Employing of Some Criteria in Soil Pollution Magnitude Estimation by Residues of Electricity Musayyib Thermal Station

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Abstract. The research dealt with the effect of the residues of Al-Musayyib electricity thermal station in soil pollution with Vanadium, Chromium and Arsenic in Babylon governorate located between Longitude °32 99’ 861ˊˊN and Latitude °44 29’ 00ˊˊE. The content of study soils from heavy metals was estimated by XRF, it was high, especially V and Cr 210-265, 326.3-1126.0mg kg-1 respectively. Consequently, the CF reached the highest values in sample Ss 12 via V and Cr: 3.73, 10.73; 3.63, 10.54 respectively compared with Sco1 and Sco2, and so, PLI reached 4.56, 4.45 for heavy metals group in the same sample. While As recorded the highest values in sample Ss11. Igeo recorded the highest values in sample Ss12 for V: 0.75, 0.73; Cr: 3.73, 10.73; 3.63, 10.54 respectively compared with Sco1 and Sco2.

Keywords: Pollution factors; Geo-accumulation Index; Vanadium; Chromium; Arsenic; XRF.

1. Introduction

The human impact on the environment has become widespread since the beginning of the industrial revolution leading to environmental changes were a clear risk to health and natural balance in many ecosystems through the accumulation residues of mining operations and the burning of fuel such as coal, petroleum and other Industries[1,2]. Vanadium, Chromium and Arsenic are considered heavy elements resulting from fuel combustion, especially electric generation stations are soluble compounds in an ambit of pH towards into alkaline [3,4]. Since the Iraqi soils locate within the dry and semi-dry areas characterized by pH is tended to alkaline and prevail in them long-life power stations are located on the banks of the Tigris and Euphrates rivers such as the Musayyib thermal power station, which surrounded an important agricultural soils irrigated with Euphrates water and vegetation cover from trees and orchards and crops with economic benefits[5]. it is expected an accumulation of these heavy elements reaching humans is expected to be facilitated by food chains from their agricultural and industrial sources[6].
There are several indicators that can estimate the magnitude of soil pollution in heavy elements as a result of inputs of human activity, including the pollution factor (CF) provides a measure of the degree of overall contamination of surface layer depending on human activity inputs and lithogenic source[7]. Pollution Load Index (PLI) is a quick tool in order to compare the pollution status of different places through determined pollution severity and its variation along the sites[8]. While Index of Geo-accumulation (Igeo) has been used widely to evaluate the degree of environmental contamination because of parent material pollution for the terrestrial, aquatic and marine environment [9]. In this study, an attempt has been made to: 1) estimation of soil content of heavy metals V, Cr and As; 2) using of some criteria in the assessment of soil pollution magnitude via the residues of electricity Musayyib thermal station.

2. Materials And Methods

In order to study the effect of electricity Musayyib thermal station in soil pollution with heavy metals, surface soil samples were selected at a depth of 1-50cm, according to [10] of the city of Musayyib in Babylon Governorate between Longitude °32 99’ 861”N and Latitude °44 29’ 00”E. The sample SS1 and SS2 from the middle of the agricultural soil are 500m away from the station, the sample SS21 and SS22 are 5km from the station toward the right, and the sample SS31 and SS32 are 15km from the station to the north. The comparative soil was selected in Hashemia judicature of the Governorate itself between Longitude °32 22’ 265”N and Latitude °44 38’543”E represented by the samples Sco1 and Sco2.

