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Heavy Metals in Exchangeable Sediments Core along Shatt AL-Arab Estuary

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Abstract In The present study we determined the concentrations of eight heavy metals (Lead, Nickel, Copper, Chrome, Zinc, Cobalt, Cadmium and Iron) in exchangeable phase by using Flame Atomic Absorption Spectrophotometer (FAAS) for sediment core at six stations along Shatt Al-Arab estuary they are: (Al-Qurna, Al-Deer, Al-Qarma, Al-Ashar, Abu-Alkasib and Al-Fao). The Total Organic Carbon (TOC %) and Grain Size were also analyzed. The results obtained for the sediment samples were high except for Cd and Co which were relatively low. They were followed in order as: Fe >Cr > Ni > Zn >Pb>Cu > Co > Cd. Higher concentrations of some heavy metals in sediments indicated that the sediments acted as a sink and source for these metals. Also we observed decreasing values with increasing depth because these layers are oldest age so the decomposition processes took place for a long time as compared with the layers above it. The lowest mean concentration in some stations because of the fewness sources of pollution in this region whereas the highest mean concentration in other stations such as Al-Ashar and Al-Fao station because of there are a lot of pollution sources such as : Sewage pollutants, Industrial wastes, Oil Pollution (Al-Muftia oil refineries) and Municipal Wastes (Al-Ashar river). The highest rate of Total Organic Carbon recorded in Al-Qarma amounted to (1.67%) while the lowest rate recorded in Al-Fao (0.049%) due to the lack of pollution sources in this region. The Grain Size of sediment were also analyzed, the silt and clay was predominate in most of the study stations. There is mainly a significant Correlation between metals and Total Organic Carbon and there is no significant Correlation with grain size.

Keywords Heavy metals, Exchangeable, sediment core, Shatt AL-Arab estuary

Introduction

The Shatt al Arab River is formed after the confluence of the Euphrates and the Tigris Rivers near the city of Al-Quarna in southern Iraq [1]. Downstream of Al-Quarna, the area draining to the Shatt Al-Arab region is shared between Iran and Iraq. In addition to the Euphrates and Tigris Rivers, the Karkheh and the Karun sub-basins contribute water to the Shatt Al-Arab. Both the Karkheh and the Karun Rivers originate in the Zagros Mountains in Iran and discharge into the Shatt Al-Arab. Heavy Metals is an imprecise term generally taken to include the metallic Metals with an atomic weight greater than 40, which have specific gravity greater than $5g/cm^3$. The most important Heavy Metals from the point of view of water pollution are zinc, copper, lead, cadmium, iron, nickel and manganese. Some of these metals (e.g. copper, zinc and iron) are essential Heavy Metals to living organismsand play irreplaceable roles in the functioning of critical enzyme systems , but become toxic at higher concentrations. Others, such as lead and cadmium, have no known biological function, and may be toxic even at Heavy levels to exposure [2]. Pollution sources in Shatt Al-Arab estuary urban areas are both anthropogenic (industrial emission, traffic emission, coal combustion, waste incineration, and agriculture waste) and natural. Urban surface soil acts as sinks for heavy metals and many other pollutants that persist for long time periods. Typically, the heavy metal concentrations are used to measure the pollution status of the sediment core of this important environment.

Materials and Methods

The sediment core samples were taken from six sampling stations which represent different sector of Shatt Al-Arab estuary for analysis and estimation the concentration of some heavy Metals (Cr, Co, Cd, Cu, Pb, Ni, Fe and Zn) in exchangeable phase in these sediment core.GPS instrument is used to fix the positions of these stations. They are : Al-Deer , Al-Qarma , Al-Qurna , Al-Ashar , Abu-Alkasib and Al-Fao as shown in Fig. (1) .Sediment cores (Acid washed PVC pipe of 1m lengthX10 cm diameter) were collected from six stations. The cores were inserted into the water-sediment interface and pushed to ensure that it reached maximum depth. The cores were slowly retrieved back, closed with its cover immediately and marked as to which is the upward direction.

