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Heavy Metals Pollution Assessment of the Soil in the Northern Site of East Baghdad Oil Field, Iraq

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Abstract

Twenty four soil samples were collected from different sites in north sector of East Baghdad oil field, Iraq , and analyzed to assess the impact of urbanization and industrialization essential pollution. The soil samples were analyzed for heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) by using inductively coupled plasma–mass spectrometry (ICP-MS). Mean concentration of heavy metals in soil samples follows this pattern: Zn > Ni > Cr > Cu >Pb > As> Cd> Hg. The results show significant variations (lower and higher) in the concentrations of heavy metals compared with local and world studies, this variation is attributed to the natural anthropogenic sources. The pollution of studied soil was assessed using many soil pollution indices; Contamination Factor (CF) shows for Zn , Ni , Cr , Cu ,Pb , As, Cd and Hg were distributed between low to moderate contamination, while the Degree of Contamination (C_d)values ranges from moderate degree of contamination very high degree of contamination indicating serious anthropogenic pollution, the Pollution Load Index (PLI) values were >1 confirming there is considerable contamination ,and the Ecological Risk Factor (Er^i) values were classified as low to high potential ecological risk. These results indicate the significant need for the development of pollution prevention and reduction strategies to reduce heavy metal pollution for regions undergoing fast industrialization and urbanization.

Keywords: Heavy metal, contamination factor, ecological risk factor, pollution load index, East Baghdad oil field.

تقييم تلوث الفلزات الثقيلة للتربة في الموقع الشمالي من حقل شرق بغداد النفطي

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قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تم جمع 24 عينة تربة من مواقع مختلفة في القطاع الشمالي من حقل نفط شرق بغداد، تم تحليلها لتقييم التلوث البيئي الناجم عن الفعاليات الحضرية الصناعية. تم تحليل للفلزات الثقيلة (الارسنك، الكادميوم، الكروم، النحاس، الزئبق، النيكل، والرصاص، والزنك) باستخدام تقنية (الطيف الكتلي). اظهرت النتائج ان معدل تراكيز الفلزات الثقيلة في عينات التربة يتبع النمط التالي: الزنك> نيكل> كروم> النحاس> الرصاص> الارسنك > الكادميوم> زئبق. أظهرت النتائج اختلافات كبيرة (أقل واعلى) في تراكيز الفلزات الثقيلة مقارنة مع الدراسات المحلية والعالمية، والتي تعزى الى كل من المصادر البشرية و الطبيعية. تم تقييم تلوث التربة باستخدام عدة معاملات لتلوث التربة : حيث تراوحت قيم عامل التلوث (CF) للعناصر: الزنك، النيكل، الكروم، النحاس، الرصاص، الارسنك و الزئبق بين قليل التلوث إلى تلوث متوسط، بينما تراوحت قيم درجة التلوث(C_d) من متوسطة الى عالية جدا مما يعطي دليل واضح على تاثير الفعاليات البشرية كما كانت قيم حمل التلوث عالية حيث كان PLI >1 ، في حين اظهرت قيم عامل الخطر البيئي (Er) مستوى خطر بيئي منخفض الى

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عالية. هذه النتائج تشير إلى حاجة كبيرة لتطوير استراتيجيات للوقاية والحد من التلوث بالفلزات الثقيلة للمناطق التي تشهد تطور صناعي و حضري سريع.

كلمات مفتاحية: الفلزات الثقيلة، عامل التلوث، عامل خطر بيئي، عامل حمل التلوث، حقل نفط شرق بغداد.

1. Introduction

The petroleum industry is organized into four broad sectors: exploration and production of crude oil and natural gas; transport; refining; as well as marketing and distribution [1]. This study deals only with the exploration and production operations. The negative effects of the exploration and production operations in the oil fields areas can be enormous. The impacts resulting from oil spills, drilling mud and fluid, formation waters and effluent discharge are of great concern because of their deleterious effects [1].

