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Research Article
Evaluation of Soil Contamination with Industrial Waste Effluent in Riyadh, Saudi Arabia

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Abstract

Background and Objective: Currently, in Saudi Arabia, wastewater production has increased manifolds due to onset of mega projects. The main objective of this study was to evaluate the soil contamination due to land disposal of industrial waste effluents. **Materials and Methods:** Soil and water samples were collected from different depth and distances from the wastewater pond. Soil and water samples were analyzed for physical and chemical contents. The regression and other statistically techniques were applied for data analysis. **Results:** Soil texture was sandy loam to sandy clay loam and was calcareous. Soil salinity was 80.3 dS m^{-1} near the pond and was normal after 100 m from the pond. Among the various heavy metals Cr showed more mobility than As and Mo. **Conclusion:** Soil was sandy loam to sandy clay loam containing gravels between 29.2-43.6% and was calcareous. Soil salinity was 80.3 and 3.2 dS m^{-1} near the pond and at 100 m distance, respectively. The mobility index of Cr was high followed by As and Mo in descending order.

Key words: Soil salinity, heavy metals, contamination, wastewater pond, soil depth, chromium (Cr), arsenic (As), molybdenum (Mo)

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Recent industrial development in the Middle East, especially in Saudi Arabia, is producing huge quantities of industrial waste effluent containing chemical, organic and biological pollutants. As such, waste effluents are a serious threat to the environment particularly to the living organisms around the land disposal sites causing an imbalance in the equilibrium of ecosystems. Normally, soil contamination is defined as any natural, synthetic or anthropogenic material that accumulates in the soil and can cause adverse changes in the bio-soil system. The main source of pollutants in the industrial waste effluents are excess use of agriculture fertilizers, insecticide, pesticides, detergents in house hold affairs and the chemicals used in hospitals and other similar activities. It has been also noticed that soil contamination along roadsides is mainly due to the emission of hydrocarbons from different types of transport machineries. Therefore, presence of heavy metal ions is a potential threat to the environment due to their toxicity when present in excess of the permissible limits for water reuse.

Ahmed[1] reported that industrial waste effluents played an important role in water sources contamination with some heavy metals such as mercury, lead, cadmium and zinc. Alwan[2] stated that water pollution in most of the Arabian countries is due to the land disposal of industrial waste (combined source of pollutants from many activities) into the adjacent costal areas. Previously, many investigators observed that the origin along with human activities in the surrounding areas are the two major factors of water pollution[3-7]. In addition to that, the main source of soil and groundwater contamination is by chemical pollutants from fertilizers, chemical and petrochemical residues as stated by Al-Hubailand El-Dash[8].

The possible major sources of heavy metals are mines and factories (paints, metal pipes, batteries), agriculture, explosive materials, industrial waste water, dispersion and oxidation of alloys during mining operations, producing waste effluents containing high concentration of heavy metals[9]. Heavy metals, such as lead, arsenic, nickel and cadmium are among the most potential sources of soil pollution. The most important sources of this pollution are domestic wastes, plant waste, smelting, coal combustion and car exhaust on the levels of some heavy metals (copper, Chromium, nickel, lead and zinc element) collected from outdoor and indoor dust in Riyadh, Saudi Arabia[10]. The study results showed soil contamination in the old industrial zone with high levels of toxic metals especially adjacent to the highways. The concentration of cadmium, chromium, copper, lithium, nickel, lead and zinc was 2.5±0.3, 2.7±35.1, 93.9±41.9, 4.6±0.3, 43.9±5.6, 1762±593 and 443±223 mg kg^{-1}, respectively and the concentration of these elements was in 2.0±1.1, 69.2±16.5, 271±140, 6.2±0.5, 52.9±17.7, 639±279 and 547±197 mg kg^{-1}, respectively. The main source of these heavy metals, in both the outdoor and indoor dust was emissions from cars[11].

According to a study by Al-Saleh and Taylor[12], the concentration of lead was high both in the air samples and the soil samples from the same 13 locations in the main city of Riyadh during the weekdays (Saturday and Wednesday). The results show that the increase was much higher during working days in areas with higher traffic density compared to the residential areas. The relationship between lead concentration in air and the soil was significant at 1% level of significance ($p<0.01$) based on the soil samples collected from 55 sites including the areas around the mine. The rate of pollution also decreased with increasing depth, where the enrichment coefficient was more than 40 in 41% of the total number of samples from soil surface (0-15 cm). However, the enrichment coefficient was 27 and 23% in 15-30 cm and more than 39 cm soil depths, respectively. Also the variation in heavy metals pollution followed the order as Cd> Hg> Pb> Zn> Cu> As> Mo> Be as reported by Tytła[13].

