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Soil Pollution: A Case Study on the Determination of Toxic Elements in Soil in Jeddah City, Saudi Arabia

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Abstract

A considerable increase in the population of Jeddah City and the construction of new residential areas in the last few years has been noticed. Thus, a total of 23 soil samples were collected from three different areas of Sewage Lake, namely, Area A (polluted; the highest concentration of toxic elements), Area B (Southeast), and Area C (Northwest) for the analysis of toxic elements. The soil samples were digested by acid digestion to quantify the As, Co, Cr, Hg, Ni, V, Pb, and Zn using Inductively Coupled Plasma- Optical Emission Spectrometry (ICP-OES). Zn has the highest concentration in all studied areas (4821±10.2 mg/kg for A, 1108.6±9.5 mg/kg for B and 2339.8±8.7 mg/kg for C). On the other hand, Cr concentration was found 872±2.5 mg/kg for A, 1128±5.4 mg/kg for B and 680±3.4 mg/kg for C. These elements were above the level of the quality guidelines (300 mg/kg for Zn and 4.0 mg/kg for Cr). In majority of the area C samples, the concentration of Hg was found below the detection limit. The results indicated that the area A has a significantly higher metal contents as it is an inference polluted area. Hence, it is influencing the level of metal concentrations in area B, and area C might be due to wind spread. The indiscriminate disposal of hazardous waste in the study area causes a significant source of the soil contamination.

Keywords: Heavy metal, Jeddah, Saudi Arabia, Sewage Lake, Soil assessment

1. Introduction

There has been an immense amount of global concern over the last three decades about attributing polluted environmental influences to the public health (UNEP 2011). The World Health Organization estimates that about a quarter of the diseases facing humaneness nowadays occur due to the long exposures of environmental pollution. In many cities, the inappropriate management of solid waste was the main reason of environmental pollution even in the developed countries (Sow et al., 2013). In urban areas, toxic elements can be easily transmitted into the human body because of inhalation, dermal contact absorption, and ingestion. Then, because of their non-biodegradable nature and long biological half-lives for eliminating the heavy metals accumulated in the human body (Li Z et al., 2014; Zhao et al., 2012).

Solid wastes have been classified as garbage, rubbish, household refuse, and litter. It is well known that the sea dumping (creates water pollution and destroys marine habitats), incineration (leads to atmospheric pollution, if not conducted under controlled conditions), The landfill (the most widely used method till its limitations are realized in recent years), and recycling were the four main ways of disposing of solid wastes (Lim et al., 2008). Moreover, the elements travel for considerable distances were also deposited onto the soil, vegetation, and water depending on their density (Alloway and Ayres, 1997). Solid pollutants can be a source of air and water pollution. In addition, open dumps were a cause of land pollution. Therefore, Solid wastes discharged into the water can be hazardous to aquatic life directly or indirectly (Kelepertzis, 2014).

Jeddah is the most important commercial city in the Kingdom of Saudi Arabia. The UNESCO recognizes the historical town of Jeddah as World Heritage site (CIA, 2012; Habibullah, 2014). It has not been dated precisely that Jeddah as a coastal settlement was a transit point for Eastern trade in the past. However, the environmental pollution has always been one of the last concerns when it comes to the city activates and development. Since1962, Jeddah has been expanding rapidly at an astonishing rate. The biggest source of pollution was the sewage lake in Jeddah (Jeddah east) because it contained toxic elements due to the deposition of water in the residential area (Magram, 2009). Toxic elements, such as As, Ba, Be, Cr, Cd, Pb, Hg, Ni, and Zn, are the presence of the waste of incineration and coal combustion, which may be detrimental to human health from their exposure to emissions (Lawrence, et al., 2005). The industrialization of modern societies resulted in a vast increase of refuse generated per person. In 2016 Saudi Arabia, solid waste reached 15 million tons per year, commonly known as trash or garbage more than 6 million tons per year the solid waste rate of the three biggest cities- Riyadh, Jeddah, Dammam (EcoMENA, 2016).

