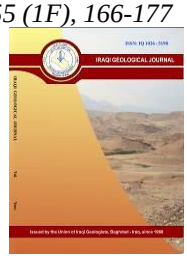
Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org



Assessment of the Contamination of Baghdad Soils with Lead Element

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Received:
15 February 2022

Accepted:
5 April 2022

Published:
30 June 2022

Abstract

The present study aims to study the content and spatial distribution of lead (Pb) contamination in the soils of some Baghdad cities (Middle of Iraq). Twenty soil samples were randomly collected from different land-use in the studied area at a depth between 5 to 30 cm. Ten samples are collected from Al-Rissafa side areas (Adhamiya, Al-Wazeeria (Battery Manufacturer), Shikh Omer, Ziyouna, Karada, Shaab, Sadr city, Al-Za'franiya, Al-Dora expressway, and Alselikh) and other ten samples are collected from Al-Krakh side areas Al-Dora, Al-Masafi junction, Al-Dora, Sayidia, Al-Salam university college, Al-Bayaa (Industrial District), Jehad, Amirya, Abu Ghraib, Al-hurriya, and Kadhimiya. The soil samples have been analyzed for the lead (Pb) with the utilization of the X-Ray Fluorescence. Based on the results, there is a notable difference in the concentration of Pb compared with the national and international permissible limits. The mean concentrations of Pb are 19507.5, 12.8, 2.2 mg/kg for industrial, roadside, and agricultural respectively and <1 for commercial, residential, and waste dumping sites. The high Pb concentration in the soils has been related to anthropogenic activities. Further, the spatial analysis map showed the high concentration of Pb distribution in the Al-Rissafa side of Baghdad city. The geoaccumulation factor and contamination factor indicate that all the soil samples are uncontaminated except the industrial sites are very high contamination with Pb. Also, by calculating the potential ecological risk, It has been found there is a very high ecological risk in the industrial sites, while a low ecological risk in other sites in the study area. The results showed that the average concentration of Pb in soil was greater than the global soil average.

Keywords: Lead; Contamination; Spatial distribution; Soil; Baghdad city

1. Introduction

Lead (Pb) is categorized as a heavy metal and considered the most common contaminant in soil. It is widely used to produce batteries, paints, and electronics. Besides, released into the soil as impurities from fertilizers, pesticides, application of municipal, industrial wastewater, and emissions from vehicles exhaust (Markus and McBratney, 2001). The Pb compound particles are suspended in the atmosphere for more than three weeks, and then distributed by the wind over hundreds of kilometers before settling in moist deposits. Particles bigger than 10 mm, which account for up to 95% of the emission, can accumulate over short distances (Binh et al., 2021), Atmospheric deposition continually increases the Pb content of surface soils (WHO, 1989). Pb is very low mobility and non-biodegradable, once incorporated in the soil; it is persisted for a long time and readily accumulated to a toxic level

DOI: 10.46717/igj.55.1F.14Ms-2022-06-29

(Kirpichtchikova et al., 2006). This can lead to a decline in biodiversity, animals and plants (Wani et al., 2015). In addition, the increase in Pb concentration above the natural limit leads to the degradation of soil quality and soil erosion is the main causes of the reduction in soil quality where Salah and Al-Madhhachi (2016) have been figured out that the soil erodibility increased directly as Pb concentration increase. As a result, controlling Pb emissions and remediating Pb-polluted soil is critical. Subsequently, Baghdad is regarded as one of Iraq's most significant and most industrialized cities, there are many sources of Pb emissions in Baghdad, industrial factories such as Al-Dora fuel production plants contributes to an increase in Pb concentration about 846 mg/kg due to adding Pb additives during fuel production (Sahib, 2005; Habib et al., 2012) and Babil car Batteries factory in al-waziryah city caused Pb contamination up to 25069.6 mg/kg predominantly according to using the Pb in battery production (Rahi et al., 2014). As well as, smelting processes for metal scrap in Al-Sadr city increasing the Pb concentrations in the environment. These factories employed very old techniques, have weak management, no pollution control system, and no wastewater treatment systems. As a result, some areas of Baghdad are considered to be at high risk of lead contamination. Lead is the most important element that need to disappear from the soil because have a very harmful effect on human health and environment. Lead is a part of many major industries like the Battery industry, motor gasoline, fertilizers, and pesticides so need to monitor it continuously. Thus, this research is very important for the environmental impact assessment to build a database on the Pb concentration in Baghdad's soil (Fakhre and Abdulhussein, 2020). The present study aimed to measure the content and evaluate the spatial distribution of Pb in Baghdad city and to assess the soil samples contamination by using indices Geo-Accumulation (I_{geo}), Contamination Factor (CF), and Ecological Risk Index (Er).

