# Geochemical Assessment of Some Trace Elements in Selected Locations at Thi-Qar Governorate Soil, Southeast Iraq

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**Abstract:**

Trace elements (Co, Cr, Mn, Mo, Ni, Rb, Th, U, and V) in surface soil of Al-Aslah (NH1), Nasiriyah refinery (NH2), Gharraf (NH3), and Tall Al-Laham (NH4) at Thi-Qar governorate, southeast Iraq, were studied. The study aims to detect their distribution and pollution levels to reduce the subtracted from industrial sources and avoid using contaminated areas for agricultural purposes before the soil treatment process. Inductivity Coupled Plasma Mass Spectrometry (ICP-MS) technique was used to determine the concentrations of these elements, and the results showed that there is a high concentration of Cr, Ni, Mo, and Mn in the soil of the study area, which exceeded the international levels compared with other elements (Co, Th, U, and V). The Geo accumulation index (I $_{geo}$) values showed that the soil area was classified as low contamination in all sites and for all trace elements except for Mo, which is polluted in Al-Gharraf and strongly polluted in Tall Al-Laham. The values of the enrichment factor (EF) were indicated to be minimal enrichment of (Mn and V) in all sites and moderate enrichment of (Co) in all sites except in the Gharraf soil sample, which is considered as minimal enrichment. At the same time, it suffers from significant enrichment of (Cr) in all sites. The values of contamination factor (CF) showed extreme contamination of Cr and Ni in all sites due to the oil industry (Nasiriyah refinery), except for Ni in the Gharraf soil sample, which is considered as high contamination and moderately contamination with Co in all sites, and low contamination with Mn and V. The main cause of the increasing trace element concentrations in the study area that the samples located in industrial sites where trace elements are one of the waste products from fuel combustion from the oil fields and the waste of the brick factories near the study area, also the nature of the study area soil which is clay soil that absorb the trace elements on its surfaces.

**Keywords:** Trace elements; Thi-Qar Governorate; Enrichment factor; Contamination factor

التقييم الجيوكيميائي لبعض العناصر النادرة في مواقع مختارة في ترب محافظة ذي قار، العراق

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الخلاصه:

الدراسة غير ملوثة في جميع المواقع بالعناصر النادرة ما عدا عنصر Mo في الغراف وتل اللحم ولتي
كانت شديدة التلوث, بينما كانت قيم معامل الاغناء (EF) تشير الى وجود اغناء قليل بالعناصر (Mn, V) في
جميع مواقع النمذجة اغناء معتدل لعنصر (Co) في جميع المواقع ما عدا منطقة الغراف والتي تعد واطئة
التلوث, فيما تعاني جميع المواقع المدروسة بإغناء ملحوظ بعنصري (Cr, Ni) بسبب العمليات الصناعية
النفطية في مصفى الناصرية. اما بالنسبة لمعامل التلوث (CF) فقد تبين النتائج بأن جميع مواقع المنطقة
المدروسة تعاني من تلوث كبير بعنصري (Cr, Ni) بسبب نواتج اشتعال مصفى الناصرية باستثناء عنصر
(Ni) في منطقة الغراف والتي تعد ذات تلوث عالي , بينما كانت منطقة الدراسة ذات تلوث معتدل بعنصر
(Co) و تلوث واطئ بعنصري (Mn, V). يعد السبب الرئيسي لارتفاع تراكيز العناصر النادرة في منطقة
الدراسة الى كون النماذج واقعة في مناطق صناعية حيث تعد العناصر النادرة احدى نواتج احتراق الوقود
الرئيسية من حقول النفط ومخلفات مصانع الطابوق القريبة من منطقة الدراسة, بالإضافة الى طبيعة تربة
المنطقة الطينية والتي تمتاز بقابليتها على امتزاز العناصر النادرة على سطحها.

## 1. Introduction:

Soil is a specific component of the biosphere because it is not only a geochemical sink for contaminants but also acts as a natural buffer controlling the transport of chemical elements and substances to the atmosphere, hydrosphere, and biota. Nonetheless, it is the responsibility of humankind to maintain the ecological and agricultural functions of soil. Trace elements from diverse sources may reach the surface soil, and their further fate is determined by the chemical and physical properties of the soil [1].The regional contamination of soils primarily occurs in industrial areas and within the centers of large cities, where factories, vehicles, and municipal wastes are the most significant sources of trace elements. However, assessing the natural background values for some trace elements in soils has become difficult because of the long-distance aerial transport of trace pollutants, especially those that produce volatile compounds (e.g., As, Se, Sb, and Hg) [1].

Enriching trace elements in urban soil has become a major regional environmental risk. Many researches on the soil and trace elements in cities deals with the risk spatial correlation analyses between trace elements, and there is a relative lack of assessments of the ecological and health risks[2].

The common feature of trace elements is a single electron in the outermost energy level and highly reactive chemical behaviour. These cations do not usually form complex ionic species but can be bound in some chelates and organometallic compounds [3]. Trace elements are compounds that naturally occur in soil, some of which are essential micronutrients for plants and animals and are considered very important for human health. Thus, high concentrations of trace elements turn potentially toxic. Therefore, their anthropogenic input into the natural environment poses a range of ecological and health problems, and their occurrence in soils has received widespread legislative and scientific attention. The important role soil characteristics can play in controlling trace element sorption-desorption processes and how they subsequently impact plant uptake, leaching to groundwater or ecotoxicity [4].

