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Monitoring of Heavy Metals under Agriculture Land in Jaipur District of Rajasthan, India

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ABSTRACT

Agriculture is an important sector in India, and is among the top three global producers of many crops. Agricultural practices, such as the use of agrochemicals, such as pesticides and fertilizers, can add heavy metals to the soil, which can be absorbed by the crop and tend to be eaten by humans. Heavy metals can also be naturally present in soil. Heavy metals can travel from the soil to water bodies and plants, which become part of the food chain. Heavy metals from agricultural land were assessed in the Jaipur district. Soil samples were analyzed for As, Cd, Hg, and Pb in surface and subsurface soils. Three divisions with five villages in each division of Jaipur district were selected for soil sampling and heavy metal analysis. In the surface soil samples from the Sanganer division, arsenic values varied from 1.375 to 2.810 ppm, cadmium ranged from 0.035 to 0.130 ppm, mercury varied from 0.013 ppm to 0.028 ppm, and lead varied between 3.650 and 5.625 ppm. In the Bassi division, arsenic varied from 0.030 to 0.425 ppm, mercury varied from 0.013 to 0.030 ppm, and lead varied between 3.360 and 6.278 ppm. For the Amber division, arsenic values varied from 1.493 to 3.638 ppm, cadmium ranged from 0.050 to 1.440 ppm, mercury varied from 0.015 ppm to 0.060 ppm, and lead varied from 4.118 to 11.353 ppm.

Key words: *Soil quality, Heavy metals, Soil testing, Agriculture land*

Introduction

Soil-related heavy metal pollution is a major threat to humans. Heavy metal pollution is caused by anthropogenic activities and natural sources. The major sources of heavy metals in agricultural soils are the disposal of toxic metal untreated wastes, use of fertilizers, pesticides, manure, sewage sludge, compost, and wastewater irrigation (Kaparwan *et al.*, 2020). Agricultural soils require essential micronutrients and macronutrients for better plant growth and development. However, improper use of fertilizers and pesticides can contaminate agricultural soil with potentially toxic heavy metals, causing agricultural soil to become a source of pollution (Reddy *et al.*, 2013). Assessing soils for heavy metals can be helpful in determining the status of soil pollution caused by the accumulation of heavy metals.

Heavy metals have a high atomic weight and a density greater than 5 g/cm^3 (Kumar *et al.*, 2017) . Heavy metals refer to metals and metalloids that possess biological toxicity, such as cadmium, mercury, arsenic, lead, and chromium (Zhang *et al.*, 2010; Le *et al.*, 2019). Soil polluted with heavy metals can harm crops, alter the food chain, and endanger human health. Heavy metals are added to the soil from manure, fertilizers, sewage sludge, pesticides, wastewater irrigation, and atmospheric deposition. Soil polluted with heavy metals results in human health risks, groundwater pollution, plant phytotoxicity, and a decline in crop and soil production (Nyiramigisha and Sajidan, 2021).

Several studies have shown that there are physiological changes in agricultural crops that are influenced by exposure to heavy metals, such as Hg, Cd, Pb, Cu, and Ni (Fatoba and Udoh 2008; Hananingtyas *et al*., 2022). Environmental pollution due to heavy metal contamination poses a high health risk to people worldwide (Nag *et al*., 2022). Various studies have shown that vegetables growing in such soils are harmful to people because they take up heavy metals from their roots.

Heavy metals pose a threat to the environment, plants and animals, soil and water, as well as human health, and it is important to continuously monitor heavy metal pollution in the environment. The examination of heavy metals is crucial because slight variations in their concentrations are above the acceptable limits if natural or anthropogenic factors can result in serious environmental and health problems (Nyiramigisha and Sajidan, 2021).

To understand the heavy metal situation in agricultural land in Jaipur, soil samples were collected from cultivated land and investigated for heavy metal accumulation. This will help to develop proper remediation methods to deal with the overabundance of these metals' contamination in the agriculture soils.

