The Concentration of the Toxic Elements (Cd, Hg, As) in Diyala Governorate Soil Utilizing GIS Techniques

Jaafar S. Muhammad¹, Kareem A. Jasim² and Auday H. Shaban³

¹Department of Physics, College of Science, University of Diyala, Iraq
²Department of Physics, College of Education, Ibn Al-Haytham College of Sciences, Pure, University of Baghdad, Iraq.
³College of Science, University of Baghdad, Iraq.

auday.h.s@ihcoedu.uobaghdad.edu.iq

Abstract. The heavy elements (Cadmium, Mercury, and Arsenic) are considered to be highly toxic for human and living creatures. This research focused on the concentrations of these elements in the soil of Diyala Governorate. The 25 samples of soil were collected from different areas included (industrial, residential, and agricultural) with an average sample rate for each region with a depth (10 cm). The samples were compressed to prepare them for measurement by dispersive spectroscopy of X-ray energy (EDX). The results are compared with the global determinants World Health Organization (WHO), where the results indicates the highest concentration of cadmium in the Injanah region and the lowest concentration in the Alma’amil region. The highest concentration of mercury in the regions of Mohammed Sakran and Diyala Bridge and the lowest concentration in the region of Mundhiriyah. The Arsenic elements concentrated become high in the Rashidiya region and less concentrated in the Hamrin hills region. It is known that these elements are more toxic than other elements when they are found in a higher rate than the permissible level in the soil.

Keywords: Cadmium, Mercury, Arsenic, high toxicity, and soil elements.

1. Introduction
The general meaning of heavy elements is those elements with a density greater than (5g/cm³) [1]. The soil in many regions of the world is exposed to pollution by toxic heavy elements as a result of human activity in many areas, especially industry and agriculture, adding phosphate fertilizers, manufacturing and mining. These activities are a great source of air pollution that loaded the air particles with heavy elements, so these particles are deposited directly on the soil surface, then by rain it will be transported into the soil. The soil pollution is affected by the plants that been cultivated in this area. The pollutant elements are entering the plants which will be harvested to get into the food chain, and that increases the risks to human health [2, 3].

Cadmium (Cd) which is a metallic silver-colored white substance with atomic number 48 and atomic weight 112.41g/mol. Its boiling point is 765 °C, its melting point is 321 °C, and its density is 8.65 g/cm³. The cadmium is a metal and is ignited by heating giving CdO, which is a brown oxide. As for physically, it is satin (malleable and withdrawn) [4, 5]. Cadmium is found in ordinary soils with a small concentration of 0.5 ppm or less, but in sedimentary soils its concentration may be 25 ppm. One of the properties of cadmium is that it is very stable in the environment and accumulates in the soil where
living organisms coexist and can be easily absorbed from the roots of plants. It is known that cadmium is a toxic element associated with zinc extraction and other industrial processes. However, it is a dangerous air pollutant (cadmium dust), and thus cadmium accumulates on the soil surface and accumulates in plants, including herbaceous plants, without toxic symptoms, and the amount of cadmium in the environment is increased by the disposal of solid waste. Contamination of soil surface, subsurface areas and water surface results in cadmium. Also, the amount of cadmium in the soil may increase as a result of the application of fertilizers [6, 7].

**Mercury (Hg)** is a chemical element symbolized by Hg, atomic number 80 and molecular weight 200.59 g/mol. Its density (13.54 g/cm³) freezes at (-38.9 °C), and its boiling point (356.9 °C). Which is a silver, bluish liquid that looks like lead in appearance. When an electric spark passes through mercury vapor, it emits a bright flash and ultraviolet light. It evaporates at room temperature and thus its atoms are mixed with the air without the human being realizing it, especially since it has no odour and color, and when a person inhales this air, the mercury atoms enter the lung and thus reach the blood and brain. Many studies have shown that high exposure to mercury causes toxicity to the central nervous system, which can lead to irritability, fatigue, behavioral changes, convulsions, headaches, hearing loss, loss of perception, and hallucinations to death.[8,9]

**Arsenic (As)** and atomic number 33 in the periodic table of elements. Its atomic mass is 74,922 in the fifteenth group of the periodic table. Arsenic is found in many chemical compounds, as well as a pure crystalline component, and has been achieved in conjunction with minerals and sulfur. Arsenic is a semi-metal, has a multi-rootedness, but the gray form is important in the industry. It was known to be one of the most toxic substances, and was often used to get rid of enemies due to its easy accessibility. It can be detected easily regardless of trying to clean tools used in the arsenic handling and transport process. Arsenic is naturally found in soil, air, and water. In some countries, arsenic is found in large quantities in groundwater. It is very toxic when present in an inorganic form. Table 1 represents the general permissible limit for the presence of elements (Cd, Hg, As) in the soil of the World Health Organization [10].

| Element name | Cd | Hg | As |
|--------------|----|----|----|
| WHO(mg/kg)   | 1  | 0.5| 20 |

2. **Geographic Information Systems (GIS)**

It is the science that is defined by collecting, processing and analyzing spatial data. There are several programs used for geographic information systems, including those that operate on a directional information system such as ArcGIS and that operate on a raster system such as ERDAS. The trend system is more suitable for storing high-precision data such as ownership and boundary maps, so it is preferable in these cases to choose programs that run on the vector information system [11-13].