The accumulation of heavy metals in surface soils is affected by many environmental variables, including parent material and soil properties, as well as the human activities, such as industrial production, traffic, farming, and irrigation. Large areas can be contaminated by heavy metals released from smelters, waste incinerators, industrial wastewater, and from the application of sludge or municipal compost, pesticides, and fertilizers. Irrespective of their sources in the soil, accumulation of heavy metals can degrade soil quality, reduce crop yield and the quality of agricultural products, and thus negatively impact the health of human, animals, and the ecosystem [2]. Pollution index is a powerful tool for processing, analyzing, and conveying raw environmental information to decision makers, managers, technicians, and the public [3].

The aim of the present study is to assess the contaminant level and potential ecological risk in north site area of East Baghdad oil field.

1.1Study Area

The study area represented by East Baghdad oil field is situated in the northern border of Baghdad capital City. The area is lying within the Mesopotamian basin of the unstable shelf [4]. The area lies between latitude (44.3-44.3) to longitude (33.5-33.4), Figure-1. The east Baghdad oil field project is covered 1201.00 km^2. The study area is characterized by flat topography and is covered by quaternary deposits of Tigris and Euphrates rivers. The stratigraphic column in the study area is too thick due to its location in the central part of the Mesopotamian basin [5]. East Baghdad field gained great importance given to contain its column contrapuntist many reservoir rocks especially of Cretaceous period that form the basic and important reservoirs in this field [4].

