Analysis of heavy metals content in the agricultural soil of Sangrur District, Punjab, India

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ABSTRACT *The present study was conducted to investigate the heavy metals content in the agricultural soil of Sangrur district (Punjab). The samples of soil have been collected from fifty different villages of the study area during April 2015. Soil samples were analyzed for physicochemical parameters and heavy metals concentration. Heavy metal quantification of soil was done using flame atomic absorption spectrophotometer. The mean value of heavy metals (mg kg^{-1}) in the agricultural soil was in the following order: Fe (2787.39 ± 821.46) > Cu (124.6 ± 39.31) > Zn (29.98 ± 14.26) > Ni (13.46 ± 5.24) > Pb (8.85 ± 1.80) > Co (6.81 ± 1.48) > Cd (0.49 ± 0.21) > Cr (0.20 ± 0.12) respectively. The results showed that the mean value of all studied heavy metals in the agricultural soil was within the permissible limits as suggested by Indian standards.*

Keywords: *Physico-chemical characteristics, Heavy metals, Atomic Absorption Spectrophotometer, Agricultural Soil*

INTRODUCTION

Soil degradation has been accelerated by some inadequate human activities, which has resulted in the deterioration of soil productivity associated with soil pollution and fertility decline, especially in many developing countries[1]. The soil is a natural body of mineral and organic material differentiated into horizons[2], which differ among themselves as well as from underlying materials in their morphology, physical make-up, chemical composition and biological characteristics[3]. Due to the rapid industrialization, heavy metals are the major soil pollutant from the last few years in many countries all around the world and it is a matter of great concern[4]. Soil contains natural elements and heavy metals coming from earth's crust and distributed in ground formations[5,6]. Heavy metals are omnipresent due to their non-biodegradable and persistent nature and potential to accumulate in different parts of the body. Water solubility of heavy metals and lack of a proper mechanism for their removal from the body makes most of the heavy metals extremely toxic even at trace concentrations[7]. Application of fertilizers by the farmers in the fields without prior knowledge of soil fertility status might result in adverse effects on soils as well as crops both in terms of nutrient deficiency and toxicity either by the adequate or overuse of fertilizers[8]. Agricultural soils to food transfer of heavy metals via crops are the major pathway of human exposure to them. A number of factors such as local climate, atmospheric dry depositions, physicochemical properties of soil and the degree of maturity of plants at the time of harvest influence uptake and bioaccumulation of heavy metals in crops including vegetables[9,10]. Anthropogenic sources of heavy metals in agricultural fields include the addition of manures, sewage sludge, agrochemicals and may also affect the uptake of heavy metals by modifying the physicochemical properties of the soil such as pH, organic matter and bioavailability of heavy metals in the soil[11]. Keeping in view the above points, this study was undertaken to analyze the physicochemical characteristics and levels of different heavy metals in the agricultural soil of Sangrur District of Punjab.

MATERIALS AND METHODS

Study area

The present study has been conducted in fifty villages of Sangrur district of Punjab. It is located at 30.23°N 75.83°E. It falls in the southern part of the Punjab State and covers 3685 sq.km (approx.) of area bounded by Ludhiana and Ferozepur districts on the north side, Bathinda district in the west side, Patiala district in the Eastside and by Jind district (Haryana State) in the south side and is 232 m (761 ft) above the sea level. According to official census 2011, District had a population of 1,655,169 out of which male and female were 878,029 and 777,140 respectively The area from a part of the Indo-Gangetic plain is sandy, loam to clayey in nature. The rainfall in the area occurs mainly due to south-west and northeast monsoon. From the last 3 decades, District stands on the top in the productivity of wheat and paddy crops.

Soil sampling and Analysis

To study the heavy metals content and physicochemical characteristics of the agricultural soil of wheat crops of fifty different villages of the study area, a total 50 sub-surface soil samples were collected from the depth of 0-15 cm. Clean plastic bags were used to store soil samples after removing gnerts. Soil samples were air-dried, ground and sieved through a 2.0 mm sieve before analysis.