Materials and Method

In this study, soil samples from surface and sub-surface layers (0–15 cm and 15–30 cm) were collected from agricultural land. Three sites in Jaipur, named Sanganer, Bassi, and Amber, were selected for soil sampling. Under each mentioned site, six random villages were selected, from which four samples from each village were collected. A total of forty-four samples were analysed from three sites in both the surface and subsurface layers. The collected samples were analysed for heavy metals. Samples were first brought to the laboratory, then dried in the shade. The samples were then passed through a 2 mm sieve and stored in polythene bags for their subsequent analysis.

Heavy metals: To analyse the heavy metals, viz., arsenic, cadmium, chromium, nickel, lead, and zinc, 0.5 g of soil sample was digested with concentrated HNO_3, H_2SO_4 and H_2O_2 in the ratio of 2:6:6 as per the procedure prescribed by Saison *et al*. (2004). The concentration of heavy metals was estimated by using the ICP spectrometer (Model-ICAP 6300 duo) of Thermo Scientific. The heavy metal concentration has been expressed as mg/kg. In order to interpret the data, the permissible limits given in the literature were used as per Table 1.

Results

The results for heavy metals shown in Table 2 reflect higher values of arsenic ranging from 1.37 to 2.81 ppm. Cadmium values ranged from 0.03 to 0.13, mercury values ranged from 0.01 to 0.02 ppm, and lead values ranged from 3.65 to 5.62 ppm. In table 3, Arsenic ranged from 1.93 to 2.66 ppm. Cadmium ranged from 0.03 to 0.13 ppm. Mercury values were within the range of 0.01 to 0.02, and lead content was between 3.65 and 5.62 ppm. From Table 4, It is evident that arsenic content varied from 1.59 to 3.48

Table 1. Permissible limits for heavy metals (mg/kg) in soil.

Heavy metal	Permissible value in soil mg/kg (WHO/FAO)	Maximum limit in soil (mg/kg) US-EPA	Indian Standard
Arsenic	20	14	-
Cadmium	3	1.6	3
Mercury	-	0.5	-
Lead	50	60	300

WHO and FAO from Chiroma *et al*. (2014)

ppm. Cadmium has shown low values ranging from 0.03 to 0.42 ppm. Mercury values were below 0.03 ppm, and lead content varied between 3.36 and 6.27 ppm. From table 5, it is evident that arsenic in the subsurface layers of the soil in the Bassi area ranged from 1.79 to 3.04 ppm. Cadmium content was between 0.03 and 0.06 ppm. Mercury has shown the low values again, which are below 0.03 ppm. Lead concentrations are found between 3.30 and 3.40 ppm in the subsurface soil samples. From Table 6, it is evident that the surface soil of the Amber region has shown arsenic values between 1.49 and 3.63 ppm. The cadmium content of soil samples ranged from 0.05 to 1.44 ppm. Mercury content varied between 0.01 and 0.06 ppm, and lead has been observed with the highest values of 11.35 ppm, 8.40 ppm, and 4.14 ppm. Arsenic content ranged from 1.87 to 3.56 ppm in subsurface soil samples from the

Table 2. Statistical characteristics were analysed from sampling sites (Sanganer) for the surface layer (0–15 cm).

No. of Villages	Arsenic		Cadmium		Mercury		Lead	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	1.743	0.070	0.093	0.006	0.013	0.003	3.650	0.058
2	1.375	0.087	0.035	0.006	0.028	0.006	5.480	0.015
3	2.608	0.015	0.130	0.004	0.023	0.005	5.440	0.033
4	1.650	0.034	0.118	0.005	0.013	0.003	5.295	0.029
5	2.810	0.124	0.050	0.031	0.018	0.002	5.625	0.029
6	1.630	0.101	0.120	0.004	0.013	0.003	4.088	0.036
C.D.	0.206		0.040		0.010		0.101	
SE(m)	0.068		0.013		0.003		0.033	
SE(d)	0.096		0.019		0.005		0.047	
C.V.	6.891		29.128		37.131		1.341	

Table 3. Statistical characteristics were analysed from sampling sites (Sanganer) for the sub-surface layer (15-30 cm).