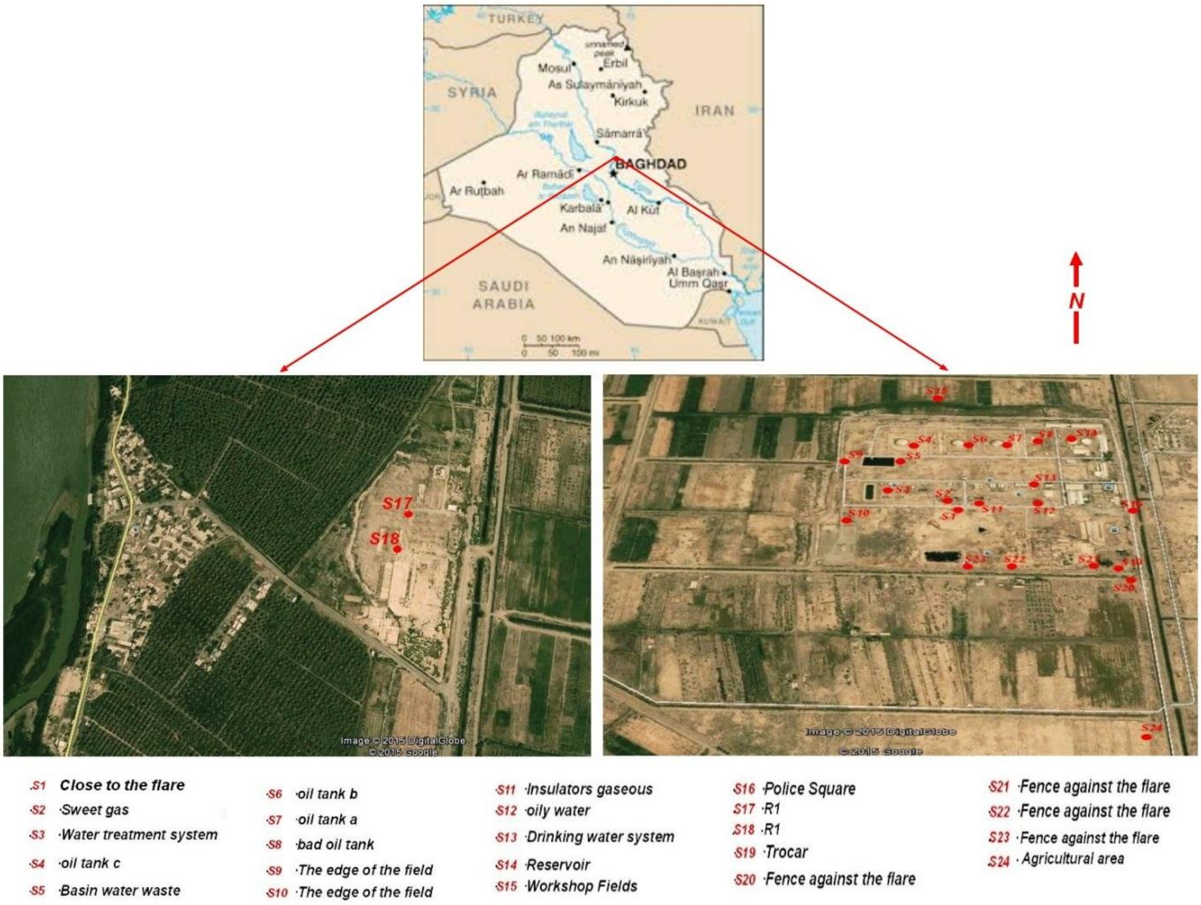

Figure 1- Location map and sampling site of the study area

2. Materials and Methods

Soil samples were taken from around oil well heads, Flare sites, Waste pit and effluent discharge point .The samples were collected at 0 – 30 cm depth. Soil samples were dried, crushed by mortar and sieved through a 2 mm sieve. The fine fraction was used for the analysis. Samples preparation method followed the standard methods [6-7]. A prepared sample (0.50g) is digested with Aqua Regia in a graphite heating block. After cooling, the resulting solution is diluted to (100 ml) volume with deionized water. The heavy metal contents of soil were determined using ICP-MS technique in ALS Group Labs. In Spain. The following factors are applied to assess the contamination level in the study area:

2.1 Contamination factor (CF), degree of Contamination (C_d) and Pollution Load Index (PLI):

A contamination factor (CF) is used to describe the contamination of a given toxic substance in a lake or a sub-basin it is defined as [8]:

$$\mathbf{CF = C\ metal / C\ background}$$

Where C metal is the mean content of the substance from at least 5 sample sites, and C background is the pre-industrial reference level for the substance. The following terminologies are used to describe the contamination factor: CF <1, low contamination factor; 1≤ CF <3, moderate contamination factors; 3≤ CF <6, considerable contamination factors; and CF ≥6, very high contamination factor.

The degree of contamination (Cd) was defined as the sum of all contamination factors.

$$\mathbf{Cd} = \sum_{i=1}^{n} \mathbf{CF}$$

Where CF = contamination factor, n = number of metals.

The following terminology was adopted to describe the degree of contamination (Cd values) for the selected metals. Cd< 6: low degree of contamination; 6 = Cd< 12: moderate degree of contamination; 12=Cd< 24: considerable degree of contamination; Cd= 24: very high degree of contamination.The pollution load index (PLI) proposed by Tomlinson *et al.* (1980) [9] has been used in this study.

The PLI for a single site is the *n*th root of *n* number multiplying the contamination factors (CF values) together.

$$PLI = \sqrt[n]{(CF1 * CF2 * CF3 * \ldots CFn)}$$

Where CF = contamination factor, n = number of metals.

The PLI value > 1 is polluted, whereas < 1 indicates no pollution [10] .The world average concentration of soil were considered as the background value after [11].

2.2 Ecological risk factor

An ecological risk factor (Er) is a quantitatively express the potential ecological risk of a given contaminant also suggested by Håkanson (1980) [8]is

$$Er = Tr * CF$$

Where Tr is the toxic-response factor for a given substance, and CF is the contamination factor. The Tr values of heavy metals by Håkanson (1980)[8] are also given in Table 1. The following terminologies are used to describe the risk factor: Er <40, low potential ecological risk; 40≤ Er <80, moderate potential ecological risk; 80≤ Er <160, considerable potential ecological risk; 160≤ Er <320, high potential ecological risk; and Er ≥320, very high ecological risk. Although the risk factor was originally used as a diagnostic tool for the purpose of controlling water pollution, it was successfully used for assessing the quality of sediments and soils in incorporated by heavy metals [12].