In another study, high concentration of lead, zinc, manganese, nickel, cobalt, copper and iron was found in soil samples collected from Buraidah area. While the low concentration of cadmium and concentrations of 3.5-49.75, 8.09-245.75, 53.0-258.15, 4.93-218.0, 0.84-11.28, 0.38-29.5, 38.0-19560.0 and 0.15-1.04 mg kg^{-1}, respectively, in untreated soils[11].

The main objective of this study was to determine the soil contamination level in the study area and its impact on drainage water contamination for developing the friendly soil environment resulting from the drainage water disposal in the open area. The research findings of this study will add new information to the previous information on soil and groundwater contamination resulting from land disposal of industrial waste effluents.

MATERIALS AND METHODS

Study area: The study area is located adjacent to the old industrial zone on the south-east side of Riyadh, Saudi Arabia allocated for land disposal of industrial and sewage waste effluents from capital city Riyadh and is surrounded by many industrial activities near the populated area. The study was

Table 1: Some soil samples to determine the natural characteristics of the soil in the study area

Clay (%)	Silt (%)	Sand (%)	Textural class	Gravel (%)	Lime (%)
19	13	68	Sandy clay loam	29.2	55.23
18	31	51	Sandy loam	30.3	38.91
18	12	70	Sandy clay loam	43.03	35.40
14	12	74	Sandy clay loam	42.0	44.20
17	32	51	Sandy loam	44.0	32.06
12	36	52	Sandy loam	43.6	44.71

Table 2: Chemical properties of some soil samples in the study area

	Sample No					
Chemicals	1	2	3	4	5	6
SP%	38.3	50	34	32	33	36
pH	7.64	7.72	7.69	7.92	8.3	8.15
dS m^{-1}	80.3	78.2	32.8	41.7	3.9	3.2
Sodium (Na)	642	609	185	272	3.04	5.44
Potassium (K)	6.39	6.05	1.62	1.61	0.33	0.52
Calcium (Ca)	321	313	123	155	17.71	19.85
Magnesium (Mg)	104	102	40.1	50.3	8.3	11.07
Carbonate (CO_3)	-	-	-	-	-	-
Bi-Carbonate (HCO_3)	2.5	2.4	2.5	3.1	0.6	0.8
Chloride (Cl)	402	391	154	193	15.8	19.7
Sulfur (S)	200	194	85.7	110	7.8	9.3
SAR	44.03	42.32	20.44	26.85	0.84	1.38
ESP	63.54	61.04	28.83	38.26	0.01	0.80
mg L^{-1}	51392	50048	20992	26688	2048	2496

conducted during 2017-2018. The disposal site of the waste effluents took the shape of a water pond which seemed to affect the soil characteristics in the surrounding areas.

Soil samples: Soil samples were collected from 0-15 and 15-30 cm depth of soil surface at regular intervals of 0, 50, 100 m distance from the left side of the wastewater pond. The soil samples were air-dried, ground and then passed through 2 mm sieve. Different soil fractions such as sand, silt, clay and gravels were determined by following the standard methods of Richards[14].

Analysis of soil samples: The soil texture was determined by using pipette method[15]. Total carbonates ($CaCO_3$) were estimated according to the procedure of Loeppert and Suarez[16]. The saturated soil paste was formed according to Richards[14] (1954) and the soil pH was determined by the method of Mclean[17]. The total amount of salts were measured in the form of electrical conductivity (EC as dS m^{-1}) according to Rhoades[18]. Soluble salts were estimated as cations (Ca, Mg, Na, K) and the anions (CO_3, HCO_3, Cl, SO_4) according to Richards[14]. Turbidity was estimated by the turbidimeter[19]. The samples were digested by burning with the acid mixture as described by Page *et al.*[20]. Heavy metals were estimated using a plasma device (ICPS, Perkin Elemer, 4300 DV) according to the method of Hossner[21]. All the soil analysis was performed with a predetermined reference soil sample for the accuracy of results.