2. Study Area

Baghdad is the largest city in Iraq and the second largest capital in the Arab World Region according to the density of inhabitance. The study area is situated in the central of Iraq between UTM coordinates northing (3672000-3704000) and easting (428000-456000), (Fig.1). The Tigris River passes through the lands of the Baghdad city divides it into two parts (Karkh and Rissafa). The study area is characterized by the presence of Industrial sites, commercial and agriculture land. Baghdad is covered by quaternary sediments (Pleistocene and Holocene) and characterized by flat topography (Jassim and Goff, 2006).

3. Materials and Methods

3.1. Sampling and Analyses

A total of 20 samples of soil were collected to cover the majority of the city's regions, with an emphasis on the nature of each area (agricultural, commercial, industrial, residential, and roadside). Ten samples are collected from Al-Rissafa side areas (Adhamiya, Al-Wazeeria (Battery Manufacturer), Shikh Omer, Ziyouna, Karada, Shaab, Sadr city, Al-Za'franiya, Al-Dora expressway, and Alselikh) and other 10 samples collected from Al-Krakh side areas (Al-Dora, Al-Masafi junction), Al-Dora, Sayidia, Al-Salam university college, Al-Bayaa (Industrial District), Jehad, Amirya, Abu Ghraib, Al-hurriya, and Kadhimiya. All soil samples were collected in 6 and 7th November 2020 from the surface at a depth between 5-30 cm by hand auger, then transferred into labeled plastic bags. The coordinate of each sample was obtained by using GPS (Table 1).