0.5g of each soil sample was mixed with 5.0 ml (HNO_3 and $HClO_4$) diacid mixture. Sample mixture was then taken in pre-cleaned Teflon vessels, left open overnight at room temperature and digested in a microwave digester (CEM MarsX, USA). The operating program for microwave digestion system for each digestion set up was optimized at a power of 800W and at a maximum operable temperature of 170 °C. When digestion was complete, vessels were cooled at room temperature and digests were quantitatively transferred into glass beakers. Then the digests were evaporated to dryness on a hot plate at a temperature of 130-150°C and residue were dissolved in double distilled water to make the desired volume (50 ml). Extracted solutions were transferred to polypropylene bottles and refrigerated until analysis. Total Fe, Cu, Cd, Ni, Zn, Cr, Co, and Pb content in soil samples was determined by atomic absorption spectrophotometer (SenSAAGBC, Australia). In case of all selected heavy metals, an oxidizing flame was used but in the detection of chromium, reducing nitrous oxide flame was used.

The methodology used for soil physicochemical analysis

Parameters	Method used	Instrument used
pH	Soil suspension	pH meter (Cyberscan pH tutor, EUTECH)
Electrical Conductivity	Soil suspension	pH meter (CM-183, ELICO)
Total Organic Carbon	(Walkley & Black, 1934)	FAS-Titration
Total calcium	(Cheng and Bray, 1951)	EDTA-Titration
Cation exchange capacity	Hesse (1971) method	Flame photometer (CL-378, ELICO)
Available sodium	Flame photometry	Flame photometer (CL-378, ELICO)
Available potassium	Flame photometry	Flame photometer (CL-378, ELICO)

RESULTS AND DISCUSSION

Physicochemical characteristics of agricultural field soil

Physicochemical characteristics of the soil played an important role in the accumulation of heavy metals from soil to crops. pH of the wheat crop fields soils of the study area collected in 2015 was in the range of 6.9 – 7.42 (Table 1.) with a mean value (7.19 ± 0.12) (Table 2.) which indicates its basic nature. pH of the agricultural soil in Kommangi Panchythi, Chintapalli Madal, Visakhapatnam varied from 6.3 to 6.9 was examined[12]. At an acidic pH, a positively charged surface develops while, at basic pH, a negatively charged surface occurs. Hence, the colloids of the most soils carry negative charges and can be electro – neutralized by cations present in the surrounding soil solution. When an excess of cations is present, they are exchanged to maintain the electroneutrality of the system. Therefore, cations adsorbed by the solid phase can be replaced by other cations like H^+ ions. It is anticipated that with increasing pH of the soil substrate, the solubility of most trace cations will decrease.

The electrical conductivity of wheat crop fields soil of the study area in 2015 was in the range of 106.5 – 262.5 µS/cm (Table 1.) with a mean value (151.66 µS/cm ± 38.49) (Table 2.). EC of agricultural soil in Kommangi Panchythi, Chintapalli Madal, Visakhapatnam varied from 0.11 to 0.2 µS/cm was examined[12]. Available Sodium (Na) content in crop fields soil of the study area was in the range of 1340.0 – 3940 (mg/kg) (Table 1.) with a mean value (1890.70 mg/kg ± 717.74) (Table 2.). Available Potassium (K) content in crop fields soil of the study area was in the range of 470 – 640 mg /kg(Table 1.) with a mean value (535.10 mg/kg ± 41.31) (Table 2.).

Cation Exchange Capacity (CEC) in crop fields soil of the study area in 2015 was in the range of 8.17 – 30.14 meq $100g^{-1}$ (Table 1.) with a mean value (21.37 meq $100g^{-1}$ ± 4.72) (Table 2.). CEC is one of the most important soil properties governing the cycling of trace elements in soils. A high CEC value indicates high clay content, a higher number of cation exchange sites to hold the cations on its surface against leaching thus good adsorption and buffering capacity of the soil for cations[13]. CEC in the present study is on the higher side and indicates the good capacity of soil in exchanging cations.

