Assessment of Soil Pollution in the Ishaqi Project Area - Salah Al-Dean Governorate, Iraq

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ABSTRACT
Ten soil samples were collected from Ishaqi project area, Salah Al-Dean Governorate, and analysed for chemical elements (Fe₂O₃, Al₂O₃, CaO, K₂O, Na₂O, Co, Zn, Cu, and Pb) to detect the pollution in the study soil using the indices of geo-accumulation (I-geo), contamination factor (CF), and pollution load index (PLI). The results of I-geo indicate that the soil of Ishaqi project area is unpolluted with Pb, Co and slightly polluted with Zn and Cu. The results of CF for Zn, Cu, and Co showed class 2 of moderate contamination and class 1 of low contamination in some samples while those for Pb demonstrated class 1 –of low contamination. The Pollution Load Index (PLI) values for Co, Zn, Cu, and Pb showed class 2 of local pollution.

Keywords: Geo-accumulation, Contamination factor, Pollution load index, Ishaqi soil.

Introduction
High probability of heavy elements contamination is expected from exhaust gases of vehicles, emissions from factories, regional / local sand and dust storms. Toxic heavy elements affecting the ecosystems could lead to geo-accumulation and bioaccumulation [1]. Pollutants enter the environment in many ways, such as by industrial discharge, municipal waste discharge and others; also by land runoff mainly by rivers, tributaries, agricultural canals and by the atmospheric fallout of pollutants transferred by the air mass onto the land surface [2]. Many authors studied the heavy elements as a

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polluted indicator using the traditional analytical methods [3], but neither one used the proposed indices to evaluate the pollution and the degree of weathering of study area soil, central Iraq. Ishaqi project area is located about 100 km to the north of Baghdad within Salah al-Din Governorate and its geographical position lies between the longitude 43° 55' 12"- 44°28' 05"E and the latitude 33°30' 28"- 34°03'07"N (Figure-1). The study area is composed of recent and quaternary sediments of Pleistocene-Holocene of the Mesopotamian plain alluvium which consists of thin layers of sand, clayey silt, and silty clay with a succession of clay, sand, and mud, and some gravel within deeper layers. The study area has been heavily used for agricultural purposes[4]. The objective of this research is to calculate the heavy elements distribution in the soil of Ishaqi project area using the geo-accumulation index (I-geo), contamination factor (CF), and Pollution load index (PLI).

Figure 1-Location map of the soil samples for the study area.
MATERIALS AND METHODS

Ten soil samples were selected at depths range of 0 – 15 cm. from -Ishaqi area during 2018 to evaluate some oxides and heavy elements in the sediments. The selected samples were investigated for Co, Zn, Cu, and Pb elements using three indices; geo-accumulation index (I-geo), contamination factor (CF), and pollution load index (PLI) to detect soil pollution. The natural levels of these chemical constituents were established according to Taylor and McLennan (1985)[5]. All samples were transferred to the Geochemical prep lab – School of environment & technology /University of Brighton / United Kingdom and laboratory of Geology Department/ University of Baghdad . and subjected to drying processes by an oven at a temperature of 60°C. Thereafter, five grams of the sediments were powdered to detect Al 2O3 CaO, Na2O and K2O as well as heavy metals Co, Zn, Cu, and Pb by XRF Methods[6].

The measured heavy metals were used to indicate the pollution by using the mentioned indices. The oxides were used to investigate the intensity of weathering by calculating the Chemical Index of Alteration (CIA) using the formula of Nesbitt and Young( 1982)[7]:

\[
\text{CIA} = \left( \frac{\text{Al}_2\text{O}_3/ \text{SiO}_2} {\text{Al}_2\text{O}_3 + \text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O}} \right) \times 100
\]

RESULTS AND DISCUSSION

The results of the measured oxides (Fe2O3 %, Al2O3%, CaO%, Na2O%, and K2O%) and heavy metals concentrations (Co, Zn, Cu, and Pb) for Ishaqi area are shown in Tables- (1 and 2). Discussion of these chemical constituents is as follows:

A- Heavy Metals and Oxides

Cobalt: Cobalt is an important and essential element for living organisms and is associated with clay minerals [8]. It was found that the mean value of Co concentration was 18.76 ppm in study area Cobalt is present in the same chemical family with Fe and shows a similar geochemical behaviour so that there is a direct relation of Co with Fe2O3. Cobalt with Al2O3, CaO, Zn, Cu, and Pb may be adsorbed on the surface of clay and carbonate minerals[9].