There are numerous natural and anthropogenic input sources for trace elements entering soils. The primary natural sources include volcanic eruptions, forest fires, weathering (including erosion and deposition of wind-blown particles), and biogenic sources[5, 6]. While inputs from natural sources provide a considerable proportion of the load of metals in the soil, the contribution from anthropogenic sources is many times greater for many metals, causing obvious environmental and health concerns [5,7]. Human activities have an important impact

on the accumulation of heavy metals in soils [8, 9]. The main anthropogenic sources of trace elements input to soils, according to [4] are:-The combustion of coal, gasoline, nonferrous and ferrous metals mining, smelting, the production of phosphate fertilizers and cement, and the burning of wood all contribute to atmospheric deposition. The main anthropogenic sources in the study area are the Nasiriyah refinery, the Gharraf oil field, the Nasiriyah electrical power plantand many brick factories. -Land application of sewage sludge, animal manure,and other organic wastes and co-products from the agriculture and food industries.
- Land disposal of industrial co-products and waste, including paper industry sludge, coal fly ash,bottom flyash, and wood ash. -The use of insecticides, fertilizers, and lime in agriculture.

The principal geological processes controlling the retention of trace elements in the soil and water are adsorption and precipitation. For these processes, the redox potential and pH are the key variables governing the distribution of metals between the solid and dissolved phases, hence their dispersion in the environment. Generally, many solids control the fixation of trace elements in the soils: clay minerals, organic matter, iron-manganese, and aluminium oxides and hydroxides for adsorption, while poorly soluble sulphide, carbonate, and phosphate minerals for precipitation [10, 11].

Understanding fundamental principles and phenomena that control the transfer of trace elements in the soil-plant-human chain can contribute to protecting the environment and human health. Soil is the main source of trace elements for plants as nutrients and pollutants. It is also a direct source of these elements to humans due to soil ingestion, dust inhalation, and absorption through the skin. The soil-plant transfer of trace elements is a part of chemical element cycling in nature. It is a very complex process governed by several factors, affected by both humans and nature. Predicting trace elements uptake by plants from a given growth medium should be based on several biotic and abiotic parameters that control their behaviour in soil [3]. The primary objective of this research is to make an environmental geochemical assessment for some trace elements in the selected area at the Thi-Qar governorate in southern Iraq.

**1.1 Previous studies**
[12] evaluated the extent of the heavy metals pollution in the surrounding roads in the city of Hilla, where the study of the soil taken on both sides of the roads of the two sites of 60 high traffic density and the 40th street with low traffic density, where the results showed that all the contents of heavy metals except for cadmium and chromium are higher than the values accepted in natural soils due to the human effects associated with the sources of traffic.
[13]Studied heavy metals along the highways between Basra, Nasiriya and Samawa, and the results show high pollution in heavy metals in the study area, especially when compared with international studies, the concentrations of heavy metals exceeded the allowed limits in soil.
[14]study the geochemical properties of recent sediments in Basrah city, southern Iraq, and the grain size analysis results showed that the sand increases towards the west and south part of Basrah, whilst clay fractions increase towards the north and eastern parts. Quartz, calcite, gypsum, feldspar, dolomite, and halite represent the light minerals in the study area sediments, while the clay minerals are described by kaolinite, palygorskite, illite, chlorite, montmorillonite, and montmorillonite- chlorite. Calcium oxide and silica are the most abundant oxides in all analyzed sediments in the study area, followed by Fe2O3, Al2O3, TiO2, MgO, Na2O, and K2O, with a high percentage of loss of ignition.
[15] studied the sediments on the banks of Shatt al-Arab and Shatt Al-Basrah to find their mineralogical variation. The result of grain size analysis showed that silt loam texture is dominant in the Shatt Al-Arab River while silty clay loam texture in the Shatt Al-Basrah

River. Quartz, calcite, dolomite, feldspar, and halite represent the light minerals in the silt fraction in the study area sediments. In contrast, the clay minerals are represented by kaolinite, palygorskite, illite, and montmorillonite-chlorite in the Shatt Al-Arab River and the same clay minerals with a small amount of montmorillonite in the Shatt Al-Basrah River. The petrographic analysis showed that the light mineral contents in the sand fraction are composed primarily of quartz, feldspar, and rock fragments. The main rock fragments are carbonate, chert igneous and metamorphic rocks, mudstone, and evaporates (Gypsum). The heavy mineral contents are opaque minerals, pyroxene, hornblende, chlorite, biotite muscovite, epidote, staurolite, kyanite, garnet, tourmaline, rutile, and zircon.

## 2. Material and methods:

### 2.1 Study area:

The study area is located in Thi-Qar governorate in the southern part of Iraq (Figure 1) between longitude (46° 13'- 46° 36') and latitude (30° 59'- 31° 41'). The sediments of the study area are a part of the Quaternary period extending from the Pleistocene-Holocene Epoch, and its part is from the Mesopotamia plane, which is formed from marine, delta, and fluvial sediments which are distinguished by the vertical and horizontal variation of facies [16]. Also, the study area is located in the Euphrates zone, which is located in the unstable zone, and characterized by its lack of rock outcrops because of its low topography and the cover of the quaternary sediments[17]