Sequential extraction of heavy elements: Sequential extraction was carried out on soil samples for identifying the various water soluble elements using soil water extract of 20 mL. The ammonium acetate (NH_4 OAc) with concentration of 1 molar at pH 7 was used to obtain the exchangeable cations. The organically bonded image was obtained using a supine solution The organic bond was obtained using hydrogen peroxide (H_2O_2) and ammonium nitrate (NH_4 NO_3). The residual amount of the elements was estimated using nitric acid (HNO_3) with a concentration of 7 molars. The kinetics of the elements in soil were calculated.

Statistical analysis: All the data was analyzed by following the regression analysis and other appropriate techniques according to FAOSTAT[22].

RESULTS AND DISCUSSION

Soil characteristics: The clay percentage in soil samples ranged from 14-19%. The soil texture was sandy loam to sandy clay loam with gravel percentage ranging between 29.2-43.6%. The soil was classified as calcareous having more than 15% lime (32.06-55.23%) as defined by Khingebid and Montgomery[23] (Table 1). The soil salinity ranged from 80.3 dS m^{-1} (close to wastewater pond) and to 3.2 dS m^{-1} at a distance of 100 m from the pond (Table 2). The results were compared with the previous studies by simple means and the standard deviation of means. Similarly, based on the SAR, the

Table 3: Concentration of heavy metal elements (mg L^{-1}) in some soil samples in the study area

	Distance from the source					
	10 m		50 m		100 m	
Sample No	1	2	1	2	1	2
Soil depth	0-15	15-30	0-15	15-30	0-15	15-30
Fe	9787	9874	5465	4107	5709	4634
Mn	1631	1705	1644	1310	1948	1219
Zn	2089	3436	143.8	122.8	104.5	74.58
As	49.25	67.41	20.65	12.16	72.3	35.37
Cd	1.38	4.02	4.43	2.81	2.55	1.44
Pb	34.87	147.3	18.99	16.78	19.65	17.29
Ni	35.86	82.84	22.31	18.61	24.75	19.69
Cu	108	211.4	31.16	23.11	51.47	36.65
Cr	191	181.0	29.31	20.68	43.42	30.1
Co	7.49	15.40	2.21	1.34	5.11	3.52

Table 4: Correlation coefficient of total quantity of heavy elements estimated in soil samples of the study area

Heavy elements	Fe	Mn	Zn	As	Cd	Pb	Ni	Cu	Cr	Co
Fe	1.00									
Mn	0.45	1.00								
Zn	0.93	0.28	1.00							
As	0.61	0.72	0.53	1.00						
Cd	0.03	0.34	0.17	-0.08	1.00					
Pb	0.72	0.27	0.90	0.53	0.43	1.00				
Ni	0.80	0.34	0.94	0.59	0.38	0.99	1.00			
Cu	0.89	0.36	0.98	0.64	0.23	0.95	0.98	1.00		
Cr	0.99	0.33	0.94	0.55	-0.08	0.70	0.77	0.87	1.00	
Co	0.86	0.41	0.94	0.73	0.21	0.95	0.97	0.99	0.84	1.00

exchangeable sodium percentage (ESP) and the total amount of salts (TDS mg L^{-1}), the study area was divided as:

- Soil severely affected by salts is located within 10 m around the wastewater pond
- Soils that are affected with salinity are mostly located within 10-50 m around the wastewater pond
- Soils useable for production are located at 50-100 m from the wastewater pond
- Natural soils that are not affected by the land disposal of sewage effluents are located at more than 100 m from the wastewater pond

Concentration of heavy elements: Table 3 shows the concentration of heavy elements in soil samples exceeding the permissible limits expected in the natural soils according to Lindsay[24]. This indicated that the level of pollution of different heavy metal elements in soil according to the model used from the general mean of concentrations of elements in soil samples based on the findings of Lindsay[24] is as follows:

Fe>	Mn>	Zn>	Cr>	Cu>	As>	Pb>	Ni>	Co>	Cd>
6596	1576	995	82.49	76.92	42.86	42.48	34.01	5.84	2.77

However, based on the results of this study (Table 3), the concentration sequence of heavy metals was:

Fe>	Zn>	Mn>	Cr>	Cu>	As>	Ni>	Pb>	Co>	Cd
9787	2089	1631	191	108	49.25	35.86	34.87	7.49	1.38

The concentration sequence observed in this study varies with the sequence reported by Lindsay[24] and Tytła[13] for some of the heavy metals which may be attributed to the variability of total effluent salinity and load of heavy metal concentration of industrial waste effluents compared to that reported by earlier study.

