Evaluation of Soil Contamination by Selected Heavy Metals Due to the Impact of Waste Dumping in Babylon Governorate

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Abstract:

This study was conducted to evaluate soil contamination and to investigate selected physical and chemical properties influencing the behavior of heavy metals resulting from landfill waste. Soil samples were collected from two sites across three transects, representing both contaminated and control conditions. The study area is located in Babil Governorate, between latitudes 32°34’58.15”–32°32’59.77” N and longitudes 44°31’36.93”–44°35’11.05” E. Particle size analysis indicated that the soils were predominantly clay in texture, followed by sand and silt. Soil pH ranged from 7.13 to 8.39, and electrical conductivity varied from 2.67 to 10.46 dS m^{-1}. Organic matter content ranged from 10.1 to 25.0 g kg^{-1} in the contaminated sites and from 7.0 to 17.7 g kg^{-1} in the control samples.

The total concentrations of heavy metals at sites S1 and S2 were 24.1 mg kg^{-1} for lead (Pb), 2.62 mg kg^{-1} for cadmium (Cd), and 186 mg kg^{-1} for nickel (Ni). Additional measurements recorded 17.2 mg kg^{-1} (Pb), 3.3 mg kg^{-1} (Cd), and 127 mg kg^{-1} (Ni) in other soil samples. Control soils showed values of 14.0 mg kg^{-1} (Pb), 3.17 mg kg^{-1} (Cd), and 127 mg kg^{-1} (Ni). Based on the values of the Simple Pollution Index (SPI), the contamination level in all studied soils ranged from uncontaminated to low contamination.

Keywords: -heavy elements; Soil pollution; waste burning; sanitary landfill.

.1 Introduction:

Environmental pollution refers to any undesirable alteration in the natural ecosystem resulting from anthropogenic or natural activities, which may affect energy flow, radiation levels, and the physical or chemical characteristics of the environment. These changes become particularly concerning when they pose risks to human health, biodiversity, or the stability of ecosystems [1,2]. Among the various categories of environmental contaminants, heavy metals are regarded as some of the most persistent and hazardous due to their non-biodegradable nature, high toxicity, and long-term accumulation in the soil. These elements can enter the food chain through plant uptake, leading to significant ecological and health-related consequences for both humans and animals. Additionally, they can adversely affect plant development and agricultural productivity [3,4 .[

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The main sources of heavy metal contamination in soils include industrial discharges, rapid urbanization, and the uncontrolled disposal of municipal and industrial solid waste. In particular, improper landfill practices—especially those involving open burning—are major contributors to the accumulation of toxic metals in both soil and air. Such activities release hazardous substances that may contaminate the environment directly or indirectly, in addition to leading to the loss of economic value associated with recoverable recyclable materials [5 .[

To determine the extent of soil contamination and its potential ecological implications, a range of scientific indices have been developed. Among these, the Simple Pollution Index (SPI) is widely used for evaluating contamination levels and assessing the potential environmental risks posed by heavy metal accumulation in soils.

This study Add aims:

-1Investigate the mineralogical characteristics of soils affected by landfill waste in the city of Al-Hilla

-2 Estimate the total concentrations of lead (Pb), cadmium (Cd), and nickel (Ni) in contaminated soils

-3 Assess the level of pollution using selected indices and determine the potential environmental impact .