Natural concentrations of toxic elements in soil derive either from the weathering of parent bedrock or come from some external source. Organic metal species are often more bioavailable and hence potentially more hazardous to higher organisms (Ron, et al., 1992). The experimental conditions, pH, redox potential, clay mineral, organic matter and water contents, have significant impacts on the mobility of heavy metals in soil. Different methods (adsorption-desorption, complex and ion-pair formation or activities of microorganisms (Gabler, 1997)) have been used in the removal of heavy metals from the soils. The most mobile is the element and complex cations, medium mobility is the exchangeable cations in organic and inorganic complexes and, slightly mobile are the chelated cations.

In Jeddah city, the Sewage Lake represents a danger to the environment surrounding it. Although it is dried in (2011) by Jeddah Municipality, toxic elements accumulated in the sediment can be translocated to the residential areas around by the blowing wind. However, there has been no systematic gathering and inter-comparison of toxic element concentrations, their levels of contamination and pollution sources. Therefore, the present article reports the levels of selected toxic metal content and subsequent soil pollution levels in Jeddah urban soils. The sample collection, sources, contamination levels, and analytical tools used are presented in this study.

2. Methods and Materials

2.1 Study Area

Jeddah has expanded in the last three decades, and the expansion continues at an unpredictable rate. New districts have continued to grow and accommodate the increasing population. Growth is also occurring in the countryside of Jeddah. One of the largest sources of pollution in the city of Jeddah is the presence of Sewage Lake (established since 1992), which extends over an expanse of 2.6 km^2. It became the central sewage downstream, with the passage of time, the stretch of residential areas, the lake poses a danger to the neighborhoods adjacent to the lake, as it became filled with toxic elements, which affecting the soil, air, and water. The movement of these elements became easier with rising water to approximately 19 million m^3. One of these new residential areas is located nearby the Sewage Lake. It is a one of the largest sources of pollution, located east of the city, east of the highway along the way Hada al-Sham extended to the Makah. Over 17 km away from the study area (districts: Al Samer 1, 2, 3, 4, and 5, and Al -Ajwad in the northwest of the lake and the National Park area in the southeast of the lake. The lake presents a substantial risk to the area surroundings and the population (Jeddah Municipality, 2010).

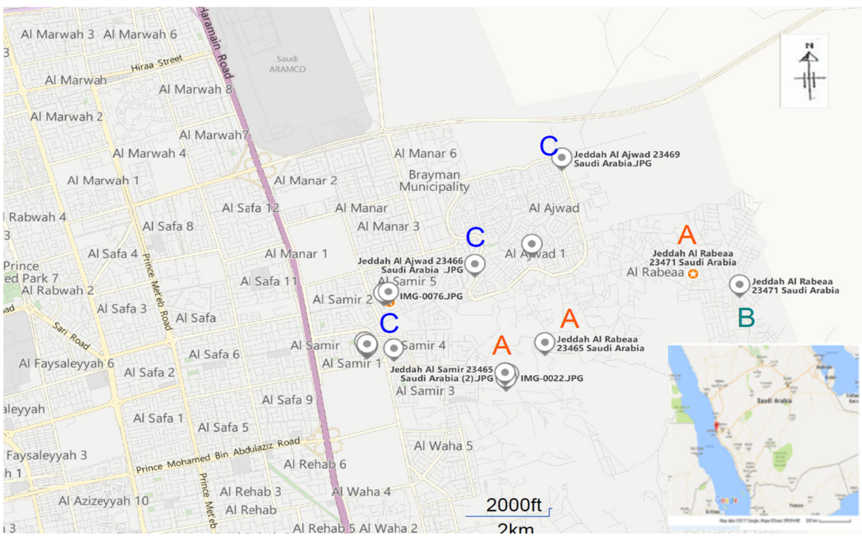

Figure 1. Location of soil samples at the Polluted area (A), Southeast polluted area (B), and Northwest polluted area (C).

