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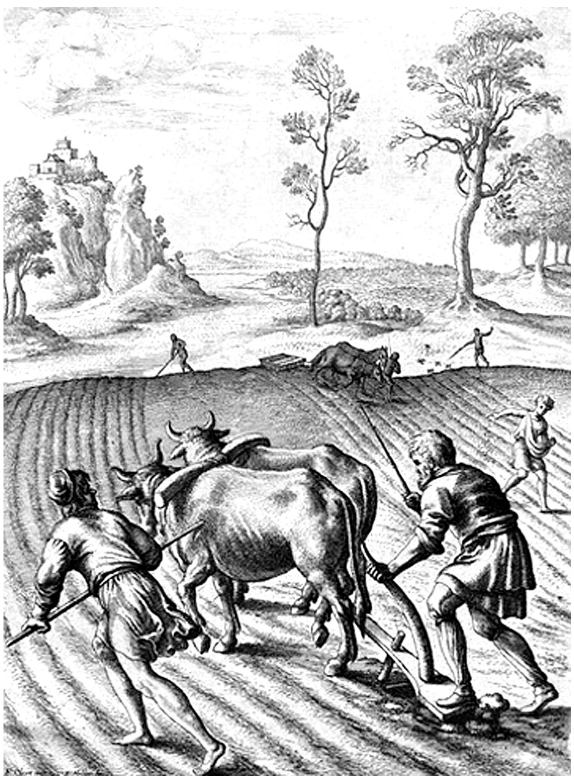

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Characterization of Heavy Metal Contaminated Soils of Coimbatore District in Tamil Nadu

M. Malarkodi, R. Krishnasamy, R. Kumaraperumal and T. Chitdeshwari
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India

Abstract: A detailed survey work was carried out in the contaminated areas of Coimbatore district to assess the level of heavy metals contamination in soils irrigated with sewage water and industrial effluents. The study showed that the soil irrigated with the sewage water contained almost all the heavy metals (Pb, Ni, Cd, Cr, Cu and Zn) exceeded the critical limit. The soils contaminated with electroplating and textile effluents were rich in Ni and Cr concentration. The results obtained from the physico chemical analysis indicated that the sewage and electroplating effluents contaminated soils recorded acidic pH. However, the soils contaminated by textile and dye effluents recorded alkaline soil pH. The electrical conductivity values of soils collected from Orathuppalayam village were > 9 dS m^{-1}. This study indicated that the major contaminants of soil in Coimbatore district are sewage water, dye and electroplating effluents.

Key words: Electroplating industry, heavy metals, industrial effluents, relative availability, sewage water

INTRODUCTION

Enormous amount of organic and inorganic wastes generated from various industries has been indiscriminately disposed before the enactment of stringent regulations in India. Compared to the organic wastes, inorganic wastes containing heavy metals pose a great threat, as they cannot be completely removed/degraded from the ecosystem like organic wastes. Hence, toxic metal contamination of soil, aqueous waste and ground water poses a major environmental and human health problem, which is still in need of an effective and affordable technological solution.

In Tamil Nadu there are so many metal-based industries located in various districts like Vellore, Erode, Dindugal and Coimbatore in an unorganized manner. Among them, Coimbatore is the second largest industrial centre in Tamil Nadu. The major industries include textile, dyeing, electroplating, motor and pumpset, foundry and metal casting industries. According to the present situation, about 500 textiles, 200 electroplating industries, 300 dyeing units and 100 foundries are present in Coimbatore district. Apart from these industries, unorganized sets of sewers numbering 21,000 (Somasundaram, 2001) are running through various zones and finally discharging into the sewage farm located in Ukkadam, which has been used for irrigating the nearby fields. To adopt any type of remedial measures, it is necessary to determine the heavy metal load in the contaminated soil. Hence, it is necessary to identify the actual source for soils contamination. Hence, this study was taken up to assess the metal contamination of soils in the Coimbatore district of Tamil Nadu.