Total Calcium (Ca) content of the crop fields soils in the study area was in the range of 1.95 – 4.65 g/kg (Table 1.) with a mean value (2.82 g/kg ± 0.61)(Table 2.). Total Organic Carbon (TOC) of the crop fields soils in the study area in was in the range of 0.87 – 2.49 % (Table 1.) with a mean value (1.79 ± 0.33) (Table

2.).Total organic carbon (TOC) was positively correlated with available Na (r = .334*, p ≤ 0.05) (Table 3.) while cation exchange capacity (CEC) was positively correlated with available K (r = .668**, p ≤ 0.01) (Table 3.) content of soil. Electrical conductivity (EC) was negatively correlated with pH (r = -.401**, p ≤ 0.01) of soil (Table 3.).

Heavy metals content in agricultural field soils

Wheat (*Triticum aestivum* L.) with a global production of 659.1 million tonnes in 2012-2013, is the most important crop worldwide in basic food commodities followed by coarse grains and rice. The range of studied heavy metals content in wheat fields soil was as follows:- Fe (875 - 4031.5) mg kg^{-1}, Cu (47.5 - 187.5) mg kg^{-1}, Zn (16 - 89) mg kg^{-1}, Ni (5 - 28) mg kg^{-1}, Pb (5- 13) mg kg^{-1}, Co (4 - 10) mg kg^{-1}, Cd (0.1 - 0.9) mg kg^{-1} and Cr (0.05 - 0.4) mg kg^{-1} respectively(Table 4.). The Mean value of heavy metals content (mg kg^{-1}) in the agricultural soil was in the following order: Fe (2787.39 ± 821.46) > Cu (124.6 ± 39.30) > Zn (29.98 ± 14.26) > Ni (13.46 ± 5.24) > Pb (8.85 ± 1.80) > Co (6.81 ± 1.48) > Cd (0.49 ± 0.21) > Cr (0.20 ± 0.12) (Table 5.). In the present study, the concentration of heavy metals (Cu, Pb, Cr, and Cd) was within permissible limits. Maximum permissible limits for Cu is (190 mg kg^{-1}), Pb (530 mg kg^{-1}), Cr (360 mg kg^{-1}) and Cd (12 mg kg^{-1})[14,15]. With reference to Indian standards[16], mean heavy metal concentrations of vegetable fields' soils were well within permissible limits for Cu (135 – 270 mg kg^{-1}), Cd (3 – 6 mg kg^{-1}), Pb (250 – 500 mg kg^{-1}), Ni (75 – 150 mg kg^{-1}) and Zn (300 – 600 mg kg^{-1}). Heavy metals content like Cu (21.45) mg kg^{-1}, Fe (605) mg kg^{-1} and Ni (33.80) mg kg^{-1} was studied in the soil of wheat crop in Okara District of Punjab[17]. In the present study, mean value of concentration of Cu (124.6) mg kg^{-1}, Fe (2787.39) mg kg^{-1} was higher while content of Ni (13.46) mg kg^{-1} in the soil of wheat crops was lower than the results reported in soil of Okara District of Punjab[17] while content of Zn (60.48) mg kg^{-1}, Pb (10.68) mg kg^{-1} and Cd (1.310) mg kg^{-1} was higher than the results of the present study. Malinowska[18] studied the content of Cd (0.205) mg kg^{-1}, Pb (2.26) mg kg^{-1} and Ni (1.22) mg kg^{-1} in the agricultural soil of wheat crops and that was lower than our results of the study. Cadmium content (0.084) mg kg^{-1} in the agricultural soil of wheat crops in Khuzestan province, Southwest (Iran) [19] and that was lower than the present study. Range of heavy metals: Cd (0.07 - 9.80) mg kg^{-1}, Co (0.05 – 38.1) mg kg^{-1}, Ni (3.81 – 93.1) mg kg^{1}, Pb (4.45 – 47.7) mg kg^{-1}, Cu (0.33 – 16.9) mg kg^{-1} and Zn (5.02 – 81.4) mg kg^{-1} respectively in agricultural soil of food crops in Kogi state of Nigeria[20].

