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Contamination of the Agricultural Land due to Industrial Activities in Karachi (Sindh)

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ABSTRACT

This study was conducted in Korangi Industrial Area, Karachi (Sindh) for possible contamination of the agricultural land due to industrial activities. The composite soil samples were collected from 0-20 and 20-40 cm soil depth. A total of 80 samples were collected from soils irrigated with industrial effluents, while 8 samples (4 samples from each depth) were taken from soils irrigated with tubewell water considered as `background soil' and analysed for the concentrations of heavy metals (Cd, Cr, Ni and Pb). The mean values of heavy metals in effluent irrigated soils at 0-20 cm and at 20-40 cm soil depth were 0.16 and 0.09, 0.37 and 0.18, 1.24 and 0.89, 2.84 and 2.18 mg kg^{-1} for Cd, Cr, Ni and Pb, respectively. Comparison with background soil, the heavy metals showed significantly higher concentrations due to effluents irrigation. The Cd, Cr and Pb were significantly ($P<0.0001$) higher in surface soils as compared to sub-surface soils.

Key Words: Industrial activity; Agricultural land; Contamination

INTRODUCTION

Industrial revolution brought special attention of the scientists towards global environmental pollution. The effluents discharged from industries have contaminated our soil and water resources and hence degraded not only our natural resources but also our agricultural production. Cheremisonoff *et al.* (1979) estimated that 90% by weight of industrial wastes are produced as liquids and according to U.S. Environmental Protection Agency (1974) 40% of the liquids are inorganic and 60% organic. This liquid may be a valuable water and nutrients resource for crops or a pollutant to land and water (Samuel *et al.*, 1985). The type of pollutant and quality reflects the presence of local industrial disposal into the sewage facilities. Heavy metals enter the soil via beneficial agricultural additives such as lime, fertilizers, manure, herbicides, fungicides and irrigation waters as well as via potentially deleterious material such as sewage sludge, municipal composts, industrial and mine wastes, dredged materials and atmospheric deposits (Berrow, 1986). In the course of its terrestrial cycling, various physico-chemical conditions may significantly change its species and its behaviour in biogeochemical processes (Nriagu, 1984). Industrial wastes carrying heavy metals to the soils are adsorbed and retained by the organic and inorganic soil colloids (Bride, 1986). Plants absorb these metals from the soil in which some are essential for metabolic processes and other enzymatic reactions (Adrian, 1986). The excessive uptake may cause phytotoxicity and consequently human toxicity as envisaged by the processes of bioaccumulation and biomagnifications. So, maximum efforts should be exercised to keep heavy metals especially Cd, Cr, Ni and Pb at the lowest rate in soils and plants. This study was conducted to determine the status of selected heavy metals (Cd, Cr, Ni and Pb) in possibly contaminated soils of the Korangi Industrial Area Karachi (Sindh). The gradual accumulation of these metals during 2000-2001 was also investigated.

MATERIALS AND METHODS

The composite soil samples were collected in polythene bags from two depths (0-20 and 20-40 cm) with the help of stainless steel auger. The criteria for selection of the sampling sites were based on the possible contamination due to irrigation with industrial wastes waters. A total of 88 soil samples were collected from Karachi, including 80 samples (40 samples from each depth) from Korangi Industrial Area soils irrigated with industrial effluents and eight samples (four samples from each depth) from Memon Goth irrigated with tube well water considered as background samples.

The samplings were done both in summer and winter seasons of the years 2000 and 2001. The soil samples brought to the laboratory were air dried, sieved (< 2 mm), extracted with AB-DTPA (Havlin & Sultanpour, 1981) and analysed for heavy metals (Cd, Cr, Ni and Pb) by atomic absorption spectrophotometer (Perkin Elmer, Model No. 2380). The significance of results were tested by t-test ($P<0.05$) as described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

To evaluate the effect of year, season and sampling depth, analysis of variance using 2^3 factorial RCBD was applied on the data for the concentrations of heavy metals (Cd, Cr, Ni and Pb) in soil samples collected from various sites of Karachi during summer and winter seasons of the years 2000 - 2001. Table I provides the summary of the statistical analysis with given level of probability. The analysis of variance (ANOVA) showed significant variations within the given sites of sampling as evident from the level of probability and co-efficient of variations, which ranged from 27.41-52.23%. This observation is understandable as soil samples were collected from diverse locations.