Table 1. Locations and numbers of samples of the studied areas, Jeddah, Saudi Arabia

Sample	Areas	Locations
1	A	Dam lake, Jeddah Al Rabeaa 23471 Saudi Arabia
2		Lake (color of the soil is light brown)
3		Lake (color of the soil is dark brown)
4		Lake's flood, Al Samir 23465 Jeddah
5		Dam, Jeddah Al Samir 23465
6		Dam near the lake, Jeddah Al Samir 23465
7	B	Border of National Park, 21.580239, 39.263786
8		Center of the National Park
9		National park under the trees
10	C	2868 Mohammed Bin Abdulla Al Amawi Street Jeddah Al Samir 23461-7384
11		3959 Abi Abdulrahman Al-Qaseer Street Jeddah Al Samir 23462-6579
12		3321 Ismail Al Mekali Street Jeddah Al Samir 23464-7245
13		Park, 2924 Ali Bin Mohammad Al Bayyari Street Jeddah Al Samir 23461-7329
14		Center of the park, 2924 Street Al Aasha Al Mazni
15		Border of the park, 2924 Street Al Aasha Al Mazni
16		Football playground in the park – AL Samer 5
17		Children playground AL Samer 5- Street Omar Bin Hussein
18		Football children playground, 6538 Omar Bin Husain Street Jeddah Al Samir 23462-3888
19		Border of the park, 6538 Street Omar Bin Hussein
20		Circular, Jeddah Al Ajwad 23469
21		Circular street in AL Ajawad -street Solayman Bin Morad
22		Border of the park, AL Ajawad 3887 Sulaiman Murad Street Jeddah Al Ajwad 23466-6713
23		Center of the park, Jeddah Al Ajwad 23466

2.2 Sampling and Soil Sample Preparation

The overall number of soil samples is 23, which were collected from the three distinct areas by using top surface soil having 5–10 cm depth. These three distinct areas (A, B, C): 1- Area (A) (6 samples) represents the lake drainage and the area around it which have, contaminated water of the lake, due to the flood to the valley and the low-lying area. 2- National Park, area (B), (3 samples) located southeast of the lake and are irrigated by the water recycled from the lake. 3- Residential neighborhoods adjacent to the lake, area (C) (14 samples) in the northwest and whose levels are below the lake level. Samples are collected from public parks the soccer field for children (16 to 19) and open land. The sampling points and their locations are shown in Fig. 1, and listed in Table 1. Soil samples were dried by spreading out on a clean plastic sheet over a bench in the laboratory, stones and plant roots were removed manually. Samples were left to dry at room temperature for a week. Air-dried samples were sieved through a 1.4 mm stainless steel sieve, and the samples were stored at room temperature in self-sealing plastic bags. The pH of the samples was measured by using a digital pH meter (Mettler Toledo MP220), and the range was found to be a 7.45 - 9.3. The average conductivity of the soil was 3000µs.

2.3 Concentration of Samples in the Soil

The acid digestion technique was used for the determination of environmentally toxic elements (Ure, 1995) even at low concentration. Aqua regia was prepared by mixing three parts 6 M HCl to one part HNO_3 6M. Soil samples (0.5g) were weighed using a four-figure balance in three replicates. Each sample was poured into a 50 ml beaker containing 10 ml of aqua regia solution. The solution was allowed to stand for at least 12 h to allow the acid to equilibrate with the soil, which was placed on the hot plate preheated at 125^0C. The digestion was run for 3 h until the evaluation of brown gas. The beakers were cooled and a 10 ml of deionized water was added for dilution. The digests were filtered using a hardened filter paper Whatman No. 50, and washed with deionized water. The filtrate and washing were collected in 50 ml volumetric flasks and made up to volume. Average values of three replicas were taken for each determination for precision and accuracy. Samples were measured by ICP-OES (7000 DV Perkin Elmer).