Fe content of the soil was positively correlated with Zn (r = .281*, p ≤ 0.05) and also positively correlated with Pb (r = .332, p ≤ .332*) while Fe was negatively correlated with Cd (r = -.388**, p ≤ 0.01) of the soil (Table 6.).

Table 1. Physico-chemical parameters of the agricultural field soil of wheat crops

S. No.	Villages	Ph	EC (µS/cm)	Na (mg/kg)	K (mg/kg)	CEC (meq/100g)	Ca (g/kg)	TOC (%)
1	Ghamoorghat	7.18	111.8	3500	490	8.17	2.45	2.37
2	Bhulan	7	199.7	3890	500	22.30	2.6	2.17
3	Andana	7.32	161.1	2080	590	22.91	2.95	1.75
4	Makorar sahib	7.15	206.6	1825	540	20.97	1.95	1.2
5	Raja heri	7.23	170.9	1665	515	20.19	2.1	1.45
6	Dhela	7.13	166.5	1615	575	23.47	2.7	1.87
7	Chotian	7.16	179.9	1450	540	18.78	3	2.04
8	Bakhera	7.13	161.3	1500	475	17.90	2.55	1.69
9	Raidhairana	6.91	262.2	1505	545	24.37	4.65	1.78
10	Gaga	7.18	112.1	1345	555	23.57	4	1.83
11	Kohrian	7.2	109.9	1405	550	25.05	2	1.75
12	Hariau	7.01	106.8	1355	475	20.30	3.8	1.57
13	Rogla	7.2	171.8	1730	485	17.83	2.1	1.65
14	Chatthe Nanhere	6.98	143.5	2135	530	19.31	3.1	1.01
15	Chhajli	7.29	170.9	1920	595	26.25	2.7	2.11
16	Kanakwal	7.34	126.7	1595	490	22.11	3.45	1.57
17	Dirba	7.31	121.3	1965	510	20.72	2.6	1.93
18	Khanal Khurd	7.24	113.4	1540	535	24.10	2.5	1.5
19	Kular Khurd	7.4	106.5	1480	530	25.80	2.15	0.87
20	Kotla Amru	7.33	142.7	1555	490	22.00	2.85	1.90
21	Chiman	7.25	155.8	1445	545	20.51	3	1.57

22	Nagran	7.2	112	3495	485	8.35	2.05	2.35
23	Balad Khurd	7.02	199.9	3885	495	22.63	2.4	2.07
24	Nadampur	7.34	161.2	2055	585	23.17	2.7	1.78
25	Bharauh	7.17	206.8	1820	535	20.44	3.05	2.04
26	Sakraudi	7.25	171.1	1660	510	20.45	2.85	1.90
27	Saron	7.15	166.7	1615	570	23.90	2.25	1.87
28	Illwal	7.18	180.1	1445	535	19.04	3.95	2.1
29	Akoi	7.15	161.5	1495	470	18.15	3.1	1.62
30	Sheron	6.93	262.5	1500	540	24.80	2.95	2.49
31	Longowal	7.2	112.3	1340	550	23.91	2.75	2.22
32	Dhadrian	7.22	110.1	1400	545	24.53	3.25	1.81
33	Kanoi	7.02	107	1350	470	18.33	2.1	1.65
34	Balian	7.22	172	2130	525	24.10	2.5	1.62
35	Mulowal	7	143.7	1915	590	23.17	2.95	1.92
36	Sherpur	7.31	171.1	1590	485	8.52	4.45	1.96
37	Thuliwal	7.36	126.9	1960	505	22.13	3.6	1.75
38	Ghanauri Khurd	7.33	121.5	1535	530	19.40	2.25	1.92
39	Jahagir	7.26	113.6	1475	525	23.83	3.1	1.81
40	Babbanpur	7.42	106.7	1550	485	8.53	2.95	1.63
41	Kaulsaheri	7.35	142.9	1440	540	21.15	2.1	1.47
42	Chhapar	7.27	156	3550	540	21.34	3.1	2.35
43	Dhuler Kalan	7.22	112.2	3940	550	24.80	2.5	1.62
44	Hussainpura	7.04	200.1	2130	640	29.76	2.1	1.72
45	Rataul	7.36	161.4	1875	590	23.17	3.05	1.87
46	Amargarh	7.21	110	1715	565	23.84	2.6	1.8
47	Lasoi	7.01	106.9	1665	625	30.14	2.95	0.99
48	Khanpur	7.21	171.1	1400	590	23.02	2.25	1.92
49	Ratola	6.99	143.6	1550	525	20.46	3.1	1.77
50	Mahali Kalan	7.3	171	1555	595	26.97	2.75	1.54