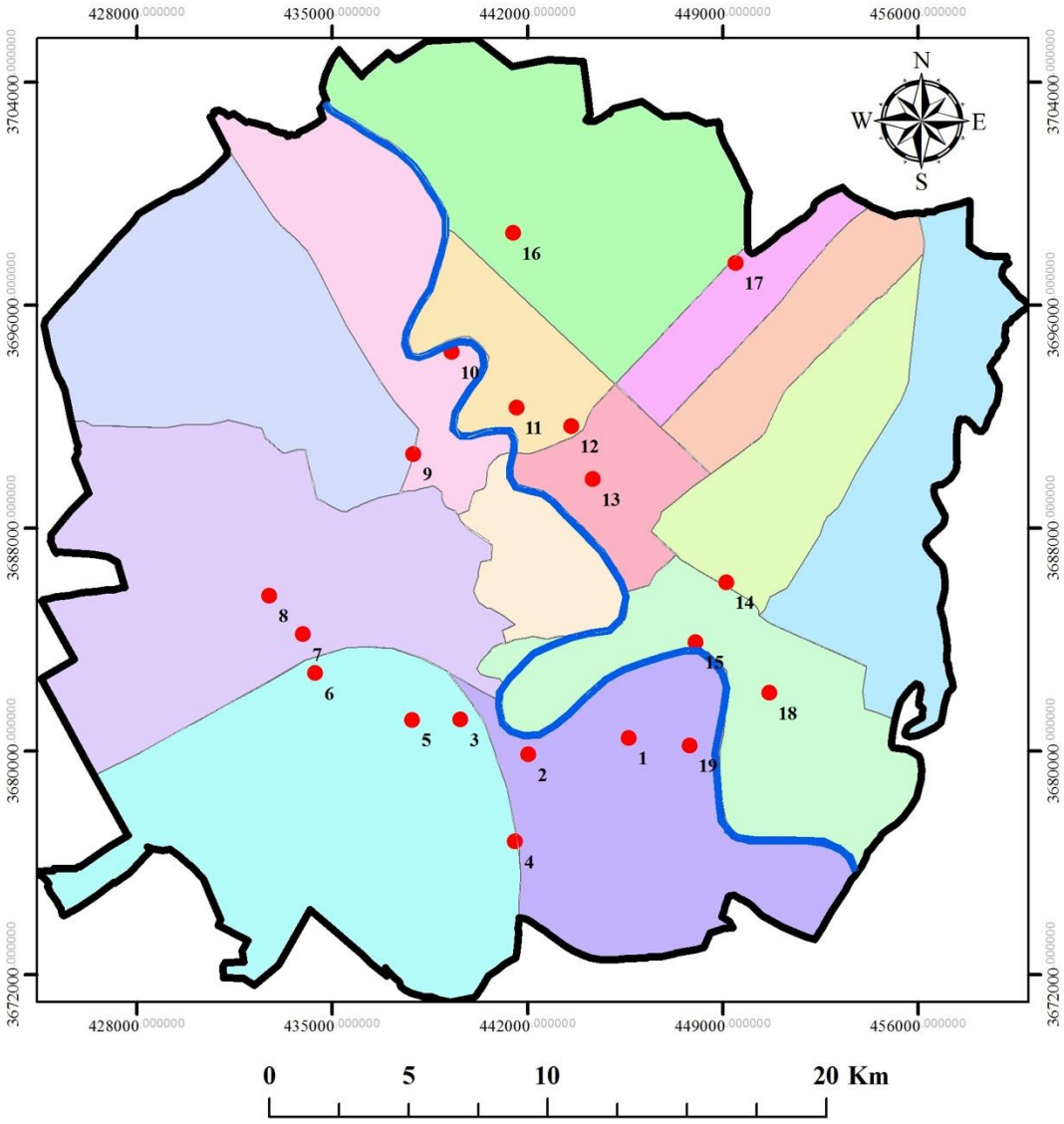

Fig.1. The location map of the soil samples

After that, all samples were sent to the laboratory for processing in preparation for the required analysis. The wet samples were dried in the laboratory using an oven set to 40Cº, homogenized, and then sieved with a 2 mm sieve in order to remove large debris, stone, gravel, plant materials, and other materials. The Pb content of the soil was determined using the X-Ray Fluorescence technique (XRF) in XRF Laboratory in Directorate of Environmental and Water Research and Technology, Ministry of Science and Technology. Mineralogical identification was performed for 19 samples by using X-Ray Diffraction (XRD), nineteen samples were subjected to identify the non-clay minerals, and four samples (5,12,13,17) were chosen to identify the clay minerals. XRD analysis was carried out in Directorate of Materials Research, Ministry of Science and Technology The spatial analysis map was designed by Arc GIS 10.4.1. Data obtained from the laboratory analyses have been subjected to descriptive statistics analysis by using IPM SPSS statistics 25.

