.59	4.56	5.85	23.22
2. Peelamedu-Ref									
0-12	Ap	37.00	0.20	1.41	2.19	4.81	3.92	5.03	19.98
14-27	B1	28.00	ND	1.06	1.96	3.64	2.97	3.81	15.12
27-45	B ₂ ss	3.50	ND	0.13	0.25	0.46	0.37	0.48	1.89
45-58	C	ND	ND	0.11	ND	ND	ND	ND	ND
3. Noyal-C									
0-18	Ap	151.00	6.58	5.74	9.57	19.63	16.00	20.54	81.54
18-35	B1	121.00	2.31	4.60	8.47	15.73	12.83	16.46	65.34
35-55	B ₂ ss	88.00	0.11	3.34	6.16	11.44	9.33	11.97	47.52
55-84	C	35.00	ND	1.33	2.45	4.55	3.71	4.76	18.90
4. Noyal-Ref									
0-18	Ap	35.00	0.91	1.33	2.45	4.55	3.71	4.76	18.90
18-35	B1	8.50	0.05	0.32	0.60	1.11	0.90	1.16	4.59
35-55	B ₂ ss	3.20	ND	0.12	0.22	0.42	0.34	0.44	1.73
55-84	C	ND	ND	ND	ND	ND	ND	ND	ND
5. Palladam-C									
0-13	Ap	110.00	3.18	4.18	7.70	14.30	11.66	14.96	59.4
13-32	B1	68.00	0.93	2.58	4.76	8.84	7.21	9.25	36.72
32-46	C	21.00	ND	0.79	1.47	2.73	2.23	2.86	11.34
6. Palladam-Ref									
0-13	Ap	30.00	0.75	0.49	0.91	4.39	2.88	4.77	17.02
13-32	B1	2.31	0.03	0.09	0.16	0.30	0.25	0.31	ND
32-46	C	ND	ND	ND	ND	ND	ND	ND	ND
7. Pallathurai-C									
0-20	Ap	250.00	13.80	9.50	15.50	32.50	26.50	34.00	135.00
20-50	B ₂	171.00	8.30	6.50	11.97	22.23	18.13	23.26	92.34
50-63	B ₂ l	75.00	3.50	2.85	5.25	9.75	7.95	10.20	40.50
63-85	C	56.00	1.80	2.13	3.92	7.28	5.94	7.62	30.24
8. Palathurai-Ref									
0-20	Ap	47.00	2.82	1.79	3.29	6.11	4.98	6.39	25.38
20-48	B ₂	11.00	1.37	0.42	0.77	1.43	1.16	1.49	5.94
48-69	B ₂ l	8.00	0.81	0.30	0.56	1.04	ND	1.09	4.32
69-86	C	2.00	ND	0.08	0.14	0.26	ND	ND	ND
9. Irugur-C									
0-15	Ap	91.00	4.85	3.46	6.37	11.83	9.65	12.38	49.14
15-26	B1	45.45	2.37	1.73	3.18	5.91	4.82	6.18	24.54
26-43	B ₂ ss	20.00	0.95	0.76	1.40	2.60	2.12	2.72	10.80
43-58	C	15.00	ND	0.57	1.05	1.95	1.59	2.04	8.10
10. Irugur-Ref									
0-15	Ap	13.00	0.98	0.49	0.71	1.69	1.38	1.77	7.02
15-26	B1	9.50	ND	0.36	0.67	1.24	1.01	1.29	51.30
26-43	B ₂ ss	2.30	0.20	0.09	0.16	0.29	0.24	0.31	1.24
43-58	C	ND	ND	ND	ND	ND	ND	ND	ND
11. Peelamedu-C (Ukkadam)									
0-20	Ap	198.00	23.80	7.52	13.86	25.74	20.99	26.93	106.92
20-54	B ₁	76.00	6.51	2.88	5.32	9.88	8.06	10.34	41.04
54-79	B ₂ ss ₁	71.00	3.75	2.70	4.97	9.23	7.53	9.66	38.34
79-115	B ₂ ss ₂	64.00	ND	2.43	4.48	8.32	6.78	8.70	34.56
115-142	B ₃	51.00	1.31	1.94	3.57	6.63	5.41	6.94	27.54
12. Peelamedu-Ref (Ukkadam)									
0-20	Ap	35.00	1.30	1.33	2.45	4.55	3.71	4.76	18.90

Table cont....

Cont table...

20-54	B ₁	27.00	0.80	1.03	1.89	3.51	2.86	3.67	14.58
54-80	B _{ss1}	4.50	ND	0.17	0.32	0.59	0.48	0.61	2.43
80-116	B _{ss2}	0.03	0.07	ND	ND	ND	ND	ND	ND
116-150	B ₃	ND	ND	ND	ND	ND	ND	ND	ND
13. Somayanur-C									
0-33	Ap	161.00	17.31	6.12	11.27	20.93	17.06	21.89	86.94
33-59	B1	80.00	9.80	3.04	5.60	10.14	8.48	10.88	43.20
59-94	B ₂ 1	79.00	3.50	3.00	5.53	10.27	8.37	10.74	42.66
94-135	B ₂ 2	60.00	ND	2.28	4.20	7.80	6.36	8.16	32.40
135-180	B ₂ 3	22.00	1.70	0.84	1.54	2.86	2.33	2.99	11.88
14. Somayanur-Ref									
0-30	Ap	21.00	2.81	0.79	1.47	2.73	2.23	2.86	11.34
30-62	B1	11.00	1.70	0.42	0.77	1.43	1.17	1.50	5.94
62-90	B ₂ 1	10.00	0.91	0.38	0.70	1.30	1.06	13.60	5.40
90-132	B ₂ 2	8.00	0.45	0.30	0.56	1.04	0.85	1.09	4.32
132-170	B ₂ 3	ND	ND	ND	ND	ND	ND	ND	ND

amounts of other lead fractions were 0-1.31, 0-4.81, 0-85.81, 0-89.31, 0-63.52, 0-50.81 ppm for water soluble, exchangeable and adsorbed, organically bound, carbonate bound, Fe-Mn oxide and residual fraction respectively. Lead is occluded mainly in carbonate and oxide phases, with lesser amounts in residual and organic phases. Mobile form of lead is dangerous as mostly seen in road side profiles of Ganapathy and Ukkadam. Hence, there is a possibility of groundwater pollution and food chain contamination of Pb in these areas.

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