EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(8), 316–330
https://doi.org/10.12912/27197050/190124
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Received: 2024.06.05
Accepted: 2024.06.19
Published: 2024.07.01

Studying the Effects of Pollutants from Industrial Facilities on Soil and Plant Pollution

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ABSTRACT

Industrial facilities that participate significantly in the production of many human needs and are useful in various activities. This study evaluates the impact of an electric power generation station, an oil refinery, and a brick factory on emissions and liquid waste that pollute soil and plants with lead and cadmium in the surrounding areas. Soil samples were taken in four dimensions, with a distance of 500 m between each sample. the results showed that the levels of heavy metals analyzed were high for both lead and cadmium, as the lead concentration ranged between 150.30–22.15, 240.40–30.20, and 250.33–21.91. The results indicated the total concentration of cadmium, which ranged between (0.50–2.20) and (0.9–2.51) and (0.55–1.66) $mg \cdot Cd \cdot kg^{-1}$ soil for each of the electric power generation station, oil refinery, and brick factories, respectively. The highest value of the pollution factor was recorded at distance of 500 m, which amounted to 11.42, which is within the range of CF > 6. This indicates very high pollution. As for the distance of 2000 m, it reached 3.65, which indicates high pollution. The highest value for the environmental risk index Er with lead in the soil of brick factories was at the distance of 500 and 1000 m, as it reached 57.10 and 41.10 respectively. It was with low limits to Moderately toxic to lead and moderate to highly toxic to cadmium. However, a mechanism must be developed to reduce the concentrations of these elements, which are enriched by these industrial facilities.

Keyword: pollutants, heavy metals, environmental risk, contamination factor, oil refinery, brick factories.

INTRODUCTION

Industries have recently exhibited alarming trends, notably in the diversity and complexity of industrial operations (Ozyigit et al., 2022). This has led to severe pollution, resulting in the degradation of the biosphere and the disruption of natural environmental systems. Environmental scientists have debated the precise definition of environmental pollution. Generally, pollution refers to the quantitative or qualitative changes in environmental elements that disrupt the ecosystem (Kumari et al., 2022). It is caused by undesirable changes in the natural environment, adversely affecting the atmosphere and its components. Pollutants are substances, in liquid, solid, or gaseous form, that become contaminants when their concentrations exceed natural levels (Khasanova et al., 2023). Industrial effluent, wastewater produced by industrial activities, often contains materials deemed useless during manufacturing processes. In Bangladesh, approximately 6,000 large and medium industries, along with 24,000 small industries, generate pollutants (IEDS, 2003). The Department of Environment recently identified 900 large polluting industries lacking functional treatment facilities. Despite regulations requiring effluent treatment plants (ETPs) in every industry, these plants are often not operated due to high costs. The discharge of untreated effluent poses significant risks to sustainable resource use (Eruola et al., 2011). Such effluent degrades surface water and soil, negatively impacting crops, pests, animals, and human health (Hossain et al., 2010). Industrial processes produce not only finished products but also numerous by-products that are frequently released into the environment, polluting air, water, and land. Fresh water and unpolluted soil are essential for plant growth, whereas polluted resources are detrimental to plants. Lahori et al. (2023) conducted a study to investigate the effects of clay fertilizer and a compound on stabilizing lead and cadmium in contaminated soil. The findings showed that both the clay fertilizer alone and the compound positively impacted plant growth, immobilized cadmium and lead in the soil, and reduced the absorption of these metals by sorghum.

Pollution is a major global issue, exacerbated by human activities. Heavy metals from industrial activities accumulate in living organisms' tissues, causing health disorders as they are not biodegradable. Air pollution, a significant concern, contributes to soil pollution through industrial expansion driven by modern technology. Industries such as oil refineries and energy production stations are major pollution sources. The escalation of environmental pollution disrupts ecological balance, leading to the extinction of animals and the destruction of plants. Addressing this issue requires understanding the relationship between health and environmental pollutants. Potential solutions include adopting environmentally friendly electric cars and replacing fossil fuels with renewable energy sources like wind and solar energy (Yadav et al., 2024). Research institutions and international organizations have established permissible limits for heavy elements and various compounds in soil, water, food, and air due to extensive experiments and research. The increasing environmental pollution and accumulation of heavy pollutants in the soil underscore the importance of this topic. This study aims to examine the impact of industrial facilities, such as power generation stations, oil refineries, and brick factories, on soil pollution with heavy elements using modern pollution standards (contamination factor CF, environmental risk index R1). It also seeks to evaluate the relationship between the concentration of heavy metals in soil and their concentration in plants. the metal concentrations in soil generally reflect the influence of various local industrial activities which include metal and mining, chemical and petrochemical, textile, leather, cement, and ceramic industries. Observations of generally enhanced metal levels in soils around various industrial facilities are explainable by unregulated, untreated solid and fluid wastes released by the industries to the nearby land. Among the 9 reference trace metals examined, it is seen that Cu, Cd, Pb, and Zn were monitored the most frequently. Evaluation of soil metal data indicates that their maximum values occur in relation to particular industry types, that is, Pb, Zn, Ni, Cu, Fe, and As in smelter and metal industries, Mn and Cd in the textile industry, and Cr in leather industry studies. more efforts should be made to characterize the soil pollution in relation to various industrial activities. This may also help us set proper soil regulation guidelines for sustaining a healthy and balanced environment and protecting human health (Kabir et al., 2012).

MATERIALS AND METHODS

Study area

Three sites within Diwaniyah Governorate were identified as pollution sources:

1. The electric power generation station located in the Al-Furat neighborhood in the center of Diwaniyah Governorate.
2. A brick factory situated in the Aziz Allah district of Al-Hamza district.
3. The Al-Diwaniyah oil refinery in the Al-Haffar district of Al-Shinafiya district (Table 1, Fig.1).