Following the necessary field and laboratory measures in the fundamentals of scientific research, the grained size distribution of soil fractions as sand, silt and clay was estimated by the pipette international[11], and estimation of the soil content from V, Cr and As by XRF. And through the soil content of these heavy metals were assessed the state of pollution according to the following Equations:

\[
\text{CF}_{\text{soil}} = \frac{C_m \text{Sample}}{C_m \text{Background}} \quad (2)
\]

Where: CF was Contamination Factor, \(C_m\) Sample and Background were concentration of metal in contaminated and non-contaminated soil samples respectively[7].

\[
\text{PLI} = (\text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \ldots \times \text{CF}_n)^{1/n} \quad (3)
\]

Where: PLI is pollution load index; \(\text{CF}_1\) and \(\text{CF}_2\) to \(\text{CF}_n\) are values of the pollution agent for a group of heavy metals in each site; \(n\) means number of heavy metals in that site[12].

\[
\text{I}_{\text{geo}} = \log_2 \frac{C_{\text{metal}}}{1.5 \times C_{\text{metal(control)}}} \quad (4)
\]

Where: \(I_{\text{geo}}\) is Index of Geo-accumulation. \(C_{\text{metal}}\) is the concentration of heavy metal in enrich sample and \(C_{\text{metal(control)}}\) is the concentration of metal in unpolluted sample. The factor 1.5 is used for possible variations of background or control values due to lithological variations in soil [13,14].

Pollution levels and degrees for these indicators: CF, PLI and I_{\text{geo}} as shown in Table 1 and 2 [15, 16, 17].

| Table1. Grades and levels of cf and pli |
|----------------------------------------|
| **Grades** | **Levels** | **Grades** | **Level** |
| CF < 1 | Low | PLI= 0 | Perfection |
| 1 ≤ CF ≤ 3 | Moderate | PLI<1 | Baseline Level |
| 3 ≤ CF ≤ 6 | Considerable | PLI<1 | Baseline Level |
| CF > 6 | Very high | PLI>1 | Polluted |
Table 2. Grades and levels of $i_{geo}$

| $i_{geo}$   | Level                    |
|------------|--------------------------|
| $i_{geo}$ ≤ 0 | Unpolluted              |
| 0 < $i_{geo}$ ≤ 1 | Unpolluted to Moderate   |
| 1 < $i_{geo}$ ≤ 2 | Moderate               |
| 2 < $i_{geo}$ ≤ 3 | Moderate to Heavy       |
| 3 < $i_{geo}$ ≤ 4 | Heavy                  |
| 4 < $i_{geo}$ ≤ 5 | Heavy to Severity       |
| $i_{geo}$ ≤ 5 | Severity                |

3. Results And Discussion

Table 3 shows dominance of clay, followed silt and sand respectively in soil samples $S_{s11}$ and $S_{s12}$. While sand was more than clay and silt which alternate by the quantity in samples $S_{s21}$ and $S_{s22}$. Quantity of clay and sand were alternation, and silt finally in sample $S_{s31}$, $S_{s32}$. Results indicate effecting river sediment in the soils of studying and the flow rate and its ability to carry the granules according to size[18]. Therefore sand is near to sedimentation source for its large size compared to silt and clay which is transferred to far away distances because of size less than 0.002 mm.

Accordingly, the comparison soil samples had a texture between clay loam- clay due to river source may be far away, pH of soils was towards alkaline(Table 3), perhaps encouraged an accumulation of heavy metals in current study soils.

Table 3. Size distribution of soil fractions and pH

| Samples | Grain Size Distribution (g kg$^{-1}$) | Class of Texture | pH  |
|---------|--------------------------------------|------------------|-----|
|         | Sand | Silt | Clay     |                 |     |
| $S_{s11}$ | 105.7 | 170.0  | 724.3 | C | y,y |
| $S_{s21}$ | 77.7  | 125.3  | 797.0 | C | y,y |
| $S_{s22}$ | 519.0 | 113.0  | 368.0 | SC | y,y |
| $S_{s2}$  | 527.0 | 305.0  | 168.0 | L  | y,4 |
| $S_{s31}$ | 235.9 | 119.3  | 644.8 | C  | y,A |
| $S_{s32}$ | 426.1 | 209.5  | 364.4 | CL | y,A |
| Sco$_1$   | 377.9 | y,y   | 392.9 | CL | 7.5 |
| Sco$_2$   | 255.8 | 325.5  | 418.7 | C  | 7.6 |