The toxic response factor represents the potential hazard of heavy metal contamination by indicating the toxicity of particular heavy metals and the environmental sensitivity to contamination. The toxic response factor was determined according to the "elements abundance principle" and the "elements release principle" of Hakanson et al[8]. According to the standardized toxic response factor proposed by [8], Cd, Hg, As, Pb, Cr, Cu, Zn, and Ni have toxic response factors of 30, 40, 10, 5, 2, 5, 1, and 5, respectively [13].

3. Results and Discussion

Heavy metals in soil: Table 1 shows the results of total concentration of heavy metals in the tested soil samples in comparison to the other local studies. It was found that these heavy metals are order as: Zn > Ni > Cr > Cu >Pb > As> Cd> Hg.

The heavy metals are present in considerable amount in the soil. This may due to the wide use of chemicals containing heavy metals being discharged into the environment as a result of petroleum exploration and production activities [1].

The concentration of Zn varies from 50 ppm in S18 to 1080 ppm in S7 with mean of 169.791 ppm. Zinc can be a pollutant, especially in areas close to industrial plants engaged in processing of petroleum, because zinc is directly added to the drilling fluids as zinc carbonate and act as corrosion inhibitor for mud formations and part of the zinc can be trapped by the soil layer [14]. Elevated Zn values are affected by agricultural activities, where some fertilizers and in particular super phosphate can significantly contribute to Zn levels in soils [15].

The concentration of Nickel varies from 51ppm in S22 to 196.5 ppm in S24 with mean of 142.525ppm. Ni in soil is strongly associated with Fe and Mn oxides. Also clay minerals, in particular montmorillonite, exhibit great capability to bind this metal [16]. The spatial distribution of elevated Ni concentrations may be related to oil combustion and agricultural activities (phosphate fertilizers)[15].

The concentration of Cr varies from 45ppm in S22 to 123 ppm in S6 with mean of 90.25 ppm. Chromium (VI) is toxic. The world median content of Cr in soils has been established as 54 ppm. Its content in soils is due to its abundance in the parent material. Since soil Cr is inherited from parent rocks, higher contents are generally found in soils derived from mafic rocks and argillaceous sediments. The Cr content of surface soils is known to have increased due to pollution from various sources, of which the main ones are COPR (chromite-ore processing residue), pigments and tannery wastes, leather-manufacturing wastes, and municipal wastes [15].

Table 1- Range and mean values of heavy metals in soil samples in comparison to the other local and world studies.

Heavy Metal (ppm)	Present Study		Ali , 2013[17]	Ali, 2012[18]	Abdullah, 2010[19]	AL-Basssam 2014[20]	Lindsay, 1979[21]
	Range	Mean					
As	5-12.2	6.4125					
Cd	0.14-4.31	0.4725	10.019	<1	4.02		0.06
Cr	45-123	90.25	61.281	112.8	75.27	180	100
Cu	23-82	32.5125	6.68	41.9	25.34	15	30
Hg	0.01-0.74	0.0558					
Ni	51-196.5	142.525	38.194	135.8	82.04	83	40
Pb	6.8-31	13.358	10.016	66.8	108.7	5	10
Zn	50-1080	169.791		116.4	113.1	55	50

The concentration of Cu varies from 23ppm in S18 to 82ppm in S22 with mean of 32.5125ppm. Copper is generally higher in soil derived from igneous rocks and tends to be lower in extreme acid and alkaline soil. Excess amount of copper can be harmful and pollution occurs in areas where copper are found and worked [22]. Several significant sources such as fertilizers, sewage sludge, manures, agrochemicals, industrial by-product wastes and the quality of irrigation waters have contributed to increase Cu level in the agricultural soil [15].

The concentration of pb varies from 6.8 ppm in S18 to 31 ppm in S21 with mean of 13.35833ppm. Its abundance in sediments is a function of clay fraction content and thus argillaceous sediments contain more Pb than sands, sandstones and limestones. Soil pollution due to Pb from mining and industrial activities is not a new problem. Marked soil-Pb contamination occurs in the vicinity of mining and industrial activities, in urban areas, and along high-traffic roads.Waste products from the use of chemicals like pipe lax, lube 106 and other lubricants like diesel oil, which are used in the production of petroleum result in pollution of soils by lead [15].

