# Assessment of heavy metals pollution in polluted soils in Basrah city, Iraq

**Fadya M. Saleem***, **Hussain T. Khreebsh and Sukaina M. Altaher**

Department of Ecology, Department of Ecology, College of Science, University of Basrah, Basrah, Iraq.

***Corresponding author E-mail**: fadya.saleem@uobasrah.edu.iq

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**ABSTRACT**

Soil pollution with heavy metals has wide attention in recent years because of its hazardous and toxicity to human health. This study is carried out to evaluate the heavy metals contamination in soils near thermal power plants and private electrical generators in Basrah city and assessed the metal pollution status of soil using geoaccumulation Index. The results showed that the concentration of Cd ranged (0.93 - 4.905) µg $g^{-1}$, Pb ranged (22.96 - 38.995) µg $g^{-1}$, Ni ranged (13.66 - 63.635) µg $g^{-1}$ and Cu ranged (4.645 - 44.66) µg $g^{-1}$. Heavy metals in this study showed increasing in their concentration comparing with the background concentration of these metals in the earth crust. The Igeo values of the four metals were as follows: Cd > Ni > Pb > Cu. The annual mean of Igeo values of Cd, Pb, Ni and Cu ranged (2.6 – 5), (– 0.4 - 0.4), (– 1.1 - 1.1) and (– 3.0 - 0.3) respectively. The using of Igeo of soil provides a view on soil contamination assessment with heavy metals in the studied area.

## 1. Introduction

The environmental pollution is a main problem in the world due to anthropogenic activities and modern technology that add many pollutants to air, water and soil **[1, 2]**. Soil quality is destroyed due to existence of pollutants such as heavy metals **[3]** which are released to the earth crust either by natural sources such as rocks alteration and erosion **[4]** or anthropogenic sources such as mining, industrial and agricultural sources, vehicles emissions, as well as incomplete combustion of fuel **[5-7]**. Heavy metals are non-biodegradable and persistent for many years in the various environments **[8, 9]**.

Some heavy metals have an important role in the functioning of enzyme systems but at high concentrations they become toxic. Whereas others metals, such as Pb and Cd do not have any biological function therefore they may be harmful even at low concentrations **[10]**. The humans, animals and plants exposure to heavy metals happens by various ways including inhalation, direct ingestion, absorption by plants, food chains and contaminated water and soil **[11, 12]**. The toxicity of heavy metal can decrease the levels of energy and impact on many organs such as brain, lungs, kidney and liver causing damage on their functions. Exposure to toxic metals for Long-term can lead to many diseases while the repeated exposure to some metals and their compounds for Long-term may cause cancer **[13]**. The risks associated with heavy metals contamination in soil are multiple. These include the effect on soil microorganism activities and diversity, degradation of organic matter, concentration in all organisms and transmission by the food chain lead to infection of many diseases **[14-16]**.

The spread of industries, especially heavy industries such as mining industries and electric power plants led to heavy metals contamination and minerals accumulation in surrounding soils **[17, 18]**. The stations of electrical power generation pollute the surrounding air, water, soil and plants due to gaseous emissions loaded with fly ash and heavy metals, as well as high-temperature water emitted from them loaded with many pollutants **[19, 20]**. The soil in areas near thermal power plants suffered from high-risk metal pollution. The combustion in thermal power plants releases hazardous pollutants into the air then reach to the soil where they are deposited and remain for many years **[21-23]**.

Private electrical generators are widespread in Iraq after 2003 due to frequent electrical power outage resulting from low electricity production from power plants and these generators are located within residential areas nearby the citizens **[24, 25]**. These generators use diesel or gasoline and produce many toxic substances, including hydrocarbons, oxides, particulate matters and heavy metals which cause numerous risks to the environment and humans **[26]**.

The objectives of this study are determine the concentration of heavy metals in soils near thermal power plants and private electrical generators in Basrah city and assess the metal pollution status of soil using geoaccumulation Index.

## 1. Materials and Methods

### 2.1. Study area

This study was conducting in Basrah city that located in south of Iraq on the western bank of Shatt Al-Arab. Basrah city is the economic capital of Iraq; it has many industrial and service facilities such as oil companies, thermal power plants and private electrical generators which contribute the heavy metals contamination and other contaminants. Soil samples were collected during winter and summer seasons 2023 from six stations include (four soil samples near private electrical generators (Al-Dear, Al-Jubailah, Al-Kibasi and Al-Baradieah) and two soil samples near thermal power plants (Al-Najibiah and Al-Hartha)) (as shown in **Table 1, Figure 1**).