EXPERIMENTAL

Field work

Soil samples were taken at 4 dimensions, 500 m apart, at a depth of 0–30 cm. The comparison sample was taken at a distance of approximately 4 km from the same source, at a single depth, with three repetitions for each distance during the month of August. To determine plant

Table 1. The coordinates of the three sites in UTM

Location	x	y
electric Power generation station	31.97387	45.589208
brick Factories/Al-Hamzah	31.81063	45.12253
oil Refinery/Al-Shenafiya	31.88529	44.76273

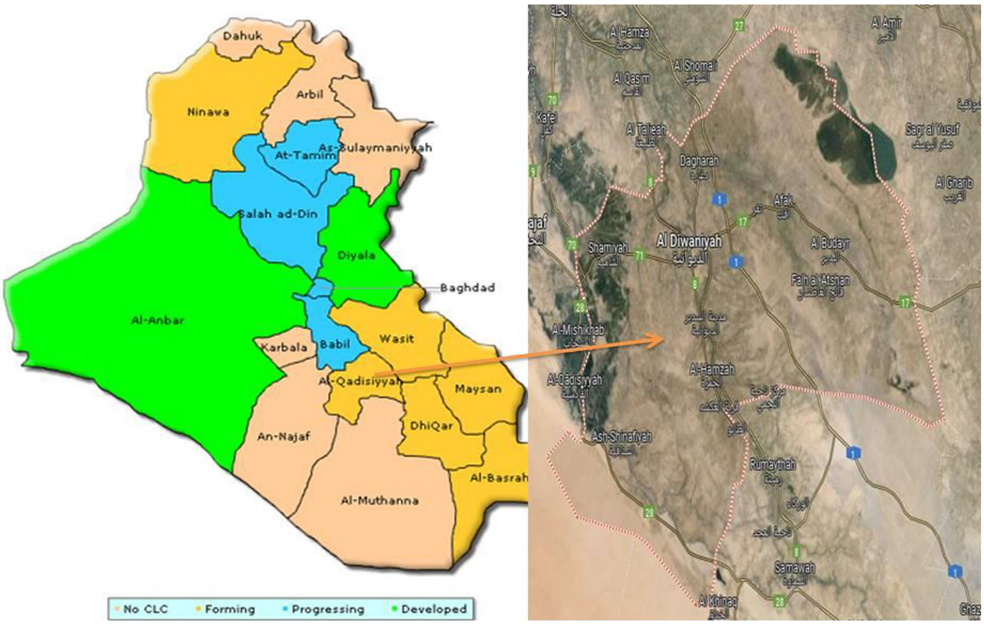


Figure 1. A satellite image of the study sites in Diwaniyah Governorate and the sites for taking soil and plant samples

contamination, plant samples were taken within the scope of the study soil samples for the vegetative part only (stem and leaves), with three replicates for each sample. The locations of all samples were determined using the Global Position System (GPS).

Plants used in the study

Eucalyptus comaldulensis

The Eucalyptus plant belongs to the Myrtaceace family. Its scientific name is *Eucalyptus camaldulensis*. Locally, it is called Calamus and Qalam Tuz, while in Arabic it is called Camphor.

Tamarix plant

The tamarisk plant belongs to the Tamaricaceae family, a type of perennial shrub. It is considered an evergreen tree of medium height, ranging in height from 1–18 m. It is spread in desert areas and central regions of the continent of Asia.

Laboratory work

Analysis of soil and plant samples

The soil samples for the study were collected from designated sites, air-dried, and then ground using a wooden hammer. These samples were sieved through a 2 mm mesh and stored in plastic bags for subsequent chemical and physical analyses, following the procedures of Day et al. (1965) and Page et al. (1982). Plant samples were also collected, thoroughly washed with water, air-dried, ground with an electric grinder, and sieved through a 2 mm mesh. Both the plant shoots and soil samples were digested using concentrated acids and analyzed with an atomic absorption spectrometer to measure heavy metals (lead, cadmium) based on the method outlined by Jones et al. (2001). Additionally, the available heavy metals in the soil were extracted using the chelating agent diethylene triamine pentaacetic acid (DTPA) (Tab. 2).

Calculate soil pollution indexes

Some pollution indexes were calculated to determine the pollution status of each element within the study soil models according to the methods mentioned in Adamn et al. (2014). Table 3 shows the ranges of pollution indexes.

Contamination factor

$$CF = \frac{C_{m\,sample}}{C_{m\,background}} \quad (1)$$

where: $C_{m\ sample}$ – concentration of the studied element in the soil, $C_{m\ background}$ – concentration of the same element in the comparison soil 1.5 – an estimated factor for this Equation to reduce the effect of possible changes in $C_{m\ background}$ values.

Table 2. The physical and chemical characteristics of the study soils

Location	Distance	EC 1:1	pH 1:1	CEC	$CaCo_3$	O.M	Texture
	m	dsm^{-1}		$Cmol^{-1}$	$gm \cdot kgm^{-1}$		
Electric power generation station	500	33.5	7.2	14.05	188.5	8.5	Sandy loam
	1000	55.2	7.5	12.01	198.13	6.53	Sandy loam
	1500	87.17	7.14	13.07	205.13	6.4	Sandy loam
	2000	126.17	7.03	15.09	236.9	8.8	Sandy loam
	المقارنة	19.28	7.95	12.39	274.5	4.77	Sandy loam
Oil refinery / Al-Shenafiya	500	3.92	7.23	14.87	232.05	7.77	Sandy loam
	1000	9.58	7.25	15.88	249.5	5.7	Sandy loam
	1500	10.21	7.58	16.17	255.75	6.9	Sandy loam
	2000	50.73	7.63	17.3	253.8	7.3	Sandy clay loam
	Control	52.54	7.77	18.48	243.15	5.73	Clay
Brick factories	500	57	7.46	15.16	214.7	6.67	Loamy sand
	1000	116.27	7.58	14.2	220.1	5	Loamy sand
	1500	150.63	7.6	14.02	223	4.2	Loamy sand
	2000	130.87	7.73	16.84	264.85	5.57	Sandy loam
	Control	76.13	7.87	17.07	267.9	4.7	Clay

Ecological risk index

$$E_r^i = T_r^i \times \text{CF} \quad (2)$$

$$\text{RI} = \sum E_r^i \quad (3)$$

where: E_r^i: Environmental risk index for the element RI: Total environmental risk index CF: pollution factor T_r^i: Toxic response factor for a single polluting element, which varies depending on the element (Cao et al., 2018).