Table 2. Range and Mean ± SD of physico-chemical characteristics of agricultural field soil

Year	Statistics	pH	EC (µS/cm)	Na (mg/kg)	K (mg/kg)	CEC (meq/100g)	Ca (g/kg)	TOC (%)
2015	Min	6.91	106.50	1340.00	470.00	8.17	1.95	0.87
	Max	7.42	262.50	3940.00	640.00	30.14	4.65	2.49
	Mean	7.19	151.67	1890.70	535.10	21.37	2.82	1.79
	±SD	0.13	38.49	717.74	41.31	4.72	0.61	0.33

Table 3. Correlation among physicochemical characteristics of agricultural field soil

	pH	EC	Na	K	CEC	Ca	TOC
pH	1						
EC	-.401**	1					
Na	-.108	.061	1				
K	-.063	.144	-.097	1			
CEC	-.190	.141	-.166	.668**	1		
Ca	-.108	.146	-.217	-.087	-.085	1	
TOC	-.060	.264	.334*	-.075	-.258	.122	1

**Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table 4. Heavy metals concentration (mg kg^{-1}) in agricultural field soil

S.No.	Villages	Fe	Cu	Zn	Ni	Pb	Co	Cd	Cr
1	Ghamoorghat	2473	155	39	15.5	7	8	0.9	0.45
2	Bhulan	3333	70	89	23.5	7.5	7.5	0.4	0.05
3	Andana	2904	85	25	11	7	8.5	0.35	0.1