Table I. Analysis of variance of the data showing the effect of year, season and sampling depth on the concentrations of heavy metals at the given level of probability

Sources of variation	Heavy Metals			
	Cd	Cr	Ni	Pb
Year	0.003	>0.15	<0.0001	>0.15
Season	0.074	<0.0001	>0.15	0.025
Depth	<0.0001	<0.0001	>0.15	<0.0001

Table II shows data for the concentrations of Cd, Cr, Ni and Pb in soil samples collected during summer and winter seasons of the years 2000 - 2001. The comparison of the mean values of heavy metals in effluent irrigated soil samples with the concentrations in tube well irrigated soil samples based on t-test is given in Table III.

AB-DTPA extractable heavy metals concentrations of Cadmium (Cd). The concentrations of Cd varied between 0.06-0.19 mg kg^{-1} in surface soils (0-20 cm) and from 0.04-0.14 mg kg^{-1} in subsurface (20-40 cm) with the mean values of 0.11 and 0.09 mg kg^{-1}, respectively in summer 2000 (Table II). During winter 2000, Cd ranged from 0.09 -0.30 in surface and 0.02 - 0.20 mg kg^{-1} in sub-surface soil samples having mean values of 0.19 and 0.08 mg kg^{-1}, respectively.

Similarly, in summer 2001, Cd ranged from 0.12-0.32 with the mean value of 0.21 mg kg^{-1} in surface soils while 0.03 to 0.18 with the mean value of 0.10 mg kg^{-1} in sub-soils. The Cd during winter 2001, varied between 0.08-0.42 and 0.05-0.18 with the average values of 0.21 and 0.10 mg kg^{-1} in surface and subsurface soil samples, respectively. The data showed reverse trend as compared to other elements and the Cd tended to increase in winter as compared to summer which might be due to high input from different industrial activities during winter season. The Cd decreased with increasing soil depth.

The overall mean value of Cd in effluent irrigated soil samples was 0.16 mg kg^{-1} against the background value of 0.07 mg kg^{-1} for 0 - 20 cm soil depth while 0.09 mg kg^{-1} against 0.05 mg kg^{-1} for 20-40 cm soil depth (Table III).

The analysis of variance of the data showed that Cd was significantly higher in surface soils than sub-surface soils (Table I). The t-test comparison showed that Cd in effluent irrigated soil samples is significantly ($P<0.05$) higher than that in tube well irrigated soil samples (Table III). The accumulation of Cd in soil increased during the year 2001 as compared to the values observed in 2000.This increased Cd accumulation can be attributed to the effect of effluents from different industries carrying Cd to the soil in irrigation. The higher values in the surface soils suggested contamination of soil.

Table II. Concentration of heavy metals (mgkg^{-1}) in effluent irrigated soil samples collected from Korangi Industrial Area, Karachi (Sindh) during summer and winter seasons of the years 2000 and 2001

Soil depth (cm)	Heavy metals	Values	Year 2000		Year 2001	
			Summer	Winter	Summer	Winter
0-20	Cd	Min	0.06	0.09	0.12	0.08
		Max	0.19	0.30	0.32	0.42
		Mean	0.11	0.19	0.21	0.21
	Cr	Min	0.26	0.05	0.32	0.06
		Max	0.84	0.28	0.98	0.42
		Mean	0.53	0.17	0.58	0.23
	Ni	Min	0.07	0.05	0.28	0.98
		Max	1.98	0.50	2.64	2.52
		Mean	0.92	1.37	1.57	1.58
	Pb	Min	0.76	1.82	1.16	1.28
		Max	4.12	3.46	4.88	4.26
		Mean	2.96	2.65	3.03	2.91
20-40	Cd	Min	0.04	0.02	0.03	0.05
		Max	0.14	0.20	0.18	0.18
		Mean	0.09	0.08	0.10	0.10
	Cr	Min	0.02	0.03	0.09	0.02
		Max	0.38	0.19	0.42	0.22
		Mean	0.21	0.13	0.22	0.13
	Ni	Min	0.04	0.30	0.12	0.68
		Max	0.95	2.12	1.28	1.62
		Mean	0.53	1.26	0.87	1.05
	Pb	Min	0.94	0.06	0.89	0.98
		Max	3.60	2.48	3.25	2.94
		Mean	2.56	1.81	2.01	1.80