MATERIALS AND METHODS

The study was conducted in the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu (India) during 2002. A detailed survey work has been performed by collecting soil samples in the industrial areas (Table 1) of Coimbatore district to assess the heavy metal status. About 500 soil samples were collected, processed and analyzed for their physico chemical properties viz., pH, EC, organic carbon content by using standard procedures outlined by Jackson (1973) and Walkley and Black (1934), respectively. The samples were digested with diacid mixture (HNO_3: $HClO_4$ in 2:1 ratio; Hesse, 1994) and the extract was used for analyzing total metal status using Atomic Absorption Spectrophotometer, Model SpectrAA, 200. Heavy metal concentration was estimated using the DTPA extractant by adopting the procedure outlined by Lindsay and Norvell (1978). The relative availability of heavy metals in soils was calculated by:

Corresponding Author: M. Malarkodi, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India

Table 1: Details of sampling locations and sources of contamination

S. No.	Location	Source of contamination	Soil series	No. of soil samples collected
L_1	Ukkadam	Sewage water	Pilamedu	35
L_2	Selvapuram	Sewage water	Pilamedu	10
L_3	Therappalayam	Sewage water		5
L_4	Velandipalayam	Sewage water		5
L_5	Pollachi	Sewage water		10
L_6	Ponnaiyarajapuram	Dyeing effluent		20
L_7	Thelungupalayam	Dyeing effluent	Pilamedu	15
L_8	SITCO	Sewage water, EPE, Foundry, casting etc.	Palathurai	25
L_9	Vellalore	Sewage water	Pilamedu and Palathurai	5
L_{10}	Nanjundapuram	Sewage water	Pilamedu	30
L_{11}	Ramanathapuram	Sewage water, EPE	Pilamedu	25
L_{12}	Avarampalayam	Sewage water, EPE		30
L_{13}	Periyanaikanpalayam	EPE	Periyanaikan	15
L_{14}	Pilamedu	Foundry	Pilamedu	20
L_{15}	Sanganoor	Sewage water	Palathurai & Noyyal	10
L_{16}	Ganapathy	EPE	Pilamedu & Palathurai	25
L_{17}	Maniyakarampalayam	EPE, foundry		15
L_{18}	Vellakinaru	Sewage water	Palathurai	5
L_{19}	Kurudampalayam	Sewage water	Somayanur	10
L_{20}	Thudiyalur	Textile effluent	Palathurai	5
L_{21}	Karamadai	Textile effluent	Irugur	20
L_{22}	Thenthirupathi	Textile effluent	Irugur	15
L_{23}	Sirumugai	Viscose, textile effluent	Irugur	20
L_{24}	Mettupalayam	Textile effluent	Irugur	10
L_{25}	Jadayampalayam	Textile effluent		10
L_{26}	Singanallur	EPE, sewage water	Palathurai	5
L_{27}	Therkupalayam	Textile effluent		5
L_{28}	Madukkarai	Textile effluent	Palathurai	15
L_{29}	Udayarpalayam	Textile effluent		15
L_{30}	Sundarapuram	Sewage water		20
L_{31}	Goundampalayam	EPE	Palathurai and Noyyal	30
L_{32}	Vadamadurai	Sewage water, EPE		10
L_{33}	Rathinapuri	Sewage water, EPE		10
		Total		505

EPE-Electroplating effluent

$$\text{Relative availability} = \frac{\text{DTPA extractable metal content in soil (mg kg}^{-1}\text{)}}{\text{Total metal content in soil (mg kg}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

Characterization of heavy metal contaminated soils

Physiochemical properties: The soil samples were analyzed for various physico chemical properties and the data were furnished in Table 2. The soils contaminated by the sewage water and electroplating effluent showed acidic soil reaction (6.33 and 6.78 in Ukkadam and Ganapathy areas, respectively) than other soils. Generally, during stripping process (removing of rust and scales), nitric, sulphuric and hydrochloric acids are used in electroplating industry, which results in more free acids in the electroplating effluents which renders the effluent with a pH below 2.5 (Manivasakam, 1987). This might be the reason for acidic pH of soils contaminated by this effluent. On the other hand, alkaline soil reaction was noticed in soils contaminated by textile and dyeing effluents and the values ranged from 8.18 to 8.96 and 8.27 to 9.30, respectively. The highest pH values were noticed in Karamadai (8.96), Thenthirupathi (8.96), Ponnaiyarajapuram (9.24) and Thelungupalayam (9.30) areas nearer to textile and dyeing industries. This might be attributed to the addition of alkaline earth metals like Ca, Mg and alkali metals like Na, which are present in the effluent water in higher proportion. Similar results of increased soil pH due to textile effluent irrigation have been reported by Srinivaschari *et al*. (2000). No drastic change in areas contaminated by foundry wastes and mixture of industrial effluents was noticed.