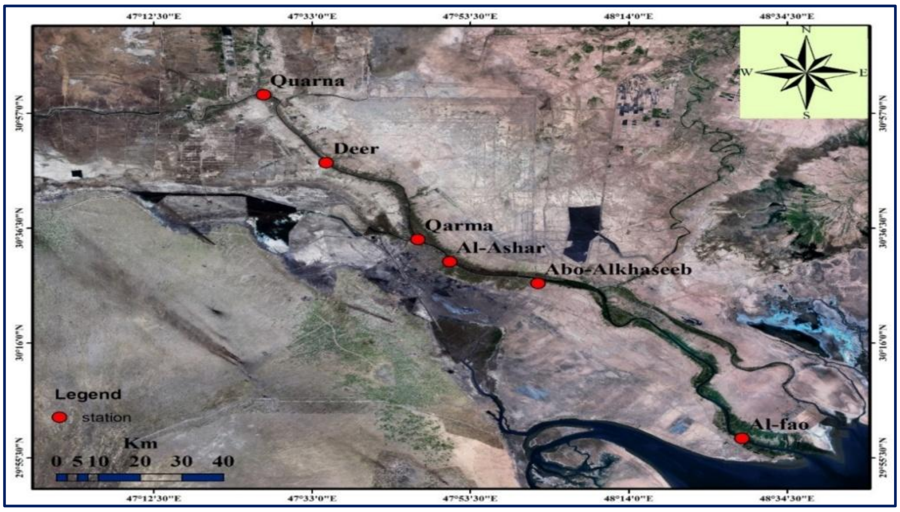

Figure 1: The study stations

The exchangeable heavy metals ions were extracted from sediment according to the method of [3]. Samples were measuring using Flame Atomic Absorption Spectrophotometer (FAAS). The Total Organic Carbon content in the sediment samples was determined according to the method of [4]. Mean grain size were analyzed by using Sedigraph and the grain size (sand, silt , and clay) was determined as percentage of sediments.