3. Results and Discussion

3.1 Acid Digestion

The toxic metals concentrations are summarized in Table 2, and representative data are depicted in Fig. 3. It was detected that the study areas have the highest Zn content (4821±10.2 mg/kg for A, 1108.6±9.5 mg/kg for B and 2339.8±8.7 mg/kg for C) and obvious is much higher than the tolerable level 300 mg/kg for Zn. The Zn concentration in the area (A) is low in the drainage lake. The fact that the lake is a waterborne sewage from homes, which has a high zinc content due to the containment of water by the zinc composition of the detergents and soap. In all areas Cr concentration was found very high 872±2.5 mg/kg for A, 1128±5.4 mg/kg for B and 680±3.4 mg/kg for C, comparing with the permissible limit 4.0 mg/kg. Many of the metals have a strong affinity to a natural organic material because of its many functional groups. Therefore, it is adsorbed and accumulated in the upper soil layers, which has most abundant organic materials. Metal ions may also have adsorbed on the surface of the clay mineral and Mn, Fe and Al oxides/hydroxides. In general, Pb and Cu are adsorbed most strongly, while Zn and Cd are adsorbed more weakly to the soil. Consequently, the metals which are adsorbed less strongly are more bioavailable (Ron, et al., 1992). Zn and V followed the descending order: area (A) > area (C) > area (B). The average grades and tolerable level of toxic metals using aqua regia digestion in area A, B, and C are listed in Table.3. Moderately high concentration of Pb was noticed in the area (A) (700.5±149 mg/kg), in the northwest to the polluted area (C) is (674.6±184 mg/kg) and in area (B) the southeast is (792.33±167 mg/kg) this high concentration of Pb in area B may be due to the irrigation of the soil by recycling water from the sewage lake. As, Co, and Hg followed the descending order: area (A) > area (B) > area (C). Ni and Cr exist in the orders area (B) > area (A) > area (C), the high concentration in area B might be due to wind blowing.

The direction of the wind in the city of Jeddah from south to north leads to the movement of air from the contaminated area to the northwestern region, which includes the neighborhoods adjacent to the lake. Thus the concentration of toxic elements is less in the southeastern region, including the National Park which is located almost a back of the lake drainage and thus the direction of the wind does not help in the transmission of heavy elements to it. Also in this region is geographically higher than the area of Sewage Lake; hence water rains and floods spread from the highlands to the lower area, and thus led lake water flood to the northwestern region. Air winds carry the dust particles who contaminated by heavy metals. It remains in the air for varying the length of time depending on the size of the carrying particle, relative humidity, and wind speed and precipitation amount. The particles with a diameter < 10 µm may remain in the atmosphere for 10-30 days and are removed primarily by washout and can be transported several thousand kilometers away from their sources, depending on the air mass movements (Sow, et al., 2013).

Adham, et al., 2011 have reported the toxic metal pollution in Riyadh city. The levels of Ni, Cu, Pb and Hg were found 14.37, 53.64, 5.223 and 0.24 µg g^{-1}, respectively. Thus, the metal concentrations in this study were higher than those from that the mean concentrations of Cu, Zn and Pb in the soil of Shenyang, China reached to 51.26, 140.02 and 75.29 mg/kg, respectively. The Hong Kong (0.36±0.16 $mgkg^{-1}$Cd, 16.2±5.92 $mgkg^{-1}$Cu, and 103±91.3 $mgkg^{-1}$Zn) (Odewande, and Abimbola, 2008). The Thrace region (0.2 $mgkg^{-1}$, Cd 20 $mgkg^{-1}$Cu, 33 $mgkg^{-1}$ Pb and 45 $mgkg^{-1}$ Zn) (Lee, et al., 2006) the Zagreb region (20.8mg kg^{-1}Cu, 25.9 $mgkg^{-1}$Pb and 77.9 $mgkg^{-1}$ Zn) (Cos, et al., 2006). The worldwide average and much lower than other cities, e.g. Ibadan (8.4±19.78 $mgkg^{-1}$Cd, 95.1±126.68 $mgkg^{-1}$Pb and 228.6±366.28 $mgkg^{-1}$Zn) (Romic, and Romic D., 2003) and Mortagne du Nord (1.92±0.81 $mgkg^{-1}$ Cd and 230.8±146.3 $mgkg^{-1}$Pb) (Douay, 2007).