Table 1. The Site name of land use type and coordinates (UTM)

Sample No.	Site name	Land use type	Coordinates (UTM)	
			Easting	**Northing**
1	Al-Dora (Al-Masafi junction)	Roadside	445637	3680485
2	A-Dora	Agricultural	442041	3679889
3	Sayidia	Agricultural	439595	3681134
4	Al-Salam university college	Agricultural	441565	3676765
5	Al-Bayaa (Industrial District)	Industrial	437871	3681120
6	Jehad	Agricultural	434398	3682802
7	Amirya	commercial	433959	3684200
8	Abu Ghraib	Waste dumping site	432747	3685586
9	Al-hurriya	Residential	437921	3690662
10	Kadhimiya	Agricultural	439283	3694319
11	Adhamiya	Agricultural	441620	3692327
12	Al-Wazeeria (Battery Manufacturer)	Industrial	443585	3691668
13	Shikh Omer	Industrial	444355	3689755
14	Ziyouna	Residential	449130	3686058
15	Karada	commercial	448043	3683911
16	Shaab	Agricultural	441488	3698587
17	Sadr city	Industrial	449475	3697518
18	Al-Za'franiya	Residential	450674	3682094
19	Al-Dora expressway	Agricultural	447821	3680205
20	Alselikh	Residential	441820	3695015

3.2. Soil Pollution Assessment Methods

The evaluation of the soil pollution was carried out with different methods, for this purpose different indices were used for the evaluation of lead (Pb) pollution in different land use in Baghdad soil. The indices used were applied by many researchers for example Awadh (2015). These indices are Geoaccumulation index (Igeo), contamination factor (CF), and Ecological Risk Index (Er).

3.2.1. Index of Geoaccumulation (I_{geo})

The index of geoaccumulation (Igeo) is a quantitative measure that compares current and preindustrial concentrations of metals in soil to describe the extent of metal pollution proposed by Muller (1969) and given by Nowrouzi and Pourkhabbaz (2014). This heavy metal index (I_{geo}) is computed according to the following equation:

$$I_{geo} = \log2 [C_n/1.5B_n] \quad (1)$$

Where C_n is the measured heavy metal concentration in the soil sample and B_n is the heavy metal geochemical background concentration. The constant 1.5 is used to mitigate the influence of achievable fluctuations in background values caused by lithological variances (Abrahim and Parker, 2008). The values of this 7-grade index range from subzero to more than 5 (Muller, 1969), (Table 2).

Table 2. Geoaccumulation index (I geo) for soil pollution levels

I_{geo} Class	I_{geo} value	Pollution level
0	<0	practically unpolluted
1	0-1	unpolluted to moderately polluted
2	1-2	moderately polluted
3	2-3	moderately to strongly polluted
4	3-4	strongly polluted
5	4-5	strongly to extremely polluted
6	>5	extremely polluted

3.2.2. Contamination Factor (CF)

The contamination factor (CF) is calculated by dividing the heavy metal concentration in the soil by the same metal's background value (Håkanson, 1980).

$$CF = C_{\text{Heavy metal}} / C_{\text{Background}} \quad (2)$$

Where $C_{background}$ is the average concentration of the corresponding heavy metal in the background samples and $C_{heavy\ metal}$ is the measured concentration of heavy metal in a sample. According to Håkanson (1980), there are four types of contamination factors (Table 3).

Table 3. Soil pollution classifications depending on the level of contamination (CF)

CF Value	contamination Level
CF<1	Low contamination
1<CF<3	Moderate contamination
3<CF<6	Considerable contamination
CF>6	Very high contamination

3.2.3. The Potential Ecological Risk Index (Er)

Assesses the toxicity of specific trace elements in sediments (Zheng, 2013) and is presently utilized in soil analysis to identify the ecological risk of lead in the soil of the research region. To determine the Potential of Ecological Risk index (Er) for each metal, the following equation from Håkanson (1980) was used:

$$Er = Tr * CF \quad (3)$$

Where Tr is the toxic response factor, with a standard value of 5 for Pb, CF is the contamination factor. Table 4 shows the categorization of the potential ecological risk index:

Table 4. The categorization standard for possible ecological risk in soil

Er value	Pollution degree
Er <40	low potential ecological risk
40≤ Er <80	moderate potential ecological risk
80≤ Er <160	considerable potential ecological risk
160≤ Er <320	high potential ecological risk
Er ≥320	very high ecological risk

4. Results

4.1. Content and Spatial Distribution of Lead in the Soil

Table 5 shows the total lead content in soil samples taken from the study area in mg/kg, as well as national and international background values and the spatial distributions of lead in soil are displaying in Fig.2.

