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Distribution of Heavy Metals Depth Wise in Agricultural Soils

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Abstract

With the fast development of industrialisation, the environment has been exposed to various elements which are hazardous. The soils are found to be the major sink of variety of contaminants. Most important of these contaminants are heavy metals. The study aimed to investigate heavy metal soil profile from five locations of an agricultural field in vertical direction. The study area chosen is village Salarpur in Tehsil Tijara, District Alwar, Rajasthan, India. Presence of Heavy metals is also compared at two depths i.e. 0 to 1 cm and 1 to 5 cm at each location. Zn, Pb, Cd, Cu, As, Fe, and Ni concentrations in the soil samples were determined using inductively coupled plasma mass spectrometry ICP-MS. Cr III was estimated by spectrophotometric method. The study of the area reveals that Total Zn, Total Pb, Total Cu, Fe and Ni content in soil decreases with depth at locations 1, 2, and 3 but increase with depth at locations 4 and 5. Total Cd content of soil increases with depth at location 1, 2, 3, and 4 but decreases with depth at location 5. The non-uniform distribution of Total Zn, Total Pb, Total Cu, Fe, Cd and Ni contents with depth is revealed. Concentration of Cr-III of soil increases with depth at all locations. Strong positive correlation of Zn with Pb, Cu, Fe and Ni, Pb with Cu, Fe and Ni, Cu with Fe and Ni, Fe with Ni is revealed at both the depths i.e. 0-1 cm and 1-5 cm.

Keywords: *Heavy metals, soil profile, depth wise, correlation*

1. Introduction

Soils are the major sinks of heavy metals such as Zn, Pb, Cu, Ni, Fe, Cd etc. Their release into atmosphere may be natural as well as anthropogenic. Origin of heavy metals is found to be the basic igneous rocks, which have higher levels of metals as compared to other rocks such as gneisses, sandstones, granites and siltstones [1] [2]. Organic matter and clay (quantity and composition) may also impact the concentration of heavy metals in soils [3]. Anthropogenic sources responsible for heavy metals in the soil are industrial emissions and agricultural sources [4]. Landfills are found to be the chief point sources of heavy metals and organic compounds to the environment. Waste and liquids combine producing landfill leachate that percolates through waste in landfills. This is the main route of these pollutants from the landfill to nearby environments [5]. Mining activity is also found to be resulted in raised levels of these contaminants in the environment [6]. Long-term recharging with secondary effluent impacts the chemical characteristics of soil and negatively affects soil properties, pose the threat of hazardous heavy metals [7]. Heavy metals are non-biodegradable which can be a part of secondary effluent and thus may accumulate in the soil [8]. Toxic metals affect the upper 25cm surface layer of soil where the roots of the plants or crops are found [9]. Another study reveals that the cause of heavy metal contamination in different areas of North India is the discharge of sewage sludge, fly ash, untreated industrial waste disposal on agricultural land, extensive use of agrochemicals, fertilizer, pesticides used in the agricultural practices [10]. A study was carried out to assess the distribution of

heavy metals along the depth of soil and the result revealed non uniform distribution of heavy metals [11]. A number of studies reveal the transfer of heavy metals from soil to the plants that may be a big cause of serious health hazards.

The study area is also surrounded by a big industrial belt that is supposed to affect the quality of soil. As the area is mostly covered by agricultural fields, the exposure of the agricultural soil towards heavy metals was assessed along with depth wise distribution of heavy metals.

2. Materials And Methods

a) Study Area

The study area of the present study belongs to village Salarpur in Tehsil Tijara, District Alwar that comes in the state of Rajasthan, India. Latitude and longitude are 27.9824217 and 76.8519159 respectively. Samples of soil were collected from an agricultural land of the study area to find the presence of heavy metals in the agricultural soil as the area is surrounded by a number of industries belonging to Bhiwadi, Dharuhera, Khushkhera and Tapukara. These industries involve production of chemicals, automobiles textiles, dyes, vegetable oils etc. Metal industries here involve Zinc and copper smelting. The residents talked about the poor quality of soil and groundwater of the area and the reason given was the improper disposal of industrial effluents.

b) Sampling and analysis

Ten soil samples (each about one kilogram) were taken from 2500 square meters of an agricultural land from five locations in a straight line along vertical direction. Sampling locations were at a distance of about ten meters from each other. Sampling was done at two depths at each location i.e. at 0 to 1cm and 1 to 5 cm to compare the availability of heavy metals at these different depths. Soil samples were placed in clean and dry labelled polythene bags and transferred to laboratories of **Vardan EnviroLab, Manesar**, **Gurugram, Haryana, India approved by** MoEF & CC, NABL, and HSPCB.

Estimation of various heavy metals in soil was done following standard methods given by IS and APHA. The clods were broken and the samples were dried in air. pH of soil samples was measured by Electrometric method with the help of a calibrated pH meter (Scientech, Model No. LT-11) Soil samples were digested with Nitric acid and hydrogen peroxide. Inductively coupled plasma mass spectrometry ICP-MS (Agilent Technologies-7800) was used for analysis of heavy metals such as Zn, Pb, Cd, Cu, As, Fe, and Ni. Cr III was estimated by spectrophotometric method [Systronics Model-117].