V was 210-265, Cr: 326.3-1126.0 and As: 10.2-12.2 mg kg$^{-1}$ in soils affected by electricity thermal station residues(Table 4). These heavy metals were 70-73, 104.6-106.8 and 4.5-4.6 mg kg$^{-1}$ respectively in the compared soil. V exceeded the value 60.4 mg kg$^{-1}$ cited by[19,20] for the topsoil, as well as Cr was much greater than the limit1-5 mg kg$^{-1}$ mentioned by[21]. Results indicate the accumulation of these heavy metals due to station residues, especially the V which uses in the power generating units (Crude Oil).
Table 4. The content of heavy metals in soils

| Samples | Heavy metals (mg kg⁻¹) |
|---------|------------------------|
|         | V          | Cr          | As          |
| Ss₁₁    | 254.0      | 326.3       | 12.2        |
| Ss₂₁    | 265.0      | 1126.0      | 11.1        |
| Ss₂₁    | 253.0      | 411.0       | 11.6        |
| Ss₂₂    | 221.0      | 372.6       | 10.2        |
| Ss₃₁    | 210.0      | 520.3       | 10.5        |
| Ss₃₂    | 223.0      | 464.0       | 10.4        |
| Sco₁    | 71.0       | 104.6       | 4.5         |
| Sco₂    | 73.0       | 106.8       | 4.6         |

CF of heavy metals V: 2.96⁻⁻3.73, Cr: 3.12⁻⁻10.76 and 2.27⁻⁻2.71 in soil polluted samples with the Sco₁ comparison, while they were 2.88⁻⁻3.63, 3.06⁻⁻10.54 and 2.22⁻⁻2.65 respectively compared with Sco₂. The levels of contamination were moderate to considerable for V, but they for Cr between very high to considerable, Level of contamination via As was moderate(Table 5). CF for V and Cr recorded the highest values 3.73, 10.72 respectively in the sample Ss₂₁, and As was 2.71 in the sample Ss₁₁ compared with Sco₁ (Fig. 1).

Table 5. Contamination factor of heavy metals in soils

| Samples | CF of heavy metals in samples with Sco₁ | CF of heavy metals in samples with Sco₂ |
|---------|----------------------------------------|----------------------------------------|
|         | V          | Cr          | As          | V          | Cr          | As          |
| Ss₁₁    | 3.5        | 3.12        | 2.7         | 3.4        | 3.06        | 2.65        |
| Ss₂₁    | 3.7        | 10.7        | 2.4         | 3.6        | 10.5        | 2.41        |
| Ss₂₁    | 3.5        | 3.93        | 2.5         | 3.4        | 3.84        | 2.52        |
| Ss₂₂    | 3.1        | 3.56        | 2.2         | 3.0        | 3.49        | 2.22        |
| Ss₃₁    | 2.9        | 4.97        | 2.3         | 2.8        | 4.87        | 2.28        |
| Ss₃₂    | 3.1        | 4.44        | 2.3         | 3.0        | 4.34        | 2.26        |
| Levels  | M-C        | VH- C       | M-C         | VH- C      | M           |

M: Moderate; C: Considerable; VH: Very High

Figure 1. Maximum and minimum values of cf in soils
Table 6 shown results of PLI which were 2.90-4.56, 2.83-4.45 in soil polluted samples with compared Sco₁ and Sco₂ respectively. According to the Levels of contamination in Table 1 that all soil samples were polluted by heavy metals in the present study.