Table 5. Lead element concentration in the study area

Sample No.	Site name	Land use	Concentration of Pb (mg/kg)
1	Al-Dora (Al-Masafi junction)	Roadside	12.8
2	A-Dora	Agricultural	2.2
3	Sayidia	Agricultural	<1
4	Al-Salam university college	Agricultural	<1
5	Al-Bayaa (Industrial District)	Industrial	2620
6	Jehad	Agricultural	<1
7	Amirya	commercial	<1
8	Abu Ghraib	Waste dumping site	<1
9	Al-hurriya	Residential	<1
10	Kadhimiya	Agricultural	<1
11	Adhamiya	Agricultural	<1
12	Al-Wazeeria (Battery Manufacturer)	Industrial	73420
13	Shikh Omer	Industrial	1400
14	Ziyouna	Residential	<1
15	Karada	commercial	<1
16	Shaab	Agricultural	<1
17	Sadr city	Industrial	590
18	Al-Za'franiya	Residential	<1
19	Al-Dora expressway	Agricultural	<1
20	Alselikh	Residential	<1
Min			2.2
Max			73420
Av.			13007.5
Std. Deviation			29612.49
National background (AL-Basssam, 2014)			5
International background (WHO, 2003)			100

B.D.L: Below detection Limit; LLD of Pb (mg/kg) = 1.0 (Bruker Advance X-Ray Solution: Application Report); WHO: World health organization

4.2. Mineralogical Identification

The mineralogical analysis results of nineteen samples were subjected to XRD analysis are shown in Table 6. According to these analysis results, quartz, calcite, and albite are the main non-clay mineral, dolomite and gypsum were distinguished as minor minerals. Clay minerals analysis results demonstrate the presence of illite, kaolinite, chlorite, palygorskite, and montmorillonite.