No. of Villages	Arsenic		Cadmium		Mercury		Lead	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	2.628	0.076	0.043	0.005	0.010	0.000	3.835	0.013
2	2.663	0.040	0.098	0.008	0.013	0.003	3.740	0.036
3	2.280	0.024	0.045	0.006	0.010	0.000	4.503	0.060
4	2.173	0.066	0.048	0.005	0.013	0.003	4.253	0.011
5	2.170	0.067	0.028	0.005	0.013	0.003	4.183	0.021
6	1.938	0.043	0.043	0.005	0.010	0.000	3.763	0.037
C.D.	0.154		0.017		N/A		0.098	
SE(m)	0.051		0.006		0.001		0.032	
SE(d)	0.071		0.008		0.002		0.045	
C.V.	4.378		22.299		24.343		1.586	

Table 4. Statistical characteristics were analysed from sampling sites (Bassi) for the surface layer (0-15 cm).

No. of Villages	Arsenic		Cadmium		Mercury		Lead	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	3.485	0.031	0.425	0.006	0.018	0.005	5.728	0.053
2	2.370	0.038	0.050	0.004	0.023	0.006	4.155	0.014
3	2.535	0.042	0.070	0.004	0.020	0.004	6.278	0.053
4	2.545	0.042	0.030	0.004	0.030	0.004	3.825	0.022
5	1.698	0.053	0.040	0.004	0.013	0.003	3.403	0.093
6	1.593	0.034	0.050	0.007	0.028	0.005	3.360	0.123
C.D.	0.132		0.015		N/A		0.184	
SE(m)	0.043		0.005		0.005		0.060	
SE(d)	0.061		0.007		0.007		0.085	
C.V.	3.663		9.171		44.589		2.709	

Table 5. Statistical characteristics were analysed from sampling sites (Bassi) for the sub-surface layer (15-30 cm).

No. of Villages	Arsenic		Cadmium		Mercury		Lead	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	3.045	0.068	0.060	0.004	0.013	0.003	4.408	0.060
2	1.793	0.045	0.048	0.006	0.013	0.003	3.550	0.036
3	2.515	0.104	0.050	0.004	0.023	0.003	4.190	0.020
4	2.708	0.075	0.030	0.004	0.015	0.003	3.553	0.044
5	2.203	0.046	0.060	0.004	0.020	0.004	4.110	0.029
6	1.905	0.033	0.048	0.006	0.023	0.006	3.405	0.057
C.D.	0.197		0.015		N/A		0.127	
SE(m)	0.065		0.005		0.003		0.042	
SE(d)	0.092		0.007		0.004		0.059	
C.V.	5.490		20.112		35.635		2.151	

Table 6. Statistical characterstics analysed from sampling sites (Amber) for the surface layer (0-15 cm)

Treatment	Arsenic		Cadmium		Mercury		Lead	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	1.565	0.016	0.060	0.004	0.023	0.005	4.788	0.169
2	1.745	0.035	0.050	0.004	0.015	0.003	4.310	0.028
3	3.638	0.036	1.440	0.016	0.033	0.009	11.353	0.134
4	1.953	0.164	0.135	0.006	0.060	0.004	8.407	0.052
5	1.493	0.024	0.075	0.006	0.018	0.005	4.118	0.012
6	2.535	0.010	0.050	0.004	0.015	0.003	4.740	0.039
C.D.	0.221		0.026		0.013		0.230	
SE(m)	0.073		0.008		0.004		0.076	
SE(d)	0.103		0.012		0.006		0.107	
C.V.	6.744		5.569		32.737		2.406	

Table 7. Statistical characteristics were analysed from sampling sites (Amber) for the sub-surface layer (15-30 cm).

Treatment	Arsenic		Cadmium		Mercury		Lead	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	1.898	0.018	0.043	0.005	0.018	0.005	4.593	0.037
2	2.063	0.024	0.055	0.006	0.013	0.003	4.263	0.016
3	3.560	0.046	1.255	0.014	0.030	0.004	11.355	0.244
4	2.090	0.023	0.135	0.006	0.078	0.009	9.155	0.049
5	1.870	0.022	0.058	0.028	0.030	0.004	4.145	0.026
6	2.138	0.009	0.048	0.005	0.013	0.003	4.573	0.044
C.D.	0.085		0.044		0.014		0.338	
SE(m)	0.028		0.015		0.004		0.111	
SE(d)	0.040		0.021		0.006		0.157	
C.V.	2.467		10.997		29.814		3.497	