### 2.2 Sampling and Analysis:

The sampling campaign was conducted in November/2022. Four sites of surface soil were sampled in Thi-Qar Governorate using a hand auger and then stored in labelled polyethene bags. Soil samples included the following areas (Al-Aslah (NH1), Nasiriyah refinery (NH2), Gharraf (NH3), and Tall Al-Laham (NH4)) (Figure 1). Chemical analyses were conducted at the Australian Laboratory Services (ALS Laboratory Group) in Seville, Spain, using an Inductivity Coupled Plasma Mass Spectrometry (ICP-MS) to determine the concentrations of the following trace elements (Co, Cr, Mn, Mo, Ni, Rb, Th, U, and V). The land use in sampling sites included industrial areas with many industries, such as oil, electrical power plants, and brick factories.
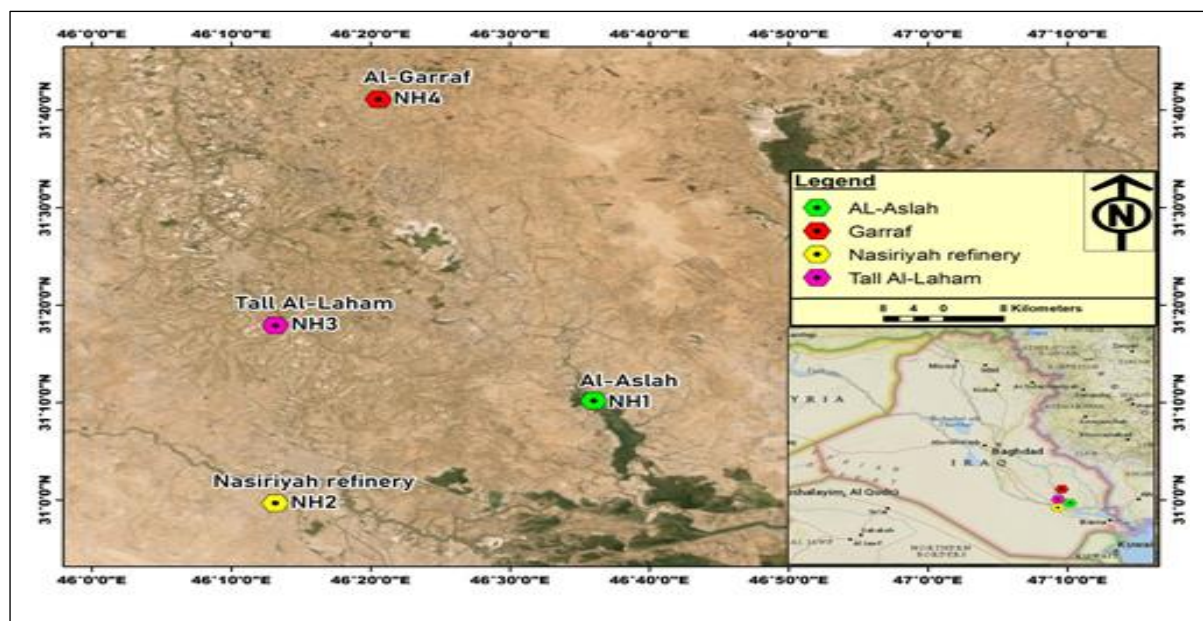
**Figure 1:** Location Map showing sampling points.

### 2.3 Grain Size Analysis:

The grain size analysis was performed for all samples, the samples were analyzed according to the British standard specification [18], the American standard specification [19], and [20] by using the hydrometer method in the laboratory at the University of Basrah-College of Science- Department of Geology, where the type of hydrometer that used in the experiments is (Hydrometer, 152H, France). Chemical analyses were carried out at the ALS Laboratory Group in Seville, Spain, using an Inductivity Coupled Plasma Mass Spectrometry (ICP-MS) to determine trace element concentrations, which included (Co, Cr, Mn, Mo, Ni, Rb, Th, U, and V). The LOI was calculated by burning the sample in a Gallenkamp Muffle furnace at 1050°C for two hours [21].

### 3.   Results and discussion:
### 3.1Grain size analysis:

To separate the mud from the sand, grain size analysis was carried out using a 63-micron sieve and the Hydrometer method type (152H, France) for the muddy part according to the British standard specification were applied [18], American standard specification [19], and [20], the results of grain size of soil samples was showing in Table 1, and Figure 2. From these results, it was noted that the soil samples contain clay ranging from 52% to 92% with an average of 71%, while the silt ranged between 7.58% to 23.85%, an average of 22%, then the sand ratio ranges between 0.42% to 19.58% with the average of 7%.

**Table 1:** Grain size results (percentage of Clay, Silt, and Sand).

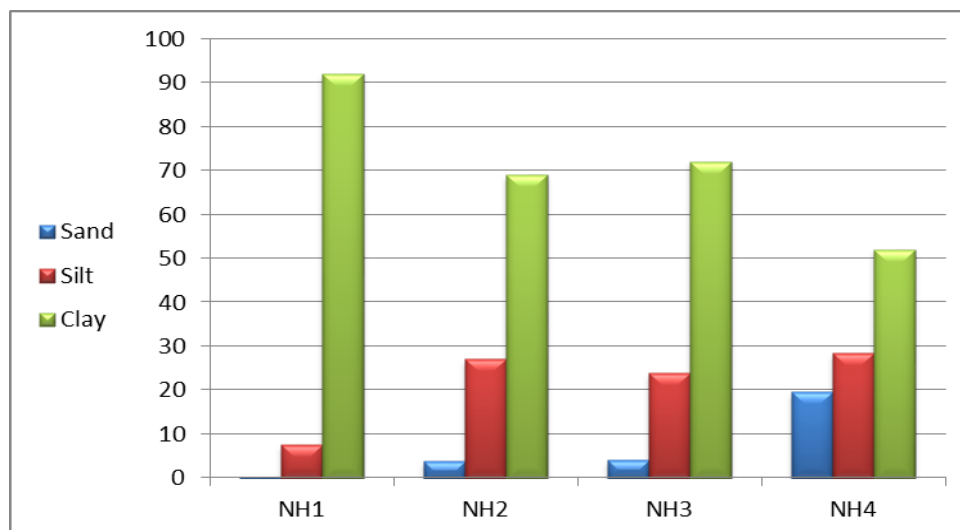| GRAIN SIZE | | | |
|---|---|---|---|
| Samples No. | **Sand** | **Silt** | **Clay** |
| **Al-Aslah** | 0.42 | 7.58 | 92 |
| **Nasiriyah refinery** | 3.85 | 27.15 | 69 |
| **Gharraf** | 19.58 | 28.42 | 52 |
| **Tall Al-Laham** | 4.15 | 23.85 | 72 |
| Mean | 7 | 22 | 71 |

