

Distribution of Different Fractions of Lead at Various Horizons of Contaminated Soil Pedons of Coimbatore District, Tamilnadu

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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 bioavailable. Hence, it is necessary to reduce the fraction of toxic elements which is potentially mobile or bioavailable. Total lead varied from traces to 250 mg/L. The amounts of other lead fractions were 1.31, 4.81, 85.81, 89.31, 63.52 and 50.81 mg/L for water soluble, exchangeable and adsorbed, organically bound, carbonate bound, Fe-Mn oxide, and residual fractions respectively. Mobile form of lead was very dangerous and mostly seen in roadside profiles of Ganapathy and Ukkadam.

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 bioavailable. Hence, it is necessary to reduce the fraction of toxic elements that is potentially mobile or bioavailable. Environmental mobility is the capacity for toxic elements to move from contaminated materials to any compartment of the soil or groundwater. Hence, the movement of contaminants through the soil profile is of great concern to the society.

The concentration of lead in soil ranges from traces to 250 mg/L in Coimbatore district due to pesticides, mining industries and automobiles. The present study has been made to find different fractions of lead in contaminated soils of Coimbatore district, Tamilnadu. All these ultimately increase the lead status of the soil which is harmful to man, animals and other biota.

MATERIALS AND METHODS

The profile study was carried out at Ganapathy, Peelamedu, Kurichi and Ukkadam 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 experimental profiles were dug out nearby road sides near electroplating industries, as well as sewage water irrigated fields. Soil samples of various soil series of both contaminated and uncontaminated sites of Coimbatore districts 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 1973). The sequential extraction used in this study is summarized by (Krishnamoorthy et al. 1995).

Water soluble fractions: Two grammes 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 analysed for water soluble fractions.

Exchangeable and adsorbed fraction: 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, filtered through Whatman No. 42 filter paper and analysed.

Organically bound fraction: To the sample residue 50 mL of 0.5 M NaOH was added, shaken for 16 hours, centrifuged at 800 rpm for 10 minutes, filtered through Whatman No. 42 filter paper.

Carbonate bound fraction: To the sample residue, 50 mL of 0.05 M Na_2EDTA is added, shaken for 16 hours, centrifuged at 800 rpm for 10 minutes, filtered through Whatman No. 42 filter paper and analysed.

Fe-Mn oxide fraction: To the sample residue, 0.04 M $\text{NH}_2\text{OH.HCl}$ in 25% acetic acid was added, shaken for 16 hours, centrifuged at 800 rpm for 10 minutes, filtered through Whatman No. 42 filter paper and analysed.

Residual fraction: To the sample residue, 50 mL of 4.0 M HNO_3 was added and digested at 70-80°C. The digested sample was analysed for residual fraction of lead.

RESULTS AND DISCUSSION

The metal contaminated profiles are characterized by high pH, EC, organic carbon and CaCO_3 contents. This might be due to increase in soluble salts concentration in effluents, the richness of organic materials in sludges, and also the translocation of organic acids produced during the degradation of organic matter in the tilled layer leading to increase in pH from upper horizon to lower in contaminated soil profiles. Though texture plays a major role in metal retention, there are not as much as textural variations as noticed between contaminated and uncontaminated soil profile. 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 (Table 1).

The total Pb content ranges from 123 to 250 mg/L in contaminated soil pedons whereas it is between 21 and 47 mg/L in reference soil pedons. The total content of lead decreased with increase in depth. The highest concentration of lead occurred on surface, with lesser amounts in deeper layers. These observations were supported by Garcia (1984). The high lead in the surface may be due to the fact that lead originating from contamination or from decayed plant materials is immobilized in the top soil due to fixation or due to low mobility from surface to lower depths in the soil.

The amount of water soluble, and exchangeable and adsorbed lead ranges from below detection limit (BDL) to 1.31 and 4.81 mg/L respectively at various horizons of contaminated soil pedons. The amount of water soluble, exchangeable and adsorbed lead was comparatively small which decreased with increased depths. This has also been reported by Garcia (1984) and Xian (1989). They reported

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

Depth (cm)	Horizon	pH	EC	Organic C (g/kg)	CaCO ₃ (g/kg)	Texture	CEC (C mol/kg)	Clay (%)
1. Ganapathy-C (Somayanur soil series)								
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
Ganapathy-ref								
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
2. Peelamedu-C (Pilamedu soil series)								
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
Peelamedu-Ref								
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
3. Kurichi-C (Palathurai soil series)								
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	7.2	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
Kurichi-Ref								
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	vgscl	28.0	6.2
4. Ukkadam-C (Pilamedu soil series)								
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	Bss ₁	8.89	1.71	3.52	10.7	Sc	56.0	30.3
79-115	Bss 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
Ukkadam-Ref								
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	Bss ₁	8.11	0.89	0.30	8.4	sc	45.6	8.3
80-116	Bss 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

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

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
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
2. 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
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
3. 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
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
4. 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 1	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
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 1	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
5. 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
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

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6. 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 _{ss1}	71.00	3.75	2.70	4.97	9.23	7.53	9.66	38.34
79-115	B _{ss2}	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
Peelamedu-Ref (Ukkadam)									
0-20	Ap	35.00	1.30	1.33	2.45	4.55	3.71	4.76	18.90
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
7. Somayanur-C									
0-33	Ap	161.00	17.31	6.12	11.27	20.93	17.06	21.89	86.94
33-59	B ₁	80.00	9.80	3.04	5.60	10.14	8.48	10.88	43.20
59-94	B ₂₁	79.00	3.50	3.00	5.53	10.27	8.37	10.74	42.66
94-135	B ₂₂	60.00	ND	2.28	4.20	7.80	6.36	8.16	32.40
135-180	B ₂₃	22.00	1.70	0.84	1.54	2.86	2.33	2.99	11.88
Somayanur-Ref									
0-30	Ap	21.00	2.81	0.79	1.47	2.73	2.23	2.86	11.34
30-62	B ₁	11.00	1.70	0.42	0.77	1.43	1.17	1.50	5.94
62-90	B ₂₁	10.00	0.91	0.38	0.70	1.30	1.06	13.60	5.40
90-132	B ₂₂	8.00	0.45	0.30	0.56	1.04	0.85	1.09	4.32
132-170	B ₂₃	ND	ND	ND	ND	ND	ND	ND	ND

that low solubility and mobility of lead in the soil were the reasons for this. Also, most of the lead in the soil is strongly absorbed in nonexchangeable forms and undergoes in 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 & Saxeena 1991).

Organic matter bound lead fractions range from BDL to 85.81 mg/L at various horizons of the contaminated soil pedons. 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%). This leads to higher organic matter bound lead fractions (85.81 mg/L) as identified in the top soil which decreases with depth. This indicated the formation of stable lead organic complexes due to combination of lead with organic matter. Similar strong affinity of lead with humic acids has also been reported by Tsadilas (1999).

Fe-Mn oxide bounded fraction of lead observed in soil indicated that the content decreased with the 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 (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 pedons. The increase may be attributed to the increasing status of carbonates with increase in the soil depths. In Peelamedu and Kurichi, the increase in CaCO₃ content in B_{2ss} and B₂₁ horizons respectively 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 PbCO₃ is quite low (12.8 mg/L) as compared to other lead compounds (Santilian & Jusinals 1975).

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 that obtained with total lead status.

It can be concluded that lead is occluded mainly in carbonate and oxide phases with lesser amounts in residual and organic phases. Mobile forms (water soluble and exchangeable + adsorbed) of lead are very dangerous as there is a possibility of groundwater pollution and food chain accumulation of lead in the contaminated areas.

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