### 2.2. Samples collection and preparation

Soil samples were collected from three places at each station using stainless steel shovels at depth 0-15 cm and were mixed together as a composite sample, then placed in plastic bags. All samples were air dried in laboratory at room temperature then removed all stones and any other materials. The dried soil samples were grinded finely using porcelain mortar then sieved through mesh 63 microns. 1 gm of each soil sample was digested with an acidic mixture (HF, $HClO_4$, $HNO_3$), then it was transferred to a solution of 0.5M HCl (50 ml) **[27]**. The samples were analyzed using the Atomic Absorption Spectrophotometer (AAS) type Phoenix 986 (UK) to measure the elements (Cd, Pb, Ni and Cu).

**Table 1.** The coordinates of the studied locations

| Stations | Longitude (E) | Latitude (N) |
|---|---|---|
| **ST1** | 47º 34 20 | 30º 48 10 |
| **ST2** | 47º 48`55 | 30º 34`30 |
| **ST3** | 47º 48`43 | 30º 32`45 |
| **ST4** | 47º 51 13 | 30º 29 57 |
| **ST5** | 47º 44 57 | 30º 40 40 |
| **ST6** | 47º 46 01 | 30º 34 25 |

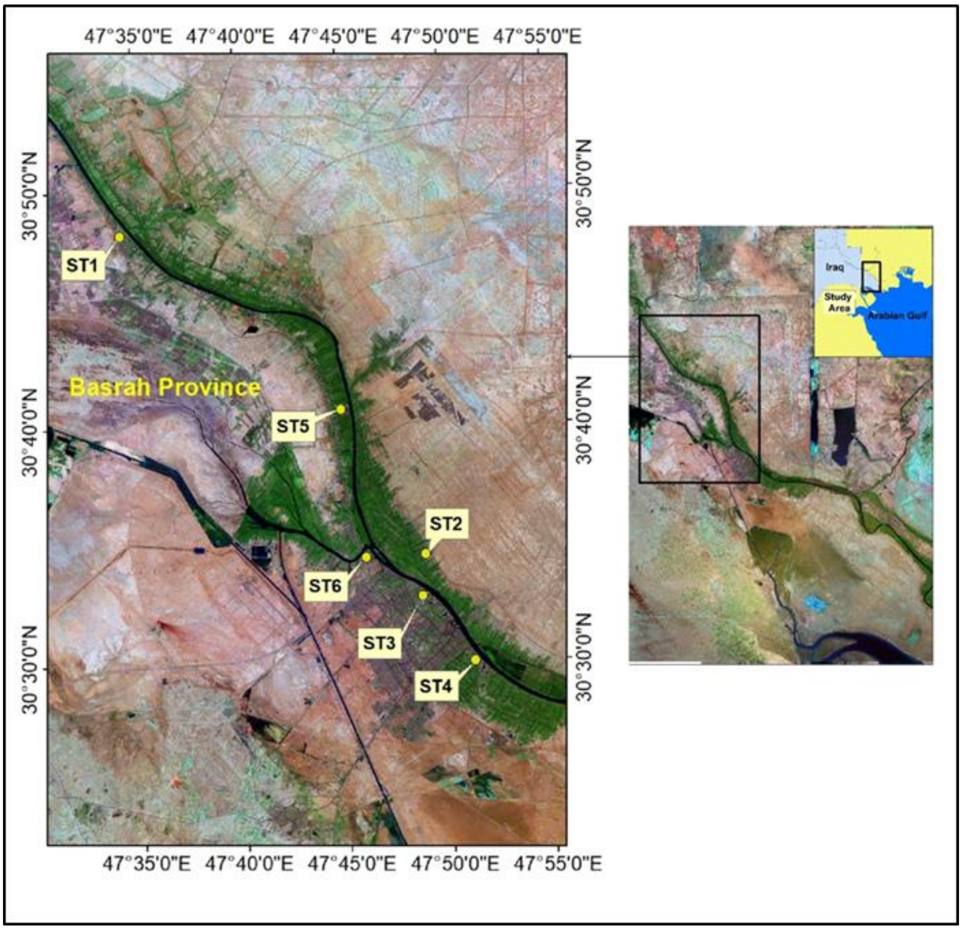


**Figure 1.** Map of studied areas in Basrah

### 2.3. Geoaccumulation Index ($I_{geo}$)

The geoaccumulation index is used widely to assess the metal contamination in the environment by comparing the level of heavy metal measured to a background level of metal in the earth crust **[28, 29, 22]**. The $I_{geo}$ of each metal in soil can be calculated using the formula as shown below:

$$I_{geo} = log_2(\frac{cn}{1.5Bn})$$

Where:

Cn : the measure of concentration of the examined metal in the soil.

Bn : the geochemical background concentration of the same metal.

1.5 : factor is introduced to minimize the effect of possible variations in the background

The degree of metal contamination is evaluated based on seven contamination classes (as shown in **Table 2**):

**Table 2.** The contamination classes of metals according to geoaccumulation index

| Sub - index | Classes |
|---|---|
| $I_{geo} < 0$ | not polluted |
| $0 < I_{geo} \leq 1$ | not polluted to moderately polluted |
| $1 < I_{geo} \leq 2$ | moderately polluted |
| $2 < I_{geo} \leq 3$ | moderately polluted to heavily polluted |
| $3 < I_{geo} \leq 4$ | heavily polluted |
| $4 < I_{geo} \leq 5$ | heavily polluted to extremely polluted |
| $I_{geo} > 5$ | extremely polluted |

### 2.4. Statistical analysis:

#### 2.4.1. SPSS ver. 19 software program

The results were statistically analyzed to find standard deviation and correlation coefficients among studied locations and between two seasons using SPSS ver. 19 software program.

#### 2.4.2. Principal Components Analysis (PCA)

PCA is a multivariate statistical method which determines what the most important variables that have the greatest impact **[30]**. PCA is done using the statistical program (XLSTAT software).

## 3. Results and discussion

### 3.1. Heavy metals in soil

The air precipitation in industrial regions is one of the most important sources of soil pollution with heavy metals that poison the humans and other organisms **[20]**. The concentrations of heavy metals during winter and summer seasons are detailed in (**Table 3**).

Generally, the metal concentrations were higher in winter than summer in the studied locations. The lower metal concentration in the present study was Cadmium whereas the highest was Nickel. Statistical analysis showed significant differences at ($P>0.01$) among locations and between the two studied seasons. (**Figure 2**) illustrates the annual mean of heavy metals in the studied locations. Heavy metals in this study showed increasing in their concentration comparing with the geochemical background concentration of these metals which are (0.1, 20, 20 and 25) µg $g^{-1}$ for Cd, Pb, Ni and Cu respectively **[31, 22]**.

The lower annual mean of Cd was 0.93 µg $g^{-1}$ recorded in ST4 while the higher was 4.905 µg $g^{-1}$ in ST2. The results showed that Cd values are very rise in all soil samples comparing with the background value of Cd in the earth crust. This is due to emission of fuel combustion from power plants and electrical generators and other sources such as vehicles emission **[32]**. The lower annual mean of Pb was 22.96 µg $g^{-1}$ recorded in ST3 while the higher was 38.995 µg $g^{-1}$ in ST2. There is a clear rise in Pb in all soil samples comparing with the background value of Pb in the earth crust. This may be because of the use of leaded fuel, which comes from electrical generators and car exhaust and other human activities **[33]**.

**Table 3.** The concentration of heavy metals (µg $g^{-1}$) and basic statistics in the studied areas during winter and summer seasons