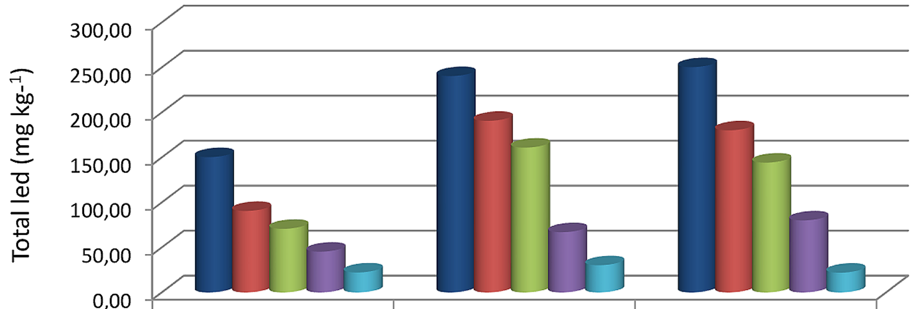
RESULT AND DISCUSSION

Total concentration of heavy metals in the study soil

Figure 2 shows differences in the values of the total concentration of heavy elements (lead, cadmium) in the soil of different industrial facilities within the distances of 500, 1000, 1500 and 2000 meters, in addition to the comparison sample, which is about 4 km away from the industrial facilities, as the lead concentration ranged between 150.30–22.15, 240.40–30.20, and 250.33–21.91 for each of the electric power generation station, oil refinery, and brick factory, respectively. The highest concentration of lead was recorded in the soil of brick factories at a distance of 500 m, amounting to 250.33 $mg \cdot Pb \cdot kg^{-1}$ soil, as a result of the presence of more than one brick factory in the same area and the increase in fumes rising from the factories without treatment, which shows an increase in the concentration of harmful heavy elements in particular. Lead element: The above facilities recorded a decrease in lead concentration at a distance of 2000 m, reaching (45.3, 66.9, 80.0) $mg \cdot Pb \cdot kg^{-1}$ soil for each of the electric power generation station, oil refinery, and brick factories, respectively Three different types of facilities were chosen in order to find out which of them has the greatest impact on soil and plant contamination with lead and cadmium due to the difference in the type of fuel used in these three facilities, as the type of fuel used in the electric power generation station is black oil, while in the brick factories two types of fuel are used: Kerosene and black oil, while oil refineries depend on kerosene and crude oil, so these facilities were chosen to compare the severity of their gaseous emissions pollution to both soil and plants due to the difference in the type of fuel used as well as their production capacity for the purpose of taking the necessary measures to reduce the impact of those emissions, examining various industrial activities allows for a detailed and nuanced understanding of the sources and impacts of trace metal pollution in soils, which is crucial for effective environmental management and remediation efforts Kabir et al., 2012; Long et al., 2021. The results showed that all concentrations were higher than the global average concentration of lead in the soil, which was 27 $mg \cdot kg^{-1}$, and within the critical limit of 20–300 $mg \cdot kg^{-1}$, and

Table 3. Ranges of pollution standa

(CF) Contamination factor			
CF < 1	Low contamination		
1 ≤ CF < 3	Moderate contamination		
3 ≤ CF ≤ 6	Considerable contamination		
CF > 6	Very high contamination		
Ecological risk index			
E_r^i value	Grade of ecological risk of single metal	Ecological risk index (RI) total	
		RI value	Grade of potential ecological risk of environment
E_r^i < 40	Low risk	RI <150	Low risk
40 ≤ E_r^i < 80	Moderate risk	50 ≤ RI < 3001	Moderate risk
80 ≤ E_r^i < 160	Considerable risk	300 ≤ RI < 600	Considerable risk
160 ≤ E_r^i < 320	High risk	RI ≥ 600	Very high risk
E_r^i ≥ 320	Very high risk		



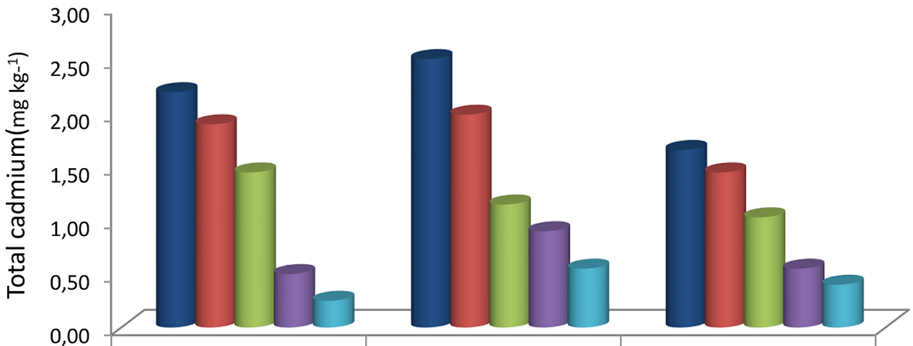
	Power plant	Oil refinery	Brick factories
500 m	150,30	240,40	250,33
1000 m	90,52	190,61	180,08
1500 m	70,67	160,88	144,25
2000 m	45,25	66,88	80,00
Control	22,15	30,20	21,91

Figure 2. Total lead concentration in soil mg·kg^{-1}

they exceeded the upper limit for the limestone content of 17–65 mg·kg^{-1}, with the exception of a sample. For comparison, the power station at a distance of 2000 m was within the permissible limits according to Kabata-Pendias (2011).