Most of the soils were having electrical conductivity values more than two, especially in the soils contaminated with sewage water (3.28±1.283), textile effluent (6.75±0.844), dyeing effluents (7.28±1.382) and sewage water plus electroplating effluents (3.86±1.341), which might be due to higher salt content of the effluents (Manivasakam, 1987). The soil collected from Orathuppalayam village had higher soluble salt content (9.15 dS m^{-1}) than other areas. The salt-rich dye effluents and sludge disposal on the sampling sites are the possible reasons for highest soluble salt content in soils.

Table 2: Physicochemical properties of the contaminated soils

Source of contamination	pH Range	pH Mean	EC (dS m^{-1}) Range	EC (dS m^{-1}) Mean	Organic carbon (g kg^{-1}) Range	Organic carbon (g kg^{-1}) Mean
Sewage water	6.33-7.20	6.68±0.277	1.38-5.20	3.28±1.283	0.084-0.320	0.229±0.877
Electroplating effluent	6.78-8.50	7.39±0.506	0.48-0.60	0.52±0.033	0.056-0.085	0.064±0.076
Sewage water + Electroplating effluent	6.03-7.50	6.80±0.415	1.38-5.15	3.86±1.341	0.141-0.176	0.147±0.103
Textile effluent	8.18-8.96	8.32±0.098	5.64-8.20	6.75±0.844	0.075-0.098	0.079±0.037
Dyeing effluent	8.27-9.30	8.99±0.325	5.42-9.15	7.28±1.382	0.032-0.075	0.047±0.143
Foundry wastes	8.18-8.45	8.27±0.079	0.44-2.87	1.18±0.818	0.032-0.049	0.039±0.071
Mixture of effluents	8.00-8.32	8.14±0.112	0.24-3.27	1.74±3.270	0.049-0.096	0.056±0.074

Table 3: Total heavy metal content of contaminated soils

	Total Heavy metals (mg kg^{-1})											
	Ni		Pb		Cd		Cr		Cu		Zn	
Source of contamination	R	M	R	M	R	M	R	M	R	M	R	M
Sewage water	120.3-230.6	171.4±32.92	130.0-310.0	175.5±47.46	1.7-12.8	8.07±3.402	75.0-150.8	114.9±25.62	88.5-235.6	157.1±45.91	220.0-678.0	397.4±155.3
Electroplating effluent	115.0-268.6	192.5±50.96	46.0-150.0	93.42±39.86	1.1-6.6	2.68±1.63	48.5-160.0	105.6±39.64	82.5-242.6	143.1±54.04	35.6-105.5	120.88±18.72
Sewage water + Electroplating effluent	85.8-188.9	126.9±35.49	141.0-326.4	166.3±59.53	1.2-12.8	5.528±4.4031	137.0-587.3	371.3±190.15	39.11-185.0	114.6±56.64	76.6-275.0	123.7±63.33
Textile effluent	51.5-116.4	86.84±19.42	68.0-160.0	94.95±26.86	0.2-5.8	3.039±1.688	55.4-180.5	136.9±47.24	44.5-108.6	57.94±17.97	75.5-268.7	157.7±64.38
Dyeing effluent	58.4-150.8	112.7±35.98	56.0-136.0	84.18±28.03	0.2-5.6	2.445±1.757	28.4-72.4	51.28±16.85	20.6-83.75	48.98±24.59	40.75-188.7	86.32±36.86
Foundry	81.8-110.4	87.68±7.619	105.0-176.0	126.9±24.26	0.2-6.4	3.681±2.276	47.0-70.8	60.18±7.445	14.65-70.8	37.62±19.25	46.6-105.5	95.39±28.34
Mixture of effluents	62.8-205.8	128.4±41.62	46.0-160.0	127.4±49.99	1.3-8.6	5.159±2.547	33.8-147.4	106.42±36.67	45.45-175.6	129.7±46.26	38.60-115.4	95.03±24.76