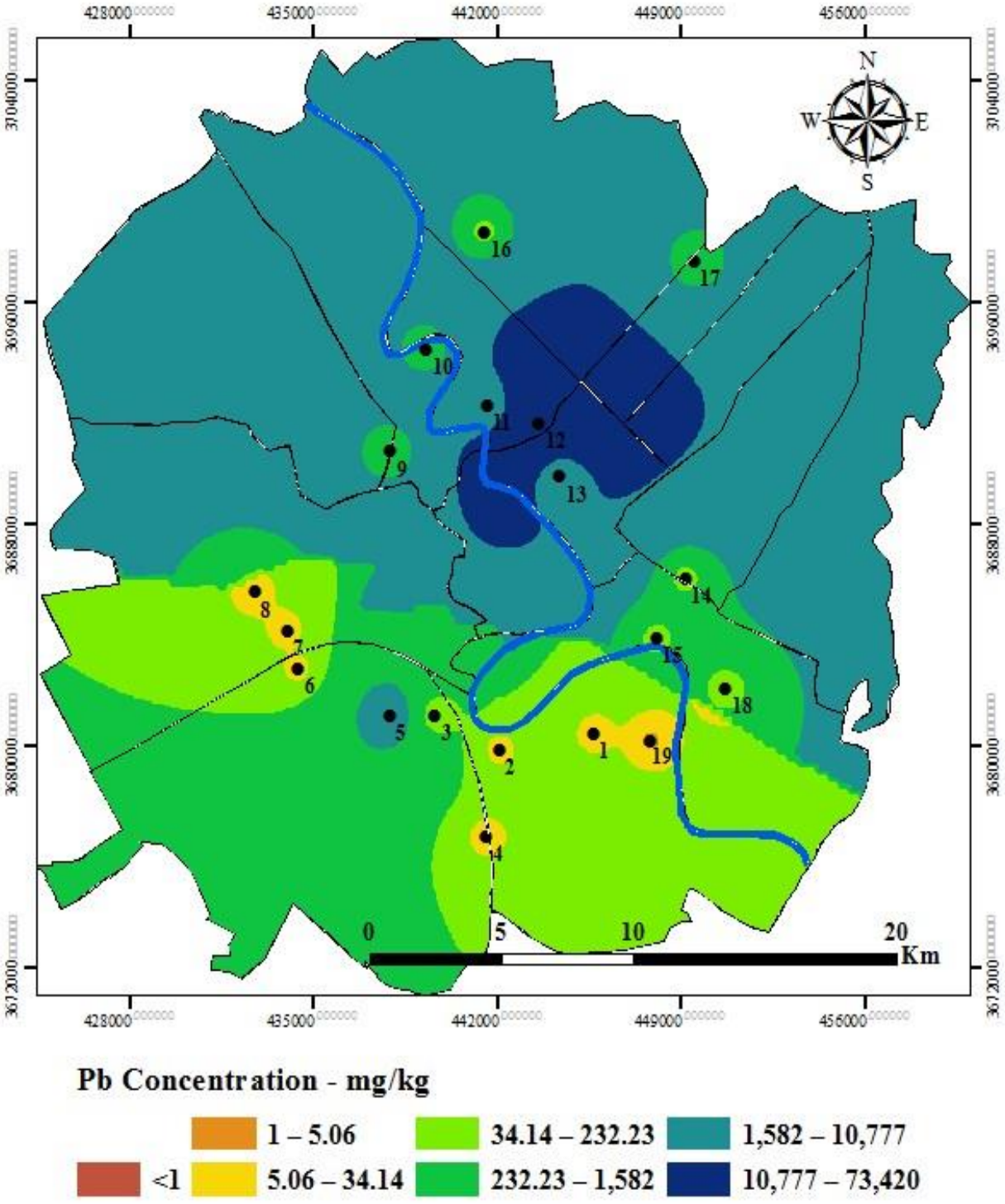

Fig. 2. The spatial distribution map of Lead (Pb) in soil of study area

Table 6. Mineralogical identification of soil samples collected from Baghdad city

Sample No.	Quartz	Calcite	Albite	Illite	Dolomite	Kaolinite	Chlorite	Gypsum	Palygorskite	Montmorillonite
1	44.3	11.1	12.1	3.4	26.1	-	2.5	-	-	-
2	35.4	25.9	24.8	8.3	4.8	-	-	0.6	-	-
3	51.2	21	13.1	5	6.9	2.3	-	-	-	0.6
4	24.9	36.7	12.7	14	4.1	6	-	0.5	-	0.6
5	39.5	26	7.3	13.2	3	-	6.5	4.5	-	-
6	70	9	8.6	5.6	-	-	6.8	-	-	-
7	36.2	32.1	-	9.9	1.6	7	-	4.3	-	-
8	33.5	26.2	25.7	8.3	2.2	-	2.3	1.9	-	-
9	66.7	8	20	0.1	-	3.5	-	1.7	-	-
10	43.6	27.3	12.1	-	2.2	12	-	2.6	-	0.2
11	53.2	21.8	16.6	4.4	-	3.8	-	0.2	-	-
12	67.8	10.3	15	-	-	3	-	3.9	-	-
13	40.8	37.4	8.3	4.3	5	2.2	-	2	-	-
14	47	22.2	11.8	11.1	-	3.2	-	0.5	-	1.7
15	82	6.9	9.3	-	-	1.8	-	-	-	-
16	45.3	23.7	15.8	9.9	-	1.7	-	3.2	-	0.2
17	20.5	28.2	11.5	8.6	-	1.6	2.4	23.9	4	-
18	28.6	20.6	14.7	6.8	6.3	8.3	-	4.9	9.9	-
19	29	36.8	13.4	8.3	8	-	-	0.2	3.2	-
Min	20.5	6.9	7.3	0.1	1.6	1.6	2.3	0.2	3.2	0.2
Max	82	37.4	25.7	14	26.1	12	6.8	23.9	9.9	1.7
Mean	45.23	22.69	14.04	7.57	6.38	4.33	4.10	3.66	5.70	0.66

4.3. Assessment of Soil Pollution

The normative calculation of the pollution assessment method is presented in Tables 7,8, and 9.