We conclude from the above that the rate of lead in the surface layer of the soil is affected by what is deposited and accumulated in the atmospheric air emitted from industrial sources and gradually decreases with distance from the source of pollution.

Figure 3 shows the total concentration of cadmium in the soil of various industrial facilities, as it ranged between (0.50–2.20), (0.90–2.51), and (0.55–1.66) mg·Cd·kg^{-1} soil for each of the electric power generation station, oil refinery, and brick factories. In succession. The highest value was recorded at a distance of 500 meters from the oil refinery, amounting to 2.51 mg·Cd·kg^{-1} soil. In general, the results showed a noticeable decrease in the concentration of cadmium with increasing distance from industrial facilities, as the highest value was recorded at the first and second distances of 500 and 100 meters and for all industrial facilities. As can be seen from the figure, the oil refinery is ahead of the rest of the sites in soil cadmium content for all distances, as a result of the large pollution caused by the gases and smoke of the refinery, in addition to its use of three types of fuel, namely white oil, kerosene, and gasoline, which causes the release of heavy polluting elements (Achadu et al., 2015) Increased contamination of the soil near the Doura refinery with cadmium due to gases emitted from the refinery. All of these values were higher than the comparison



	Power plant	Oil refinery	Brick factories
500 m	2,20	2,51	1,66
1000 m	1,90	1,99	1,45
1500 m	1,45	1,15	1,03
2000 m	0,50	0,90	0,55
Control	0,25	0,55	0,40

Figure 3. Total cadmium concentration in soil mg·kg^{-1}

sample, and this may be due to the fallout of smoke resulting from various industrial facilities into the nearby soil, which leads to the binding of cadmium to the organic matter in the surface layer of the soil.

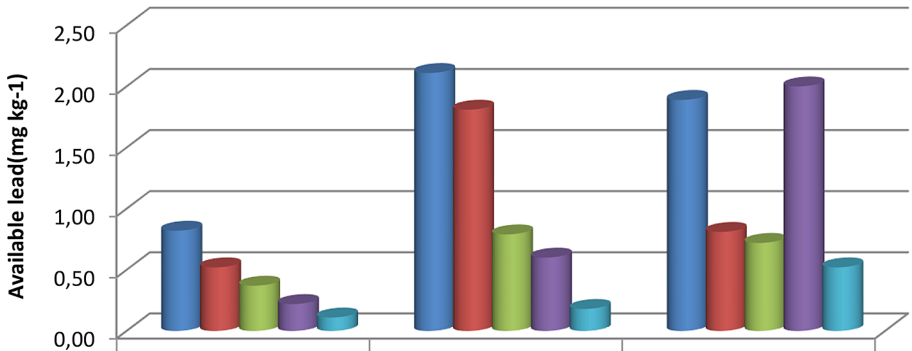
When comparing the values of the current study with the concentration of cadmium in soil globally, we note that all concentrations were higher than the global average, which is 0.41 mg·kg^{-1}, with the exception of the comparison sample for the electric power plant and brick factories, which amounted to 0.25 and 0.40 mg·Cd·kg^{-1} soil, respectively. And below the critical upper limit for cadmium, which is 1–5 mg·kg^{-1} according to Kabata-Pendias (2011).

As for the comparison soils, which were about 4 km away from the source of pollution, all values were below the critical minimum because the comparison was within agricultural areas far from traffic, and against the direction of the wind, in addition to the large number of irrigation operations there. We also find that all of the above values were higher than the limestone content of 0.4–0.8 mg·kg^{-1}, with the exception of the comparison sample for the electric power plant, which amounted to 0.25 mg·kg^{-1}. This is due to the effect of different soil characteristics, such as pH, where the cadmium concentration increases with the degree of reaction. The comparison soil was within a lower range of limestone content because the comparison soil for the oil refinery and the brick factory had a clay texture, while the electric power generation station was agricultural soil and irrigation operations in it were continuous, which prevented the contaminated elements from remaining in it. We also notice a decrease in the concentration of cadmium with increasing distance from the source of pollution, and this is consistent with Saloumi and Alabadi (2023) who indicated an increase in the concentration of cadmium near the source of pollution, which is released to the external environment in the form of gases or dust.

Available concentration of heavy metals in study soils

Figure 4 shows the available-made lead element content of the study soil within the range of distances 500, 1000, 1500, and 2000 for the studied sites, which ranged between (0.22–0.82), (0.60–2.11), and (0.67–1.89) mg·Pb·kg^{-1} soil per From the electric power generation station, the oil refinery, and the brick factories in succession, as the highest concentration was recorded at a distance of 500 meters for each of the three industrial facilities, amounting to 12.1 mg·Pb·kg^{-1} soil at the oil refinery, followed by the brick factories with a concentration of 1.89 mg·Pb·kg^{-1} soil, and the generation station. Electrical energy amounted to 0.8 mg·Pb·kg^{-1} soil, while the lowest concentration of available lead was recorded at a distance of 2000 m for all the facilities studied, as it reached 0.2, 0.6 and 0.67 mg·Pb·kg^{-1} soil for each of the electric power generation station, oil refinery, and brick factories, respectively.