**Figure 2:** Graph of grain size analysis

### 3.2 Trace elements:

Trace elements provide substantial geochemical and geological information based on their presence. As a result of affinity, its radius and charges with other elements, it can either adsorb into or replace these elements in the mineral composition [22]. The results of the adapted trace elements will be discussed separately in the next paragraph. Tables 2 and 3 represent the concentrations of trace elements and the correlation coefficient of these elements:

**Table 2:** Concentrations of trace elements in the study area ppm. * [20]

| Samples No. | Co | Cr | Mn | Mo | Ni | Rb | Th | U | V |
|---|---|---|---|---|---|---|---|---|---|
| **Al-Aslah** | 25 | 223 | 821 | 5 | 191 | 47 | 5.7 | 1.7 | 103 |
| **Nasiriyah refinery** | 24 | 248 | 852 | 5 | 190 | 46 | 5.8 | 2.1 | 100 |
| **Gharraf** | 28 | 307 | 744 | 14 | 148 | 45 | 5.5 | 2.3 | 91 |
| **Tall Al-Laham** | 21 | 261 | 875 | 32 | 96 | 50 | 6 | 2 | 110 |
| Range | 21-28 | 223-307 | 744-875 | 5- 32 | 96- 191 | 45- 50 | 5.5-6 | 2- 2.3 | 91- 110 |
| Mean | 25 | 260 | 823 | 14 | 156 | 47 | 6 | 2 | 101 |
| Int. Soils* | 27 | 135 | 620 | 3 | 59 | 49 | 5.6 | 1.3 | 138 |

**Table 3:** Correlation Coefficient of trace elements

| | Co | Cr | Mn | Mo | Ni | Rb | Th | U | V |
|---|---|---|---|---|---|---|---|---|---|
| **Co** | 1 | | | | | | | | |
| **Cr** | 0.487 | 1 | | | | | | | |
| **Mn** | -0.958* | -0.652 | 1 | | | | | | |
| **Mo** | -0.572 | 0.341 | 0.318 | 1 | | | | | |
| **Ni** | 0.469 | -0.451 | -0.204 | -0.992** | 1 | | | | |
| **Rb** | -0.909 | -0.346 | 0.770 | 0.764 | -0.681 | 1 | | | |
| **Th** | -0.998** | -0.466 | 0.961* | 0.566 | -0.466 | 0.889 | 1 | | |
| **U** | 0.393 | 0.909 | -0.471 | 0.189 | -0.283 | -0.432 | 0.648 | 1 | |
| **V** | -0.953* | -0.629 | 0.908 | 0.509 | -0.400 | 0.941 | 0.065 | 0.373 | 1 |

### - *Cobalt (Co):*

Cobalt is found in the environment in oxidation states $Co^{+2}$ and $Co^{+3}$[8], Co is associated with ferromagnesian minerals and can replace Fe in iron oxides. In soil, it is strongly adsorbed by Mn and Fe oxides [11], because Co is very soluble in acidic environments, it easily leaches from acidic soil[4]. pH reduces the amount of sorption by organic matter and mineral surfaces[23].

The concentration of Co ranges between (21- 28 ppm)with a mean of (25 ppm)which isalmost equal to the international average in soil (27 ppm) (Table 2), according to [24].

### - *Chrome (Cr):*

The terrestrial abundance of Cr means that ultramafic and mafic rocks are its primary sources. The Cr level of acid igneous and sedimentary rocks is significantly lower and usually ranges from 5 to 120 ppm, with argillaceous sediments with the highest content. The highly variable oxidation states of Cr range (+2 to +6). The primary valences of naturally occurring Cr compounds are +3 (chromic) and +6(chromate). Most of the $Cr^{+3}$ is present in the mineral chromite ($FeCr_2O_4$). Chromite, a common Cr mineral that resists weathering, accounts for most of the Cr in the remaining material. However, The chromate ions produced by the gradual oxidation of Cr are movable and very easily absorbed by clays and hydrous oxides. It has been demonstrated that most soil Cr is found as $Cr^{+3}$ and is contained inside mineral structures or as mixed $Cr^3$ and $Fe^3$ oxides. While Cr+6 is highly mobile in both acidic and alkaline soils and is extremely unstable in soils, Cr+3 is only slightly mobile in a very acidic medium and is almost entirely precipitated at pH 5.5 [1].

The results of Cr in the present work range between 223 and 307 ppm with an average of 260 ppm, which is higher than the global average in soils (135 ppm) (Table 2). The increase of chromium in the Iraqi soil is due to clastic sediments that formed the stratigraphic column of the Mesopotamian plain. These clastics are transported from the north-east of Iraq as a result of weathering processes, then move with the Tigris River and its tributaries, which are rich with Chromium metals and Serpentine metals and Olivine as Chromite ($Cr_2O_4$) [25,26]. Anthropogenic activities like fuel combustion in electrical power stations, oil well drilling, and vehicles may cause an increase of Cr in the soil of the study area, where the samples are located in the industrial area[27].