The concentration of As varies from 5 ppm in S8 to 12.2 ppm in S20 with mean of 6.4125 ppm. Agricultural practices may be a significant source of As, as its contents may be elevated in pesticides, fertilizer, sludge and manure. Thus, increased contents of arsenic in agricultural soils have recently become a real problem. Especially the irrigation with arsenic loaded groundwater increases its level in soils [24].

The concentration of Cd varies from 0.14 ppm in S18 to 4.31 ppm in S12 with mean of 0.4725ppm. Cadmium and its compounds are currently classified carcinogen for humans. Occupational human exposure has been correlated with lung cancer [25]. The sources of cadmium are from natural weathering processes, mining, metal smelters, industries, agricultural use of sludges, fertilizers and pesticides, burning of fossil fuels, and the deterioration of galvanized materials and cadmium-plated containers [27].

The concentration of Hg varies from 0.01 ppm in S3 to 0.74 ppm in S22 with mean of 0.05583 ppm. Mercury enters soils from several sources: atmospheric fall out and rainfall, sewage sludge application, Hg-based pesticides, disposal of industrial, domestic solid waste products, and municipal incinerator ash [15].

Mean concentrations of the present results were compared with the mean concentrations of the previous studies of Baghdad soil and the world soil mean values Table -1.The results show significant variations in the concentrations of the above trace elements, which may indicate the effect of soil type, type of the parent rocks and anthropogenesis and industrial activates. The release of industrial wastes directly into the environment without any treatment and fuel incinerator products can also be regarded as other sources contributing to soil samples pollution [18]. The soil of the studied area was deposited from the flooding seasons of the Tigres River, which lies about 3 km west of the plant site. It is Quaternary deposits and comprises the sediments which were derived from the Zagros Mountains, the source of originated branch rivers of Tigres River. The size fraction of the soil is controlled by the flooding seasons in which the coarse fraction c. coarse and medium sands were deposited in the flooding periods. While the fine fraction silt and clay was deposited in the non-flooding periods. The content of the trace elements is most probably reflects its content the source rocks e.g., various types of igneous, metamorphic and sedimentary rocks.

Contamination factor: Table-2 and Figure-2 show the range and mean values of CF follows the order:

Ni> Zn > Cu >Cr >As >Hg >Pb > Cd.

CF values Zn, Ni , Cr , Cu ,Pb , As, Cd and Hg were distributed between low to moderate contamination, except sites S19 and S24 for Ni and S6, S7 for Zn which shows very high contamination. This is may be due to industrial and agricultural activities. These results disconfirm the work of [27] to assessment of some heavy metals pollution in water, sediments Tigris River at Baghdad city, which contamination factor and showed that the Cd was recorded high concentrations and exceeded to its background values and may be caused high risk to aquatic environment. Also the results disconfirms the work of [28] to assess heavy metals pollution in Tigris River sediment in Baghdad that showed the CF values of metals Mn, Cu, and Ni are low contamination, but, CF values for Pb. and Cd shows moderate contamination due to the influence of industrial activities, agricultural runoff and other anthropogenic inputs.

Table 2- Range and Mean of CF value of trace elements

Heavy Metal	CF		CF class
	Range	Mean	
As	1.06-2.5	1.36	moderate contamination factor
Cd	0.12-3.9	0.42	low contamination factor
Cr	1.07-2.9	2.14	moderate contamination factor
Cu	1.65-2.5	2.32	moderate contamination factor
Hg	0.1-0.74	0.55	low contamination factor
Ni	2.8-10.9	7.9	very high contamination factor
Pb	0.35-1.24	0.53	low contamination factor
Zn	0.8-17.4	2.7	moderate contamination factor
C_d	13.7-31	17.7	considerable degree of contamination
PLI	0.7-1.6	1.29	polluted

C_d values ranges from moderate degree of contamination (station S10) and very high degree of contamination (station S7), with average of considerable degree of contamination Table-2, indicating serious anthropogenic pollution. Many stations can be classified as pollution areas, that have PLI values values >1 confirming there is considerable contamination, while the few others have PLI values < 1 .Variation of PLI of sampling stations was shown in Table-3. These results may be due to found many pollutants in the area.