3. **Interpolation**

There are several interpolation methods, such as Kriging, global polynomial, local polynomial, inverse distance weight (IDW) etc. Spatial interpolation is the process of using points with known values to estimate values at other unknown points. For example, to create a precipitation map for a country, you won't find enough weather stations to cover the entire region. Spatial interpolation can estimate the temperature at locations without data recorded using temperature readings known at nearby weather stations calculated using internal interpolation. In GIS, spatial interpolation of these points can be applied to create a vector surface with estimates values. The results of the interpolation analysis can then be used for analyses the whole area and for modelling. There are many methods for implementation in ArcGIS. Inverse Distance Weight (IDW) interpolation method, is one of many methods of interpolation.
The sample points are weighted during interpolation such that the influence of one point with respect to other declines with distance from the unknown point you want to create [12,14,15].

4. Study Area
Diyala Governorate is located in the eastern part of central Iraq, and from the provinces that have international borders, it is bordered to the north by the Sulaymaniyah Governorate and part of the Salahuddin Governorate, while it is bounded to the west by the Baghdad and Salahuddin governorates and to the south by the Wasit Governorate and To the east is the Islamic Republic of Iran. This region situated between (33.3–35.6) latitude and (44.22–45.56) longitude, as shown in Figure 1.

![Figure 1. Photomap of Iraq and DiyalaShapefile](image)

5. Modeling and working methods
The work in the current study is divided into three phases:
- **First stage**: is the field work (collection of samples).
- **Second stage**: is the laboratory work.
- **Third stage**: is the information processing and discussion.

Figure 1 displays Diyala map, which represents the borders of the study area as well as the areas from which samples were collected for the purpose of the study. Twenty-five (25) soil samples were collected from Diyala governorate at a depth of 10 cm. These samples were taken from many regions (industrial, residential, agricultural). The samples were configured by numbering the nylon bags that consists of the samples. The samples were transferred to the laboratory for the purpose of preparing them for measurement to study the concentrations of the heavy elements (Cd, Hg, As).

The work’s procedure is summarized by:
- Drying the samples in the sun for several days.
- Grinding the samples separately: very fine grinding using a ceramic mortar for two hours.
- Compressing the soil samples using a hydraulic press,
- Finally, examining the concentration of heavy elements in the samples by the (EDX). Table (2) illustrated the location were the samples collected.
Table 2. Symbolized sampling locations

| ID | Location name       | East   | North  | Elevation m |
|----|---------------------|--------|--------|-------------|
| 1  | kalar               | 45.32916 | 34.57248 | 835         |
| 2  | mandhiria           | 45.4333  | 34.20412 | 656         |
| 3  | Aleazim Dam         | 44.55443 | 34.53553 | 470         |
| 3  | injanah             | 44.60147 | 34.42877 | 289         |
| 5  | khaniqin            | 45.27905 | 34.2664  | 815         |
| 6  | Aleazim             | 44.5172  | 34.20332 | 248         |
| 7  | khan oil            | 45.35477 | 34.17022 | 747         |
| 8  | Alnay               | 44.54785 | 34.054   | 188         |
| 9  | Hamrin Hills        | 45.06267 | 34.06082 | 458         |
| 10 | almqdady            | 44.9569  | 33.9823 | 155         |
| 11 | Imam Wes            | 45.14028 | 33.9359  | 187         |
| 12 | hay mazid           | 44.741   | 33.80382 | 124         |
| 13 | mandeley            | 45.54053 | 33.74133 | 373         |
| 14 | Canaan              | 44.7976  | 33.6936  | 127         |
| 15 | cintarbeqwb         | 44.61293 | 33.7459  | 101         |
| 16 | alkhalis            | 44.52183 | 33.84487 | 102         |
| 17 | jadidatalshat       | 44.4009  | 33.68145 | 87          |
| 18 | Rashidiya           | 44.4148  | 33.6878  | 84          |
| 19 | Mohammed sakran     | 44.45653 | 33.56708 | 91          |
| 20 | almaemil            | 44.525   | 33.4947  | 99          |
| 21 | qzanyh find         | 45.50671 | 33.2367 | 151         |
| 22 | qzanyhcinter        | 45.54952 | 33.65292 | 250         |
| 23 | Baldrozfatmyh       | 45.1333  | 33.5044  | 144         |
| 24 | diyala bridge       | 44.5184  | 33.2326  | 73          |
| 25 | almadayin           | 44.5803  | 33.0968  | 95          |

6. Results and discussion

The results gained from the EDX are the concentrations of each element in the samples. These data were illustrated in Table 3. The results show the variations of the presence of the elements at different locations. The variation of the concentration is a reflection of the pollution degree in that area due to the presence of industrial activities or any human activities.