.Materials Methods: 2

Soil samples were taken at depths of 0-30 and 60-90 cm. The first site, located inside the left corner of the landfill towards the east, included samples S11 and S12, respectively, at the mentioned depths. The second site, located north of the landfill, included samples S21 and S22. The coordinates of the study sites were limited to longitudes 32°34'57.61 - 32°34'58.15 North, and latitudes 44°31'16.64 - 44°31'36.93 East. In addition, surface samples with a depth of 0-30 cm were taken from the soil of three tracks located between longitudes 32°34'18.21"-32°34'48.15" North, and latitudes 44°31'32.57"-44°31'36.93" East. The first track was chosen to the left of the landfill, starting with the comparison sample (T01), which was far from the landfill site on the northern side, passing through the first pit and ending at the borders of the palm groves near the Nile, with samples distributed among the cultivated areas (T11, T12 and T13). The second track passed through the middle of the landfill, starting with the comparison sample (T02). In the same manner as the first track, it was represented by samples T21, T22 and T23, respectively. The third track, which was chosen to the right of the landfill, started with the comparison sample (T03), passing through the third pit, and samples T31, T32 and T33. Soil samples were taken to the laboratory and subjected to physical analyses. The volume distribution and texture of the study soils were determined using an international pipette, as described by [6].The required chemical properties of the soil were determined as follows: Soil reactivity was measured using a pH-meter, type 710 WTW, after calibration according to the method described in[7]. using a 1:1 soil:water extract. Electrical conductivity was measured in a 1:1 soil:water suspension using a HACH/EC 71 EC-meter, according to the method described in [7]. Organic matter was determined by the wet oxidation method, using the Walkley-Black method described in [8].The total content of heavy elements in the soil was estimated according to the method mentioned by [9] by taking one gram of air-dried soil sample sieved with a sieve with a diameter of (2 mm) holes and placing it in a 250 ml Pyrex bottle. Next, 5 ml of nitric acid ($HNO3$) is added for 24 hours. The samples are then placed on a hot plate at 80°C for an hour. The samples are then air-cooled for a period of time. Then, 5 ml of perchloric acid ($HClO4$) is added at 180°C for 2 to 3 hours on

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a hot plate until the color changes from dark brown to a colorless clear solution. The clear solution is then filtered using Whatman No. 42 filter paper, and the volume is brought to 10 ml. The samples are then ready for measurement of lead, cadmium, and nickel using a Shimadzu AA-7000 Atomic Absorption Spectrophotometer (made in Japan). To predict the availability of heavy elements in soil, several pollution indicators have been adopted to estimate the extent of contamination in the soil

Basic Simple Pollution Index :

It is called simple because it indicates the relative concentration of any heavy element in soils affected by pollution sources compared to unaffected soils (comparator). It is abbreviated as PI, as proposed by Yang et al. (2011), and was estimated using the following equation

)PI = Ci / Si…………….(1

where: Pi = the simple pollution index; Ci and Si = the amount of heavy metals in the contaminated soil, and the comparison is based on the sequence Hakanson (1980), and Table 1 shows the standard limits for the simple pollution index.

Table1: Limits and levels of soil contamination with heavy elements for the simple indicator

Simple pollution lndex (PI)	
الدرجة	Pollution Level
PI<1	Unpolluted
1≤ PI<2	Low pollution
2≤ PI<3	Moderate pollution
3≤ PI<5	Strong pollution
PI>5	Very stron

Results and discussion: 3

. Size distribution of soil classes: 3.1

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Table2: Size distribution of the components and tissue class of the soil samples of the current study

Study sites		Depth(cm)	Size distribution of the particle (g kg^{-1})			Texture
			Caly	Silt	Sand	
Site 1	S11	30-0	375	50	575	SC
	S12	90-60	635	50	315	C
Site2	S21	30-0	725	50	225	C
	S22	90-60	615	200	185	C
T1	T11	30-0	405	50	545	SC
	T12	30-0	485	60	455	SC
	T13	30-0	555	280	165	C
	T10	30-0	705	20	275	C
T2	T21	30-0	680	70	250	C
	T22	30-0	425	30	545	SC
	T23	30-0	535	70	395	C
	T20	30-0	675	40	285	C
T3	T31	30-0	505	110	385	C
	T32	30-0	515	140	345	C
	T33	30-0	515	190	295	C
	T30	30-0	815	30	155	C

Chemical Properties 3.2

Soil Reactivity (pH) and Electrical Conductivity (EC):): 3.2.1

Table 3 The soil reactivity values of the current study soil samples at a depth of 0-30 cm, ranging from 8.0-7.35, and at a depth of 60-90 cm, ranging from 8.39-7.41. In the soil samples at a depth of 0-30 cm, the values were between 7.13-8.05, and in the samples at a surface depth, the values were between 7.31-7.21. The results indicate that the soil reactivity was within the range of the Iraqi alkaline soils [10]. The electrical conductivity in Table 5 for samples at depths of 0-30 cm ranged between 9.10 and 2.59 dS m-1 and at depths of 60-90 cm, between 10.22 and 2.46 dS m-1. In the soil samples from the soil paths