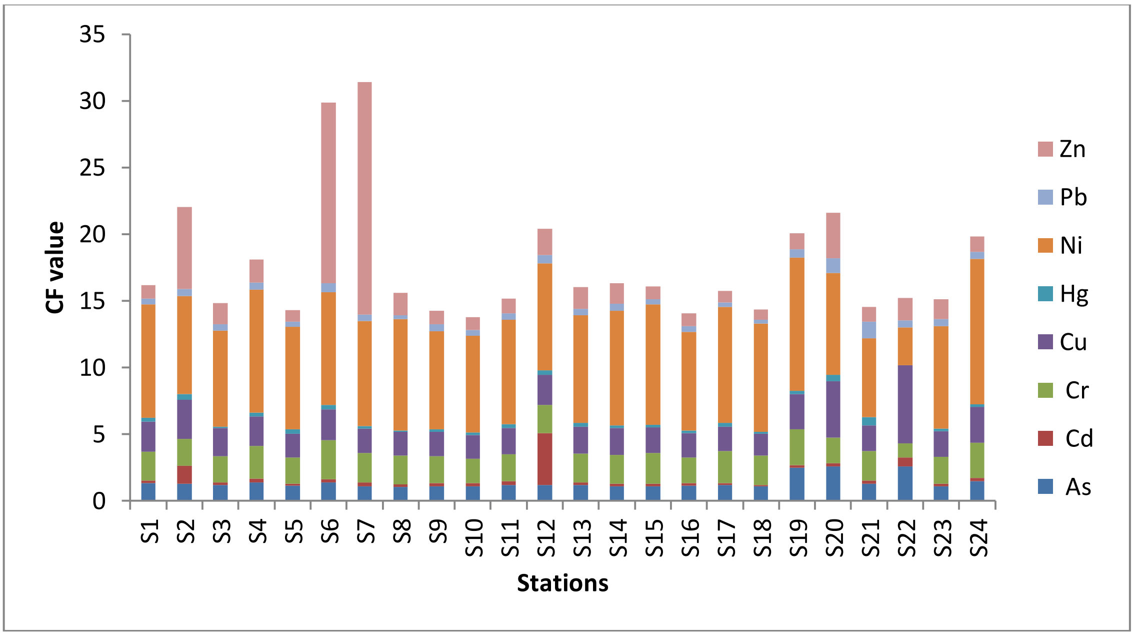

Figure 2- CF values of tested soil samples.

Table 3- PLI values of tested soil samples.

station	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
PLI	1	1.7	0.9	1.2	0.9	1.6	1.4	0.8	0.9	0.9	1	1.6
station	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24
PLI	1	1	0.9	0.9	0.9	0.7	1.2	1.6	1.2	1	0.9	1

Ecological risk factor: Er values Zn, Ni, Cr, Cu, Pb, As, Cd and Hg were classified as low potential ecological risk, except sites S12 for Cd is considered as potential ecological risk and S24 for Ni is moderate potential ecological risk, Table-3 and Figure-3. These results disconfirm the work of [27] to assessment of some heavy metals pollution in water, sediments Tigris River at Baghdad city, which showed that potential ecological risk index indicate a high risk of Cd to the people of Baghdad city.
These results confirm the work of [12] of Beijing City, park soil qualities varied from low polluted to unpolluted. While disconfirms the work of [29] of potential ecological risk and trend of soil heavy metal pollution around a coal gangue dump in Jilin Province (Northeast China) which show a strong potential ecological risk of Cd, and other heavy metals in soil around the coal gangue dump only presented a slight potential ecological risk.