3. Results and Discussion

a) Concentration of heavy metals

Table 1 presents the concentration of various heavy metals and pH [12] in the samples of soil at 5 locations which are at ten meters from each other. Soil samples were taken from two different depths i.e. from 0-1 cm and 1-5 cm.

At 0-1 cm depth: pH varies from 7.91 to 8.31 with mean value 8.072. Total Zinc in the soil samples varies from 3.22 mg/kg to 31.4 mg/kg with mean value of 17.568 mg/kg. Total lead from 0.14 mg/kg to 7.7 mg/kg with mean value of 3.926 mg/kg. Total cadmium varies from 0.14 mg/kg to 0.27 mg/kg with mean value of 0.206 mg/kg. Total Copper varies from 0.16 mg/kg to 11.93 mg/kg with mean value of 6.116 mg/kg. Iron varies from 58.21 mg/kg to 7249.94 mg/kg with mean value of 3160.068 mg/kg. Nickel varies from 0.7 mg/kg to 14.73 mg/kg with mean value of 7.692 mg/kg. Chromium-III varies from 0.36 mg/kg to 0.47 mg/kg with mean value of 0.42 mg/kg.

At depth of 1-5 cm: pH varies from 7.88 to 8.31 with mean value 8.132. Total Zinc in the soil samples varies from 4.43 mg/kg to 47.12 mg/kg with mean value of 18.438 mg/kg. Total lead from 0.37 mg/kg to 6.57 mg/kg with mean value of 2.84 mg/kg. Total cadmium varies from 0.19 mg/kg to 0.4 mg/kg with mean value of 0.278 mg/kg. Total Copper varies from 1.15 mg/kg to 17.04 mg/kg with mean value of 6.376 mg/kg. Iron varies from 193.83 mg/kg to 6723.61 mg/kg with mean value of 2750.986 mg/kg. Nickel varies from 1.07 mg/kg to 16.19 mg/kg with mean value of 6.652 mg/kg. Chromium-III varies from 0.44 mg/kg to 0.5 mg/kg with mean value of 0.466 mg/kg.

Table 1 Concentration of heavy metals in soil samples from 0-1 cm and 1-5 cm depth

Parameters	VS-depth (cm)	Location-1	Location-2	Location-3	Location-4	Location-5	Min.	Max.	Mean
pH	0 to 1	**7.92**	7.99	8.23	**7.91**	8.31	7.91	8.31	8.072
	1 to 5	**8.31**	7.88	8.17	**8.29**	8.01	7.88	8.31	8.132
Total Zinc (as Zn)	0 to 1	22.78	22.7	31.4	**3.22**	**7.74**	3.22	31.4	17.568
	1 to 5	5.12	4.43	8.56	**47.12**	**26.96**	4.43	47.12	18.438
Total Lead (as Pb)	0 to 1	5.7	5.59	7.7	**0.14**	**0.5**	0.14	7.7	3.926
	1 to 5	0.38	0.37	0.69	**6.19**	**6.57**	0.37	6.57	2.84
Total Cadmium (as Cd)	0 to 1	0.18	0.19	0.27	0.14	**0.25**	0.14	0.27	0.206
	1 to 5	0.19	0.24	0.33	0.4	**0.23**	0.19	0.4	0.278
Total Copper (as Cu)	0 to 1	8.15	8.6	11.93	**0.16**	**1.74**	0.16	11.93	6.116
	0 to 5	1.4	1.15	2.24	**17.04**	**10.05**	1.15	17.04	6.376
Iron (Fe)	0 to 1	5622.33	2595.37	7249.94	**58.21**	**274.49**	58.21	7249.94	3160.068
	0 to 5	215.52	193.83	326.64	**6723.61**	**6295.33**	193.83	6723.61	2750.986
Nickel (Ni)	0 to 1	10.8	10.59	14.73	**0.7**	**1.64**	0.7	14.73	7.692
	0 to 5	1.41	1.07	2.07	**16.19**	**12.52**	1.07	16.19	6.652
Chromium(Cr-III)	0 to 1	0.43	0.47	0.46	0.36	0.38	0.36	0.47	0.42
	0 to 5	0.44	0.48	0.5	0.44	0.47	0.44	0.5	0.466

Abbreviations: VS = vertical soil, Min. = minimum, Max. = maximum

Units: pH = unit less, Concentration of heavy metals (Zn, Pb, Cd, Cu, Fe, Ni, Cr-III) = mg/kg

b) Comparative Study (Table 1)

Variation of values of pH [12] and heavy metals with depth is revealed in Table 1

Soil becomes less alkaline with depth at Location 2, 3 and 5 but alkalinity increases with depth at Location 1 and 4. Concentration of Zinc, Lead, Copper, Iron and Nickel decreases with depth from Location 1 to 3 but increases with depth at Location 4 and 5. Total Cadmium content is reverse of other heavy metals such as Zinc, Lead, Copper, Iron and Nickel. Cadmium content increase with depth from Location-1 to 4 but decrease with depth at Location 5. Concentration of Chromium-III increases with depth at all locations.