R- Range; M- Mean ± standard deviation

Table 4: DTPA extractable heavy metal content of contaminated soils

	DTPA Heavy metals (mg kg^{-1})											
	Ni		Pb		Cd		Cr		Cu		Zn	
Source of contamination	R	M	R	M	R	M	R	M	R	M	R	M
Sewage water	0.89-16.76	12.89±3.125	1.72-16.11	10.11±3.986	0.862-2.316	1.623±0.422	0.253-4.12	2.856±0.851	1.075-3.75	2.724±0.886	1.65-15.575	6.478±3.984
Electroplating effluent	0.98-12.86	6.345±3.348	0.89-3.16	2.672±0.633	0.046-0.562	0.325±0.181	1.165-6.282	4.206±1.399	1.312-5.166	3.528±1.183	0.126-0.860	0.532±0.249
Sewage water+ Electroplating effluent	0.71-6.89	4.233±2.016	1.31-12.76	7.419±3.684	0.212-0.646	0.451±0.151	0.212-4.268	2.617±4.547	0.75-3.15	2.543±0.783	0.723-4.625	3.168±1.398
Textile effluent	0.29-1.16	0.825±0.229	2.53-1.239	2.534±1.239	0.060-0.312	0.166±0.066	2.48-5.123	3.62±0.923	0.232-0.986	0.501±0.237	1.628-5.080	3.312±1.203
Dyeing effluent	0.64-3.73	2.486±1.238	2.27-1.45	2.273±1.448	0.003-0.124	0.045±0.045	0.121-0.638	0.375±0.159	0.235-0.975	0.645±0.278	0.435-0.934	0.722±0.189
Foundry	0.73-0.89	0.805±0.064	1.22-0.26	1.219±0259	0.006-0.037	0.016±0.009	0.126-0.413	0.257±0.110	0.142-0.708	0.428±0.219	0.123-0.656	0.570±0.202
Mixture of effluents	1.76-5.90	3.558±1.421	4.19-1.77	4.192±1.767	0.102-0.426	0.193±0.097	0.165-4.524	1.343±1.365	1.213-1.595	3.553±1.595	0.135-2.060	1.330±0.639

R- Range; M- Mean±standard deviation

Generally, the organic carbon content of the soil was higher (>1%) in areas receiving sewage water for irrigation at Ukkadam, Nanjundapuram, Ramanathapuram and Avarampalayam, which could be mainly due to the addition of high soluble organic matter through sewage material (Somasundaram, 2001).

Total and DTPA extractable heavy metals content: The total and DTPA extractable heavy metal content (Cu, Zn, Mn, Fe, Ni, Pb, Cd and Cr) in the soils of different sites collected from different industrial zones are presented in Table 3 and 4, respectively. The soils irrigated with sewage water had higher concentration of almost all the heavy metals (Ni, Pb, Cr, Cd, Zn and Cu) as compared to other places. Such accumulation was found to be more in Ukkadam and Avarampalayam areas due to continuous irrigation for more than 20 years (Jayabaskaran and Sree Ramulu, 1996). The concentration of DTPA extractable metals was also increased by sewage water irrigation (Ni 12.89±3.125, Pb 10.11±3.986, Cd 1.623±0.422, Cr 2.856±0.851, Cu 2.724±0.886 and Zn 6.478±3.984 mg kg^{-1}) and was significantly correlated with total heavy metals content. The sewage water contains almost all the heavy metals and several studies have shown that application of sewage water markedly increased the heavy metal load in soil (Lavado *et al*., 1999; El-Motaium and Badaway, 1999; Somasundaram, 2001; Jayabaskaran and Sree Ramulu, 1996).

The data clearly showed that the soils around electroplating industries are severely contaminated with heavy metals like Ni (192.5±50.04 mg kg^{-1}), Cr (105.57±39.64 mg kg^{-1}) and Cu (143.08±54.04 mg kg^{-1}). Among the contaminated sites, the highest Ni content was noticed in Ganapathy (265.45 mg kg^{-1}) and Avarampalayam (250.75 mg kg^{-1}) areas. Large quantities of Ni, Cu and Cr are used during Ni, Cu and chrome

Table 5: Mean relative availability of heavy metals in contaminated soils

Source of contamination	Relative availability (%)					
Sewage water	Cd>(20.11)	Ni>(7.52)	Pb>(5.76)	Cr>(2.48)	Cu>(1.73)	Zn>(1.63)
Electroplating effluent	Cd>(12.13)	Cr>(3.98)	Ni>(3.29)	Cu>(2.47)	Fe>(0.89)	Zn>(0.44)
Sewage water + Electroplating effluent	Cd>(8.16)	Pb>(4.46)	Ni>(3.33)	Cu>(2.22)	Mn>(1.37)	Cr>(0.70)
Textile effluent	Cd>(5.46)	Cr>(2.85)	Pb>(2.67)	Ni>(0.95)	Cu>(0.86)	Fe>(0.76)
Dyeing effluent	Pb>(2.70)	Ni>(2.21)	Cd>(1.84)	Fe>(1.17)	Zn>(0.84)	Cr>(0.73)
Foundry	Fe>(1.16)	Cu>(1.14)	Pb>(0.96)	Zn>(0.59)	Cd>(0.43)	Cr>(0.43)
Mixture of effluents	Cd>(3.74)	Pb>(3.29)	Ni>(2.77)	Mn>(1.88)	Zn>(1.39)	Cr>(1.26)