Results and Discussion

Results of the present study are shown in Table (1) to (6). The concentrations of lead in the exchangeable phase inversely proportional with the depth for all stations, whereas the highest value of concentrations of lead in the exchangeable phase was (37.54 µg/g dry weight) at (0-5 cm) depth in Al-Ashar station and the lowest value was (20.15 µg/g dry weight) at (45-50 cm) depth in Al-Deer station , the highest mean value (32.97 µg/g dry weight) in Al-Ashar station and the lowest mean value (28.29 µg/g dry weight) in Al-Qarma station.The increasing in Pb concentrations are due to Iraq –Iran war and the Gulf war 1and 2 a lot of shooting and military actions were done during these times which release Pb to the environments. The concentrations of Nickel inversely proportional with the depth for all stations except Al-Fao station, whereas the highest value of concentrations of Nickel in the exchangeable phase was (65.93 µg/g dry weight) at (0-5 cm) depth in Al-Fao station and the lowest value was (30.07 µg/g dry weight) at (45-50 cm) depth in Al-Ashar station, the highest mean value (52.65 µg/g dry weight) in Abu-Alkasib station and the lowest mean value (43.84 µg/g dry weight) in Al-Qurna station. The increasing in Ni concentrations are due to the oil refinery of Abadan discharge [5]. The concentrations of Copper inversely proportional with the depth for all stations, whereas the highest value of concentrations of Copper in the exchangeable phase was (26.49 µg/g dry weight) at (0-5 cm) depth in Abu-Alkasib station and the lowest value was (9.17 µg/g dry weight) at (45-50 cm) depth in Al-Deer station, the highest mean value (20.70 µg/g dry weight) in Al-Qarma station and the lowest mean value (14.94 µg/g dry weight) in Al-Deer station.This fluctuation in Cu concentrations is mainly due to the different source of pollution in these stations such as the discharge of Industrial wastes, Oil refinery, sewage pollution [5].The concentrations of Chrome inversely proportional with the depth for all stations, whereas the highest value of concentrations of Chrome in the exchangeable phase was (65.91 µg/g dry weight) at (0-5 cm) depth in Al-Fao station and the lowest value was (50.88 µg/g dry weight) at (45-50 cm) depth in Al-Deer station, the highest mean value (60.07 µg/g dry weight) in Al-Ashar station because of the sewage pollution and the lowest mean value (54.55 µg/g dry weight) in Al-Qurna station. The concentrations of Zinc inversely proportional with the depth for all stations, whereas the highest value of concentrations of Zinc in the exchangeable phase was (43.17 µg/g dry weight) at (0-5 cm) depth in Al-Qarma station and the lowest value was (23.34 µg/g dry weight) at (45-50 cm) depth in Al-Qarma station, the highest mean value (36.63 µg/g dry weight)in Al-Ashar station due to effects of interior rivers discharge such as Al-Khorah river and Al-Rebat river, and the lowest mean value (31.89µg/g dry weight)in Abu-Alkasib station. The concentrations of Cobaltinverselyproportional with the depth for all stations, whereas the highest value of concentrations of Cobalt in the exchangeable phase was (15.85 µg/g dry weight) at (0-5 cm) depth in Al-Ashar station and the lowest value was (4.46 µg/g dry weight) at (45-50 cm) depth in Al-Deer station, the highest mean value (12.47 µg/g dry weight)in Al-Ashar station because of there are a lot of pollution sources such as: Sewage pollutants, Industrial wastes, Oil Pollution (Al-Muftia oil refineries) and Municipal Wastes (Al-Ashar river). and the lowest mean value (8.67 µg/g dry weight) in Al-Deer station. The concentrations of Cadmium inversely proportional with the depth for all stations, whereas the highest value of concentrations of Cadmium in the exchangeable phase was (13.32 µg/g dry weight) at (0-5 cm) depth in Al-Qarma station and the lowest value was (5.01 µg/g dry weight) at (45-50 cm) depth in Al-Qurna station, the highest mean value (11.20 µg/g dry weight)in Al-Qarma station and the lowest mean value (8.07µg/g dry weight) in Al-Qurna station. The increasing of Cd due to increased human activities and continued launch of pollutants without treatment. The concentrations of Iron inversely proportional with the depth for all stations except Al-Deer station, whereas the highest valueof concentrations of Iron in the exchangeable phasewas(4987.92 µg/g dry weight) at (0-5 cm) depth in Al-Qarma station and the lowest value was (950.78 µg/g dry weight) at (45-50 cm) depth in Al-Qurna station, the highest mean value (4169.79 µg/g dry weight)in Al-Qarma station and the lowest mean value (2026.62 µg/g dry weight)in Al-Qurna station. This fluctuation in concentration of Fe due to the seasonal changes and weather Conditions of heat, light, wind speed and erosion and sedimentation processes which affect the sedimentation of Iron as a result of oxidation and reduction processes.

In Al-Ashar, Abu-Alkasib and Al-Fao stations Pollution is continuously becoming a serious problem, mainly caused by the disposal of untreated sewage and industrial waste, nitrates from animal waste and chemical fertilizers. It is important to report that the continuous increase the demographic and the urbanized expansion and the increased weight for inhabitants of the cities. However, rivers in urban areas play a major role in carrying of industrial and municipal wastewater,manure discharges and runoff from agricultural fields and streets, which are responsible for river pollution [6-7].

In this study there is mainly a Significant Correlation between metals at ($p > 0.05$) as shown as Table (9).

Table 1: Concentration of Exchangeable Heavy Metals (µg/g) dry weight in sediment core from Al-Qurna station

Depth cm	pb	Ni	Cu	Cr	Zn	Co	Cd	Fe
0-5	37.24	62.48	20.68	60.24	41.09	11.98	10.95	2856.11
5-10	36.48	60.03	19.79	59.93	40.5	11.9	10.56	2651.61
10-15	36.17	57.21	19.75	59.33	39.91	10.88	9.28	2427.42
15-20	30.89	53.23	15.3	56.84	39.66	10.48	9.14	2279.75
20-25	30.75	50.26	15.09	56.13	39.33	8.59	9.22	2686.18
25-30	30.3	44.37	12.75	54.96	30.94	8.04	8.11	1489.59
30-35	29.17	44.13	12.31	54.8	30.66	7.92	8.04	1225.15
35-40	25.72	35.78	12.83	51.91	29.04	6.27	7.3	1175.09
40-45	23.89	35.37	11.73	51.41	27.61	6.16	6.16	1952.68
45-50	20.15	30.75	9.17	50.88	26.25	4.46	6.05	1685.81
Total	300.76	473.61	149.4	556.43	344.99	86.68	84.81	20429.39
Mean	30.076	47.361	14.94	55.64	34.50	8.67	8.481	2042.94
±SD	5.65	11.07	3.94	3.50	6.07	2.59	1.67	624.79