Enrichment coefficient (EF) as a function of the extent of soil contamination: The extent of soil contamination of an element was determined by estimating the enrichment factor (EF) of that element in the soil and was compared to the soil enrichment coefficient calculated based on the values reported by Lindsay[24]. This was applied according to the criteria suggested by Sutherland and Tolosa[25] and Kartal *et al.*[26] for determining the extent of soil contamination with heavy metal[25,26]. Similar results were found in a study conducted in Al-Qassim[11]. The soil contamination category consisting of normal, medium, highly and severely affected was found in less than 5, 5-20, 20-40 and more than 40 m distance from the wastewater pond, respectively.

On the other hand the correlation coefficient of different heavy metal on is presented in Table 4 that indicates the relationship between metal ions in the soil.

Table 5: Maximum and minimum limits, concentration of some heavy metal elements, enrichment coefficient parameters in the soil of study area and their common limits in soils

	Total concentration in soil			EF			Common range in soil		
Elements	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
As	12.16	72.30	42.86	16.56	150.58	60.35	50	1	5
Cd	1.38	4.42	2.77	134.11	921.55	325.25	0.7	0.01	0.06
Co	1.34	15.40	5.84	2.28	32.06	5.14	40	1	8
Cr	20.68	190.90	82.50	1.41	397.59	5.81	1000	1	100
Cu	23.11	211.37	76.92	15.73	220.11	18.05	100	2	30
Fe	4107.30	9873.79	6595.94	0.51	2.94	1.22	550000	7000	38000
Mn	1219.00	1947.74	1576.13	27.66	202.83	18.50	3000	20	600
Ni	19.69	82.84	34.01	2.68	34.51	5.99	500	5	40
Pb	16.78	147.30	42.48	5.71	153.39	29.91	200	2	10
Zn	74.58	3435.51	995.12	16.93	715.52	140.13	300	10	50

Source: Lindsay[24]

Table 6: Industrial waste discharged into sea by some GCC Countries (t/year)

Description	UAE	Bahrain	Saudi Arabia	Qatar	Kuwait	Total
Water volume (1000 m^3)	736.00	29906.00	52740.00	3347.00	19225.00	105954.00
Solid suspended objects	1102.00	129.00	1063.00	87.00	4012.00	6393.00
Petrol	45.00	11063.00	6077.00	5016.00	35604.00	57805.00
Nitrogen	1.00	349.00	4224.00	5860.00	8075.00	18509.00
Sulfur	1.30	71.00	130.00	-	33.00	235.30
Phenols	-	62.00	101.00	-	00.60	163.60
Mercury	-	-	00.60	-	1.10	1.70
Chromium	-	-	7.00	-	-	00.70
Copper	-	-	-	-	3.50	3.50
Fluoride ions	387.0	-	-	-	-	378.00
BOD	11.000	161.000	2197.00	488.00	9563.00	13140.0

Source: Kassem[5]

A study of Table 5 shows that the soil of the study area varied considerably for the contamination of each heavy metal element depending on the type of element, location of soil samples from the wastewater pond and the soil depth as reported by Lindsay[24]. It is also evident from the calculated enrichment factor (EF) for the concentration of heavy metal elements in the soil. Based on the results, it was possible to divide the polluted areas around the wastewater pond according to distance from the pond and the degree of pollution as follows:

- Soil is highly contaminated with heavy metals within 10 m distance from the edge of pond. According to the model used, the maximum concentration of heavy elements in the soil followed the following trend:

Elements	Cd>	Mn>	Zn>	As>	Cu>	Pb>	Ni>	Co>	Cr>	Fe
EF	134.11	27.66	16.93	16.56	15.73	5.71	2.68	2.28	1.41	0.51

- Sequence for minimum concentration of different heavy metal elements according to the model was:

Elements	Cd>	Zn >	Cr>	Cu>	Mn>	Pb>	As>	Ni>	Co>	Fe>
EF	921.55	715.52	397.59	220.11	202.83	153.39	150.58	34.51	32.06	2.94

- Mean values of different elements according to the model were:

Elements	Cd>	Zn>	As>	Pb>	Mn>	Cu>	Ni>	Cr>	Co>	Fe>
EF	325.25	140.13	60.35	29.91	18.50	18.05	5.99	5.81	5.14	1.22

This study results are in line with those reported by Al-Oud[11], who found almost identical pattern of the heavy metal elements in soil of Al-Qassim region irrigated with waste effluent from different sources.