### - *Manganese (Mn):*

Although manganese is much less abundant than $Fe^{+3}$ in the earth's crust, still markedly above trace concentrations in many soils, Its biogeochemistry bears much similar to Fe. It accumulates in the form of oxides and hydroxides as secondary soil minerals, accumulates in the form of oxides and hydroxides as secondary soil minerals. Humic acids can fix Mn at high pH, so Mn deficiency is also found in peaty soils with calcareous subsoil[4]. The deficiency of Mn in the soil is caused by processes that decrease the concentration of free divalent Mn in the soil solution. Manganese deficiency due to leaching is frequent in podzols and other extensively weathered acidic soils acidic sandy soils low in native Mn[28]. It is concentrated at certain spots in soils, usually enriched in several other trace elements. Colloidal Mn oxides demonstrate a strong affinity for the adsorption of organic and inorganic substances and cationic and anionic forms of elements [1].

The concentration of Mn ranges between (744-875ppm) with a mean of (823 ppm) which exceeds their concentration in the upper continental crust value (620 ppm) (Table 2). The

increase of Mn is associated with the high clay content in the study area (Table 1), where the variability of Mn content of surface soil appears to be correlated with soil typology but is highly associated with clay concentrations[1]. Mn availability increases as soil pH decreases [29]. Therefore, it can be concluded that the studied soil is acidic.

### - *Molybdenum (Mo):*
Molybdenum differs from the other main trace minerals in occurring as an oxyanion or hydroxyl anion in soil solution except for very acidic conditions (pH<5), where it appears as molybdic acid. Roots mainly absorb mo as molybdate, which may help to explain why high soil sulfate concentrations might aggravate Mo deficiency[4].

Mo in this study ranges between 5 and 32 ppm and an average of 14 ppm. Its concentration exceeds the global average (3ppm) (Table 2), increasing Mo availability, which appears to be at least partially due to competition between phosphate and molybdate for sorption sites. Shale, clay, schist, and granite are soil's primary geogenic sources of Mo [30].

### - *Nickel (Ni):*
The most important factor that impacts the behaviour of Ni in soils appears to be pH, while attributes like clay content and Fe and Mn oxides in soils are of secondary importance. For example, as the pH and cation exchange capacity (CEC) decline, Ni mobility in soils rises[31, 4]. Other factors, like organic manures and sewage sludge soil, also influence the fate and behaviour of Ni in soil [4]. Ni values were between (96- 191ppm) and the mean was (156 ppm) the concentration of Ni was above the global limits (59 ppm) according to [24] (Table 2) because of the high content of clay in the study area (Table1).

### - *Rubidium (Rb):*
Rb abundance in the major rock types reveals its geochemical association with Li; therefore, it has higher concentrations in acidic igneous rocks and sedimentary aluminosilicates. In weathering, Rb is closely linked to K; however, its bonding forces to silicates appear stronger than K's; therefore, the K: Rb ratio continually decreases in soil-forming processes. The behaviour of Rb in sedimentary and pedogenic processes is controlled mainly by adsorption on clay minerals. The Rb content of soils is primarily inherited from the parent rocks. Rb values ranging between (45- 50 ppm), the average of Rb (47 ppm) was less than its global average (49 ppm) (Table 2).

### - *Thorium (Th) and Uranium (U):*
Among the actinide series, only two elements are naturally present in relatively significant quantities on Earth and have long lived as nuclides (U and Th). Th and U are typically present in higher concentrations in acid rocks than mafic rocks, and in sediments, argillaceous deposits are more likely to contain these elements than sandstones and limestone.

The current study reveals that U and Th range between (2- 2.3 ppm) (5.5- 6 ppm) with an average of (2 ppm) (6 ppm) respectively. Both elements are almost within their average in global soils (1.3 ppm) (5.6 ppm) respectively (Table 2). The carrier of Th is mainly monazite mineral, Ce (PO4), which is very resistant to weathering; thus, Thorium is concentrated in some weathered deposits. U and Th are coherent. In most geologic environments, they exist in the 4 and 6 oxidation states.

U produces complexes that are primarily organic, soluble, and movable during the weathering process. However, in arid conditions, U creates several stable compounds (e.g.,

oxides, carbonates, phosphates, and arsenates). The distribution of U and Th in the lithosphere is highly controlled by the oxidation state and the Eh-pH system [1].

### - *Vanadium (V):*

V is dominated significantly in mafic rocks and shale (within 100 to 250 ppm). The geochemical properties of V are highly dependent on its oxidation state (+2, +3, +4, and +5) and on the medium acidity. During weathering, the movability of V depends on host minerals. It has often been noted that some crude oils have an extensive range of V. The deposition of V residues in soils will increase because of the industrial processing of certain mineral ores (ore smelters, cement, and phosphate rock plants), as well as the burning of coal and oils. An especially serious source of V in the soil is the combustion of fuel oils [1].