Table 2: Concentration of Exchangeable Heavy Metals (µg/g) dry weight in sediment core from Al- Deer

Depth cm	pb	Ni	Cu	Cr	Zn	Co	Cd	Fe
0-5	35.54	60.55	20.72	60.71	40.32	10.96	10.76	3850.65
5-10	33.92	58.63	19.65	58.54	39.95	10.81	10.34	2538.61
15-20	33.62	53.79	19.27	58.35	37.19	10.45	10.02	2485.21
20-25	33.45	47.65	19.19	54.92	35.71	10.35	8.65	2238.42
25-30	31.24	47.35	15.55	54.31	33.44	10.11	8.49	2077.83
30-35	30.72	38.72	12.48	52.62	31.42	9.89	7.62	2126.4
35-40	29.41	38.14	12.12	52.16	29.61	9.75	7.16	1562.73
40-45	29.63	32.23	11.84	51.74	27.63	9.43	7.04	1369.61
45-45	29.33	30.77	10.22	51.13	26.72	9.28	5.61	1065.92
45-50	29.29	30.54	10.06	51.05	25.63	8.79	5.01	950.78
Total	316.15	438.37	151.1	545.53	327.62	99.82	80.7	20266.16
Mean	31.62	43.84	15.11	54.55	32.76	9.98	8.07	2026.62
±SD	2.32	11.38	4.25	3.49	5.41	0.69	1.95	855.32

Table 3: Concentration of Exchangeable of Heavy Metals (µg/g) dry weight in sediment core from Al- Qarma

Depth cm	Pb	Ni	Cu	Cr	Zn	Co	Cd	Fe
0-5	31.72	63.93	24.51	63.91	43.17	14.87	13.32	4987.92
5-10	30.49	58.13	23.35	62.96	41.17	14.23	13.14	4598.19
10-15	30.27	55.14	23.22	61.9	39.56	13.43	12.11	4568.18
15-20	29.71	52.9	22.35	59.26	37.55	12.87	12.04	4357.16
20-25	28.27	46.57	21.65	58.28	36.11	12.12	11.26	4248.49
25-30	27.51	42.75	21.22	56.02	35.06	11.8	11.16	4149.66
30-35	27.34	37.95	19.34	55.02	31.91	11.21	10.73	4024.76
35-40	26.53	34.2	18.77	53.19	27.82	10.83	10.36	3951.27
40-45	25.61	33.4	17.61	52.19	25.05	10.82	9.58	3482.92
45-50	25.47	32.48	15.02	51.89	23.34	9.49	8.33	3329.33
Total	282.92	457.45	207.04	574.62	340.74	121.67	112.03	41697.88
Mean	28.29	45.75	20.70	57.46	34.07	12.17	11.20	4169.79
±SD	2.17	11.33	2.97	4.48	6.84	1.68	1.55	505.55

Table 4: Concentration of Exchangeable of Heavy Metals (µg/g) dry weight in sediment core from Al-Ashar

Depth cm	pb	Ni	Cu	Cr	Zn	Co	Cd	Fe
0-5	37.54	63.88	23.11	64.26	43.1	15.85	11.92	3425.15
5-10	36.92	63.55	22.76	64.01	42.75	14.87	11.44	3256.26
10-15	36.65	63.05	22.2	63.53	42.5	14.82	10.19	3121.59
15-20	36.46	59.78	20.32	60.71	40.27	14.58	11.75	3085.23
20-25	31.92	52.77	19.79	60.13	40.19	13.28	11.61	2925.31
25-30	31.72	52.53	19.23	59.13	35.4	11.52	10.45	2895.1
30-35	31.52	46.88	19.06	58.1	35.24	11.26	9.63	2852.16
35-40	30.64	46.26	18.45	58.48	30.82	10.35	9.27	2554.23
40-45	28.2	37.53	18.54	58.08	30.67	10.25	9.11	2212.24
45-50	28.11	30.07	14.12	54.22	25.39	7.92	7.49	1025.18
Total	329.68	516.3	197.58	600.65	366.33	124.7	102.86	27352.45
Mean	32.97	51.63	19.76	60.07	36.63	12.47	10.29	2735.25
±SD	3.63	11.58	2.63	3.18	6.14	2.59	1.44	693.23