Table 2. Concentrations (mg/kg) Average of three replicate of toxic metals in soil using aqua regia

Sample	Areas	As	Co	Cr	Ni	Pb	V	Zn	Hg
1		100.0±0.002	262.0±0.012	734.0±0.032	362.0±0.009	826.0±0.036	310.0±0.026	1690±0.09	378.0±0.91
2		114.0±0.013	290.0±0.014	884.0±0.046	412.0±0.017	957.0±0.010	288.0±0.048	3090±0.352	264.0±0.132
3	A	112.0±0.008	298.0±0.018	830.0±0.022	392.0±0.010	710.0±0.010	142.0±0.018	1878±0.010	136.0±0.068
4		132.0±0.006	324.0±0.017	1054±0.078	552.0±0.021	545.0±0.010	BDL *	9428±0.155	BDL
5		142.0±0.006	340.0±0.014	830.0±0.065	412.0±0.015	422.0±0.022	BDL	6338±0.166	176.0
6		136.0±0.005	346.0±0.003	900.0±0.006	478.0±0.014	743.0±0.020	176.0±0.022	4504±0.114	294.0±0.102
7		106.0±0.005	280.0±0.003	1190±0.019	912.0±0.006	865.0±0.023	266.0±0.022	1238±0.089	208.0±0.090
8	B	106.0±0.002	236.0±0.010	1018±0.009	800.0±0.002	769.0±0.002	BDL	1290±0.297	BDL
9		88.00±0.009	274.0±0.009	1176±0.004	898.0±0.005	1095.0±0.022	BDL	798.0±0.121	204.0±0.147
10		88.00±0.003	162.0±0.005	562.0±0.013	376.0±0.013	525.0±0.025	56.00±0.033	1196±0.029	BDL
11		130.00±0.004	332.0±0.011	876.0±0.009	552.0±0.015	505.0 ±0.023	134.0±0.029	4800±0.061	162.0±0.081
12		94.00±0.002	144.0±0.005	510.0±0.022	370.0±0.031	577.0 ±0.022	62.00±0.031	1274±0.078	BDL
13		96.00±0.013	378.0±0.016	820.0±0.015	446.0±0.003	812.0±0.022	290.0±0.089	5718±0.091	BDL
14		94.00±0.008	242.0±0.014	742.0±0.039	474.0±0.027	709.0±0.012	76.00±0.011	2992±0.149	BDL
15		86.00±0.003	170.0±0.002	594.0±0.025	412.0±0.018	531.0 ±0.002	258.0±0.109	1972±0.223	BDL
16	C	72.00±0.024	168.0±0.015	478.0±0.113	316.0±0.015	1503.0±0.022	292.0±0.037	1586±0.085	BDL
17		62.00±0.014	104.0±0.003	502.0±0.010	218.0±0.002	679.0±0.029	192.0±0.074	578.0±0.016	BDL
18		58.00±0.006	178.0±0.008	582.0±0.018	296.0±0.006	607±0.022	BDL	1694±0.033	BDL
19		70.00±0.003	164.0±0.001	806.0±0.029	396.0±0.007	538.0 ±0.022	202.0±0.047	564.0±0.088	BDL
20		32.00±0.001	220.0±0.003	678.0±0.010	378.0±0.003	565.0 ±0.009	BDL	4506±0.116	BDL
21		30.00±0.004	200.0±0.006	458.0±0.004	270.0±0.009	813.0±0.022	BDL	3998±0.031	BDL
22		30.00±0.003	244.0±0.007	936.0±0.045	490.0±0.015	444.0 ±0.012	384.0±0.118	752.0±0.013	BDL
23		36.00±0.001	234.0±0.002	976.0±0.012	534.0±0.002	636.0 ±0.002	BDL	1126±0.198	BDL