Zinc: The agricultural practice is considered as an important source of Zn. Zinc is directly related to Fe and with clay minerals as one host[9]. It was found that the mean value of Zn concentration was 114.9 ppm in the study area. Nickel and zinc are present in the same chemical family of Fe and show similar geochemical behaviour, so that there is a direct relation with Fe2O3. The positive relation with Al2O3, CaO, Cu, and Pb may be due to the adsorption of these two elements on the surface of clay and carbonate minerals[9].

Copper: Cu is a component of several enzymes and is necessary for the utilization of iron[10]. The mean value of Cu concentration was 51.78 ppm in Ishaqi area. The sediment content of copper depends on the source rocks, organic matter, clay concentration and PH value [11]. The correlation of copper with the other elements in the samples of the study area showed that it has positive relations with each of Al2O3, Fe2O3, and CaO. These relations may be due to copper adsorption on the surface of clay, iron and carbonate minerals. The direct relation with Co and Pb elements may reflect the same source rocks for these elements (mafic rocks).

Lead: The anthropogenic source of Pb is leaded gasoline. Lead may be found in carbonates, Fe – Mn oxides, inorganic matter and clay minerals [9]. Pb is a toxic metal that is harmful to human health; there is no safe level for lead exposure. The degree of exposure depends on the concentration of lead and route of exposure (air, water, and food)[12]. It was found that the mean value of Pb concentration was 14.25 ppm in the study area.

Iron oxide: The concentration of Fe oxides (Fe2O3) in the sediment is related to parent material, degree of weathering, and pedogenic accumulation or depletion processes. Iron is present in opaque minerals and in the clay mineral structures such as chlorite, montmorillonite and kaolinite minerals, as well as in the iron minerals[13]. It was found that the mean value of Fe2O3 was 6.11% in the study area.

Aluminum oxide: Aluminum is a common element in primary silicate minerals, from which it may be released by weathering[13]. Alumina element is present in the clay minerals structure. In addition, it is found as Al (OH)3 between the layers of montmorillonite or adsorbs on clay minerals[14]. It was found that the mean value of (Al2O3) was 8.75% in the study area.

Calcium oxide: Calcium oxide is common in primary carbonate minerals, from which it may be released by weathering. There is a correlation of CaO with the other oxides in the sediments; it has
direct relations with \( \text{Fe}_2\text{O}_3 \) and \( \text{Al}_2\text{O}_3 \), and these relations may be attributed to the association of these metals in the clay minerals. It was found that the mean value of \( \text{CaO} \) was 17.18% in the study area.

**Sodium oxide:** Sodium oxide content in the samples is due to its relation with clay minerals especially montmorillonite [15]. Navratilova and Kula (2000) showed that sodium element was considered as a major element in the montmorillonite minerals [16]. Also, Gregor (1976) reported that sodium element is fixed in the clay minerals by institution of potassium by sodium element. This study also mentioned the ability of sodium element to adsorb on clay minerals in the basic condition [17]. It was found that the mean value of Na\(_2\)O was 1.26% in the study area.

**Potassium oxide:** It was found that the mean percent of K\(_2\)O was 1.44% in the study area. The correlation of K\(_2\)O with the other oxides in the sediments of the study area reflected an indirect relation with Fe\(_2\)O\(_3\) and Na\(_2\)O, due to the lack of potassium element and carbonate minerals in the clays.

