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**Mustafa Abdullah Theyab**[*1,2], orcid.org/0000-0003-4711-637X,
**Hiba Kamal Lafta**[3], orcid.org/0009-0003-4599-5638,
**Basma Mohammed Ismail**[3], orcid.org/0009-0001-7578-233X,
**Fadila Sami Lafta**[3], orcid.org/0009-0001-7503-645X,
**Shaima Mahmoud Mohamed**[3], orcid.org/0009-0000-9138-6911,
**Marwah M. Rajab**[4], orcid.org/0000-0001-8021-0099

1 – Applied Chemical Department, College of Applied Sciences, University of Samarra, Samarra, the Republic of Iraq
2 – Department of Geology Engineering, Çukurova University, Adana, Turkey
3 – Applied Chemical Department, College of Applied Sciences, University of Samarra, Samarra, the Republic of Iraq
4 – Geology Department, College of Science, Tikrit University, Tikrit, the Republic of Iraq
[*] Corresponding author e-mail: mustafa.a@uosamarra.edu.iq

# SOIL CONTAMINATION STATUS USING CONTAMINATION INDICATORS AND THE HEALTH RISK

**Purpose.** Knowing and evaluating the degree of pollution caused by the elements under study, and Statement of the potential environmental hazards index. in Samarra city-Iraq to know the limits of mineral pollution, because an increase of them is harmful to humans.

**Methodology.** The first step in starting work for the current study, as the modeling was carried out in a field tour in November for each region in depth, the concentrations of heavy elements approved in the current study (manganese, copper, cadmium, mercury) using the atomic spectrometer, was used to process the results of analyzes of heavy elements in soils and represent them graphically and statistically, and then write the research in its final form.

**Finding.** To find out the source of soil pollution, whether it is a natural source or human-induced, in addition to the application of two models of environmental risk indicators. (Environmental risk factor and potential environmental risk index) to find out how the elements are dangerous to the plant or animal environment.

**Originality.** In this study measuring soil pollution is determined by the Contamination factor, Pollution Load Index, Degree of contamination, Ecological risk factor, and Potential Ecological Risk Index.

**Practical value.** In the study area (1M on the right side, 2M on the side behind the SDI Factory, 3M inside the SDI Factory, and 4M on the left of the SDI Factory), which primarily shows an increase in the concentrations of the element's cadmium and mercury in all areas of the study area by comparing them with the concentrations of the same elements in the earth's crust.

**Keywords:** *heavy metals, soil pollution, contamination factor, pollution load index, ecological risk factor, potential ecological risk index*

**Introduction.** Heavy elements, or what is known as heavy gases, are defined as those whose density is five times greater than the density of water, 5 mg/cm$^3$, and it has negative effects on human, animal, and plant health. Among the heavy elements are lead, Pb, mercury, Hg, copper, Cu, Zn, arsenic, nickel, Ni, and other elements, which are some of the most dangerous toxic substances that pollute the soil, water, and air, as the agricultural soil is exposed to contamination with heavy elements, which leads to the loss of its fertility, as it causes a decrease in the bacteria responsible for the decomposition of the organic matter present in the soil and the fixation of the nitrogen element for them [1]. Also, all heavy elements are considered toxic if they are present in high concentrations, as they can interact with all components of cells and disrupt their functions, whether in plants, animals, or humans [2]. Plants absorb these elements if they are present in soil or water, and then they reach the man after that, through the food chain. Thus, preserving the soil from pollution or deterioration is an inevitable necessity of the era because it is related to human health [2].

The toxicity of heavy elements is due to two reasons [3].

*First:* Heavy metals are linked with functional groups in enzymes by stable bonds and in the form of complexes, which leads to the disruption of molecules that create metabolic reactions.

*Second:* heavy elements appear on the cell membrane, which changes its structural composition, thus impeding the exchange of ions and organic substances necessary for life, such as proteins and sugars, or completely preventing them from being transported. The heavy elements accumulate in human organs.