Table 7 shows that the concentrations of Total Organic Carbon (TOC %) inversely proportional with the depth for all stations, whereas the highest value of concentrations of Total Organic Carbon (TOC %) was (1.67 µg/g dry weight) at (0-5) in Al-Qarma station, the lowest value was (0.049 µg/g dry weight) at (45-50 cm) in Al-Fao station. There is mainly a significant Correlation between metals and TOC%.

Table 5: Concentration of Exchangeable of Heavy Metals (µg/g) dry weight in sediment core from Abu- Alkasib

Depth cm	Pb	Ni	Cu	Cr	Zn	Co	Cd	Fe
0-5	32.3	61.53	26.49	65.01	42.94	12.74	11.48	4261.56
5-10	31.63	61.21	26.11	64.49	41.92	12.15	11.32	4125.47
10-15	31.54	60.14	24.85	61.24	39.53	11.4	10.95	3987.18
15-20	31.23	55.97	24.4	60.24	30.14	11.14	10.75	3562.66
20-25	29.71	55.88	21.03	58.91	30.07	10.18	9.29	3485.87
25-30	29.37	50.87	20.57	58.54	28.97	10.04	9.15	3258.59
30-35	28.24	50.39	16.26	58.2	28.28	9.25	8.61	3025.28
35-40	24.92	48.23	16.88	54.91	26.82	8.87	8.21	2836.3
40-45	24.11	42.23	13.01	54.5	26.78	8.55	5.42	2551.25
45-50	21.61	40.07	10.61	51.39	23.41	8.25	5.22	2245.68
Total	284.66	526.52	200.21	587.43	318.86	102.57	90.4	33339.84
Mean	28.47	52.65	20.02	58.74	31.89	10.26	9.04	3333.98
±SD	3.69	7.63	5.62	4.32	6.93	1.56	2.27	677.79

Table 6: Concentration of Exchangeable Heavy Metals (µg/g) dry weight in sediment core from Al-Fao station

Depth cm	pb	Ni	Cu	Cr	Zn	Co	Cd	Fe
0-5	31.72	65.93	22.51	65.91	41.17	13.95	12.06	4261.66
5-10	30.71	54.13	21.18	64.15	40.16	12.17	11.75	4125.66
10-15	30.27	50.94	20.42	60.9	39.56	11.93	11.33	3562.27
15-20	30.23	50.6	20.35	60.26	39.55	11.27	10.64	3250.92
20-25	28.97	51.57	18.65	60.28	39.11	11.12	10.31	3211.33
25-30	28.51	48.75	18.22	59.52	36.96	10.8	10.25	3200.83
30-35	27.34	41.2	17.84	58.92	36.81	10.21	10.06	2835.92
35-40	26.53	46.4	17.77	58.19	32.82	9.83	8.16	2751.19
40-45	26.11	36.48	14.61	53.19	32.05	8.22	9.78	2635.18
45-50	25.47	33.65	13.02	51.89	25.34	8.49	9.76	2567.19
Total	285.86	479.65	184.57	593.21	363.53	107.99	104.1	32402.15
Mean	28.59	47.97	18.46	59.32	36.35	10.80	10.41	3240.22
±SD	2.15	9.28	2.92	4.29	4.93	1.72	1.13	592.10

Table 7: Concentration of Total Organic Carbon (TOC %)