Due to the high concentration of V compared to the average of Iraqi soils, all samples in this study showed extremely concentrated V levels (39 ppm) [32]. Vanadium ranged between (90.6- 110 ppm) with an average of (101 ppm). This concentration is less than the global average (138 ppm)(Table 2). Figure 3 represents the concentrations of trace elements.
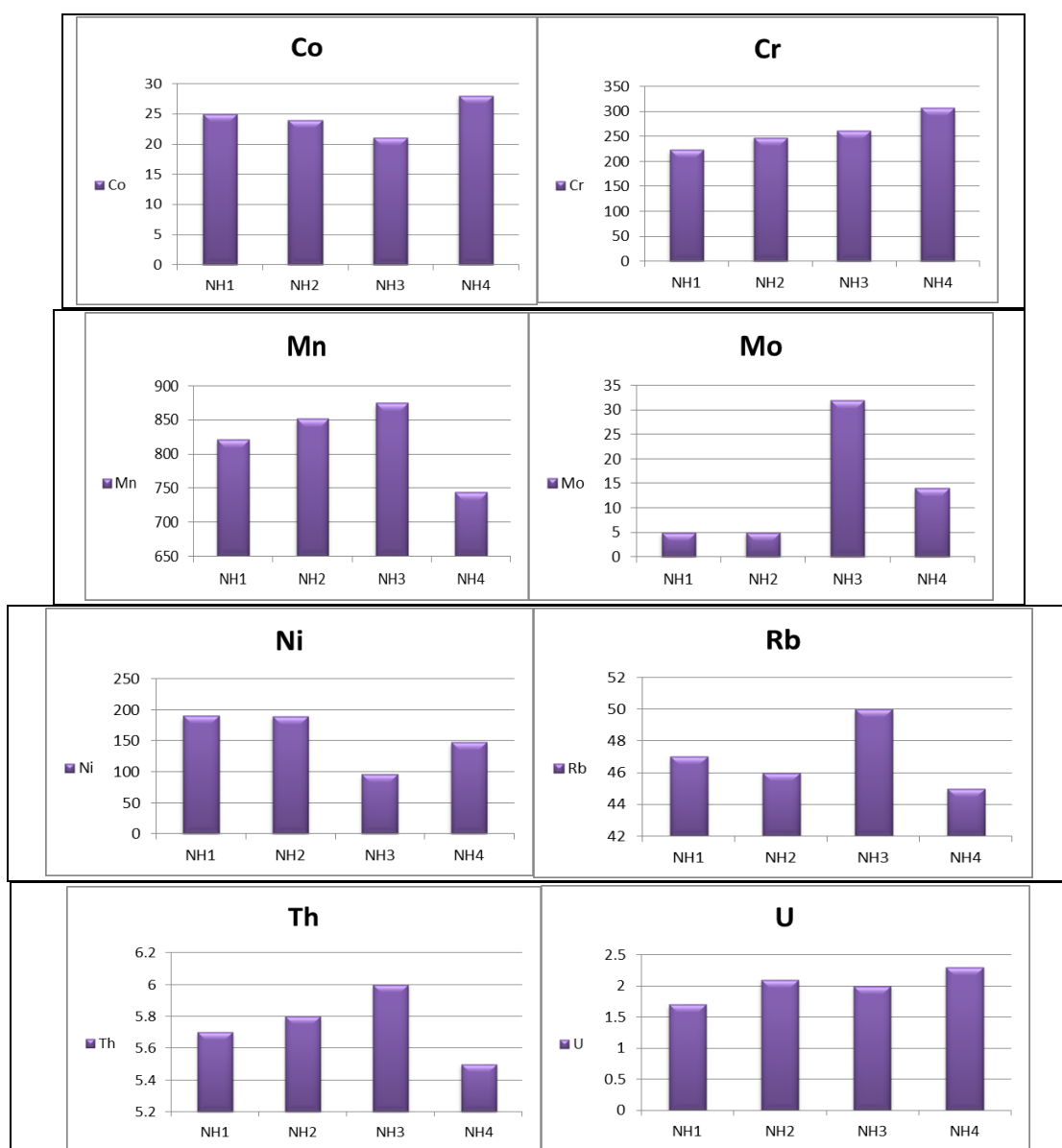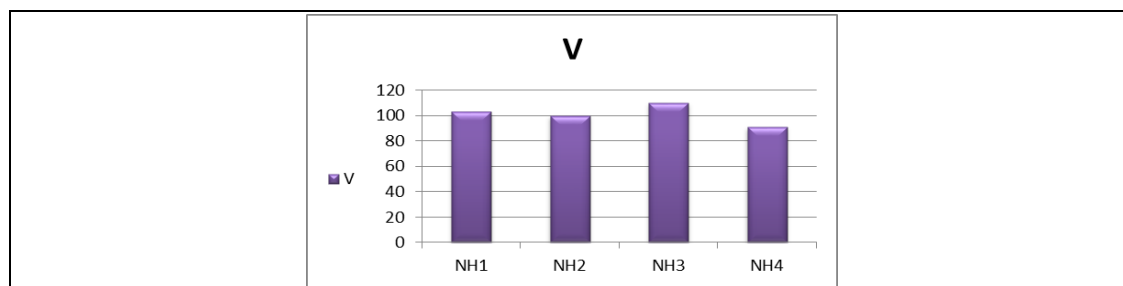
**Figure 3:** Graphs of the concentrations of trace elements

### 3.3 Estimation of pollution:

The indices that are employed to assess the density and presence of anthropogenic pollutants in soil are the Geo-accumulation index (Igeo), Enrichment Factor (EF), and contamination Factor (CF).