Table 3. Concentrations the heavy metals (Cd, Hg, As)

| ID | Cd ppm | Hg ppm | As ppm |
|----|--------|--------|--------|
| 1  | 7.3    | 0.36   | 0      |
| 2  | 0      | 0      | 0      |
| 3  | 0      | 0.54   | 0      |
| 4  | 10.5   | 0.74   | 0      |
| 5  | 0      | 0.09   | 11.3   |
| 6  | 0      | 0.21   | 0      |
| 7  | 0      | 0      | 0      |
| 8  | 0      | 0      | 38     |
| 9  | 0      | 0      | 0      |
| 10 | 4.9    | 0.54   | 1.33   |
| 11 | 8.06   | 1.53   | 32.66  |
| 12 | 0      | 0      | 33.33  |
| 13 | 1.4    | 0      | 0      |
Geographic information analysis provides the ability to estimate variables throughout the studied area using interpolation functions. The IDW interpolation method was chosen to be applied to the data collected. Figure 2 represents the estimation of cadmium concentration in the studied areas. Through the estimation map, using ArcGIS software, areas were calculated and illustrated in Table 3. The highest concentration of cadmium. It was recorded in Region No. 1 (7.3 ppm) and in Region No. 2 (10.5 ppm) No. 10 it was recorded (4.9 ppm) and in No. 11 it was recorded (8.06 ppm). And in No. 15 it was recorded (7.86 ppm). And at No. 11 it was recorded (8.06 ppm). And in No. 15 it was recorded (7.86 ppm) and in 17.21 4.46, 5.1 of the cadmium element were recorded in these areas due to the nature of the earth's formation, as well as the reason for throwing industrial waste containing cadmium waste as she the Figure(2).

|   |   |   |   |
|---|---|---|---|
| 14 | 0 | 0 | 0 |
| 15 | 7.86 | 1.53 | 0 |
| 16 | 0 | 0 | 0 |
| 17 | 4.46 | 0.21 | 0 |
| 18 | 0 | 0.44 | 61.3 |
| 19 | 0 | 0 | 5.33 |
| 20 | 1 | 0.15 | 0 |
| 21 | 5.1 | 1.13 | 0 |
| 22 | 0 | 0.33 | 0 |
| 23 | 0 | 0.45 | 0 |
| 24 | 3 | 1.260 | 0 |
| 25 | 2.73 | 1.02 | 0 |

Figure 2. Distribution of Cadmium concentration
The highest concentration of (Hg) was recorded in Region No. 11 (1.53 ppm), while in Region No. 21 (1.13 ppm), and in Region No. 24 (1.26 ppm), it was recorded in Zone 25 (1.02 ppm). Per million), and these four regions are high compared to the (World Health Organization). Adult (0.5 ppm) As for the rest of the regions, the mercury concentration was within or below the required level as shown in Figure 3, which indicates the presence of mercury in the study area. Mercury is naturally present in the earth's crust, and it is released into the environment due to volcanic activities and human activity, which indicates the main reason for the release of mercury into the environment are, especially, from coal-fired power plants, coal burning in homes, cooking, industrial activities and waste incinerators as shown in Figure 3.

The highest rise in arsenic was recorded in region No. 8 (38 ppm), in region No. 6 it was recorded (32 ppm), in region No. 11 and in region No. 12 it was recorded (33.33 parts per million). In region No. 18 and recorded the highest rise (61.3 ppm)
As for the rest of the regions, there was no presence of arsenic (Figure 4) representing the sites of arsenic and its concentrations in the studied areas, and the arsenic increases in the areas most used in the industry as an ingredient in the manufacture of alloys, as well as in the treatment of glass, dyes, textiles, paper, metal adhesives and preservatives for wood and ammunition. Arsenic is also used in leather tanning and, to some extent, in pesticides, food additives, and pharmaceuticals.
7. Conclusion
A high concentration of most heavy elements in depth (10 cm), which indicates the absence of movement and transmission of these elements through the soil layers. Soil samples showed contaminated with cadmium, which reached the highest concentration (10.4) compared to the permissible limit (1 part per million) in area No. 4 and the highest concentration of mercury, which reached (1.53 part per million) compared to the maximum. Allowed by the World Health Organization (0.5 part per million) in the 11 and 15 regions, and the highest concentration of arsenic in the 18th region, reaching (61.3 parts per million) compared to the permissible limit of the World Health Organization (20 parts per million). Soil is often contaminated with cadmium, mercury, and arsenic due to the use of agricultural pesticides and chemical fertilizers that contain these elements. Human factors that increase the use of these elements, which leads to an increase in these elements in the soil.

The method that been used in this research is an effective way to illustrate and evaluate the concentrations of heavy elements and their reasons. The focal points in the concentrations maps are exact because they are measured in the lab.

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