| | | **Conc. in winter season** | | | | **Conc. in summer season** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Station Type** | **No** | **Cd** | **Pb** | **Ni** | **Cu** | **Cd** | **Pb** | **Ni** | **Cu** |
| **Electrical generators** | **ST1** | 2.28 ±0.06 | 30.96 ±0.01 | 62.31 ±0.01 | 67.20 ±0.05 | 0.39 ±0.01 | 41.67 ±0.05 | 42.89 ±0.08 | 15.26 ±0.08 |
| | **ST2** | 6.62 ±0.07 | 29.20 ±0.03 | 86.20 ±0.01 | 37.14 ±0.01 | 3.19 ±0.04 | 48.79 ±0.06 | 41.07 ±0.01 | 32.16 ±0.03 |
| | **ST3** | 2.80 ±0.01 | 23.82 ±0.04 | 18.06 ±0.02 | 4.86 ±0.06 | 2.79 ±0.01 | 22.10 ±0.06 | 9.26 ±0.07 | 4.43 ±0.01 |
| | **ST4** | 1.27 ±0.06 | 36.32 ±0.03 | 40.18 ±0.01 | 22.18 ±0.07 | 0.59 ±0.02 | 38.16 ±0.11 | 9.22 ±0.01 | 40.94 ±0.08 |
| **Power plants** | **ST5** | 0.39 ±0.01 | 54.12 ±0.04 | 90.63 ±0.01 | 66.83 ±0.06 | 2.97 ±0.01 | 18.55 ±0.07 | 12.61 ±0.01 | 2.88 ±0.01 |
| | **ST6** | 2.66 ±0.07 | 34.51 ±0.01 | 25.11 ±0.03 | 20.21 ±0.01 | 2.40 ±0.02 | 41.68 ±0.06 | 83.55 ±0.01 | 69.11 ±0.03 |
| **Min** | | 0.39 | 23.82 | 18.06 | 4.86 | 0.39 | 18.55 | 9.22 | 2.88 |
| **Max** | | 6.62 | 54.12 | 90.63 | 67.20 | 3.19 | 48.79 | 83.55 | 69.11 |
| **Mean** | | **2.67** | **34.82** | **53.75** | **36.40** | **2.06** | **35.16** | **33.10** | **27.46** |

The lower annual mean of Ni was 13.66 µg $g^{-1}$ recorded in ST3 while the higher was 63.635 µg $g^{-1}$ in ST2. There are high levels in the Ni concentrations in most soil samples comparing with the background value of Ni in the earth crust. These high levels of Ni are due to either natural source found in earth's interior rock or anthropogenic sources which are the main sources of Ni such as power plants and incomplete combustion of fuel in electrical generators and the other activities **[34]**. The lower annual mean of Cu was 4.645 µg $g^{-1}$ recorded in ST3 while the higher was 44.66 µg $g^{-1}$ in ST5. There is a clear rise in Cu values in most soils comparing with the background value of Cu in the earth crust. The sources of Cu may be natural whereas the main sources are anthropogenic activities such as combustion emissions from power plants and electrical generators **[20]**.