Table 7. Mean value of Geoaccumulation I_{geo} for different land use

Land use	I_{geo} value	I_{geo} Class	Pollution level
Industrial	2.415	3	moderately to strongly polluted
Agricultural	-1.53	0	practically unpolluted
Residential	<0	0	practically unpolluted
Roadside	-0.76	0	practically unpolluted
Commerical	<0	0	practically unpolluted
Waste dumping site	<0	0	practically unpolluted

Table 8. Mean value of Contamination factor for different land use

Land use	CF Value	contamination Level
Industrial	195.075	Very high contamination
Agricultural	0.022	Low contamination
Residential	<1	Low contamination
Roadside	0.128	Low contamination
Commerical	<1	Low contamination
Waste dumping site	<1	Low contamination

Table 9. Mean value of Ecological Risk Index (Er) for different land use

Land use	Er value	Pollution degree
Industrial	975.375	very high ecological risk
Agricultural	0.11	low potential ecological risk
Residential	<1	low potential ecological risk
Roadside	0.64	low potential ecological risk
Commerical	<1	low potential ecological risk
Waste dumping site	<1	low potential ecological risk

5. Discussion

The Pb content in soil samples ranged from 1 to 73420 mg/kg in Al-Wazeeria city (battery manufacture) (Table 5). The observed values in the industrial areas (Al-Wazeeria city, Al-Bayaa, Shikh omer and Sadr city) exceed the acceptable limits (100 mg/kg) of a world health organization (WHO, 2003). whereas, the Pb concentration in other sites are within the permissible limits. In comparison with the Iraqi standards 5 mg/kg (AL-Basssam, 2014) industrial areas and roadside are showed high differences. The Mineralogical analysis of soil samples shows the dominance of the non-clay mineral (quartz, calcite, albite, and gypsum) which are common minerals in Iraqi soil whereas, illite is dominant in the clay mineral (Table 6). The kind of clay mineral has an influence on heavy metal absorption. For example, montmorillonite may absorb more trace and heavy metals due to its expandable nature. The observed high concentration of Pb in Al-Wazeeria city (Battery manufacture) is mostly related to the manufacture of lead-acid batteries. lead is mainly the life cycle toxicity potential of lead-acid batteries, particularly the emissions of total lead into the environment (Liu et al., 2015). Whereas, the elevated concentrations of Pb in Al-Bayaa (industrial District) and Shikh Omer could be due to the application of municipal and industrial wastewater, using paints and also petroleum products. In the Sadr city elevated Pb concentration is mainly due to smelting operation which is conducted in primitive method without control. Roadside (Al-Masafi junction site) is considered as a high-density traffic site, thus Pb elevated concentration is due to the vehicles using leaded gasoline and lead-acid batteries and maybe form atmospheric emission of Al_Dora refinery. Generally, the industrial sites have the highest concentrations of Pb than roadside sites and other land-use sites. Thus, conclude the source of high Pb concentrations is anthropogenic activities.

The spatial analysis map elucidates the concentrations of Pb in Al-Rissafa side more than Al-karkh side and the reason is due to the numerous industrial areas in Al-Rissafa side. Table 7 showed the mean values of geoaccumulation index (I_{geo}) ranged between <0 – 2.415. All I_{geo} mean values for soil samples were less than 0 and within class 0 which indicates that it is practically unpolluted except the industrial area where I_{geo} mean value was 2.415 within class 3 which indicates that is moderate to strongly polluted. These results support the hypothesis that pollutants from anthropogenic activity, such as industrial activity, which effect on study area.