This may be attributed to an increase in the total lead concentration at a distance close to the



	Power plant	Oil refinery	Brick factories
500 m	0,82	2,11	1,89
1000 m	0,52	1,81	0,81
1500 m	0,37	0,79	0,72
2000 m	0,22	0,60	2,00
Control	0,11	0,18	0,52

Figure 4. Concentration of lead in soil, mg·kg^{-1}

source of pollution, which increases its permeability in the soil. This is consistent with Alawsy and Nafawa (2022) who showed the available lead concentration in the soil is directly proportional to the total lead concentration. The results showed that available-made lead values were somewhat similar for all sampling sites, as there was an increase in values at distances close to the facilities and then began to decrease as the distance increased. This is in line with Celenk and Fatma (2015). Current studies also confirm that the location of sampling is an important factor in determining the extent of soil contamination with heavy metals. The level of lead in the surface layer of the soil is also affected by the rate at which it accumulates and is deposited in the atmospheric air emitted from industrial sources. The soil near the industrial facilities under study was exposed to lead contamination, but all values were below the critical limits mentioned in Nunes et al. (2014), amounting to (2.33±3.16) mg·kg^{-1}. The results of Figure 5 indicated the concentration of available-made cadmium in soil samples of the industrial facilities studied for the distances. 500, 1000, 1500, 2000 AD. The results showed that the highest value of available-made cadmium was within the 500 m distance of the oil refinery soil, amounting to 1.67 mg·Cd·kg^{-1} soil, followed by the brick factory, which recorded 0.92 mg·Cd·kg^{-1} soil, while the electric power generation station ranked last with 0.75. mg·Cd·kg^{-1} soil because the absorptive capacity is limited compared to other facilities.

The fact that the soil of the oil refinery has the highest content of available-made cadmium indicates the large pollution resulting from the gases and smoke of the refinery. Petroleum distillates also cause many environmental pollutants, as well as water steam and electric power plants. Oil tanks are also considered one of the largest sources of gaseous emissions. The lowest concentration of available-made cadmium was recorded at a distance of 2000 m in the soil of the studied sites at (0.09, 0.16, and 0.25) mg·Cd·kg^{-1} soil for each of the brick factories, the electric power generation station, and the oil refinery, respectively, as all values decreased at Compare it with the location near the source of pollution. All results were higher than the critical limits of 0.23±0.24 mg·kg^{-1} proposed by Nunes et al. (2014), with the exception of the soil of brick factories at a distance of 2000 meters, which is 0.09 mg·kg^{-1}. Thus, the soil of the industrial facilities under study is considered contaminated with cadmium. It is clear from the results of our current study that the increase in the concentration of finished lead and cadmium elements in all study soil sites coincided in its general trend with an increase in the total concentration of those sites. This is clear from the positive moral correlation between the prepared and total elements, which reached r = 0.90** and r = 0.89** For lead and cadmium, respectively (Table 4). The results of the statistical analysis also showed that there is a negative significant correlation with the available concentration of

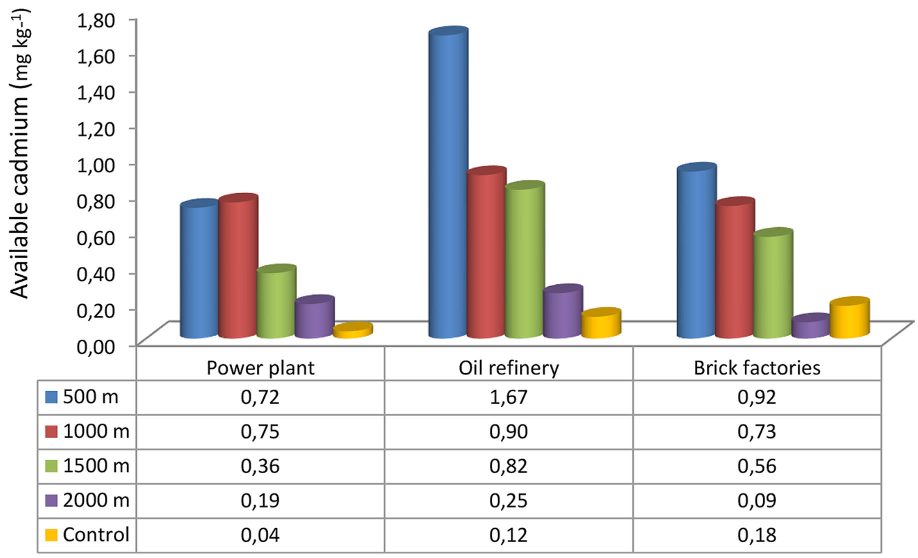


Figure 5. Concentration of available cadmium in soil mg·kg^{-1}

Table 4. Correlation between available concentration of heavy metals and the total concentration of the soil of the study sites

Heavy metals	Pb_Av	Cd_Av	Pb_T
Cd_Av	0.87**		
Pb_T	0.90**	0.90**	
Cd_T	0.79**	0.89**	0.78**

Note: ** Significant at ($P \leq 0.01$)

lead and cadmium with both pH and $CaCO_3$, amounting to (r = -0.36 and r= -0.25) and (r= -0.50, r= 30.40) respectively (Table 5). Because they have an important effect on the release of heavy elements and increasing their readiness in the soil, as a decrease in the degree of soil interaction indicates an increase in hydrogen ions in the soil solution, which encourages an increase in the readiness of heavy elements through its interaction with the active groups present on the surface of the exchange complex, which contributes to Removing heavy elements from the soil surface and replacing them. Calcium carbonate contributes to reducing the availability of heavy elements by increasing its surface area, which allows the element to be absorbed, in addition to its role in raising the degree of soil interaction, which reduces its availability in the soil. This is consistent with what Liu et al., 2018; Mohammed et al., 2019; Akol et al., 2021; Mohammed et al., 2022 indicated that there is a negative correlation between the available concentration of cadmium, zinc and nickel elements with the degree of soil interaction.