* BDL= Below detection limit

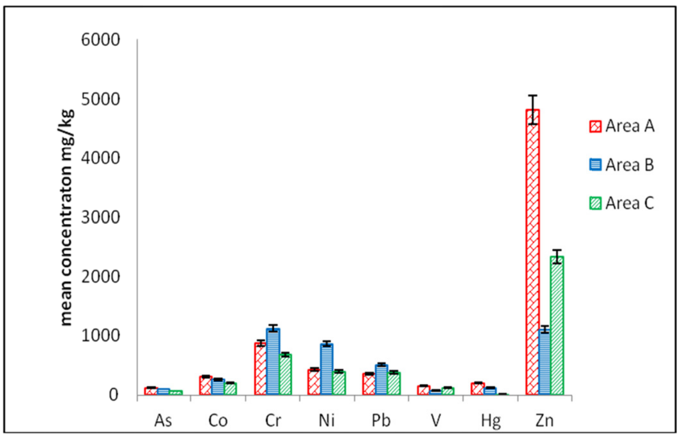

Figure 2. Average concentrations of heavy metal ions in soil at areas (A, B and C) by acid digestion.

Table 3. Average concentrations of toxic metal in area A, B, and C using aqua regia digestion in mg/kg and tolerable level of soil

Element	Area (A)	Area (B)	Area (C)	Tolerable level (mg/kg) (Lee et. Al., 2009).
As	122.6 ± 0.2	100.0 ± 0.5	69.4 0± 0.4	6.0
Co	310.0 ± 0.8	263.4 ± 1.4	210 .0± 0.9	100
Cr	872 .0± 2.5	1128 ± 5.4	680.0 ± 3.4	4.0
Ni	434.6 ± 3.1	870.0 ± 2.5	394.8 ± 1.8	40
Pb	700.5±149	792.33±167	674.6 ±184	100
V	152.6 ± 2.5	75.40 ± 3.1	124.8 ± 1.4	4.0
Hg	208.0 ± 2.6	120 .0± 2.1	11.60 ± 1.0	4.0
Zn	4821± 10.2	1108.6 ± 9.5	2339 ± 8.7	300

3.2 Environmental Quality Guidelines

The use of environmental quality guidelines assists the evaluation of other metal-contaminated sites. The tolerable level of soil describes in Table 3 (Lee et. al., 2009). Table 3 shows that the arsenic, mercury, chromium, cobalt, lead, vanadium, nickel and zinc were found to be above the tolerable level in comparisons with the other results. This is indicated that almost toxic metals in the three areas were exceeding the tolerable level. Thus, confidently state that the study areas were contaminated with most toxic metals that might pose a potential environmental risk. These results are in good agreement with the observation of Hakami and El-Sayed, 2014. In fact, water represents an important pathway for the dispersion of metals over large areas; while soils are significant basins for metals (FOrstner and Wittmann, 1981). The microorganism can be affected when metals are introduced to its life process.

Groundwater and surface water pollution occurs by dissolution in rainwater (or any other liquid solvent that may be present) and transport through the soil by gravitational, diffusional, and capillary forces. Various metals, such as Ca, Co, Cr, Cu, Fe, K, Mn, Mg, Na, Ni, and Zn, are essential. Required as micronutrients and for the redox processes to stabilize molecules through electrostatic interactions (components of several enzymes) for regulation of osmotic pressure (Gerber, 1991). Toxicity of nonessential metals occurs when the displacement of essential metals from their binding sites or through ligand interactions. It is well known that the Hg^{2+}, Cd^{2+} and Ag^{+} tend to bound with SH groups of biomolecules (proteins and/or enzymes). Thus, inhibit the activity of sensitive enzymes and produces a smell of hydrogen sulfide.

Table 4. Latin Square Design (LSD) for multiple comparisons of significance areas