Table III. Comparison of the average values (mgkg^{-1}) of heavy metals in effluent and tube well irrigated (background) soil samples collected from various sites of NWFP Province

Heavy Metals	Soil Depth (cm)	Effluent irrigated soil mean values (n=40)	Tube well irrigated soil mean values (n=4)	t-value
Cd	0-20	0.16	0.07	4.10*
	20-40	0.09	0.05	2.87
Cr	0-20	0.37	0.14	2.70
	20-40	0.18	0.09	3.76*
Ni	0-20	1.24	0.12	8.43**
	20-40	0.89	0.09	5.25*
Pb	0-20	2.84	1.53	3.53*
	20-40	2.18	1.02	12.22**

*, Tube well irrigated soil values are significantly lower than the mean values of effluent irrigated soils at $P < 0.05$ and 0.01, respectively

The observed values of Cd can be compared with those reported by Alloway (1968), who observed that natural Cd concentrations in soil ranged from 0.01-7.0 mg kg^{-1} with an average value of 0.06 mg kg^{-1} while Khattak *et al.* (2002) found Cd concentration in the range of 0.13-0.33 mg kg^{-1} in soils within the proximity of Abbottabad.

Chromium (Cr). The concentration of Cr in summer 2000, ranged from 0.26 –0.84 and 0.02 to 0.38 with the average values of 0.53 and 0.21 mg kg^{-1} for 0 - 20 and 20 - 40 cm soil depth, respectively. The ranges of Cr observed during the winter 2000 for surface and subsurface soil samples were 0.05 to 0.28 and 0.03 to 0.19 with the mean values of 0.17 and 0.13 mg kg^{-1}, respectively (Table II).

Similarly, the observed range of Cr during summer 2001 was 0.32 - 0.98 with the average value of 0.58 mg kg^{-1} for 0-20 cm and 0.09 to 0.42 with the average value of 0.22 mg kg^{-1} for 20-40 cm soil depth. During the winter 2001, the Cr ranged from 0.06 - 0.42 with the mean concentration of 0.23 mg kg^{-1} and from 0.02 to 0.22 with the average value of 0.13 mg kg^{-1} in surface and subsurface soil samples, respectively (Table II).

The overall mean concentrations of Cr in effluent irrigated soil samples were 0.37 and 0.18 mg kg^{-1} in surface and sub surface soil samples, respectively. While, the mean values of Cr in tube well irrigated soil samples were 0.14 and 0.09 mg kg^{-1} for the given respective soil surfaces (Table III). The Cr increased in summer as compared to winter and decreased with depth.

The analysis of variance (Table III), showed that difference in season and sampling depth has significantly affected Cr at $P < 0.001$ and 0.01, respectively (Table I). Comparison of means by t-test revealed that Cr in effluent and tube well irrigated soil samples differed non-significantly.

The observed values of Cr in effluent irrigated soils were higher than those in tube well irrigated soils and lower than those reported by Tjell and Hovmand (1972), Aaby and Jacobson (1978), Aichberger (1980) and Czarnowska and Majehrzak (1991). According to Tjell and Hovmand (1972) and Aaby and Jacobsen (1978) the Cr concentration in surface soils of Denmark ranged from 1.8-10 mg kg^{-1} while Aichberger (1980) observed Cr concentration ranging from 1.4-3.5 mg kg^{-1} in surface soils of Australia. However, Czarnowska and Majehrzak (1991) reported Cr concentration in the range of 4-28 mg kg^{-1} in soils of Kabacki Forest, Poland.