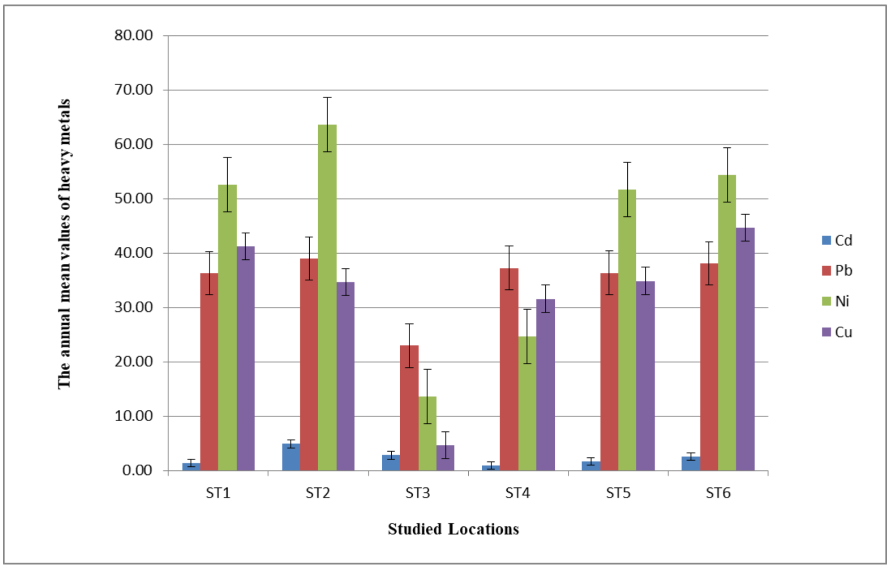


**Figure 2.** The annual mean values of heavy metals (µg $g^{-1}$) in all studied locations

The results of this study in all locations showed that the combustion emissions are the main contributor in the most heavy metals content in soil near the power plants and electrical generators that excrete these metals to the outside as fumes or dust which remain suspended in the air for duration of time, then precipitate on soil and contain a significant amounts of heavy metals. As well as the earth's interior rock from which soils are derived naturally contain heavy metals. This finding is agreed with previous studies **[32, 33, 24, 31, 35, 20, 36]** who found that the emissions of power plants and electrical generators added a significant amounts of heavy metals in the surrounding soil, especially the studied locations do not have any agricultural activities that could contribute the total content rising of heavy metals such as Cd, Pb, Ni and Cu which are found in the composition of pesticides and fertilizers. This confirms that industrial activities are the main contributor of soil pollution with metals.

### 3.2.Geoaccumulation index

The using of geochemical accumulation index provides a soil contamination assessment of metals in the studied area. The Igeo values of all studied locations are detailed in (**Table 4**). The annual mean of Igeo values of the four metals were as follows: Cd > Ni > Pb > Cu. The lowest value of Igeo in the studied metals is -0.7 for Ni in winter and Pb in summer, while the highest is 5.5 for Cd in winter. Generally the Igeo values in winter are higher than summer.

The annual mean of Igeo of Cd ranged from 2.6 in ST4 to 5 in ST2 thus, it is classified within the two categories, moderately polluted to heavily polluted and extremely polluted. The Igeo values were higher than zero indicate that all studied locations were much polluted with Cd. The annual mean of Igeo of Pb ranged from – 0.4 in ST3 to 0.4 in ST2 thus, it is classified within the two categories, not polluted and not polluted to moderately polluted indicate that there are very little contamination with Pb according to Igeo values.

The annual mean of Igeo of Ni ranged from – 1.1 in ST3 to 1.1 in ST2 thus, it is classified within the two categories, not polluted and moderately polluted indicating that there is a little contamination with Ni according to Igeo values.

**Table 4.** The values of geoaccumulation index in the studied areas

| Stations | Winter season | | | | Summer season | | | | Annual mean | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cd | Pb | Ni | Cu | Cd | Pb | Ni | Cu | Cd | Pb | Ni | Cu |
| **ST1** | 3.9 | 0.0 | 1.1 | 0.8 | 1.4 | 0.5 | 0.5 | -1.3 | 3.2 | 0.3 | 0.8 | 0.1 |
| **ST2** | 5.5 | 0.0 | 1.5 | 0.0 | 4.4 | 0.7 | 0.5 | -0.2 | 5.0 | 0.4 | 1.1 | -0.1 |
| **ST3** | 4.2 | -0.3 | -0.7 | -2.9 | 4.2 | -0.4 | -1.7 | -3.1 | 4.2 | -0.4 | -1.1 | -3.0 |
| **ST4** | 3.1 | 0.3 | 0.4 | -0.8 | 2.0 | 0.3 | -1.7 | 0.1 | 2.6 | 0.3 | -0.3 | -0.2 |
| **ST5** | 1.4 | 0.9 | 1.6 | 0.8 | 4.3 | -0.7 | -1.3 | -3.7 | 3.5 | 0.3 | 0.8 | -0.1 |
| **ST6** | 4.1 | 0.2 | -0.3 | -0.9 | 4.0 | 0.5 | 1.5 | 0.9 | 4.1 | 0.3 | 0.9 | 0.3 |
| Min | **1.4** | **-0.3** | **-0.7** | **-2.9** | **1.4** | **-0.7** | **-1.7** | **-3.7** | **2.6** | **-0.4** | **-1.1** | **-3.0** |
| Max | **5.5** | **0.9** | **1.6** | **0.8** | **4.4** | **0.7** | **1.5** | **0.9** | **5.0** | **0.4** | **1.1** | **0.3** |
| Mean | **3.7** | **0.2** | **0.6** | **-0.5** | **3.4** | **0.1** | **-0.4** | **-1.2** | **3.8** | **0.2** | **0.4** | **-0.5** |

The annual mean of Igeo of Cu ranged from – 3.0 in ST3 to 0.3 in ST6 thus, it is classified within the two categories, not polluted and not polluted to moderately polluted indicate that there is a very little contamination with Cu according to Igeo values.