plating processes, respectively (Manivasakam, 1987), which might have caused the excessive metal accumulation. The DTPA extractable Ni content was higher in areas contaminated with electroplating effluents which might be due to the acidic nature of effluents. The values ranged from 0.98 to 12.86 mg kg^{-1}. The soils of Ganapathy, Avarampalayam and Maniyakarampalayam recorded the highest DTPA-Ni contents than the other places.

High concentrations of Cr (126.98±47.24 mg kg^{-1}) and Zn (157.77±64.38 mg kg^{-1}) were noticed in areas contaminated with textile effluents. The values ranged between 55.4 to 180.5 mg kg^{-1}. Among the areas, Sirumugai, Karamadai and Thenthirupathy were severely contaminated with Cr and Zn due to the presence of high number of textile industries in these areas. The soils of Sirumugai, Thenthirupathi and Mettuppalayam recorded the highest DTPA-extractable Cr (4.52, 5.002 and 4.43 mg kg^{-1}, respectively) and Zn (4.987, 4.526 and 4.75 mg kg^{-1}, respectively) contents, where the source of contamination is textile effluents.

The use of dyeing effluent contaminated canal water for irrigation in Orathuppalayam village had shown high contents of heavy metals especially Ni and Cr. The DTPA Ni content in soils collected from the dyeing effluent contaminated sites ranged between 0.64 and 3.73 mg kg^{-1}, which might be due to the metal rich nature of the effluent. The mean Ni content of the dyeing effluent contaminated soil was 112.69±35.98 mg kg^{-1}, which exceeded the critical level of 100 mg kg^{-1}.

The presence of many number of foundries in Peelamedu and Kuruchi areas of Coimbatore district have reflected on the severe iron contamination (546.6 to 30.284 mg kg^{-1}) of these areas. The highest DTPA Fe content was (24.37±9.41 mg kg^{-1}) noticed in areas where foundries are more. This might be due to the inherent iron content of the foundry wastes.

In general, the risk of Ni, Pb, Cr, Zn Cd and Cu toxicity in sewage water irrigated soils at Ukkadam, Nanjundapuram, Avarampalayam, Sanganoor and Vellalore was higher while Ni, Cr and Cu risk was noticed in electroplating effluent affected soils of Ganapathy and Avarampalayam. Chromium and Zn toxicity was noticed in textile effluent contaminated soils of Sirumugai, Karmadai and Thenthirupathy and toxicity levels of Ni and Cr in soils polluted by dyeing effluents and Fe in soils contaminated with foundries might be influencing the soil plant-system over the years.

Relative availability of heavy metals: Relative bioavailability of heavy metals revealed that in all the areas with minor shift in the relative position, Cd, Ni, Cr and Zn were relatively more available elements (Table 5). The Cd, Pb and Ni availability were higher in areas receiving sewage water and electroplating effluents where it was attributed to the acidic soil reaction leading to increase in DTPA extractable metals. Similar results were observed by Williams *et al.* (1980) and Patel *et al.* (2004).

CONCLUSIONS

Many metal based industries like electroplating, foundries, casting, textile and dyeing industries apart from huge amount of sewage water production are the main sources of heavy metals contamination in Coimbatore district of Tamil Nadu. The areas contaminated and the sources of contamination are given below:

Source of contamination	Metals	Areas contaminated
Sewage water	Ni, Pb, Zn, Cd, Cr, Cu etc.	Ukkadam, Sanganoor, Avarampalayam, Nanjundapuram, Ramanathapuram, Vellalore, Selvapuram
Electroplating industry	Ni, Cr and Cu	Ganapathy, Avarampalayam, Goundampalayam, Kurichi
Textile industry	Cr and Zn	Karamadai, Thenthirupathy, Mettuppalayam, Sirumugai, Madukkarai, Jadayampalayam
Dyeing industry	Ni and Cr	Thelungupalayam, Ponnaiyarajapuram, Kurichi

The highest concentrations of heavy metals in these industrially polluted areas are not only problem with respect to plant nutrition and food chain contamination but also causes a direct health hazards to human and animals, which is still in need of an effective and affordable technological solution.

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