Soil is an important element for life if we take into consideration the fact that it embraces the roots of plants, and unfortunately, we have become seriously exposed to pollution due to human activities [2]. The researchers linked the environmental problems to the industrial progress that began in the middle of the last century, as well as to various agricultural activities and other reasons [3]. Preserving the soil intact and clean is the basis for preserving the organisms that live on it [4].

Heavy metal pollution is one of the forms of environmental pollution resulting from human industrial or agricultural activity. In recent years, scientists have been interested in studying heavy metals in terms of their presence in the environment and their biological effects, and their relationship to human health [5]. The disposal of these wastes, such as putting them randomly in rivers, valleys, and others, leads to negative consequences for the oceanic environment, especially for organisms that depend directly on the water [6].

Pollutants are divided into two main groups: organic pollutants and inorganic pollutants. Among the most important inorganic pollutants are heavy elements such as lead, cadmium, arsenic, mercury, zinc, and other elements [7]. Heavy metals are naturally present in the soil in low quantities, but their quantities increase as a result of human activities [8].

As a result of the development and prosperity of the industry sector, pollutants mostly spread in the environmental system, and heavy metals had a major role in environmental pollution [9].

Heavy metals can exist in the soil within natural values, and their presence is important in giving the soil some beneficial properties, but the increase in the rates of heavy metals in the soil has a negative effect, as heavy metals may change the general soil properties, especially the biological properties of the soil from the number of microorganisms and its diversity and activities, and thus change the soil temperature, pH, clay minerals, organic and inorganic materials, as well as chemical forms of minerals, as the following works are followed to know and evaluate pollutants as well as potential environmental risks [10].

Several studies have been conducted to investigate and assess the presence of pollutants, particularly heavy metals, in soil, and to evaluate their potential environmental risks. These investigations are crucial for understanding the extent of contamination and developing strategies for remediation and prevention [11].

The effects of heavy metal contamination on soil properties, especially biological properties, have been widely studied. High concentrations of heavy metals can have toxic effects on soil microorganisms, reducing their abundance, diversity, and activities. This, in turn, can disrupt important soil processes such as nutrient cycling, organic matter decomposition, and plant-microbe interactions. Changes in soil temperature, pH, clay minerals, and the availability of organic and inorganic materials can also occur as a result of heavy metal pollution [8, 12].

To evaluate the potential environmental risks associated with heavy metal contamination in soil, different risk assessment approaches are employed. These approaches consider factors such as the toxicity of the heavy metals, their mobility and bioavailability, and the vulnerability of the surrounding ecosystems. Environmental risk assessments help in identifying the areas at high risk of contamination, prioritizing remediation efforts, and implementing measures to prevent further pollution [13].

Understanding and evaluating the presence of pollutants, particularly heavy metals, in the soil is crucial for maintaining soil health and preventing environmental degradation. Through thorough investigations, risk assessments, and appropriate remediation measures, it is possible to minimize the adverse effects of heavy metal contamination and promote sustainable land use practices [12, 14].

It is everything that is thrown into the environment and leads to a change in the environmental characteristics as a result of human and natural activities through their direct or indirect effects. Environmental pollution is the process of disturbing the natural balance of the environment, which affects the life of living organisms [15].

Natural pollution means that man has no interference with it, i.e. it is a result of the soil itself, as the soil is a mixture of minerals that resulted from the physical, chemical, and biological weathering processes of the rocks of the earth's crust, composed of the original material, and then they are naturally present in the soil because they are part of their components, volcanoes, earthquakes, and hurricanes [9, 16].

It is due to the pollutants produced by human activities and various activities into the environment, including wastewater and sewage from residential areas, as well as the extraction of mines and the resulting waste that becomes a source of pollution in the surrounding lands, as well as sewage and industrial waste and the use of pesticides that become polluted if they accumulate in large quantities and in a manner that contradicts with others [17].