### 3.3.1 Geo accumulation Index ($I_{geo}$):

This factor, which was used by [33], shows the degree of sediment contamination by trace elements based on the following equation:

$$I_{geo} = log2 \ (Cn \ / \ 1.5 \ Bn) \qquad\qquad .......(1)$$

Where Cn= the concentration of trace elements in the sample (ppm), Bn= the concentration of trace elements in the standard sample (ppm). Igeo values are classified into six groups; Igeo<1 refers to the unpolluted area, (>1-2) refers to moderately polluted, (>2-3) refers to a polluted area, (>3-4) refers to strongly polluted, (>4-5) refers to strongly to extremely polluted, and the value > 5 refers to the extremely polluted area.

The results of the geo accumulation index in the soil samples of the study area are illustrated in Table 3. Figure 3 indicates that the study area is classified as unpolluted in all sites and for all trace elements except for Mo, which is polluted in Al-Gharraf and strongly polluted in Tall Al-Laham. The trace elements were categorized from high to low, based on their contamination factor as follows: Mo <Ni<Cr< Co<V<Mn. The pollution rate of Mo in Al-Gharraf and Tall Al-Laham is high due to the presence of residues of chemical fertilizers and pesticides used previously when the areas were agricultural.

**Table 3:** Geo accumulation index of the Trace elements in the study area.

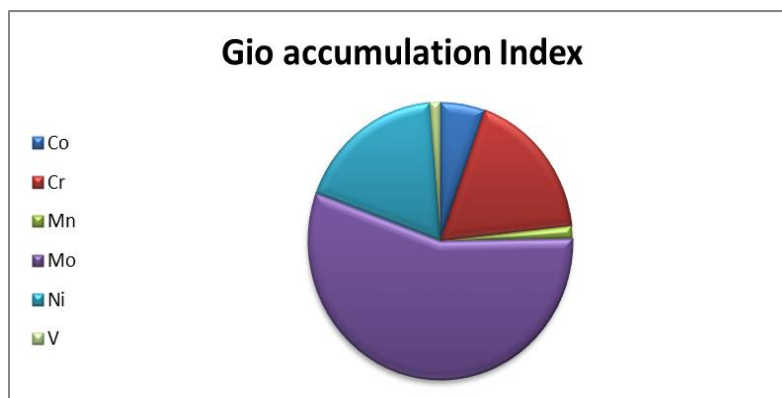| Samples No. | Co | Cr | Mn | Mo | Ni | V |
|---|---|---|---|---|---|---|
| **Al-Aslah** | 0.22 | 0.63 | -0.05 | 0.77 | 0.80 | 0.06 |
| **Nasiriyah refinery** | 0.20 | 0.67 | -0.04 | 0.77 | 0.80 | 0.04 |
| **Gharraf** | 0.14 | 0.70 | -0.03 | 2.16 | 0.51 | 0.09 |
| **Tall Al-Laham** | 0.26 | 0.77 | -0.10 | 4.94 | 0.69 | 0.00 |
| Mean | 0.21 | 0.69 | -0.05 | 2.16 | 0.70 | 0.05 |

**Figure 3:** I ₍geo₎ index for the studied elements

### 3.3.2 Enrichment Factor (EF):

The enrichment Factor is the enrichment of trace elements compared with the content of the background of trace elements [34]. The enrichment factor of the samples in the current study was determined and used to assess the rate of environmental pollution. It has been used by [33], where he depends on the concentration of Fe because it represents the prevalent elements in the crust based on the following equation:

$$EF = (CM / CFe)sample / (CM / CFe) \text{ Earth's crust} \qquad ……(2)$$

Where CM= the concentration of trace element (ppm), CFe= the concentration of Iron (ppm). EF is classified into five classes: EF<2 minimal enrichments, (2-5) moderately enrichment, (>5-20) a significant percentage of enrichment, (>20-40) very high enrichment, and>40 extremely enrichment.

The results of the enrichment factor in the studying soil (Table 4), (Figure 4)show that the study area characteristics with minimal enrichment of (Mn, V) in all sites and moderate enrichment of (Co) in all sites except in the Gharraf soil sample which considers as minimal enrichment. At the same time, it suffers from significant enrichment of (Cr) in all sites, and significant enrichment of Nickel except in the Gharraf soil sample, which was moderate and considerable enrichment in (Mo) in Gharraf and Tall Al-Laham. The main cause of high Ni, Cr, and Mo concentrations is attributed to the petroleum industry [35], especially near the Nasiriyah refiner. The following is a range of the trace elements in order of their enrichment factor, from high to low: Mo <Ni < Cr < Co < V <Mn. The high enrichment of Mo, Ni, and Cr is the residues of chemical fertilizers and pesticides, the petroleum industry, the Nasiriyah power plant, and the waste of brick factories near the study area.