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at depths of 0-30 cm, the electrical conductivity ranged between 9.32 and 2.67 dS m-1. In the comparison soils at the aforementioned depths, the electrical conductivity ranged between 7.23 and 3.03 dS m-1. This is due to the accumulation of salts in the surface layer, which is a characteristic of arid soils due to low rainfall and high groundwater levels, as well as low vegetation cover. Some soils were dark in color due to the predominance of sabkha-type magnesium chloride salts. In general, soil reaction is inversely related to electrical conductivity values[11 .[

3.2.2 Organic Matter Content

Table 3 shows that the organic matter content of the soils in the current study ranged from 17.0 to 25.0 g kg-1 for the 0-30 cm depth samples, and from 10.0 to 20.0 g kg-1 for the 60-90 cm depth samples. In the soil samples from the 0-30 cm depth, it ranged from 7.0 to 17.0 g kg-1, while in the samples from the comparison path at the surface depth, it ranged from 12.0 to 17.0 g kg-1. These values were generally low for all the study soils. The reason for the low organic matter values in these soils is attributed to the lack of vegetation cover, which was limited to some tamarisk, thistle, and clematis plants, as well as the high temperatures during the long summer season, which leads to the oxidation and rapid decomposition of organic matter. [12].indicated that organic matter accumulates in the surface layer of the soil as a result of the accumulated residues of plant remains and their retention in the surface layer due to the dominance of metals forming complexes on their ion exchange surfaces, which makes the biological activity at its most intense in the upper horizons of the soil. In addition, the lack of rainfall limits the movement of organic material residues and their transfer to the lower horizons of the soil body. Also, the presence of some esparto grasses and crops is characterized by the density of their roots in the surface layer, which hinders the movement of water and provides a suitable moisture content for the accumulation processes and microbial decomposition activity.

Table3: Soil reaction, electrical conductivity, and organic matter in the study area

Study sites		**Depth (cm)**	**Ec(**dS m^{-1})	**pH**	**organic matter**g kg^{-1})
Site 1	**S11**	**30-0**	**4.16**	**8.00**	**22.0**
	S12	**90-60**	**2.46**	**7.36**	**12.0**
Site2	**S21**	**30-0**	**9.10**	**7.35**	**25.0**
	S22	**90-60**	**10.22**	**8.39**	**20.2**
T1	**T11**	**30-0**	**9.32**	**7.58**	**15.0**
	T12	**30-0**	**3.87**	**7.28**	**15.0**
	T13	**30-0**	**3.39**	**7.80**	**16.0**
	T10	**30-0**	**3.27**	**7.31**	**17.0**
	T21	**30-0**	**6.53**	**7.96**	**14.0**

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T2	**T22**	**30-0**	**7.57**	**7.83**	**11.4**
	T23	**30-0**	**2.67**	**7.13**	**9.0**
	T20	**30-0**	**4.11**	**7.26**	**11.7**
T3	**T31**	**30-0**	**9.03**	**7.50**	**7.0**
	T32	**30-0**	**8.84**	**8.05**	**10.1**
	T33	**30-0**	**9.88**	**7.32**	**14.0**
	T30	**30-0**	**3.03**	**7.21**	**12.0**

3Total content of heavy elements in the soil:.3.2

Table 4 Refers to the total heavy element content in the soils of the current study, where lead ranged from 24.1 to 16.2 mg kg-1 in the soil at a depth of 0-30 cm, cadmium from 2.21 to 2.62 mg kg-1, and nickel from 192 to 168 mg kg-1. In the soil at a depth of 60-90 cm, lead ranged from 21.7 to 14.8 mg kg-1, cadmium from 1.73 to 2.16 mg kg-1, and nickel from 186 to 156 mg kg-1. In the soil samples from the surface depths, lead ranged from 17.2 to 10.9 mg kg-1, cadmium from 1.30 to 3.36 mg kg-1, and nickel from 127 to 49 mg kg-1. In the soil samples from the comparison depths of 0-30 cm, lead ranged from 14.0 to 10.7 mg kg-1, cadmium from 1.34 to 3.17 mg kg-1, and nickel from 88 to 38 mg kg-1. kg-1, the heavy elements in the study soils are in the following order of dominance: nickel < lead < cadmium. Therefore, the increase in the concentration of nickel is due to its adsorption by the clay minerals present, such as montmorillonite, which is one of the dominant minerals in dry and semi-dry soils [13].The increase in the concentration of nickel in the surface layer of the soil and its decrease with depth indicates that its source is a result of human activities and due to its association with organic matter in the surface layer, where nickel is classified as a medium-mobility element within the soil sector [14.[