Many vital compounds, various chemicals, and gases, which include carbon monoxide and chlorine, occur as a result of industry and wars, for example, that cause damage to living organisms on the surface of the earth [18, 19].

Water pollution is the pollution that makes water unsuitable for human, animal, and plant use, and because water is the lifeblood of all living creatures and organisms, its pollution and corruption cause the most severe health crises and problems ever [20, 21].

Soil contamination is the change in the physical, chemical, and biological characteristics of the soil through the addition and removal of substances from it [6]. The soil is considered the main medium for plant growth and its production of nutrients for the rest of the food chain, although the soil contains the main elements such as phosphorus, nitrogen, and other macro and micronutrients. It is a storehouse of other elements naturally or as a result of abnormal additions [22].

The process of soil contamination with heavy elements is a critical and detrimental indicator of its permanence and ability to continue sustaining the ecosystem with nutrients necessary for the continuation of energy flow in parts of the food web [11].

The environment is defined as the envelopes surrounding the earth which consist of the lithosphere, the hydrosphere, the atmosphere, the biosphere, and all the interactions that arise between them. In other words, it is the sum of the relationships between water, air, land, and living things [23]. As for environmental pollutants, they were defined for the first time in (1981) as industrial or natural chemicals that are liberated in nature by human activity and have a harmful effect on the environment (soil + water + air) exceeding the critical concentration that leads to harmful effects on human health and other organisms alone or by interacting with others. This system complicates its ability to get rid of these pollutants naturally, and scientists believe that human exposure to environmental pollution and environmental pollutants at the present time has increased more than ever before [24].

Environmental pollution has caused damage to various types of organisms, including plants, animals, and humans [25]. Even tropical rainforests have been affected by this pollution. Over the past three decades, there has been concern about the worsening health effects resulting from environmental pollution. The World Health Organization [26] estimates that about a quarter of the diseases that humans face are caused by environmental pollution and due to long exposure to these pollutants, as found [26]. The emergence of some diseases and their geographical distribution is linked to the high concentration of certain elements in the environment. Environmental pollution is mainly due to various human activities represented in the extraction of mineral deposits, mining, power generation and construction. In addition to the waste of the industrial establishment, there is use of wastewater, sewage sludge, pesticides and chemical fertilizers in the agricultural field [27].

There are many types of environmental pollution, such as air pollution, soil pollution, water pollution, food pollution, radioactive pollution, thermal pollution, etc., but there are many sources of environmental pollution, some of which are of natural origin, such as volcanoes, which, during their eruption, release many gases ($H_2S$, $SO_2$, HCl), which are very harmful to the environment as well. It releases huge amounts of ash, which reaches several tons, and may reach the serotosphere layer (55 km) above sea level. The World Health Organization appointed (2011) that the main cause of pollution in Iceland is volcanic ash in addition to the volcanic volume, which carries large amounts of molten sulfur and self-gases, which leads to an increase in the acidity of water and soil as a result of the dissolution of these gases in water [28]. Fires are also considered one of the natural sources of environmental pollution, as they release Cl gas such as ($CO_2$, $CO_6$, $NO_x$). According to [29], there are some rocks rich in minerals, including heavy ones such as serpentine, whose residues are a source of environmental pollution with some metals such as (Ni, Cr, Co).

Industrial sources of environmental pollution resulting from human activities include:

1. Means of transportation: in all its land and air forms. The means of land transport are the most important in the field of environmental pollution due to their large numbers and widespread, and they produce many pollutants such as carbon, sulfur, and nitrogen oxides, in addition to some heavy metals present in fuel, such as lead and others.

2. The industrial establishments, and factories are generally among the largest polluters of the environment, especially power plants, cement plants, and oil refineries [21].

3. Chemicals used in daily life, as it showed the presence of tens of thousands of chemicals used in industry, agriculture, homes, hospitals, tanneries, and other issues that are directly thrown into the environment, leading to its pollution [25].