Amber region (Table 7). Cadmium content ranged from 0.043 to 1.255 ppm. Mercury values were between 0.01 and 0.07 ppm, and lead content ranged high in subsurface samples; the highest values were 11.35 ppm, followed by 9.15 ppm, 4.59 ppm, 4.57 ppm, 4.26 ppm, and 4.14 ppm. In Figures 1, 3, and 5, there is a large positive relationship between the X and Y variables, which means arsenic-cadmium, arsenic-lead, and cadmium-lead are highly correlated with each other. Whereas Figures 2, 4, and 6 have shown small positive relationships with each other, i.e., arsenic-mercury, cadmium-mercury, and mercury-lead.

Discussion

It is documented that phosphate fertilisers are manufactured from phosphate rocks (Sahu *et al.*, 2019) that contain the following heavy metals: Cd, Pb, Hg, Cr, and As (Dissanayake and Chandrajith, 2009). In addition to P-fertilizers, copper sulfate, iron sulfate, and zinc sulfate fertilizers can also contain HM contaminants including Pb (Gimeno-Garcíaa *et al*. 1996, Satarug *et al.*, 2003; Atafar *et al.*, 2010. Several fungicides and insecticides extensively used in the agricultural lands for crop protection have been found with the significant concentrations of heavy metals elements in their active ingredients. Some of the examples include Cu containing fungicides such as copper sulfate (Bordeaux mixture also referred to as Bordo® mix) and copper oxychloride; Pb containing insecticide such as lead arsenate; and Cu containing insecticide such as copper acetoarsenite. The commonly found heavy metal elements in the active ingredients of pesticide products include Cu, As, Pb, Hg, Cr, Zn, Al, Li, Ba, B, and Ti (titanium) (Lewis *et al.*, 2016). Sometimes heavy metal presence is also related to the organic manure as it can also add heavy metals to the agriculture field. The major sources of contamination of HM elements in the manures include the minerals supplied with the commercial feeds. For example, supplementation of animal feeds with growth-promoting organic arsenical products was practiced for many years (NAS, 1977). Some studies confirmed that Zn, Cu, As, and Cd were artificially added to commercial feeds to promote animal growth and improve disease resistance (Hu *et al.*, 2018, Zhang *et al.*, 2012). However, animals cannot digest these HM elements and discharge them through manures (Jensen *et al.*, 2016). Because HMs are non-degradable elements, they are also not broken down during the composting process (Lopes *et al.*, 2011). Thus, long-term, repeated applications of manures and compost can result in the buildup of heavy metal elements to toxic levels in agricultural soil (Zhao *et al.*, 2014; Yang *et al.*, 2017), which can affect crop health and productivity.

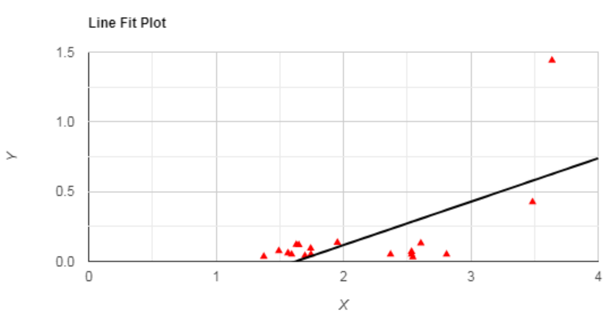

Fig. 1. Correlation between arsenic and cadmium content in Jaipur.

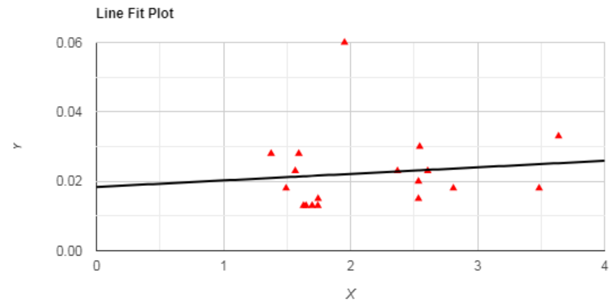

Fig. 2. Correlation between arsenic and mercury content in Jaipur.