4	Makorar sahib	4031.5	170	19	21.5	8.5	10	0.1	0.05
5	Raja heri	3393	160	22.5	17.5	12	6	0.15	0.15
6	Dhela	3972.5	87.5	57.5	10	10.5	6.5	0.75	0.05
7	Chotian	3454	62.5	21.5	15.5	13	7	0.5	0.05
8	Bakhera	2370.5	95	31.5	19.5	10	4.5	0.6	0.2
9	Raidhairana	2711.5	107.5	25	17.5	11	4	0.8	0.15
10	Gaga	2761.5	120	21.5	28	8.5	4.5	0.5	0.25
11	Kohrian	2764.5	112.5	50	13	6.5	6.5	0.2	0.05
12	Hariau	4029.5	105	43	14	9	7.5	0.1	0.15
13	Rogla	2099.5	75	22	11	10	8	0.6	0.2
14	Chatthe Nanhere	1043.5	77.5	32	9.5	6	4.5	0.55	0.15
15	Chhajli	2188.5	187.5	23.5	5	8	5.5	0.85	0.25
16	Kanakwal	875	172.5	31.5	14.5	10.5	6.5	0.45	0.45
17	Dirba	2290.5	145	21.5	17	12	7.5	0.6	0.05
18	Khanal Khurd	2832.5	47.5	36	11.5	6.5	8.5	0.4	0.35
19	Kular Khurd	2778.5	57.5	21.5	8	5.5	7	0.2	0.3
20	Kotla Amru	2071	182.5	26.5	10.5	7.5	6	0.6	0.1
21	Chiman	2421	180	18	11	7	6.5	0.65	0.4
22	Nagran	2954.5	112.5	31	6.5	11	8	0.55	0.1
23	Balad Khurd	3931	172.5	24.5	10	9.5	4	0.5	0.15
24	Nadampur	3292.5	157.5	18.5	7	11.5	4.5	0.3	0.2
25	Bharauh	3772	170	23	12	8.5	10	0.45	0.1
26	Sakraudi	3352.5	175	58	16	7.5	9.5	0.6	0.05
27	Saron	2270	185	21	17	9	8.5	0.7	0.4
28	Illwal	2661	112.5	31	11.5	10	8	0.8	0.1
29	Akoi	2710.5	122.5	25	12.5	6.5	7	0.65	0.35
30	Sheron	2614	107.5	21	10.5	7.5	6.5	0.45	0.3
31	Longowal	3979	130	55	7	8.5	6	0.25	0.4
32	Dhadrian	2622.5	125	16	14.5	7.5	5.5	0.1	0.25
33	Kanoi	3131.5	127.5	29.5	21.5	8.5	7	0.5	0.2
34	Balian	2853	122.5	22.5	9.5	9	6	0.7	0.05
35	Mulowal	3931	135	16	19.5	10	8	0.6	0.35
36	Sherpur	3293.5	145	19.5	16	12	9	0.25	0.25
37	Thuliwal	4022.5	152.5	56	14.5	10.5	5.5	0.45	0.05
38	Ghanauri Khurd	3404	155	19.5	5	9.5	6.5	0.1	0.35
39	Jahagir	2321	162.5	29.5	17.5	10	6	0.2	0.1
40	Babbanpur	2661	160	21	16	9	7	0.35	0.2
41	Kaulsaheri	2865	180	49	26	8.5	6	0.55	0.1
42	Chhapar	3979	70	41	12	10	6.5	0.5	0.25
43	Dhuler Kalan	1999	80	19.5	14.5	9	7	0.6	0.35
44	Hussainpura	992.5	107.5	21	6	8	6	0.7	0.15
45	Rataul	2138	105	29.5	8	7	5.5	0.85	0.3
46	Amargarh	924.5	112.5	19.5	14	5	7.5	0.7	0.15
47	Lasoi	2139.5	120	34.5	16.5	7.5	6.5	0.6	0.35
48	Khanpur	2881.5	127.5	18.5	10	9	7	0.55	0.15
49	Ratola	1971.5	72.5	31	6.5	10	6	0.5	0.35
50	Mahali Kalan	2903.5	70	21	11	9.5	9.5	0.45	0.25

Table 5. Range and Mean ± SD of heavy metals (mg kg^{-1}) in agricultural field soil

Year	Statistics	Fe	Cu	Zn	Ni	Pb	Co	Cd	Cr
2015	Min	875	47.5	16	5	5	4	0.1	0.05
	Max	4031.5	187.5	89	28	13	10	0.9	0.45
	Mean	2787.39	124.6	29.98	13.46	8.85	6.81	0.49	0.20
	± SD	821.46	39.31	14.26	5.24	1.80	1.48	0.21	0.12

Table 6. Inter metal Pearsons correlation in the agricultural field soil

	Fe	Cu	Zn	Ni	Pb	Co	Cd	Cr
Fe	1							
Cu	.067	1						
Zn	.281*	-.142	1					
Ni	.139	.151	.193	1				
Pb	.332*	.102	-.118	.101	1			
Co	.200	-.018	.007	.087	-.068	1		
Cd	-.388**	.000	-.007	-.079	-.088	-.107	1	
Cr	-.251	.011	-.257	-.164	-.205	-.039	.087	1

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

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