The fixation is noted of heavy metal ions on the solid phase of the soil, which includes a mineral part, an organic part, and another organometallic part. This phase is what gives the soil the ability to carry out chemical absorption exchange reactions, especially mineral ions. The organic part (mineral part) in the soil is the most capable of fixing mineral ions through mineral particles represented by clay minerals and oxides of hydrated minerals and others [30].

There are two main types of clay minerals, the first, such as kaolinite, as the basic unit of the mineral consists of a four-faceted silica layer, followed by an eight-faced aluminum layer, which are linked by hydrogen bonds, and thus water and mineral ions do not enter between the layers, and, therefore, its ability to fix heavy metals is low due to the low area of absorption surfaces, type. The second is from clay minerals, such as montmorillonite and illite. Here, the mineral consists of a tetrahedral silica layer ($Si_2O_5$) with octahedral layers ($Al_2O_4(OA)_2$). Vander Walz forces link between the layers, so water and metal ions enter between the layers, and thus the adsorption surfaces increase and the fixation increases, namely metal ions due to the ability of these metals to expand [31]. The organic matter present in the soil also has the ability to interact with heavy metals and form stable complexes with them in the soil, because the components of the organic matter, especially folic and humic acids, have functional groups such as OH and COOH, so they work to bind the heavy metal and thus sequester it and limit its movement. Organic matter complicates heavy metals and thus restricts their movement. The tendency of these metals to bind varies according to the type of mineral. Cu, Pb, Cr are the most inclined elements to bind with organic matter, and sometimes they can form some organic complexes of copper and be dissolved [32].

**Materials and Methodology.** ***Field Work.*** The fieldwork represents the first step in starting work for the current study, as the modeling was carried out in a field tour in November for each region in depth, paying attention to removing leaves and weeds and placing the samples in tight nylon bags on which the sample number and the name of the region were written [33, 34].

***Laboratory Work.*** Laboratory work After completing the fieldwork, the samples were transferred to the laboratory to process them to measure the concentrations of heavy elements approved in the current study (manganese, copper, cadmium, mercury) using the atomic spectrometer in the laboratories of the University of Baghdad (Engineering Consulting Office), as each sample was crushed and homogenized accordingly on the basics of the effective method of work from the General Company for Geological Survey and Mining [35, 36].

***Office Work.*** Reviewing previous studies related to the subject of research on the study area, and some software, including Microsoft Excel, was used to process the results of analyzes of heavy elements in soils and represent them graphically and statistically, and then write the research in its final form [37, 38].

***Contamination Indicators.*** There are different ways to evaluate the effects of human activities, where several pollution indicators (pollution factor, pollution load index, degree of pollution, land accumulation index) were applied to find out the source of soil pollution [39, 40] and whether it is a natural source or human-induced, in addition to the application of two models of environmental risk indicators. Environmental risk factor and potential environmental risk index were considered to find out how dangerous the elements are to the plant or animal environment [41, 42].

***Contamination factor (CF).*** This factor is used to classify the level of elemental contamination in soil samples by dividing the concentration of each element by the reference value [43]. It is calculated according to the following equation

$$CF = \left( \frac{(C_m)_{Sample}}{(C_m)_{Background}} \right), \quad (1)$$

where $(C_m)_{Sample}$ is the concentration of a specific element in the soil, $(C_m)_{Background}$ is the concentration of the same element in the earth's crust, and the values of the pollution factor are expressed in the categories mentioned in Tables 1–2 [43].

***Pollution Load Index (PLI).*** This indicator is used to estimate the percentage of pollution with heavy elements in the studied area. The pollution load index is extracted according to equation (2), where $n$ represents the number of elements, *CF*. Pollution factor in Table 2 shows the categories of pollution load index [43].

$$PLI = (CF_1 \cdot CF_2 \cdot CF_3 \cdot \ldots \cdot CF_n)^{1/n}. \quad (2)$$

***Degree of contamination ($C_d$).*** The degree of pollution is known as the sum of the pollution factors [43] and is found in the following equation

$$\sum_{i=1}^{n} CF \cdot C_d, \quad (3)$$

where $C_d$ is the degree of pollution, $n$ is the number of elements, *CF* is the pollution factor, and the categories (degree of pollution) are used to describe the degree of pollution [39].