Table (4) Total content of heavy metals in the soil

Study sites		**Depth (cm)**	**Soil total content of heavy elements)mg kg^{-1}(**		
			Pb	**Cd**	**Ni**
Site1	S11	30-0	20.5	2.21	168
	S12	90-60	20.0	1.78	162
Site2	S21	30-0	24.1	2.62	192
	S22	90-60	21.7	2.16	186
	T11	30-0	18.6	2.23	127

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T1	T12	30-0	17.2	1.91	119
	T13	30-0	16.5	2.67	115
	T01	30-0	14.0	3.17	80
T2	T21	30-0	15.2	1.86	107
	T22	30-0	14.4	1.30	98
	T23	30-0	13.8	3.16	94
	T02	30-0	11.3	2.39	88
T3	T31	30-0	12.5	3.36	59
	T32	30-0	11.7	1.61	55
	T33	30-0	10.9	1.64	49
	T03	30-0	10.7	1.34	38

Soil Pollution Indicators:

Simple Pollution Index (PI): 1.

The table 5 shows that the minor pollution index (PI) for heavy metals in the study soils of sample S1 ranged between 0.85-0.92 for lead, 0.80-0.84 for cadmium, and 0.87 for nickel, compared to the control soil S2. The values of the pollution index for T1, affected by waste at a depth of 0-30 cm, ranged between 1.32-1.17 for lead, 0.60-0.84 for cadmium, and 1.58-1.43 for nickel, compared to T01. Compared to T02, lead ranged between 1.34-1.22 for lead, 0.54-1.32 for cadmium, and 1.21-1.06 for nickel. Compared to T2, lead ranged between 1.16-1.01 for lead. Cadmium 1.20-2.50 and nickel 1.28-1.55 mg kg-1 when comparing T3 with T03. It is noted that the PI for all study soils is less than 1, which indicates that all study sites are free of pollution and is consistent with a study conducted by[15]. to evaluate heavy element pollution in soils, as he indicated that they are considered places free of pollution to slightly polluted.

Table(5) Total content of heavy metals in the soil

Study sites		**Depth** (cm)	**PI for S1 soils and comparison with S2 soils**		
			Pb (mg kg^{-1})	**Cd**	**Ni**
Site1	**S11**	**30-0**	**0.85**	**0.84**	**0.87**
	S12	**90-60**	**0.92**	**0.80**	**0.87**
		PI for each element in samples compared with T01			

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T1	**T11**	**30-0**	**1.32**	**0.73**	**1.58**
	T12	**30-0**	**1.22**	**0.60**	**1.48**
	T13	**30-0**	**1.17**	**0.84**	**1.43**
T2		**PI for each element in samples compared with T02**			
	T21	**30-0**	**1.34**	**0.77**	**1.21**
	T22	**30-0**	**1.27**	**0.54**	**1.11**
	T23	**30-0**	**1.22**	**1.32**	**1.06**
T3		**PI for each element in samples compared with T03**			
	T31	**30-0**	**1.16**	**2.50**	**1.55**
	T32	**30-0**	**1.09**	**1.20**	**1.44**
	T33	**30-0**	**1.01**	**1.22**	**1.28**

Conclusions . 4

Based on the results of the current study, we can conclude the following:

.1 The soil texture of the study site samples was predominantly clayey, with a high content of clay separators, compared to sand and silt. Therefore, texture may have played a role in reducing the movement and increasing the restriction of the heavy metals under study.

.2The minor contamination index, with levels between uncontaminated and low, was determined by the soil content of heavy elements (lead, cadmium, and nickel), which were affected by the landfill site, compared to the control samples.

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