**Table 1:** Results of oxides and heavy elements in the soil of the study area

| No | \( \text{Fe}_2\text{O}_3 \) | \( \text{Al}_2\text{O}_3 \) | \( \text{CaO} \) | \( \text{Na}_2\text{O}_3 \) | \( \text{K}_2\text{O} \) | \( \text{Co} \) | \( \text{Zn} \) | \( \text{Cu} \) | \( \text{Pb} \) |
|----|-----------------|-----------------|------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1  | 6.39            | 9.257           | 17.99      | 0.769           | 1.444           | 23.4            | 109.1           | 55.1            | 13.1            |
| 2  | 6.477           | 9.324           | 17.15      | 1.014           | 1.527           | 25.0            | 112             | 51.5            | 13.0            |
| 3  | 6.02            | 8.701           | 16.17      | 0.875           | 1.43            | 18.2            | 118             | 49.6            | 13.6            |
| 4  | 6.097           | 8.456           | 19.26      | 0.723           | 1.299           | 12.9            | 103.7           | 54.0             | 12.9            |
| 5  | 6.394           | 9.454           | 16.76      | 1.23            | 1.511           | 22.9            | 117             | 53.2             | 13.8            |
| 6  | 6.433           | 9.385           | 15.74      | 0.969           | 1.645           | 32.5            | 117.6           | 54.9             | 15.5            |
| 7  | 6.077           | 8.606           | 18.56      | 1.153           | 1.403           | 15.2            | 103             | 49.7             | 12.8            |
| 8  | 5.029           | 7.343           | 17.13      | 2.534           | 1.332           | 9.3             | 140.8           | 46.2             | 19.8            |
| 9  | 6.003           | 8.334           | 16.45      | 1.906           | 1.491           | 10.8            | 112.1           | 51.6             | 15.3            |
| 10 | 6.252           | 8.725           | 16.67      | 1.503           | 1.41            | 17.4            | 115.7           | 52.0             | 12.7            |
| Mean | 6.1172         | 8.7585         | 17.188    | 1.2676          | 1.4492          | 18.76           | 114.9           | 51.78            | 14.25           |
| Min | 5.029           | 7.343           | 15.74      | 0.723           | 1.299           | 9.3             | 103             | 46.2             | 12.7            |
| Max | 6.477           | 9.454           | 19.26      | 2.534           | 1.645           | 32.5            | 140.8           | 55.1             | 19.8            |

**B- Assessment of contamination:**

In this research, three soil pollution indices were selected to assess the contamination level of Co, Zn, Cu, and Pb in the soil of study area. These are the Geo accumulation index (I-geo), contamination factor (CF) and Pollution Load Index (PLI) (Tables- 2 and 3).

1- **Geo-accumulation index (I-geo)**

This index is used for comparing the levels of the analysed heavy elements to the background level. I-geo was determined by the following equation according to Taylor and McLennan (1985) Muller (1969):

\[
I\text{-geo} = \log 2 (\frac{\text{Cn}}{1.5 \text{ Bn}}) \text{ Where:} \\
\text{Cn} = \text{the analysed value of the heavy elements in the samples and} \\
\text{Bn} = \text{the crustal average background concentration of the heavy elements (Taylor and McLennan, 1985; Lu et al., 2009).}
\]

Lu et al (2009)[18] defined the constant 1.5 as a constant introduced to minimize the effect of possible variations in the background values which may be attributed to lithological variations in the sediments. Muller (1969)[19] designed a classification for the Geaccumulation index. This application was considered by many researchers like Huu et al (2010)[20]. The values of this index vary from sub-zero to more than 5 having 7 grades (Table- 3). The highest grade (6) reflects a 100-fold enrichment and (0) reflects the background concentration according to Table-3. The values of this index have seven grades and the results reflected the following: The value for Pb was found negative in study area, ranging from -0.20 to -0.9 (Table-3). The result indicates that the study area is unpolluted by Pb. I geo values of Cu in Ishaqi area ranged from 0.2 to 0.5 indicating slightly polluted
sediiments by Cu. the I-geo value of Zn in the study area ranged from -0.0 to 0.1, indicating that these samples are slightly polluted. I-geo value for Co were in Ishaqi area ranged from -0.0 to -1.4 and were considered as unpolluted sediments by Co.

2- Contamination factor (CF)
The contamination factor (CF) was determined according to Thomilson et al. (1980) equation.

\[ CF = \frac{C_{\text{Sample}}}{C_{\text{Background}}} \]

Where:
- CF: contamination factor.
- C_{\text{Sample}}: metal content in the sample.
- C_{\text{Background}}: background level of metal.

The contamination factor (CF) for Co, Zn, Cu, and Pb was calculated in the Ishaqi area (Table-3). The values of Pb in the ten sites ranged from 0.7 to 1.2, reflecting low to moderate contamination with lead. It is known to come from the use of high lead gasoline[9]. CF for Cu in the Ishaqi area ranged from 1.8 to 2.2 indicating moderate contamination (class 2). Zn in the study area was classified as class 2, representing moderate contamination ranging from 1.4 to 1.9. Zn originates from toxic waste from industrial sources[21]. Cobalt (Co) in the study area is represented low to moderate contamination, as class 2, ranging from 0.5 to 1.9. (Table-3).