***Ecological risk factor (Er).*** This factor is used to assess the environmental hazards of a trace element in soil and the value of *Er* (environmental hazard factor) and *Tr* (toxic response factor to the elements Cd, Hg, Cu) are found to be 30, 40 and 5.0, respectively [9].

CF is the pollution factor that is evaluated according to the categories classified in Table 4 [44].

$$Er = Tr \cdot CF. \quad (4)$$

***Potential Ecological Risk Index (PERI).*** It is one of the methods for evaluating pollution and is applied according to the toxicity and content of a specific pollutant [45] and is found from equation (5) where RI is the potential environmental risk index, $n$ is the number of elements, and *ER* is the

*Table 1*

The categories of pollution factors (Thomlinson, et al., 1980)

| Categories | *CF* |
|---|---|
| Low pollution factor | $1 > CF$ |
| Moderate pollution factor | $1 > CF \geq 3$ |
| High pollution factor | $3 > CF \geq 6$ |
| Extreme pollution factor | $6 \leq CF$ |

*Table 2*

Pollution load index and its categories

| Categories | *PLI* |
|---|---|
| No contamination | $1 > PLI$ |
| The soil is contaminated | $1 < PLI$ |

*Table 3*

The categories of pollution [44]

| Categories | $C_d$ |
|---|---|
| Low pollution level | $C_d < 8$ |
| Moderate contamination | $8 \le C_d < 16$ |
| High level of pollution | $16 \le C_d < 32$ |
| High to dangerous contamination | $C_d \ge 32$ |

environmental risk factor. The *RI* values are estimated according to the classification in Table 5 [38].

$$\sum_{i=1}^{n} ER \cdot RI. \quad (5)$$

**Results and Discussion.** There are different methods for evaluating the effects of human activities, where some pollution indicators (pollution factor, pollution load index, degree of pollution) were applied to find out the source of soil pollution, whether it is a natural source or human-induced, in addition to the application of two models of environmental risk indicators (environmental risk factor and environmental risk index) potential) to find out how dangerous the elements are to the plant or animal environment.

The results of the analysis of heavy metal concentrations were included in Table 6 in the study area (1M on the right side of the SDI Factory, 2M on the side behind the SDI Factory, 3M inside the SDI Factory, 4M on the left of the SDI Factory), which primarily shows an increase in the concentrations of the elements of cadmium and mercury in all areas of the study area by comparing them with the concentrations of the same elements in the earth's crust.

By applying the pollution factor index to all the elements under study, which are shown in Table 7 and Fig. 1, we notice that there are three categories, as the moderate pollution factor was for the manganese and copper elements in all regions under study, while the moderate pollution factor was for the element Mercury in regions 1, 2, 4 and cadmium in regions 2, 4, and the most dangerous category was for element mercury in the region 3 and cadmium in regions 1, 3, and these results confirm the initial interpretation through the results of concentrations of elements. The reason may be due to the place (inside) of the factory in these areas and not others, where the waste accumulates, which leads to exposure of the soil to pollution more than the rest of the areas.

The second indicator that was applied was the degree of pollution indicator, which shows, through its results shown in Table 8 and Fig. 2, that there are two categories of it, which are a low degree of pollution and a medium degree of pollution, as this indicator shows the degree of contamination of the region's soil with heavy elements. We note that area No. 3 M is the most polluted compared to the other areas under study, and the reason may be that the place is inside the factory where waste and drug residues accumulate, which leads to soil exposure to pollution more than the rest of the areas.

The results of the pollution load index were included in Table 9 and Fig. 3, which showed that the soil of two of the regions under study is considered polluted by applying the equation for the index.