In general, the Igeo of Cd was found in high contamination in all studied locations while the other metals Pb, Ni and Cu were in little contamination according to Igeo values. This indicates that the main reasons of metal pollution are anthropogenic activities such as industrialization, urbanization and car emissions. This has been found in Iraqi studies about the geoaccumulation index in soil, including the study of **[37]** in Kirkuk, the I-geo values of most metals fall into the category not polluted to moderately polluted except Cd is moderately polluted. In the study of **[38]** in Hawija area, the I-geo value for Cd was classified into two categories not polluted to moderately polluted while the other metals classified into moderately polluted to heavily polluted. According to the study of **[39]** in Al-Zubair, the Cd falls into the category of not polluted to moderately polluted while other metals fall into the category of not polluted. The study of **[40]** in Baghdad found that the I-geo value classified into moderately polluted with Ni, while for the Pb was not polluted. The other study conducted by **[41]** in Basrah the I-geo values for Cd and Cu classified into moderately polluted to heavily polluted.

After comparing the results of this study with the previous studies, the our results of Igeo index agree with the studies of **[37, 40, 41]**; but disagree with the study **[38]** and also disagree with the study of **[39]** in the Igeo value of Cd while other metals were the same.

### 3.3. Principal Components Analysis (PCA)

PCA is an important statistical method in many scientific studies, especially ecological studies, including soil pollution monitoring **[42]**. PCA is used in this study to give a better explanation of the results.

The (**Table 5, Figure 3, Figure 4**) showed the factors loading of each metal and the Eigenvalue for every Principal Components Analysis (PCA) which determines the number of axes of PCA that most accepted to explain the current results.

PCA1 contain positive loadings (0.850, 0.838 and 0.910) for Pb, Ni and Cu respectively, while Cd occur negative loading. In PCA2 only Cd occur positive loading (0.933) this means that Cd has different sources and rate of diffusion than the other metals due to the main sources of Cd was anthropogenic not natural whereas the other metals sources were mixed between natural and anthropogenic sources. This was confirms by Igeo which showed that all studied locations were much polluted with Cd while there is a little pollution with other metals. Also the mobility of Cd in soil is different comparing with the other metals, it does not precipitate with other metals in soil and this makes its behavior different.

**Table 5.** The PCA factor loadings, Eigenvalue, Variability (%) and Cumulative %

| | PCA1 | PCA2 |
|---|---|---|
| **Cd** | -0.274 | **0.933** |
| **Pb** | **0.850** | -0.331 |
| **Ni** | **0.838** | 0.474 |
| **Cu** | **0.910** | 0.154 |
| **Eigenvalue** | 2.328 | 1.229 |
| **Variability (%)** | 58.188 | 30.725 |
| **Cumulative %** | 58.188 | 88.913 |