Table 5. Correlation between chemical characteristics and available concentration of heavy metals of the study soils

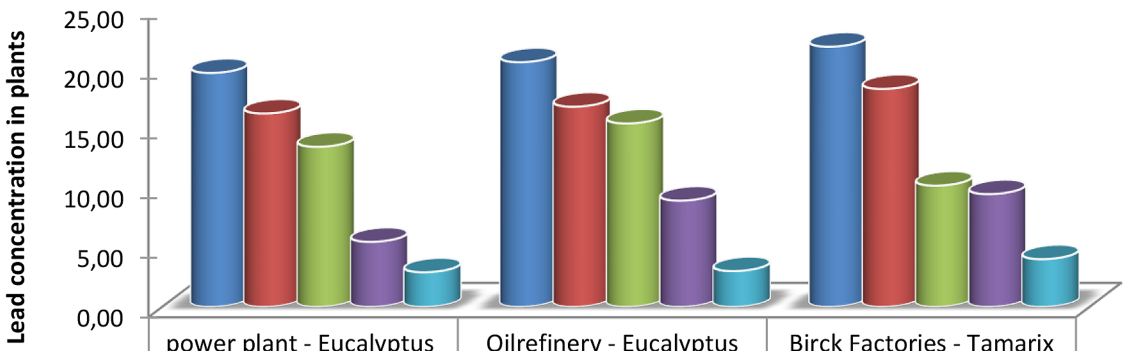
Characteristic	pH	EC	CEC	OM	Pb_AV	Cd_AV
EC	0.04					
CEC	0.38	-0.02				
OM	-0.70**	-0.28	0.00			
Pb_AV	-0.36	-0.40	-0.01	0.17		
Cd_AV	-0.50	-0.44	-0.23	0.33	0.87**	
$CaCO_3$	0.68**	-0.11	0.52*	-0.38	-0.25	-0.43

Note: *, ** Significant at ($P \leq 0.05$), ($P \leq 0.01$) respectively.

Concentration of heavy metals in plants of the study sites

The concentration of lead and cadmium within the vegetative parts of some plants growing in the soil of industrial facilities sites in the city of Diwaniyah under study was studied. Eucalyptus and eucalyptus plants were chosen as the most common plants in these sites.

Figure 6 shows, in general, a high concentration of lead in plants growing near sources of pollution. The results showed a variation in the concentration of lead, as the highest concentration was recorded in Eucalyptus plants growing in the soil of an oil refinery and for all dimensions compared to the same plant growing in the soil of a power station. Electrical energy, and this is due to the high concentration of lead in those sites compared to its concentration in the soil of the electric power generation station. This is clear from the positive significant correlation between the concentration of the element in the soil and its concentration in the plants growing there, which amounts to $r = 0.81^{**}$ (Table 6). Figure 5 shows that the highest value of lead was recorded at 21.80 mg·kg^{-1} dry matter, which was within the vegetative parts of the tamarisk plant at a distance of 500 meters from the soil of the brick factories and then the oil refinery, as it recorded 20.50 mg·kg^{-1} dry matter, despite the high available concentration of lead in The soil of the oil refinery compared to the soil of the brick factories and finally the electric power generation station had a rate of 19.60 mg·kg^{-1} dry matter. This is due to a number of reasons, including the difference in the type of plants growing in those sites and their ability to absorb lead from the polluted soil, in addition to the increase in industrial activity and the continued movement of transport vehicles. In transporting and packing bricks, which in turn affects the spread and raising of dust on plants growing near them, in addition to the intensity of operation of the factory and the dense rising smoke it produces, which works to increase dust pollution through the scattering of atoms of heavy elements as a result of burning the fuel used (black oil). The percentage of heavy elements in the atmosphere, especially when they are mixed with dust particles and then deposited on plants through wind or rain water, or when their weight is heavy and the air cannot carry them. The results also recorded the lowest value for lead in the tissues of Eucalyptus plants growing in an electric power plant, 5.45 mg·kg^{-1} dry matter, at a distance of 2000 m as a result of the distance of the sample from the source of pollution, as this distance was surrounded by a dense agricultural area far from all sources of pollution. When comparing these values for all distances and for all plants with the specifications of the World Health and Food and Agriculture Organizations (WHO/FAO, 2007; Jafaar et al., 2020; Ali et al., 2021; Jafaar et al., 2022) we find that they have exceeded the critical limit of 5 mg·kg^{-1} (Figure 5). However, in general, despite the accumulation of lead on the vegetative parts of the plant, it did not show any effect on the metabolic processes, and this is consistent with AL-Mashhadi and Alabadi



	power plant - Eucalyptus	Oilrefinery - Eucalyptus	Birck Factories - Tamarix
500 m	19,60	20,50	21,80
1000 m	16,20	16,77	18,26
1500 m	13,41	15,37	10,16
2000 m	5,45	8,90	9,45
control	2,90	3,00	4,00

Figure 6. Lead concentration in plants in the studied plants, mg·kg^{-1}

Table 6. Correlation between the concentration of the element in the plant and the available concentration in the soil of the study sites

Heavy metals	Pb_P	Cd_P	Pb_Av
Cd_P	0.89**		
Pb_Av	0.81**	0.77**	
Cd_Av	0.85**	0.85**	0.87**

(2023) Jafaar et al., 2023, who demonstrated that lead is transferred from contaminated soil to the plants growing in it, reaching a higher limit than The limit allowed globally.