After applying the individual indicator model for the environmental risk factor, we distinguish four categories, each with a specific meaning. The misleading results in yellow and red are shown in Table 10, and Fig. 4 as the large environmental risks and high environmental risks are found in areas 1, 2, 3 for the elements cadmium and mercury, and this is due to several reasons, as cadmium increases in the environment from mining, industrial work, burning coal, and household waste.

As for mercury, it increases due to volcanic activities and rock erosion, because it is found naturally in the earth's crust, so it is liberated to the environment and as a result of human activity, especially from coal-fired power plants, industrial activities, and waste dumps. Fig. 4 also explains it.

The last indicator that was applied to reach the objectives of the research is the indicator of potential environmental hazards, the results of which were included in Table 11 and Fig. 5. Near a waste dump inside the SDI Factory, which contains

*Table 4*

Environmental risk factor categories [44]

| Risks | *Er* |
|---|---|
| Low environmental risk | $Er < 40$ |
| Moderate environmental risk | $40 \le Er < 80$ |
| Upper Moderate environmental risks | $80 \le Er < 160$ |
| High environmental risk | $160 \le Er < 320$ |
| Extreme environmental risk | $Er \ge 600$ |

*Table 5*

Environmental Risk Index (PERI) and its classifications [44]

| Environmental risk index | *RI* |
|---|---|
| Low environmental risk | $RI < 150$ |
| Moderate environmental hazard | $150 \le RI < 300$ |
| High environmental risk | $300 \le RI < 600$ |
| Extreme environmental risk | $RI \ge 600$ |

*Table 6*

The results of heavy metal concentrations in the study area

| Elemental concentrations mg/kg | | | | | |
|---|---|---|---|---|---|
| Mn | Cu | Hg | Cd | Location | No. |
| 303 | 35 | 0.1 | 0.3 | 1M | 1 |
| 574 | 42 | 0.15 | 0.22 | 2M | 2 |
| 798 | 50 | 0.23 | 0.57 | 3M | 3 |
| 655 | 29 | 0.09 | 0.15 | 4M | 4 |
| Concentrations of elements in the Earth's crust | | 900 | 55 | 0.07 | 0.1 |

*Table 7*

Application of the pollution factor index to all elements under study

| Location | No | *CF* pollution factor | | | |
|---|---|---|---|---|---|
| | | Mn | Cu | Hg | Cd |
| 1M | 1 | 0.336667 | 0.636364 | 1.428571 | 3 |
| 2M | 2 | 0.637778 | 0.763636 | 2.142857 | 2.2 |
| 3M | 3 | 0.886667 | 0.909091 | 3.285714 | 5.7 |
| 4M | 4 | 0.727778 | 0.527273 | 1.285714 | 1.5 |

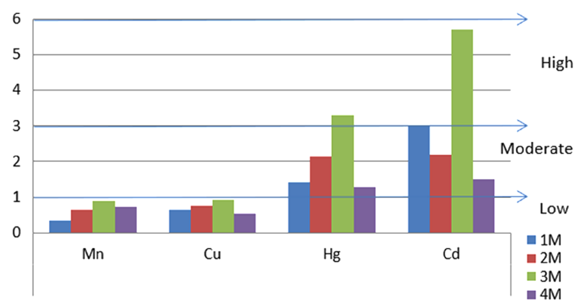


*Fig. 1. Application of the pollution factor (CF) index to all elements under study*

*Table 8*

Pollution degree index

| 4M | 3M | 2M | 1M | Location |
|---|---|---|---|---|
| 4.040765 | 10.78147 | 5.744271 | 5.401602 | Cd |

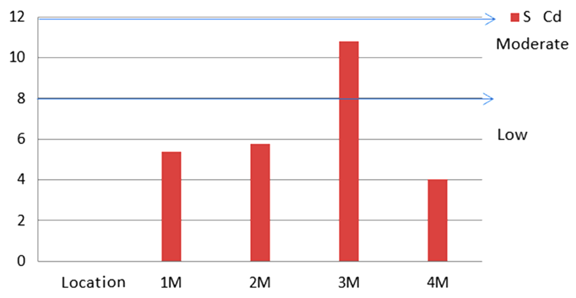


*Fig. 2. Pollution degree indicator* ($C_d$)