Nickel (Ni). The Ni concentrations varied between 0.07-1.98 in surface soils and from 0.04-0.95 mg kg^{-1} in subsurface soils with the mean values of 0.92 and 0.53 mg kg^{-1}, respectively during summer 2000 (Table II). While in winter 2000, Ni ranged from 0.05-0.50 in surface and 0.30-2.12 mg kg^{-1} in sub-surface soil samples having mean values of 1.37 and 1.26 mg kg^{-1}, respectively. Similarly, in summer 2001, Ni ranged from 0.28-2.64 with the mean concentration of 1.57 mg kg^{-1} in surface soils while 0.12-1.28 with the mean concentration of 0.87 mg kg^{-1} in sub-soils. During winter 2001, the Ni ranged from 0.98 –2.52 and 0.68-1.62 with the average of 1.58 and 1.05 mg kg^{-1} in surface and subsurface soil samples, respectively (Table II). The data showed that Ni was lower in summer than that in winter which might be due to their high input during winter season.

The overall mean value of Ni in effluent irrigated soil samples was 1.24 mg kg^{-1} against the background value of 0.12 mg kg^{-1} in surface soils while 0.89 mg kg^{-1} against 0.09 mg kg^{-1} in subsurface soils (Table III). The analysis of variance showed that significantly higher Ni were accumulated in soil during the year 2001 as compared to 2000 (Table I). This significant accumulation can be associated with effluents irrigation.

Pratt *et al.* (1964) reported that normal Ni level in soil was between 0.005 to 0.05 mg kg^{-1}. The reported mean values of Ni presented in Table II are higher than those reported for normal soil. Kabata-Pendias and Pendias (1984) reported that Ni recently has become a serious pollutant due to increase combustion of coal, oil and application of sludge.

Lead (Pb). In summer 2000, the concentration of Pb ranged from 0.76-4.12 0.94-3.60 with the average values of 2.96 and 2.56 mg kg^{-1} in surface and subsurface soil samples, respectively. During winter 2000, Pb ranged from 1.82-3.46 in surface and 0.06 – 2.48 mg kg^{-1} in subsurface soil samples having mean concentrations of 2.65 and 1.81 mg kg^{-1}, respectively (Table II).

Similarly, Pb ranged from 1.16-4.88 with the average value of 3.03 mg kg^{-1} in surface soils and 0.89-3.25 having mean value of 2.01 mg kg^{-1} in subsurface soils, during summer 2001. However, in winter 2001, Pb varied between 1.28-4.26 and 0.98-2.94 mg kg^{-1} with the average values of 2.91 and 1.80 mg kg^{-1} in surface and subsurface soil samples, respectively (Table II). The data showed that Pb tended to increase in summer as compared to winter and decrease with depth.

The overall mean concentrations of Pb in effluent irrigated soil samples were 2.84 and 2.18 mg kg^{-1} in surface and subsurface soil samples, respectively. While, the mean values in tube well irrigated soil samples were 1.53 and 1.02 mg kg^{-1}, respectively for the given soil surfaces (Table III). The analysis of variance showed that Pb is significantly affected by the difference in season and sampling depth at $P < 0.05$ and 0.01, respectively (Table I). The t-test comparison showed that Pb in effluent irrigated soils was significantly higher than that in tube well irrigated soils at $P < 0.05$ (Table III).

According to Czarnowska (1982), Pb concentration in contaminated surface soils of Poland ranged from 17-165 mg kg^{-1} while Czarnowska and Majehrzak (1991) reported Pb concentration ranging from 4-16 mg kg^{-1} in soils of Kabacki Forest, Poland. Khattak and Rehman (1992) reported AB-DTPA ext. Pb, which ranged from 3.33-5.60 mg kg^{-1} in soils of Industrial Area Amangarh and 0.49-2.05 mg kg^{-1} in soils of Pirsabak Farm. Wazir (1994) reported a Pb concentration ranging from 2.05-26.4 mg kg^{-1} in contaminated soils within the proximity of Peshawar City. Khattak *et al.* (2002) reported Pb concentration, which ranged from 1.5-10.0 mg kg^{-1} in soils within the proximity of Abbottabad. The values observed in this study are quite low than those reported for contaminated soils.

CONCLUSIONS

Based on the aforementioned discussion, it can be concluded that the soil of Korangi Industrial Area, Karachi contained higher and elevated concentrations of heavy metals as compared to that considered normal (background soil). The continuous application of industrial and domestic wastewater in irrigation may cause heavy metals build up in soils to undesirable and phyto-toxic levels. So, the longer term effluents irrigation would be risky from environmental point of view.

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