Element	Area	Areas	Mean difference	Std. Error	Sig.	95 % Confidence Interval for mean	
						Lower Bound	Upper Bound
As	A	B	22.667	18.424	0.233	-15.76	61.10
		C	52.810*	12.713	0.000	26.29	79.33
	B	A	-22.667	18.424	0.233	-61.10	15.76
		C	30.143	16.576	0.083	-4.430	64.72
	C	A	-52.810*	12.713	0.000	-79.33	-26.29
		B	-30.143	16.576	0.084	-64.72	4.43
Co	A	B	46.667	43.830	0.300	-44.76	138.09
		C	100.00*	30.246	0.004	36.91	163.09
	B	A	-46.667	43.830	0.300	-138.09	44.76
		C	53.333	39.435	0.191	-28.930	135.59
	C	A	-100.00*	30.246	0.004	-163.09	-36.91
		B	-53.333	39.435	0.191	-135.59	28.93
Cr	A	B	-256.00*	110.381	0.031	-486.25	-25.750
		C	192.000*	76.1700	0.020	33.110	350.89
	B	A	256.00*	110.381	0.031	25.750	486.25
		C	448.00*	99.314	0.000	240.83	655.17
	C	A	-192.00*	76.170	0.020	-350.89	-33.11
		B	-448.00*	99.314	0.000	-655.17	-240.83
Ni	A	B	-435.33*	62.773	0.000	-566.28	-304.39
		C	39.810	43.318	0.369	-50.55	130.17
	B	A	435.333*	62.773	0.000	304.39	566.28
		C	475.143*	56.479	0.000	357.33	592.96
	C	A	-39.810	43.318	0.369	-130.17	50.550
		B	-475.143*	56.479	0.000	-592.96	-357.33
Zn	A	B	3379.33*	1446.691	0.030	361.59	6397.08
		C	2148.286*	998.312	0.044	65.840	4230.73
	B	A	-3379.333*	1446.691	0.030	-6397.08	-361.59
		C	-1231.048	1301.639	0.356	-3946.22	1484.12
	C	A	-2148.286*	998.3120	0.044	-4230.73	-65.84
		B	1231.048	1301.639	0.356	-1484.12	3946.22

* The mean difference is significant at 95% confidence.

3.3 Statistical Analysis

The better describe to test the comparable alternative of the high level of toxic elements and the correlation factor between the three sample areas. Thus, database was analyzed statistically by Latin square design (LSD) using SPSS software. The data in Table 4 revealed that a strong association for high values of toxic metals As, Cr, Ni, Zn and Co at area A to the surrounding area B, and C. These data also reflect a significant correlation between area B and area C of the tested toxic metal ions. Sewage Lake area (A) which is major contaminated by the toxic metals that had a significant contribution in the neighborhood areas (B) and (C). Other study in the same area was performed to investigate the remediation of the same site of soil samples using HCl (0.1 M). The results showed excellent correlation between the levels of Co, As, and Hg with the distance from the central polluted area (Alghanmi et. Al., 2015). Suggest, more study need to take for monitoring the environmental geochemistry of the sewage lake area and sufficient remediation such as bioremediation (Cecchi et. al., 2017) and phytoremediation (Bolan et. Al., 2014).

4. Conclusions

The research data illustrate the influence of anthropogenic agents on the abundance of toxic metals in 23 soil samples from three areas near Sewage Lake in Jeddah. The study revealed a high accumulation of toxic metals (As, Co, Cr, Hg, Ni, V, Pb, and Zn) in the soil stimulates an increase in their level due to the random dumping of hazardous waste associated with the sewage effluents from houses, hospitals, and industries that might be causing a leaching it into the ground waters. The average concentration of Zn (4821±10.2 mg/kg) at area A was much higher than the other two areas and exceeded the permissible level of Zn 300 mg/kg. For Cr the average concentration was 1128±5.4 mg/kg at areas B was higher than the area A and C and exceeded the tolerance level 4.0 mg/kg. In area B, the concentration of Ni (870.0±2.5 mg/kg) and Pb (792.33±167 mg/kg) was also comparatively higher and above the permissible limit. The concentration of As and Hg was present minimum in area C but maximum in area A. Overall, the high level of toxic metals in soil samples were moderately or heavily contaminated at the three areas. Thus, indicated that the soil of the studied areas, mainly polluted from the uncontrolled discharge of effluents to the waterborne Sewage Lake. The correlation factor between the study areas shows a significant contribution of toxic metals concentration according to the contamination of area A Sewage Lake region with other study areas (B and C). The study points out the soil quality measurements are required in all the three areas and adequate potential treatment should execute, such as bioremediation, phytoremediation by implanting certain plants in the area that could reduce the rate of contamination and avoid the polluted problems in the future.

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