The pattern of soil contamination is closely related with the distance of soil from the wastewater pond as explained earlier for soil affected with salinity. Also the concentration of total soil salinity and the heavy metals depend on total salinity and the level of heavy metals in waste effluents of the pond. However according to various sources, the total industrial waste effluents from different GCC countries is presented in Table 6.

Levels of soil contamination:

Non-Polluted	Normal polluted	Highly contaminated	Severely contaminated
< 5	5 -20	20 – 40	> 40

The sequential extraction of heavy elements in soil samples was determined to identify the possible horizontal or vertical movement of heavy metals and other major elements in the soil of study area around the wastewater pond. Although, there is a possibility of leaching of access wastewater to the groundwater due to deep percolation or undulated underground cracks in the soil layers of study area.

Table 7: Sequential extraction of heavy elements and guide of movement in the soil of the study area

Depth (cm)	Distance (m)	Elements	F1	F2	F3	F4	F5	F6	Total	Mobility index	Total
0-15	10	Fe	3108	1875	210	275	3636	235	9340	1.25	9787
		Mn	103	61.2	13	116	101	1190	15834	0.13	1631
		Zn	22.8	95.4	134	125	374	1106	1857	0.16	2089
		As	3.21	2.78	1.18	7.20	27.88	5.82	48.07	0.18	49.25
		Cd	0.53	0.06	0.00	0.12	0.12	0.41	1.24	0.92	1.38
		Pb	2.01	3.43	1.11	1.10	9.22	16.47	33.34	0.24	34.87
		Ni	0.08	3.00	0.98	0.61	10.63	19.01	34.30	0.13	35.86
		Cu	4.93	14	1.23	3.00	3.42	78.69	105	0.24	108
		Cr	4.84	63.1	6.22	17	9.52	87.59	188	0.65	191
		Co	1.17	0.22	0.51	0.22	2.18	3.01	7.32	0.35	7.49
15-30	10	Fe	551	3162	998	996	365	3649	9721	0.94	9874
		Mn	201	113	21.1	112	1023	132	1603	0.26	1705
		Zn	177	293	200	216	258	2181	3324	0.25	3436
		As	5.54	4.22	3.05	39.6	13.05	1.16	66.64	0.24	67.41
		Cd	0.34	0.43	0.36	1.36	0.64	0.76	3.89	0.41	4.02
		Pb	8.14	15.3	2.63	17.9	28.63	74.09	149	0.22	147
		Ni	2.25	2.12	6.36	10.7	6.21	24.42	51.02	0.24	82.84
		Cu	25	17.8	31.9	23.2	24.37	86.93	209.2	0.56	211
		Cr	12.8	53.6	7.37	19	18.46	67.83	179	0.70	181
		Co	1.85	2.27	0.94	3.12	5.87	0.45	14.50	0.54	15.40
0-15	50	Fe	618	523	129	91.4	68.97	3573	5004	0.34	5465
		Mn	15.7	98.6	4.55	9.86	713	617.5	1459	0.09	1644
		Zn	1.27	34	0.23	0.33	0.37	106.6	142.8	0.33	144
		As	8.76	2.15	0.98	1.06	0.60	4.55	18.10	1.92	20.65
		Cd	0.75	0.89	0.10	0.68	1-12	0.05	3.60	0.94	4.42
		Pb	0.88	1.18	0.25	1.53	0.12	12.44	16.40	0.16	18.99
		Ni	0.28	5.32	0.34	0.98	1.07	11.61	19.59	0.43	22.31
		Cu	1.29	15.2	1.25	0.93	0.06	9.59	28.35	1.68	31.16
		Cr	6.43	8.38	0.57	0.85	0.98	9.60	26.81	1.35	29.31
		Co	0.24	0.30	0.28	0.46	0.51	0.24	2.03	0.68	2.21
15-30	50	Fe	642	1433	236	224	347	10417	3923	1.43	4107
		Mn	325	364	13.7	199	196	195	1293	1.19	1310
		Zn	7.28	24	1.23	0.09	2.36	82.24	117	0.38	123
		As	0.03	2.28	3.30	0.94	4.08	0.12	10.75	1.09	12.16
		Cd	0.00	0.02	0.00	0.00	0.04	0.20	0.26	0.08	2.81
		Pb	1.73	0.44	3.41	0.37	1.05	7.61	14.61	0.82	16.78
		Ni	2.05	1.34	0.52	0.91	0.37	11.37	16.55	0.31	18.61
		Cu	0.01	0.00	0.00	0.00	0.00	22.35	22.36	0.00	23.11
		Cr	0.54	2.27	0.03	0.93	1.07	13.59	18.43	0.18	20.68
		Co	0.00	0.04	0.01	0.86	0.08	0.24	1.23	0.04	1.34
0-15	100	Fe	1062	536	142	50	1366	2367	5523	0.46	5709
		Mn	399	140	260	118	36.76	932	1885	0.73	1948
		Zn	6.91	4.58	5.55	10.8	19.85	53.32	101	0.20	105
		As	38.1	9.63	3.69	1.83	1.09	15.86	70.22	2.74	72.30
		Cd	0.26	0.11	0.23	0.13	0.34	1.03	2.09	0.40	2.55
		Pb	3.49	8.87	2.59	1.53	2.14	0.89	19.50	3.28	19.65
		Ni	1.24	5.93	0.75	0.95	0.28	12.45	21.59	0.58	24.75
		Cu	2.57	20.9	1.07	3.08	5.17	16.82	49.59	0.98	51.47
		Cr	1.02	5.04	2.07	5.07	8.02	20.24	41.45	0.24	43.42
		Co	0.91	0.29	0.01	1.50	2.02	0.08	4.80	0.33	5.11
15-30	100	Fe	998	357	169	40.6	1187	1455	4206	0.57	4633
		Mn	112	493	227	6.54	123	229	1190	2.32	1219
		Zn	2.33	16.4	14.2	11.7	0.81	26.62	71.99	0.84	74.58
		As	14.4	2.80	1.88	0.96	0.09	12.32	32.40	1.42	35.37
		Cd	0.10	0.76	0.02	0.27	0.01	0.01	1.17	3.10	1.44
		Pb	0.59	9.09	0.62	3.61	1.91	0.45	16.27	1.72	17.29
		Ni	1.30	11.3	0.07	0.84	0.07	1.86	15.44	4.59	19.69
		Cu	5.27	12	2.13	3.07	1.06	8.43	31.97	1.55	36.65
		Cr	18.5	0.95	1.08	2.10	2.09	3.12	27.85	2.81	30.09
		Co	0.30	0.08	0.90	0.38	1.32	0.06	3.02	0.74	3.52