Depth (cm)	Al-Qurna	Al-Deer	Al-Qarma	Al-Ashar	Abu-Alkasib	Al-Fao
0-5	1.176	0.5145	1.67	1.176	1.056	0.7595
5-10	0.931	0.441	1.61	0.816	1.008	0.686
15-20	0.588	0.441	1.32	0.792	0.984	0.6125
20-25	0.539	0.4165	1.27	0.744	0.936	0.49
25-30	0.441	0.392	1.26	0.696	0.912	0.343
30-35	0.367	0.3675	1.15	0.48	0.912	0.2695
35-40	0.269	0.343	0.98	0.456	0.84	0.1715
40-45	0.196	0.319	0.94	0.336	0.768	0.098
45-45	0.147	0.269	0.9	0.216	0.768	0.098
45-50	0.12	0.25	0.82	0.144	0.72	0.049
Total	4.78	3.75	11.92	5.86	8.90	3.58
Mean	0.48	0.37	1.19	0.59	0.89	0.36
±SD	0.35	0.08	0.29	0.32	0.11	0.26

The percentage of sand, silt, and clay is descried in the grain size analysis (Table 8), showed the dominant of silt and clay in all the sediments in the study stations with little share of sand fraction.
There is no significant Correlation between metals and grain size as shown as Table 9.

Table 8: Grain Size Analysis of Sediment Core Samples in Study Stations

	Al-Qurna				Al-Deer				Al-Qarma			
Depth(cm)	**Sand**	**Silt**	**Clay**	**Texture**	**Sand**	**Silt**	**Clay**	**Texture**	**Sand**	**Silt**	**Clay**	**Texture**
0-5	%10	%74	%16	Silty clay	%35	%55	%10	Silty sand	%38	%54	%8	Silty sand
5-10	%12	%71	%17	Silty clay	%36	%56	%8	Silty sand	%36	%54	%10	Silty sand
10-15	%11	%64	%25	Silty clay	%27	%59	%14	Silty sand	%33	%55	%12	Silty sand
15-20	%12	%61	%27	Silty clay	%12	%72	%16	Silty clay	%27	%55	%18	Silty sand
20-25	%12	%63	%25	Silty clay	%9	%72	%19	Silty clay	%26	%54	%20	Silty sand
25-30	%18	%63	%19	Silty clay	%6	%74	%20	Silty clay	%0	%58	%42	Silty clay
30.35	%22	%58	%20	Silty sand	%6	%70	%24	Silty clay	%0	%60	%40	Silty clay
35-40	%22	%60	%18	Silty sand	%8	%72	%20	Silty clay	%23	%62	%15	Silty sand
40.45	%23	%63	%14	Silty sand	%6	%76	%18	Silty clay	%20	%66	%14	Silty sand
45-50	%18	%65	%17	Silty sand	%6	%76	%18	Silty clay	%21	%69	%10	Silty sand
	Al-Ashar				**Abo-Alkasib**				**Al-Fao**			
Depth(cm)	**Sand**	**Silt**	**Clay**	**Texture**	**Sand**	**Silt**	**Clay**	**Texture**	**Sand**	**Silt**	**Clay**	**Texture**
0-5	%10	%64	%26	Silty clay	%0	%91	%9	Silty clay	%1	%64	%35	Silty clay
5-10	%17	%64	%28	Silty clay	%0	%90	%10	Silty clay	%1	%64	%35	Silty clay
10-15	%11	%64	%25	Silty clay	%0	%80	%20	Silty clay	%3	%64	%33	Silty clay
15-20	%10	%64	%26	Silty clay	%1	%62	%37	Silty clay	%4	%64	%32	Silty clay
20-25	%8	%62	%30	Silty clay	%1	%62	%37	Silty clay	%2	%69	%29	Silty clay
25-30	%7	%63	%30	Silty clay	%5	%66	%29	Silty clay	%2	%70	%28	Silty clay
30.35	%9	%60	%31	Silty clay	%9	%69	%22	Silty clay	%7	%71	%22	Silty clay
35-40	%11	%61	%28	Silty clay	%9	%71	%20	Silty clay	%6	%75	%19	Silty clay
40.45	%11	%63	%26	Silty clay	%12	%70	%18	Silty clay	%8	%72	%20	Silty clay
45-50	%5	%69	%26	Silty clay	%12	%70	%18	Silty clay	%9	%69	%22	Silty clay