**Table 4:** Results of enrichment factor of the area of study.

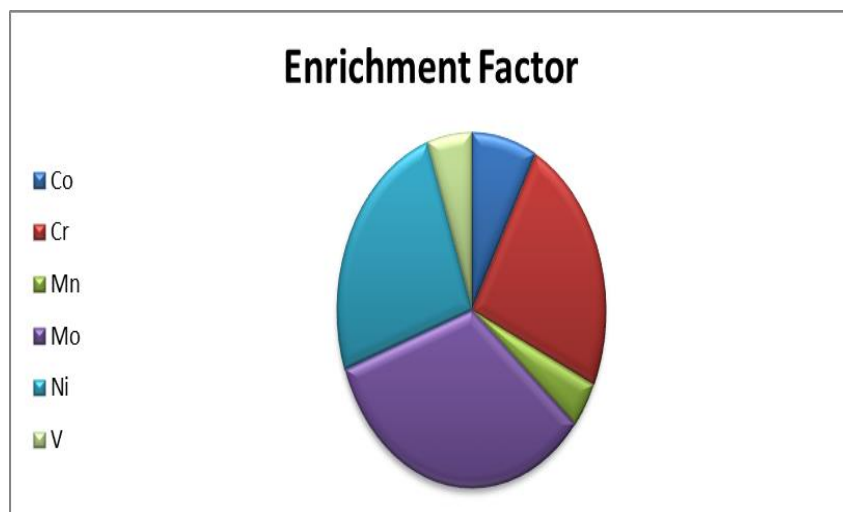| Samples No. | Co | Cr | Mn | Mo | Ni | V |
|---|---|---|---|---|---|---|
| **Al-Aslah** | 2.039 | 5.24 | 1.09 | 3.16 | 7.85 | 1.41 |
| **Nasiriyah refinery** | 2.094 | 6.18 | 1.20 | 3.36 | 8.29 | 1.45 |
| **Gharraf** | 1.612 | 5.81 | 1.10 | 10.94 | 3.74 | 1.43 |
| **Tall Al-Laham** | 2.805 | 8.91 | 1.22 | 19.17 | 7.52 | 1.53 |
| Mean | 2.14 | 6.54 | 1.15 | 9.16 | 6.85 | 1.46 |

**Figure 4:** enrichment factor of the study area

### 3.3.3 *Contamination Factor (CF):*

The contamination Factor indicates the anthropogenic inputs of trace elements in the sediments [36, 37, 38]. The contamination factor for the samples in the present study was estimated based on the following equation:

$$CF=CM\ Sample\ /CM\ Background \qquad …….(3)$$

Where CM= the concentration of trace element (ppm). CF is classified into four classes, <2 low contamination, (>2-3) moderately contamination, (>3-6) high contamination, >6 extremely contamination.

The results of the contamination factor(Table 5) and Figure 5 indicate that the study showed extreme contamination of Cr and Ni in all sites and extreme contamination of Mo in Gharraf and Tall Al-Laham due to the oil industry (Nasiriyah refinery), except for Ni in Gharraf soil samples which considers as high contamination, while moderately contamination with Co in all sites, and low contamination with Mn and V. The trace elements were arranged based on their contamination factor from high to low as follows: Mo <Ni < Cr < Co < V <Mn.

The increased contamination ratio is the remains of chemical fertilizers and pesticides, the petroleum industry, the Nasiriyah power plant,  and the waste of brick factories near the study area.

**Table 5:** Results of contamination factor.

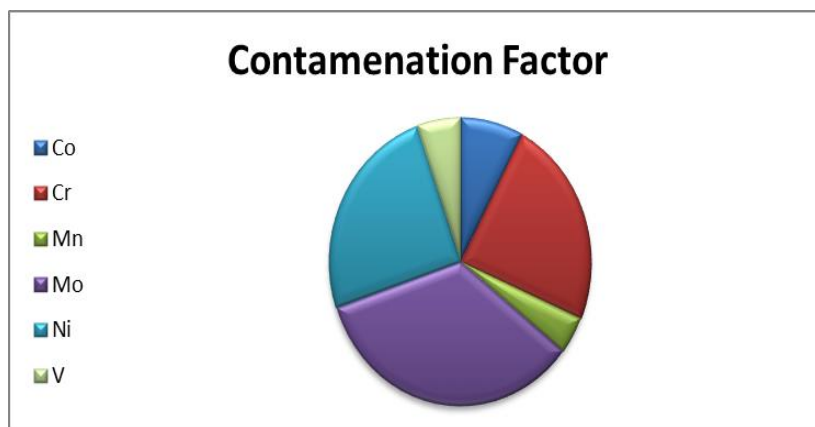| Samples No. | Co | Cr | Mn | Mo | Ni | V |
|---|---|---|---|---|---|---|
| **Al-Aslah** | 2.48 | 6.37 | 1.32 | 3.85 | 9.55 | 1.72 |
| **Nasiriyah refinery** | 2.4 | 7.09 | 1.37 | 3.85 | 9.50 | 1.66 |
| **Gharraf** | 2.07 | 7.46 | 1.41 | 10.77 | 4.81 | 1.83 |
| **Tall Al-Laham** | 2.76 | 8.77 | 1.20 | 24.62 | 7.40 | 1.51 |
| Mean | 2.43 | 7.42 | 1.33 | 10.77 | 7.81 | 1.68 |

**Figure 5 :** Graph of Contamination Factor results.

## 4. Conclusions:

This study reveals that the soil of Thi- Qar governorate contains high concentrations of (Cr, Mn, Mo, and Ni) compared to other elements (Co, Th, U, and V) due to human activities like petroleum industries (Nasiriyah refinery. I $_{geo}$ index values showed that the area is characterized by low contamination in all sites and for all the studied trace elements except for Mo, which is polluted in Al-Gharraf and strongly polluted in Tall Al-Laham. The enrichment factor index (EF) indicated minimal enrichment of (Mn, V) in all sites and moderate enrichment of (Co) in all sites except in the Al-Gharraf soil sample, which was classified as minimal enrichment. At the same time, it suffers from significant enrichment of (Cr) in all sites. Significant enrichment of Mo was noticed in the Gharraf and Tall Al-Laham. The values of the contamination factor (CF) reveal extreme contamination of Mo in Gharraf and Tall Al-Laham, extreme contamination of Cr and Ni in all sites due to the oil industry (Nasiriyah refinery), except for Ni in Al-Gharraf soil sample, which considers as high contamination, moderately contamination with Co in all sites, and low contamination with Mn and V.

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