Table 8: Heavy metals mobility index in soil of the study area

Distance (m)	Depth (cm)	Fe	Mn	Zn	As	Cd	Pb	Ni	Cu	Cr	Co
10	0-15	1.25	0.13	0.16	0.18	0.92	0.24	0.13	0.24	0.65	0.35
	15-30	0.94	0.26	0.25	0.24	0.41	0.22	0.24	0.56	0.70	0.54
50	0-15	0.34	0.09	0.33	1.92	0.94	0.16	0.43	1.68	1.35	0.68
	15-30	1.43	1.19	0.38	1.09	0.08	0.82	0.31	0.00	0.18	0.04
100	0-15	0.46	0.73	0.20	2.74	0.40	3.28	0.58	0.98	0.24	0.33
	15-30	0.57	2.32	0.84	1.42	3.10	1.72	4.59	1.55	2.81	0.74

Value more than 0.5 indicates the possible movement of an element

However, the pattern of movement of heavy metal element depends on the value of mobility index (0.5) to indicate the possible movement of an element if the value exceeds 0.5. The data in Table 7 and 8 showed a possible movement of some elements where the mobility index of the heavy metals was more than 0.5 except for some samples. It was found that the most heavy metal element that can move in the soil of the study area was Cr (chromium) followed by As and Mo in descending order. These findings also agree with the results of Al-Oud[11].

CONCLUSION

This study indicated that normal soils are affected by salinity adjacent to the land disposal site of industrial waste effluents. The soil salinity was 80.3 dS m^{-1} near the pond and was normal (3.2 dS m^{-1}) at a distance of 100 m from the disposal site. The pattern of soil contamination varied with the distance from the wastewater pond. The soil was categorized as normal, medium, highly and severely contaminated within <5, 5-20, 20-40 and >40 m distance from the wastewater pond, respectively. Movement of heavy metals in soil depends on the mobility index of an element. It was also found that the movement of heavy metal element was higher for Cr (chromium) followed by As and Mo in descending order.

SIGNIFICANCE STATEMENT

Soil was significantly affected both by salinity and heavy metals especially Cr as and Mo which highlighted the potential of soil contamination around wastewater pond. This study will help the researchers to determine the level of soil contamination due to land disposal of industrial effluents for efficient management.

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