*Table 9*

Pollution load index

| 4M | 3M | 2M | 1M | Location |
|---|---|---|---|---|
| 0.927508 | 1.971143 | 1.230957 | 0.978886 | PLI |

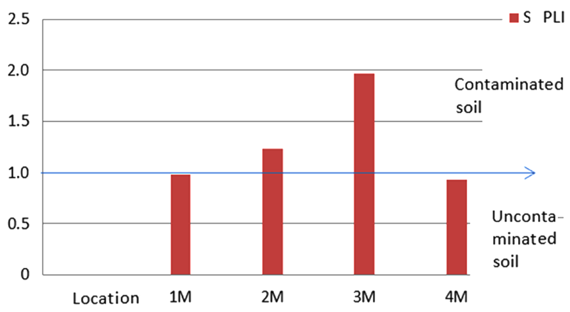


*Fig. 3. The pollution load index* (*PLI*)

*Table 10*

Individual indicators of the environmental risk factor

| Cu | Hg | Cd | Location | No | Individual Index of environmental risk factor *ER* |
|---|---|---|---|---|---|
| 3.2 | 57.1 | 90 | 1M | 1 | |
| 3.8 | 85.7 | 66 | 2M | 2 | |
| 4.5 | 131.4 | 171 | 3M | 3 | |
| 2.6 | 51.4 | 45 | 4M | 4 | |
| 5 | | 40 | 30 | *Tr* | |

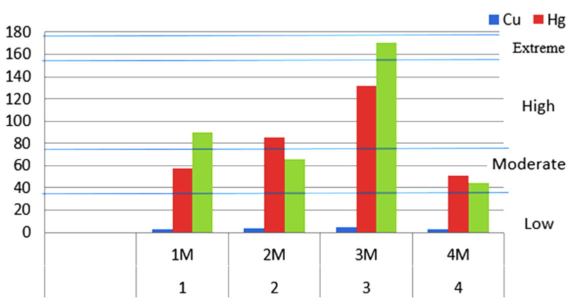


*Fig. 4. Individual indicators of the environmental hazard risk factor*

waste, it leads to the place inside the factory where waste accumulates, which leads to soil exposure to pollution more than in the rest of the areas.

Finally, within the research area, which is located at distances of 1M to the right of the SDI Factory, 2M behind the SDI Factory, 3M inside the SDI Factory, and 4M to the left of the SDI Factory, three distinct categories were observed. Moderate pollution levels were noted for the manganese and copper elements across all regions under investigation. Additionally, moderate pollution levels were observed for the element mercury in regions 1, 2 and 4, as well as for cadmium in regions 2 and 4. The most hazardous category was identified for the element mercury in region 3 and for cadmium in regions 1 and 3.

In this study, we used modeling of Contamination Indicators and the health risk assessment to explain the total contamination of heavy metals in this area instead of normal methods used in other previous works.

It is necessary to study other areas that are beside the study area and use more modeling to calculate the pollution of heavy metal.

**Conclusions.** There are different methods for evaluating the effects of human activities, where some pollution indicators (pollution factor, degree of pollution, pollution load index), in the study area (1M on the right side of the SDI Factory, 2M on the side behind the SDI Factory, 3M inside the SDI Factory, 4M on the left of the SDI Factory), we notice that there are three categories, as the moderate pollution factor was for the manganese and copper elements in all regions under study, while the moderate pollution factor was for the element mercury in regions 1, 2, 4 and cadmium in regions 2, 4, and the most dangerous category was for element mercury in the region 3 and cadmium in regions 1, 3.

The second indicator that was applied was the degree of pollution indicator, and there are two categories of it, which are a low degree of pollution and a medium degree of pollution, as this indicator shows the degree of contamination of the region's soil with heavy minerals.