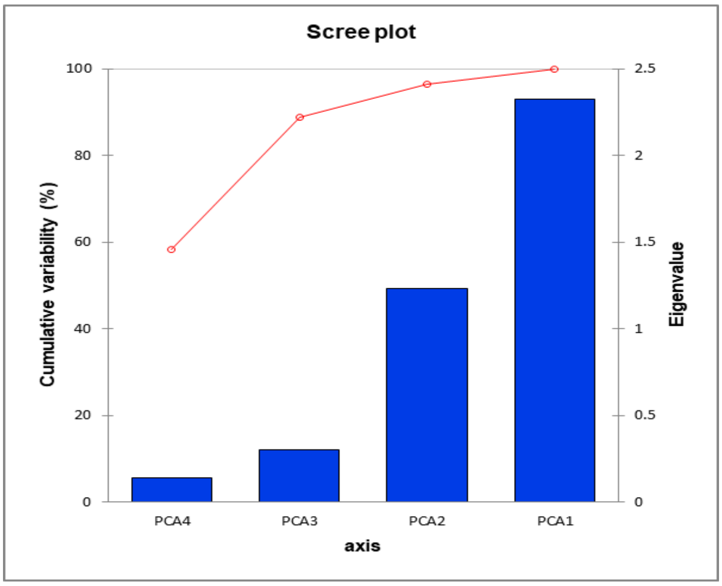


**Figure 3.** Eigenvalues for the principal components

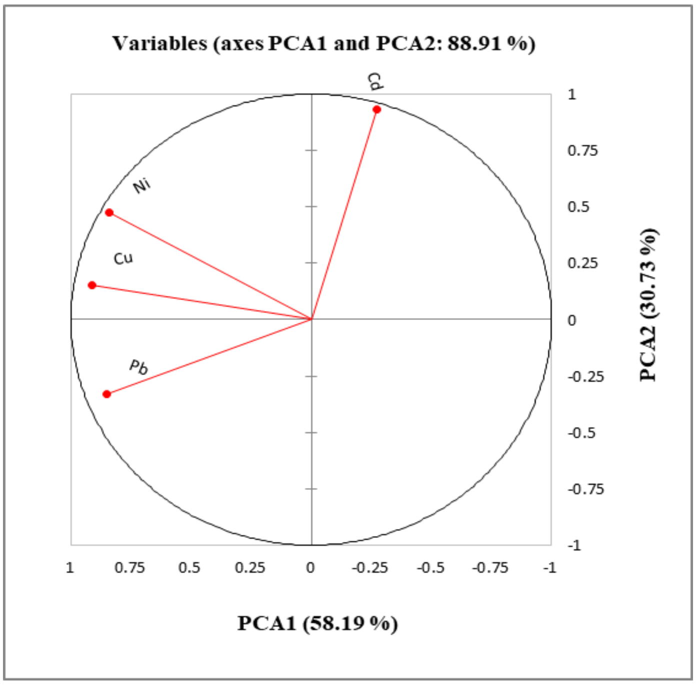


**Figure 4.** Component loading for the PCA1 with PCA2 after Varimax rotation

## 4. Conclusions

This is an essential study in environmental management that explains to the decision-makers the harmful effects of private electrical generators in residential areas and the possibility of reducing them or placing them outside residential areas. It also explains the effects of power plants in soil by adding many pollutants especially heavy metals. Heavy metals in this study showed increasing in their concentration comparing with the geochemical background concentration of these metals. The geoaccumulation index showed that there is a high contamination with Cd in all studied locations while the other metals Pb, Ni and Cu have little contamination according to Igeo values. The PCA showed that Cd have a different behavior from the other metals.

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# تقييم التلوث بالعناصر الثقيلة في الترب الملوثة في مدينة البصرة, العراق

**فاديه مشتاق سليم* , حسين طالب خريبش , سكينة منتصر الطاهر**

قسم البيئة, كلية العلوم, جامعة البصرة,البصرة ، العراق

**المستخلص**

تلوث التربة بالمعادن الثقيلة حظي باهتمام واسع في السنوات الأخيرة بسبب خطورته وسميته على صحة الإنسان. أجريت هذه الدراسة لتقييم تلوث المعادن الثقيلة في التربة بالقرب من محطات الطاقة الحرارية والمولدات الكهربائية الخاصة في مدينة البصرة وتقييم حالة تلوث التربة بالمعادن باستخدام مؤشر التراكم الجيولوجي. أظهرت النتائج أن تركيز الكادميوم يتراوح بين (0.93 - 4.905) ميكروغرام/غرام، وتراوح تركيز الرصاص بين (22.96 - 38.995) ميكروغرام/غرام، وتراوح تركيز النيكل بين (13.66 - 63.635) ميكروغرام/غرام، وتراوح تركيز النحاس بين (4.645 - 44.66) ميكروغرام/غرام. أظهرت المعادن الثقيلة في هذه الدراسة زيادة في تركيزها مقارنة بالتركيز الأصلي لهذه المعادن في القشرة الارضية، وكانت تراكيز المعادن أعلى بشكل عام في فصل الشتاء منها في الصيف. قيم مؤشر التراكم الجيولوجي للمعادن الأربعة كانت كما يلي: الكادميوم > النيكل > الرصاص > النحاس. تراوح المعدل السنوي لقيم مؤشر التراكم الجيولوجي لكل من الكادميوم والرصاص والنيكل والنحاس بين (2.6 - 5)، و(-0.4 - 0.4)، و(-1.1 - 1.1)، و(-0.3 -3.0) على التوالي. ان استخدام مؤشر التراكم الجيولوجي للتربة يعطي تقييمًا دقيقًا لتلوث التربة بالمعادن الثقيلة في المنطقة المدروسة.

**الكلمات المفتاحية:** المعادن الثقيلة, تلوث التربة, تصنيف التربة, بيئة التربة, دليل التراكم الجيولوجي