**Table 6. Pollution load index of heavy metals in soils**

| Samples | PLI for metals in samples with Sco₁ | PLI for metals in samples with Sco₂ |
|---------|------------------------------------|------------------------------------|
|         | V  | Cr | As | V  | Cr | As |
| Ss₁₁    | 3.08 |   |    | 3.01 |   |    |
| Ss₂₁    | 4.56 |   |    | 4.45 |   |    |
| Ss₂₁    | 3.27 |   |    | 3.19 |   |    |
| Ss₂₂    | 2.90 |   |    | 2.83 |   |    |
| Ss₃₁    | 3.21 |   |    | 3.14 |   |    |
| Ss₃₂    | 3.14 |   |    | 3.07 |   |    |

Index of Geo-accumulation results in Table 6 were 0.59-0.75, 0.62-2.15 and 0.45-0.54 of V, Cr and As respectively in soil polluted with comparison the Sco₁, and so was 0.58-0.73, 0.61-2.11 and 0.44-0.53 for V, Cr and As in soil polluted with comparison the Sco₂. It was a moderate level of pollution (Table 2), except for Cr was a moderate to heavy level of contamination (2.11-2.15) in Ss₁₂ sample.

**Table 7. Index of geo-accumulation for heavy metals in soils**

| Samples | Igeo of metals in samples with Sco₁ | Igeo of metals in samples with Sco₂ |
|---------|------------------------------------|------------------------------------|
|         | V  | Cr | As | V  | Cr | As |
| Ss₁₁    | 0.7 | 0.6 | 0.5 | 0.7 | 0.6 | 0.5 |
|          | 2  | 2  | 4  | 0  | 1  | 3  |
| Ss₂₁    | 0.7 | 2.1 | 0.4 | 0.7 | 2.1 | 0.4 |
|          | 5  | 5  | 9  | 3  | 1  | 8  |
| Ss₂₁    | 0.7 | 0.7 | 0.5 | 0.6 | 0.7 | 0.5 |
|          | 1  | 9  | 2  | 9  | 7  | 0  |
| Ss₂₂    | 0.6 | 0.7 | 0.4 | 0.6 | 0.7 | 0.4 |
|          | 2  | 1  | 5  | 1  | 0  | 4  |
| Ss₃₁    | 0.5 | 0.9 | 0.4 | 0.5 | 0.9 | 0.4 |
|          | 9  | 9  | 7  | 8  | 7  | 6  |
| Ss₃₂    | 0.6 | 0.8 | 0.4 | 0.6 | 0.8 | 0.4 |
|          | 3  | 9  | 6  | 1  | 7  | 5  |

It most is noted here that all the results of the polluted samples compared to the sample Sco₁ were always higher than the results of comparison with the sample Sco₂ because their content of heavy metals was high compared to the sample values Sco₁ (Table 2).

Igeo for V and Cr recorded the highest values 0.75, 2.15 respectively in the sample Ss₂₁ too, and so As was 0.54 in Ss₁₁, as a result of their higher content of these heavy metals under study (Fig. 2).

The differences between the values of the CF and the results of Igeo confirm that there are pollution inputs other than the parent material that Igeo refers to it; perhaps they were added to the study soils due to the thermal electricity station residues, and the differences between the values of the pollutant load index and the results of ground accumulation, mean that there is sedimentation of heavy
metals in the soil of the study from the sources transferred by the air or water currents in addition to parent materials.

![Igeo of metals in soil polluted samples with Sco1]

Figure 2 maximum and minimum of Igeo in soil polluted samples

The current study found that the content of the soils from V, Cr and As metals were high. Thus, the CF, especially Cr reached a very high level in some samples affected Musayyib electricity thermal station residues. The PLI was greater than one for refers to that all the sites were polluted. The Igeo was moderate to heavy, except arsenic was unpolluted to moderate.