It is believed that a considerable part of heavy elements find its way into the environment as a result of the burning of diesel oil and may be due to the disposal of heavy elements-containing wastewater.

3- Pollution load index (PLI) The pollution load index (PLI) was determined according to Thomilson et al. (1980) [22] equation, where (PLI) is expressed as follows:

\[ \text{PLI} = \sqrt{\text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \ldots \times \text{CF}_n} \]

Where:
- n = the number of analyzed metals in each site.

The Pollution Load Index (PLI) for Co, Zn, Cu, and Pb was calculated, and the samples were classified as class 2 (Deterioration on-site quality), indicating local pollution. PLI values in the study area ranged from 1.1 to 1.6 (Table-3). Higher values of PLI factor may result from the effects of untreated toxic waste that discharges to the drainage from the domestic areas, along with some anthropogenic activities that contaminate the soil by heavy metals.

**Table 2**: Results of the soil pollution indices; geo-accumulation (I-geo), contamination factor (CF), and pollution load index (PLI) values of the study area.

| Sample no | PLI | Co (ppm) | I-geo | CF | Zn (ppm) | I-geo | CF | Cu (ppm) | I-geo | CF | Pb (ppm) | I-geo | CF |
|-----------|-----|----------|-------|----|----------|-------|----|----------|-------|----|----------|-------|----|
| 1         | 1.40| 23.4     | -0.12 | 1.38| 109.10   | 0.03  | 1.54| 55.10    | 0.55  | 2.20| 13.10    | -0.87 | 0.82|
| 2         | 1.40| 25       | -0.03 | 1.47| 112.00   | 0.07  | 1.58| 51.50    | 0.45  | 2.06| 13.00    | -0.88 | 0.81|
| 3         | 1.32| 18.2     | -0.49 | 1.07| 118.00   | 0.15  | 1.66| 49.60    | 0.40  | 1.98| 13.60    | -0.82 | 0.85|
| 4         | 1.18| 12.9     | -0.98 | 0.76| 103.70   | -0.04 | 1.46| 54.00    | 0.52  | 2.16| 12.90    | -0.90 | 0.81|
| 5         | 1.42| 22.9     | -0.16 | 1.35| 117.00   | 0.14  | 1.65| 53.20    | 0.50  | 2.13| 13.80    | -0.80 | 0.86|
| 6         | 1.61| 32.5     | 0.35  | 1.91| 117.60   | 0.14  | 1.66| 54.90    | 0.54  | 2.20| 15.50    | -0.63 | 0.97|
| 7         | 1.20| 15.2     | -0.75 | 0.89| 103.00   | -0.05 | 1.45| 49.70    | 0.40  | 1.99| 12.80    | -0.91 | 0.80|
| 8         | 1.26| 9.3      | -1.46 | 0.55| 140.80   | 0.40  | 1.98| 46.20    | 0.29  | 1.85| 19.80    | -0.28 | 1.24|
| 9         | 1.19| 10.8     | -1.24 | 0.64| 112.10   | 0.07  | 1.58| 51.60    | 0.45  | 2.06| 15.30    | -0.65 | 0.96|
| 10        | 1.29| 17.4     | -0.55 | 1.02| 115.70   | 0.12  | 1.63| 52.00    | 0.46  | 2.08| 12.70    | -0.92 | 0.79|
Table 3-Classified grades of I-geo, CF and PLI indices (after Thomilson et al., 1980)

| I-geo Grade | CF contamination factor | PLI |
|-------------|-------------------------|-----|
| Practically unpolluted | <1 Low contamination (Class 1) | 1 Baseline level (Class 1) |
| Slightly polluted | 1<CF<3 Moderate contamination (Class 2) | >1 Deterioration on site Quality (class 2) |
| Moderately polluted | 3<CF<6 Considerable Contamination (class 3) |
| Severely polluted | >6 Very high Contamination (class 4) |
| Severely extremely polluted | Moderate contamination (class 5) |
| Extremely polluted | High contamination (class 6) |

CONCLUSIONS

The concentrations of heavy metals (Co, Zn, Cu, and Pb) found in the study area can mainly be due to the relatively high percentages of clay contamination. Moreover, pollution with these heavy elements is thought to be due to different sources such as urban wastes, fertilizers, etc. It is clear that the pollutants affected Ishaqi area soil that have relatively high clay.