The results of the pollution load index showed that the soil of two of the regions under study is considered polluted by applying the equation for the index, which was applied to reach the objectives of the research is the indicator of potential environmental hazards, near a waste dump inside the SDI Factory, which contains waste, it leads to the place inside the factory where waste accumulates, which results in soil exposure to pollution more than in the rest of the areas.

*Table 11*

Index of potential environmental risks

| *RI* potential environmental risk index | Location | No |
|---|---|---|
| 150.3246753 | 1M | 1 |
| 155.5324675 | 2M | 2 |
| 306.974026 | 3M | 3 |
| 99.06493506 | 4M | 4 |

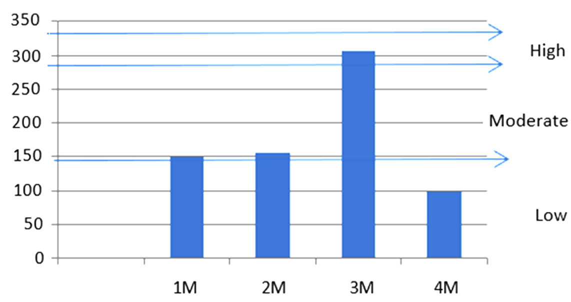


*Fig. 5. Indicator of potential environmental risk index (RI)*

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## Стан забруднення ґрунту за показниками забруднення та ризик для здоров’я

*Мустафа Абдулла Тейяб*[*1,2], *Хіба Камал Лафта*[3], *Басма Мохаммед Ісмаїл*[3], *Фаділа Самі Лафта*[3], *Шаіма Махмуд Мохамед*[3], *Марва М. Раджаб*[4]

1 – Кафедра прикладної хімії, Коледж прикладних наук, Університет Самарри, м. Самарра, Республіка Ірак
2 – Кафедра інженерної геології, Університет Чукурова, м. Адана, Туреччина
3 – Кафедра прикладної хімії, Коледж прикладних наук, Університет Самарри, м. Самарра, Республіка Ірак
4 – Кафедра геології, Коледж науки, Університет Тікрита, м. Тікрит, Республіка Ірак
[*] Автор-кореспондент e-mail: mustafa.a@uosamarra.edu.iq

**Мета.** Оцінка ступеня забруднення, спричиненого елементами, що досліджуються, і встановлення індексу потенційної екологічної небезпеки в місті Самарра, Ірак, щоб знати межі забруднення мінеральними речовинами, оскільки їх збільшення є шкідливим для людини.

**Методика.** Першим кроком на початку роботи із цього дослідження, оскільки моделювання проводилося у польових умовах у листопаді для кожного регіону, були визначені концентрації важких елементів (марганець, мідь, кадмій, ртуть) за допомогою атомного спектрометра, що надалі було використано для обробки результатів аналізів важких елементів у ґрунтах і представлення їх графічно та статистично, а потім для написання дослідження в остаточному вигляді.

**Результати.** З’ясовано джерело забруднення ґрунту, будь то природне джерело, чи антропогенне, на додаток до застосування двох моделей індикаторів екологічного ризику – фактор екологічного ризику та індекс потенційного екологічного ризику. З’ясовано, наскільки елементи є небезпечними для рослинного чи тваринного середовища та для людини.

**Наукова новизна.** У цьому дослідженні вимірювання забруднення ґрунту визначається коефіцієнтом забруднення, індексом навантаження забруднення, ступенем забруднення, фактором екологічного ризику та індексом потенційного екологічного ризику.

**Практична значимість.** На досліджуваній території в першу чергу показане збільшення концентрацій елементів кадмію та ртуті на всіх ділянках у порівнянні з концентраціями тих же елементів у земній корі.

**Ключові слова:** *важкі метали, забруднення ґрунту, коефіцієнт забруднення, індекс навантаження забруднення, фактор екологічного ризику, індекс екологічного ризику*

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