Results of Pearson correlation indicated that there is a significant large positive relation beween X and Y r(16)= 0.644, p=.004.

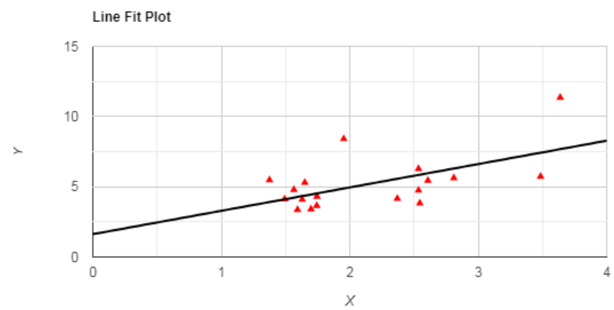

Fig. 3. Correlation between arsenic and lead content in Jaipur.

Result of the peason correlation indicated hat there is a non significant small positive relationship between X and Y, (r(16)= .114, p= .653).

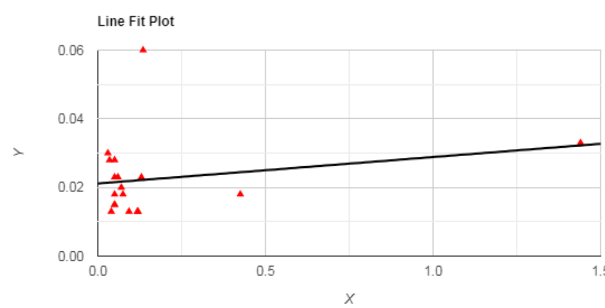

Fig. 4. Correlation between cadmium and mercury content in Jaipur.

Result of the peason correlation indicated hat there is a significant large positive relationship between X and Y, (r(16)= .579, p= .653). r = 0.12.

Result of the peason correlation indicated hat there is a non significant small positive relationship between X and Y, (r(16)= .225, p= .370).

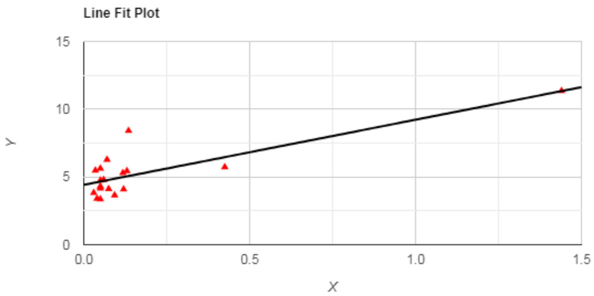

Fig. 5. Correlation between cadmium and lead content in Jaipur.

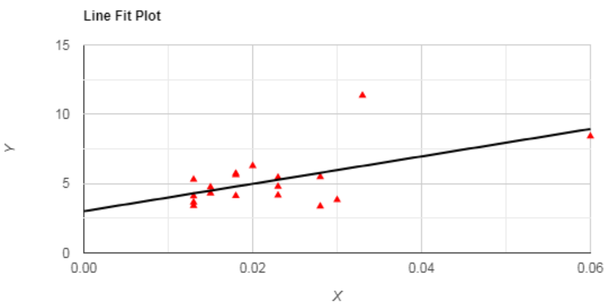

Fig. 6. Correlation between mercury and lead content in Jaipur.

Result of the peason correlation indicated that there is a significant large positive relationship between X and Y, (r(16)= .807, p< .001).

Result of the peason correlation indicated that there is a non significant small positive relationship between X and Y, (r(16)= .569, p= .014).

Conclusion

With the help of this study it can be concluded that a potential source of heavy metals in the soil could be the use of different types of fertilizers and all the heavy m metals have found to be in the permissible limit prescribed by WHO and FAO, US-EPA and Indian standards. But presence of these heavy metals can alter the soil structure and can be a source of bioaccumulation in the planted crops, which can lead to diseases in humans. Hence continuous monitoring of agriculture soil is required in order to overcome the extreme effects of the heavy metals present in the soil.

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