Table 9: Correlation coefficient

	pb 1	Ni 1	Cu1	Cr1	Zn 1	Co1	Cd1	Fe1	pb 2	Ni 2	Cu2	Cr2	Zn2	Co2	Cd2	Fe2	toc	Sand	silt	Clay
pb 1	1	.754**	.573**	.657**	.757**	.699**	.542**	.203	.681**	.730**	.817**	.705**	.754**	.654**	.520**	.551**	.238	.210	-.255-*	.013
Ni 1	.754**	1	.802**	.903**	.856**	.748**	.719**	.588**	.911**	.721**	.870**	.877**	.820**	.837**	.616**	.412**	.551**	.038	-.055	.032
Cu1	.573**	.802**	1	.884**	.745**	.820**	.884**	.837**	.858**	.508**	.729**	.801**	.706**	.721**	.503**	.366**	.703**	-.005	-.119	.137
Cr1	.657**	.903**	.884**	1	.858**	.815**	.815**	.690**	.871**	.685**	.806**	.882**	.778**	.769**	.442**	.479**	.532**	-.056	-.045	.138
Zn 1	.757**	.856**	.745**	.858**	1	.765**	.782**	.544**	.882**	.843**	.848**	.907**	.814**	.776**	.453**	.463**	.408**	.077	-.084	.009
Co1	.699**	.748**	.820**	.815**	.765**	1	.825**	.703**	.727**	.597**	.788**	.709**	.698**	.613**	.376**	.644**	.632**	.238	-.382-**	.098
Cd1	.542**	.719**	.884**	.815**	.782**	.825**	1	.828**	.816**	.518**	.724**	.805**	.664**	.723**	.317*	.428**	.633**	.087	-.250	.144
Fe1	.203	.588**	.837**	.690**	.544**	.703**	.828**	1	.688**	.279*	.496**	.628**	.486**	.553**	.335**	.172	.815**	.057	-.146	.072
pb 2	.681**	.911**	.858**	.871**	.882**	.727**	.816**	.688**	1	.730**	.830**	.937**	.801**	.831**	.592**	.308*	.591**	.049	-.120	.072
Ni 2	.730**	.721**	.508**	.685**	.843**	.597**	.518**	.279*	.730**	1	.730**	.783**	.757**	.559**	.571**	.301*	.231	.118	-.066	-.059
Cu2	.817**	.870**	.729**	.806**	.848**	.788**	.724**	.496**	.830**	.730**	1	.796**	.743**	.696**	.521**	.611**	.531**	.233	-.243	-.028
Cr2	.705**	.877**	.801**	.882**	.907**	.709**	.805**	.628**	.937**	.783**	.796**	1	.791**	.825**	.516**	.306*	.489**	.059	-.093	.032
Zn2	.754**	.820**	.706**	.778**	.814**	.698**	.664**	.486**	.801**	.757**	.743**	.791**	1	.669**	.628**	.370**	.396**	-.035	-.015	.087
Co2	.654**	.837**	.721**	.769**	.776**	.613**	.723**	.553**	.831**	.559**	.696**	.825**	.669**	1	.506**	.285*	.553**	.132	-.071	-.082
Cd2	.520**	.616**	.503**	.442**	.453**	.376**	.317*	.335**	.592**	.571**	.521**	.516**	.628**	.506**	1	-.143	.523**	.100	.007	-.129
Fe2	.551**	.412**	.366**	.479**	.463**	.644**	.428**	.172	.308*	.301*	.611**	.306*	.370**	.285*	-.143	1	.186	.076	-.247	.201
toc	.238	.551**	.703**	.532**	.408**	.632**	.633**	.815**	.591**	.231	.531**	.489**	.396**	.553**	.523**	.186	1	.244	-.215	-.092
Sand	.210	.038	-.005	-.056	.077	.238	.087	.057	.049	.118	.233	.059	-.035	.132	.100	.076	.244	1	-.608-**	-.656-**
silt	-.255-*	-.055	-.119	-.045	-.084	-.382-**	-.250	-.146	-.120	-.066	-.243	-.093	-.015	-.071	.007	-.247	-.215	-.608-**	1	-.190
Clay	.013	.032	.137	.138	.009	.098	.144	.072	.072	-.059	-.028	.032	.087	-.082	-.129	.201	-.092	-.656-**	-.190	1

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

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