The Contamination Factor (CF) is recognized as an effective and simple tool for monitoring heavy metal contamination and its high value indicates the state of pollution at that site. The values of CF for the soil samples of the investigated area are shown in Table 8, which ranged between <1 - 195.075 mg/kg and its value has increased in samples (5, 12, 13, 17) which are industrial areas and this indicates the level of pollution that arise as a result of the anthropogenic effect of human activities.

The Ecological risk index (Er) mean values for Pb element in soil samples of the study area ranged between <1 to 975.375 (Table 9). The observed results reveal that there is a minimal potential ecological risk in all locations except the industrial sites, where the mean values of soil samples exceed 320, indicating a very high potential ecological risk.

Finally, the average Pb concentration for the different land-use in the present study was compared with average concentrations from previous Baghdad soil studies and global average soil values (Table 10). Results elucidated significant variations in Pb concentrations that may indicate effects of soil type, parent rock type, and anthropogenesis due to active industry. The mean concentrations of Pb in the industrial areas of the present study were reported to be higher than those of the world soil (Lindsay, 1979) and all previous studies of Baghdad soil. these observed an increase in the accumulation of Pb in industrial areas and that might be related to poor management, the absence of waste treatment plants, and the direct discharge of industrial waste into the environment without treatment. Whereas, the agricultural, waste dumping site, commercial, roadside, and residential are lower than other previous studies.

Table 10. Comparison between the average concentration of Pb in mg/kg for different land use of present study and previous studies of Baghdad city and the world soil limit

The type of land use	Mean Concentration of Pb	References
Residential	90.98	(Al-Obaidy and Al-Mashhadi, 2013)
Commercial	107.05	
Industrial	143.91	
Roadside	117.83	
Open area soils	110.13	
Agricultural	23.3	(Ali et al., 2013)
Industrial	87.3	
Urbanization	110.1	
All soils	153.7	(Al-Maliky, 2005)
All soils	108.7	(Abdullah, 2010)
All soils	43	(Habib et al., 2012)
All soils	13.358	(Mohammed and Abdullah, 2016)
Urbanization	323.43	(Abdulateef and Naser, 2019)
Agricultural	203.46	
All soils	10	(Lindsay,1979)
Industrial	19507.5	Present study
Agricultural	2.2	
Residential	<1	
Commercial	<1	
Waste dumping site	<1	
Roadside	12.8	

6. Conclusions

The findings of the present study demonstrated the concentration of Pb in industrial site samples (5, 12, 13, 17), soil exceeds the permissible limits of health world organization (WHO) 100 mg/kg while the other sites were within the permissible limits. Furthermore, the mean concentration of Pb in industrial sites and roadside site are exceed the permissible limit of Iraqi standard for Pb 5mg/kg whereas, other sites are within permissible limits of Iraqi standards. Generally, the spatial analysis map showing the highest content of Pb was found on Al-Rissafa side. The high Pb concentration in the soils has been related to anthropogenic activities. Based on the results of soil pollution assessment methods (I_{geo}, CF and the potential ecological risk Er), the investigated soils have low Pb contamination and ecological risk in all sites except the industrial sites reported very high contamination and ecological risk. Comparison of the Pb concentration of the present study with the previous studies of Baghdad soil

and world soil mean values showed that the study area has a higher Pb concentration in industrial sites than in those of other studies and the world soil average.

Acknowledgements

The authors would like to express their gratitude to Dr. Maitham A. Sultan for his assistance during field work and laboratory analysis which was carried out in XRF laboratory of Environmental & Water research & Technology Directorate, Ministry of Science and Technology. The authors are very grateful to the reviewers, Editor in Chief Prof. Dr. Salih M. Awadh, the Secretary of Journal Mr. Samir R. Hijab, and the Technical Editors for their great efforts and valuable comments.

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