References

1. Gowd, S.S., Reddy, M.R. and Govil, P.K. 2010. Assessment of heavy metal contamination in soils at Jajmau (Kanpur) and Unnao industrial areas of the Ganga Plain, Uttar Pradesh, India. J. Hazardous Mat. 174: 113 – 121.
2. Kabata-Pendias, A. and Mukherjee, A.B. 2007. Trace Elements from Soil to Human. Springer-Verlag Berlin Heidelberg, 561.
3. Khwedim, K.H., Al-Anssari, H.R. and Al-Bassam, K. 2009. Study of distribution of some heavy metals in the soil of Basra city-south of Iraq", Iraqi Journal of Science, 50: 533 – 542.
4. Jassim, S.Z. and Goff, J.C. 2006. Geology of Iraq. 1st edition, printed in Czech Republic., 318.
5. Taylor, S.R., and McLennan, S.M. 1985. The continental crust: its composition and evolution, Blackwell, Oxford.
6. Aubert, H. and Pinta, M. 1977. Trace elements in soils, Developments in soil science, Elsevier scientific Publishing Co., Amsterdam, 395.
7. Nesbitt, H.W. and Young, G.M. 1982. Early Proterozoic Climate and Plate Motion Inferred from Major Element Chemistry of sites. Nature, 299: 715 – 717.
8. Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water (3rd ed.). USGS water- supply papers-2254, 253
9. Pendias, K.A. and Pendias, H. 2001. Trace Elements in Soils and Plants. 3rd edition, CRC Press, Boca Raton, London, N. Y., Washington, D.C., USA, 388.
10. Williams, L. D. 2005. Environmental Science Demystified, McGraw-HILL publisher. 413p.
11. Aubert, H. and Pinta, M. 1977. Trace elements in soils, Developments in soil science, Elsevier scientific publishing Co., Amsterdam, 395.
12. Hem, J.D. 1991. Study and interpretation of the chemical characteristics of natural water, U.S. Geological Survey, Water Supply, paper- 2254, 263.
13. Kabata-Pendias, A. and Sadurski, W. 2004. Trace elements and compounds in soil. In: Merian E, Anke M, Ihnat M, Stoepppler M (eds) Elements and their compounds in the environment, Wiley-VCH, Weinheim, 2nd ed., 79 – 99.
14. Jenne, E.A. 1968. Controls on Mn, Fe, Co, Ni, Cu, and Zn. Concentration in soils and water; the significant roles of hydrous Mn& Fe Oxides In: Trace inorganics in water. Adv. Chem. ser., 67: 337 – 387.
15. Weaver, C.E. and Pollared, D. E. 1975. The chemistry of clay minerals. Development in sedimentology, part 15, Elsevier scientific publ. Co., New York, 213.
16. Navratilova, Z. and Kula, P. 2000. Study of the ion exchange on vermiculite by means of carbon paste electrode. Univ. Masaryk. Brno, 28(29): 43 – 54.
17. Gregor, C.B. 1976. The geochemical behavior of sodium brokering. Holland V.N Amsterdam.
18. Lu, X.L., Wang, K., Lei, J.H. and Zhai, Y., 2009. Contamination assessment of copper, lead, zinc, manganese, and nickel in street dust of Baoji, NW China, J. Hazardous Mat. 161: 1058-1062.
19. Muller, G. 1969. Index of accumulation in sediments of the Rhine River, J. Geol. 2: 108-118.
20. Huu, H.H.; Rudy, S. and Damme, A.V. 2010. Distribution and contamination status of heavy metals in estuarine sediments near CauOng harbor, Ha Long Bay, Vietnam. Geol Belgica 13(1-2):37-47.
21. Thorpe, A., and Harrison, R.M. 2008. Sources and properties of non-exhaust particulate matter from road traffic: a review. Sci Total Environ 400: 566 – 575.
22. Thomilson, D.C., Wilson, D.J., Harris, C.R. and Jeffrey, D.W. 1980. The problem in heavy metals in estuaries and the formation of a pollution index. Helgol. Wiss. Meeresunlter. 33: 566 – 575.