As for the concentration of cadmium, the results of Figure 7 indicate that there is a variation in the concentration of the element cadmium in the vegetative part of the plant growing in the soil of the study sites, as the content of the vegetative parts of the Eucalyptus plant in the electric power generation station ranged from 1.68–4.45 mg·kg^{-1} dry matter, and at the oil refinery for the same The plant type ranged between 2.00–5.10 mg·kg^{-1} dry matter, while the cadmium content of the vegetative parts of the tamarisk plant in the brick factory was recorded between 0.88–5.00 mg·kg^{-1} dry matter. The results show that the highest value of cadmium was recorded at a distance of 500 meters in the oil refinery plant, at 5.10 mg·kg^{-1} dry matter. In second place was the cadmium content of the optimum plant, as it was recorded at 5.00 mg·kg^{-1} dry matter, with a small difference between them as a result of the soil being affected by the activity of both the refinery and the laboratories. The oil refinery releases many liquid wastes into the soil that contain various heavy elements as a result of the processes that crude oil refining undergoes. The soil is also exposed to pollution as a result of the breakage of some oil pipelines responsible for transporting petroleum materials. The results also recorded the lowest value for the element cadmium in the tissue content of the tamarisk plant at the site of the brick factories, 2.11 mg·kg^{-1} dry matter at the distance of 2000 meters. This is due to the decrease in the available concentration of the element cadmium, especially at that distance, as we find that there is a correspondence between the available concentration in the soil and the concentration The element in the plant, which was reflected in the positive correlation between them, amounting to $r = 0.85^{**}$ (Table 6).

When comparing these concentrations with the specifications of the World Health, Food and Agriculture Organizations (WHO/FAO, 2007), we find that they have exceeded the critical limit for the concentration of cadmium in the plant, which is 0.02 mg·kg^{-1} dry matter, even in the comparison sample and for all sites as a result of the effect of the comparison samples on the wind speed that has It plays a major role in carrying pollutants to greater distances or affecting the exhaust emissions of cars traveling on the road, the friction of vehicle tires with the surface, and their consumption of engine oils.

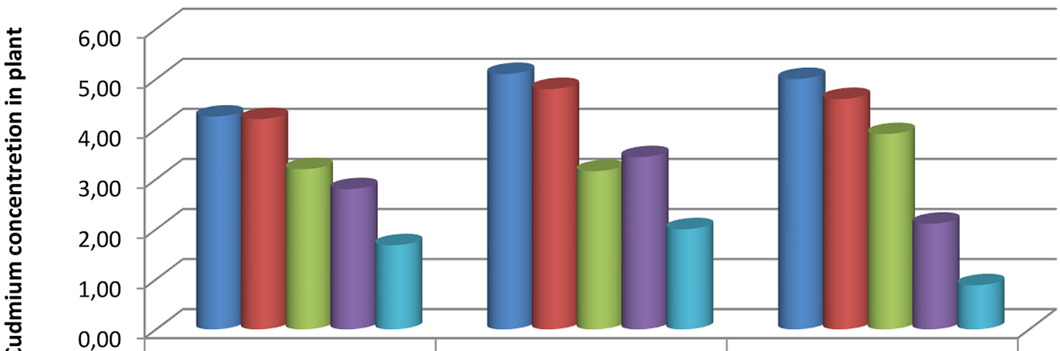
Standards for soil contamination with lead and cadmium

One of the main objectives of this study is to detect the content of heavy elements in the soil surrounding the industrial sites under study within the low, critical, or toxic ranges. To achieve this, global indicators were adopted on which to classify the soil content of lead and cadmium.

Contamination factor

To evaluate soil pollution, the pollution factor CF is applied, which is an indicator of the pollution of the single studied element, as most other pollution indicators depend on it. The sum of the pollution factors for all the heavy elements under study represents the degree of pollution CFd, so it is an indicator for measuring the overall degree of pollution of the sites (Asrari, 2014).

The results of Table 7 showed the pollution factor values for lead in the soil of industrial facilities, which ranged between 2.04–6.78, 2.21–7.96, and 3.65–11.42 for each of the electric power generation station, the oil refinery, and the brick factories, respectively. We note that the soil of the brick factories and for all distances falls within the pollution range. Very high and highly polluted, with the exception of the comparison sample, which falls within the medium level of pollution, as the highest value was recorded at the distance of 500 m, which amounted to 11.42, followed by it at the distance of 1,000 and 1,500 meters, which amounted to 8.22 and 6.58 respectively, and it is within the range of 6 CF >, which



	powe plant - Eucalyptus	Oilrefinery - Eucalyptus	Birck Factories - Tamarix
500 m	4,25	5,10	5,00
1000 m	4,20	4,80	4,60
1500 m	3,20	3,16	3,90
2000 m	2,80	3,44	2,11
control	1,68	2,00	0,88

Figure 7. Cadmium concentration in plants in the studied plants mg·kg^{-1}

Table 7. Pollution factor values for lead

	Location	Distance m				
		500	1000	1500	2000	control
CF – Pb	Electric power generation station	6.78	4.09	3.19	2.04	1
	Oil refinery	7.96	6.31	5.33	2.21	1
	Brick factory	11.42	8.22	6.58	3.65	1

indicates very high pollution, as for the distance of 2000. m, it reached 3.65, which indicates high pollution, as it falls within the range CF ≤ 6 ≥ 3.

This is due to the particles that brick factories excrete into the air, which fall on sites close to the factories. The minutes contain what resulted from the incomplete combustion of the fuel used in operating the factories, such as heavy elements that are not biodegradable unlike organic matter, so their presence continues for a long period of time, which tends to To accumulate in the environment. As for the electric power generation station, it was ranked last in terms of pollution factor values compared to the rest of the industrial facilities, but it was also classified as very highly polluted soil at a distance of 500 meters, amounting to 6.78, as it fell within the range CF > 6.

As for the distances of 1000 and 1500 meters, the values are 4.09 and 3.19, which fall within the range 3 ≤ CF ≤ 6, which indicates high pollution, compared to the distance of 2000 meters, which is 2.04, as it was classified as moderately polluted soil because it falls within the range 1 ≤ CF ≤ 3. The reason for the low values may be attributed to the pollution factor in the soil of the electric power generation station compared to the rest of the industrial facilities due to its geographical location, as it was in the center of the city and the residential area was surrounded by trees, in addition to the fact that the soil of the area is constantly subject to change as a result of the construction of buildings.