No particular order of variation of parameters is observed on moving from location-1 to Location-5

c) Correlation Analysis (Table 2)

Correlation matrix reveals the strong positive correlation of Zn with Pb, Cu, Fe and Ni in both of the depths i.e. 0 to 1 cm as well as 1 to 5 cm ($r>0.9$).

Strong positive correlation is also revealed of Pb with Cu, Fe and Ni in both of the depths.

At 0-1 cm depth there is perfect positive correlation between Pb and Ni ($r=1$)

In both of the depths there is strong positive correlation of Cu with Fe and Ni and Fe with Ni.

At depth of 0-1 cm there is strong positive correlation of- Cr-III with Zn, Pb, Cu and Ni and of Cd with pH

At depth of 0-1 cm there is moderate positive correlation ($r=0.5$ to 0.7) of Fe with Cr III. Moderate positive correlation of Cd is observed with Zn Cu and Ni at 1-5 cm depth.

Low positive correlation (r=0.3 to 0.5) of Cd is observed at depth of 1-5 cm with pH, Pb and Fe whereas at 0-1 cm depth low positive correlation of Cd with Zn, Pb, Cu, Fe, Ni and Cr-III is observed.

If we see the significant positive correlation of parameters between two depths, there is fairly strong positive correlation of Cr-III (1-5 cm) and Cd (0-1cm) r=0.815. Moderate positive correlation of Cr-III (1-5 cm) with pH, Zn, Pb, Cu, Ni and Cr-III of 0-1 cm depth. Low positive correlation is seen between Cr-III (1-5cm) and Fe (0-1 cm).

Except Cr-III all of the heavy metals of the depth 1-5 cm are negatively correlated with those of depth 0-1 cm.

Table 2 Correlation matrix of heavy metals at depth of 0-1 and 1-5 cm

	pH(0-1)	Zn(0-1)	Pb(0-1)	Cd(0-1)	Cu(0-1)	Fe(0-1)	Ni(0-1)	Cr-III(0-1)	pH(1-5)	Zn(1-5)	Pb(1-5)	Cd(1-5)	Cu(1-5)	Fe(1-5)	Ni(1-5)	Cr-III(1-5)
pH(0-1)	1															
Zn(0-1)	0.11	1														
Pb(0-1)	-0	0.993	1													
Cd(0-1)	0.926	0.475	0.37	1												
Cu(0-1)	0.089	0.999	0.995	0.454	1											
Fe(0-1)	0.056	0.93	0.929	0.417	0.919	1										
Ni(0-1)	0.021	0.996	1	0.394	0.997	0.933	1									
Cr-III(0-1)	0.025	0.933	0.935	0.359	0.944	0.743	0.933	1								
pH(1-5)	-0.4	-0.11	-0.056	-0.355	-0.12	0.253	-0.06	-0.3881	1							
Zn(1-5)	-0.07	-0.89	-0.883	-0.402	-0.89	-0.755	-0.882	-0.9181	0.313	1						
Pb(1-5)	0.242	-0.92	-0.955	-0.132	-0.93	-0.834	-0.948	-0.9309	0.074	0.905	1					
Cd(1-5)	-0.1	-0.3	-0.276	-0.217	-0.29	-0.204	-0.275	-0.369	0.334	0.679	0.388	1				
Cu(1-5)	-0.06	-0.91	-0.904	-0.398	-0.91	-0.778	-0.903	-0.9298	0.292	0.999	0.92	0.646936	1			
Fe(1-5)	0.162	-0.94	-0.965	-0.211	-0.95	-0.847	-0.96	-0.9464	0.117	0.936	0.996	0.434303	0.949	1		
Ni(1-5)	0.072	-0.94	-0.946	-0.288	-0.94	-0.818	-0.942	-0.9521	0.206	0.976	0.975	0.539399	0.984	0.99	1	
Cr-III(1-5)	0.689	0.607	0.536	0.815	0.612	0.408	0.553	0.63285	-0.59	-0.47	-0.34	0.01799	-0.475	-0.39	-0.43139	1

= Strong positive correlation, = Moderate positive correlation,

= Low positive correlation = Perfect positive correlation

4. Conclusion

The investigation of the soil samples of the study area reveal that-

1. Total Zn, Total Pb, Total Cu, Fe and Ni content in soil decreases with depth at locations 1, 2 and 3 but increase with depth at locations 4 and 5.

2. Total Cd content of soil increases with depth at location 1, 2, 3, and 4 but decreases with depth at location 5.

3. Concentration of Cr-III of soil increases with depth at all locations.

4. Strong positive correlation of Zn with Pb, Cu, Fe and Ni, Pb with Cu, Fe and Ni, Cu with Fe and Ni, Fe with Ni is revealed at both the depths i.e. 0-1 cm and 1-5 cm.

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