Table 4- Range and Mean of Er value of trace elements

Trace Element	Er		Er class
	Range	Mean	
As	10.6-25.9	13.6	low potential ecological risk
Cd	3.8-117.5	12.88	low potential ecological risk
Cr	2.14-5.85	4.29	low potential ecological risk
Cu	8.28-29.28	11.6	low potential ecological risk
Hg	4-29.6	11.23	low potential ecological risk
Ni	14-54.5	39.5	low potential ecological risk
Pb	1.3-6	2.6	low potential ecological risk
Zn	0.8-17.4	2.7	low potential ecological risk

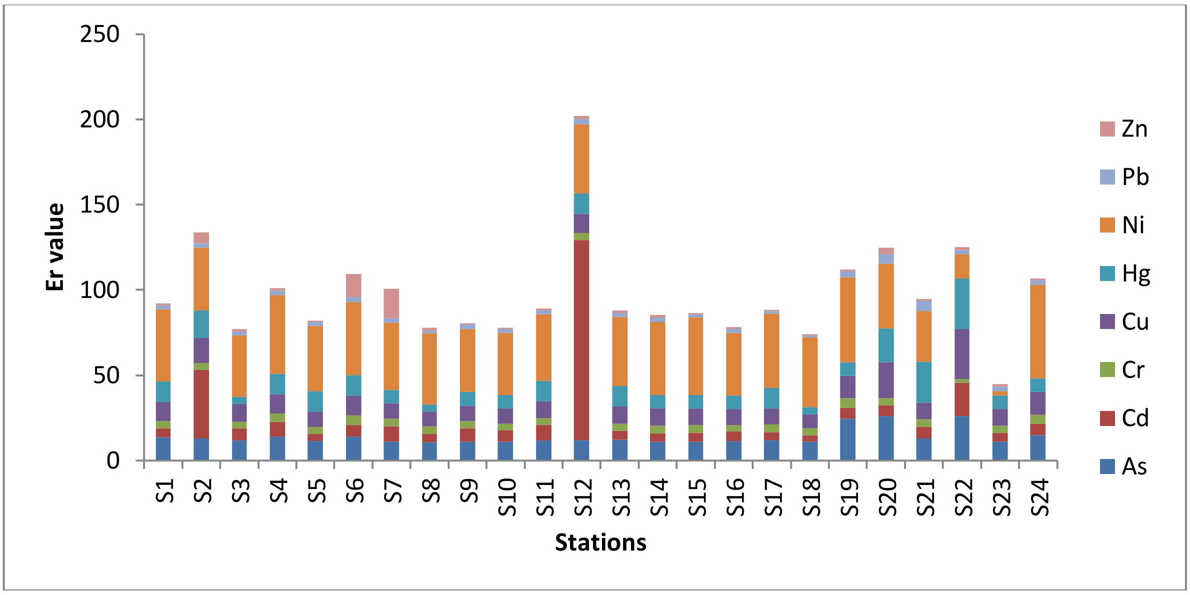

Figure 3- Er values of tested soil samples.

Conclusion

From the results of this study, The averages of heavy metals are order as: Zn > Ni > Cr > Cu >Pb > As> Cd> Hg. CF values Zn , Ni , Cr , Cu ,Pb , As, Cd and Hg are distributed between low to moderate contamination, while C_d values ranges from moderate degree of contamination to very high degree of contamination indicating serious anthropogenic pollution. Many stations (S2,S4,S6,S7,S12,S19,S20,S21) can be classified as pollution areas, where PLI values >1 confirming there is considerable contamination, while the few others (S3,S5,S8,S9,s10,S15,S16,S17,S18,S23) have PLI values < 1. Er values of the studied heavy metals are classified as low potential ecological risk. It is evident that exploration and production activities introduced significant levels of heavy metals into the soil. This has been traced to many chemicals used in these activities and most probably to industrial and agricultural activities. It is therefore suggested that remediation process be carried out so as to render the polluted soil.

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