4 References

[1] A.Piccolo, P.Conte and M.Halim, "Potential availability of heavy metals to phytoextraction from contaminated soils induced by exogenous humic substances", Chemosphere, Vol. 52, 2003: 265-275.
[2] K.S.Yadav, "heavy metals toxicity in plants an overview on the role of glutathione and phytochelatins in heavy metal stress tolerance of plants", South African Journal of Botany, Vol.76, 2010, 167-179.
[3] A.P.Vinogradov, "The geochemistry of rate and dispersed chemical elements in soils", 2nd ed. English Translation Consultant Burea Inc. New York, 1959:209p.
[4] E.M.Abdul-Moneim and A. Al-Turki, Ahmed bin Ibrahim, "Heavy elements sources and damage to the environment", promising research center in biological control and agricultural information, Qassim University, Saudi Arabia, 2012.
[5] M. A. AL-Msafree, "Evaluation of soil and plant pollution by heavy metals in Mousaeb city". MS. Agriculture Coll. AL-Qasim Green Univ., 2018: 42-51.
[6] M.Homae, R.A.Jafarnejadi G.Sayyad and M.Bybordi, "Heavy metal contaminated soils, spatial variability of cadmium concentration in wheat farm soils" 19th World Congress of Soil Science, Soil Solutions for a Changing World, 2010:243-246.
[7] I. Hakanson, "Ecological risks index for aquatic pollution control sediment logical approaches", Water Res. (14), 1980 : 975-1001.
[8] K.O. Adebowale, F.O. Agunbide, and B. Olu-Owolabi, "Trace metal concentration, site variations and partitioning pattern in water and bottom sediments from coastal area": A case study of Ondo Coast, Nigeria, Environmental Research Journal, 3 (2), 2006: 46-59.
[9] M.N. Tijani and S. Onodera, "Hydrogeochemical Assessment of metals contamination in an urban drainage system": A case study of Osogbo township, SW-Nigeria. J. Water Resource and Protection, (3),2009: 164-173.
[10] V.M. Ngole, "Using soil heavy metal enrichment and mobility factors to determine potential uptake by vegetables", Plant Soil Environ. J.57(1), 2011:75-80.
[11] M. Pansu and J.Gautheryou, "Handbook of Soil analysis.Mineralogical.Organic and Inorganic Methods", Text book, Library of Congress.Springer Berlin Heidelberg, New York,2006.
[12] D.L. Tomlinson, J.G. Wilson; C.R. Harris and D.W. Jeffrey, "Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index", Helgolaender Meeresunter.(33),1980: 566-575.
[13] A.V. Asaah, and A.F. Abimbola, "Heavy metal concentrations and distribution in surface soils of the Bassa Industrial Zone", Doula, Cameroon. The J. Sci. Eng., 31(2A), 2005: 147-158.

[14] L.L. Mediolla; M.C.D. Domingues and M.R.G. Sandoval, "Environmental assessment of an active tailings pile in the State of Mexico (Central Mexico)". Research J. of Envir. Sci. Vol 2(3): 2008: 669-676.

[15] Q. Gong, J. Deng, Y. Xiang, Q. Wang, and L. Yang, "Calculating pollution indices by heavy metals in ecological geochemistry assessment and a case study in parks of Beijing", J. Chin. Univ. Geosci. 19 (3), 2008: 230–241.

[16] P.S. Harikumar and T.S. Jisha, "Distribution pattern of trace metal pollutants in the sediments of an urban wetland in the Southwest Coast of India", Int. J. Eng. Sci. Technol. 2 (5), 2010: 840–850.

[17] H.H. Huu; S. Rudy and A.V. Damme, "Seasonal variation in heavy metal distribution in the distribution and contamination status of heavy sediment of major dams in Ekiti-State". Pakistan J. Metals in estuarine sediments near Cau Ong harbor, Nutrition, 6(6), 2010: 705-707.

[18] T. A. S. Mustafa Ahmed, "Fundamentals of Lands Science", Egyptian Society for the Dissemination of Knowledge and World Culture, Cairo, Egypt. 1985.

[19] R. L. Rudnick and S. Gao. Composition of the continental crust. Elsevier Ltd. J. Treatise On Geochemistry, (3) (ISBN: 0-08-044338-9), 2004: 1-64

[20] V. Garrett. Garrett metal detectors supplies, installs and monitors metal detectors, Torino, Italy, 2006, www.garrett.com.

[21] WHO (World Health Organization). Wastewater use in agriculture, guidance for planners, regional office for the Middle East, Regional Center for Environmental Health Activities, Amman, Jordan, 2003.