The results of Table 8 indicate the pollution factor values for the element cadmium in the soil of the study sites, which ranged between 2.00–8.80 for the electric power generation station, while the values ranged between 1.64–4.56 in the oil refinery, and the pollution factor value for the brick factories ranged between 1.37–4.15, as we note The contamination factor values for cadmium for all study sites range from Moderate contamination to Very high contamination, and the highest value was recorded in the electric power generation station at the distance of 500 and 1000 meters, which reached 8.80 and 7.60, respectively, and the lowest value was at the distance of 2000 meters at the coefficient bricks, which amounted to 1.37.

Table 8. Pollution factor values for cadmium

	Location	Distance m				
		500	1000	1500	2000	control
CF – Cd	Electric power generation station	8.8	7.6	5.8	2	1
	Oil refinery	4.56	3.62	2.09	1.64	1
	Brick factory	4.15	3.62	2.57	1.37	1

It can be said from the results of Tables 7 and 8 that, in general, the values of the pollution factor decrease as we move away from industrial facilities, which indicates the extent of the influence of industrial waste, vapors and gases emitted from those facilities on soil pollution. The contamination factor values for lead and cadmium range from moderate contamination to very high contamination (1 ≤ CF ≤ 3 – CF > 6) (Table 3).

The randomness of the distribution of the CF value of the sites indicates the emissions of gases and vapors as a result of the operation of the facilities, and their waste is thrown directly to the surface of the soil without treatment. These results are consistent with Rahman et al. (2012) and Awadh et al. (2013), who emphasized the pollution of the environment with heavy metals to increase Emissions from laboratories and factories.

Ecological risk index

This indicator is used to evaluate the degree of contamination of soil and sediments with heavy elements, based on the arrangement of the elements according to their toxicity, ability to be released, and environmental response to them (Hakanson, 1980). The results of Table 9 indicate the values of the environmental risk index Er for lead and cadmium in the soil of the study. The highest value for the environmental risk index for lead in the brick factory soil was at the distance of 500 and 1000 meters, reaching 57.10 and 41.10, respectively, and they were within the moderately polluted range ≤ 40. E_r^i < 80, followed by the oil refinery and the electric power plant at a distance of 500 meters, as it recorded 39.80 and 33.90 respectively, falling within the low-pollution range of E_r^i < 40 (Table 3). The lowest value was also recorded at The electric power generation station had a rate of 10.20 at a distance of 2000 m. In general, the results indicate that the environmental risk index for the element lead was low, as it recorded values less than the impact threshold of 40, except for the distance 500-1000 m for the brick factory, which is considered the minimum level of average risk for the element. This is due to... Mainly due to the lower values of the toxicity response factor T for lead, which is 5, which reduced the values of the environmental risk index. The superiority of the brick factor by increasing the environmental risk index for lead compared to the rest of the studied facilities is due to the large pollution caused by the laboratories as a result of throwing their gaseous wastes into the air and liquid wastes into the air. Soil without treatment.

The values of the environmental risk index Er for the element cadmium in the soil of the study ranged between 41.10–264.00, which falls within the range of moderate to highly polluted pollution.

Table 9. Environmental risk index for lead and cadmium in the study soils

Heavy metals	Location											
	Electric power generation station				Oil refinery				Brick factory			
	Distance m											
	E_r^i											
	500	1000	1500	2000	500	1000	1500	2000	500	1000	1500	2000
Pb	33.9	20.45	15.95	10.2	39.8	31.55	26.65	11.05	57.1	41.1	32.9	18.25
Cd	264	228	174	60	136	108.6	62.7	49.2	124.5	108.6	77.1	41.1
RI	297.9	248.45	189.95	70.2	176.6	140.15	89.35	65.25	181.6	149.7	110	59.35

The highest value was recorded in the soil of the electric power plant at the distances of 500–1000 m, at 264.00 and 228.00 respectively, and it was within It ranked fourth for levels of environmental risk, which indicates high pollution, followed by the oil refinery and brick factories at a distance of 500 meters, amounting to 136.00 and 124.50, which are within the third level, which indicates that the soil was of great environmental risk, while Er recorded the lowest value for the element cadmium at the brick factory, at 41.10. At a distance of 2000 m, it is within the second level, which indicates moderate pollution. Table 9 also indicates the total environmental risk index (RI) for the elements lead and cadmium under study. We notice from the table a difference in the values of the total environmental risk index according to the study sites, as their levels ranged from a low indicator to a moderate degree of environmental risk, as the highest value of RI was recorded at the station Electrical power generation for the distances of 500, 1000, and 1500 meters amounting to 297.90, 248.45, and 189.95 respectively, and they are within the second level with a medium degree of total environmental risk, $50 \leq RI < 3001$, while the RI recorded the lowest value in the brick factory at 59.35 at the distance of 2000 meters, which was classified as level. The first is characterized by a low degree of environmental risk as it does not exceed a value of 150 according to Alawsy et al., 2024; Alawsy., 2020; Hassan et al., 2020; Hassan et al., 2023; Hakanson, 1980).

CONCLUSIONS

The results showed, in general, a higher concentration of lead and cadmium in the soil and plants close to the studied sources of pollution compared to samples relatively far from these sources, and that the pollution factor values for lead and cadmium for all study sites ranged from moderate pollution to very high pollution ($1 \leq CF \leq 3$) to $CF > 6$, and that the concentration of lead and cadmium in the study plants exceeded the permissible limits. According to the values of the environmental risk index, the soils fall within the range of low to moderate toxicity for lead and moderate to high toxicity for cadmium, and the levels of the overall environmental risk index ranged from low to moderate environmental risk.

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