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Determine the Pollution Indices of the Soil Near the Najaf Refinery in the Middle of Iraq

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Abstract

Al-Najaf refinery produces many pollutants from fuel combustion, such as fumes and gases, which lead to heavy metal pollution in the soil. This research aims to study the pollution factors in the soil surrounding the refinery. Five soil samples were collected from different sites to analyse five heavy metals (Ni, Zn, Co, Cr, and Pb) to determine the chemical pollution level. The results found that the percentage of the metal (Co) in site No.3 was the highest due to its presence near the oil flame and toward the direction of the wind. Three different indices were applied to detect pollution levels: geo accumulation index (I-geo), pollution load index (PLI) and contamination factor (CF). The I-geo for Co, Cr, and Pb showed class 1 relative values, which indicated the sites were only slight pollution, while the I-geo for Zn showed class 2 relative values, which indicated moderate ranges of pollution, and the I-geo for Ni showed class 6 relative values, which indication extremely pollution sites. While the contamination factor for Zn was classed as class 2, indicating moderate contamination, the contamination factors for Co, Cr, Pb, and Ni were all rated as class 1, which indicates low contamination values. PLI levels in all investigated sites categorised as class 1 indicate no pollution (perfection). The gases released by the predominant wind impacted the metal percentage distribution pattern.

Keywords: Pollution Indices, Najaf Refinery, Heavy Metals, PLI, C_f, I_{-geo}.

دراسة مؤشرات التلوث في تربة مصفى النجف في وسط العراق

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الخلاصة

ينتج مصفى النجف العديد من الملوثات الناتجة عن احتراق الوقود على شكل ابخرة وغازات وكلها تؤدي الى التلوث المعدني في التربة. يهدف البحث الى دراسة مؤشرات التلوث في التربة المحيطة بالمصفى، جمعت 5 عينات من التربة من مواقع مختلفة لاجراء العديد من التحاليل وتحديد مستوى التلوث الكيميائي .تم تحليل خمسة عناصر ثقيلة (النيكلNi و الزنك Zn والكروم Cr والكوبلت Co والرصاص Pb) . اظهرت النتائج ان تركيز Co في الموقع رقم 3 كان اعلى تركيز وذلك لقربه من موقع الشعلة (Flare) وتاثير عامل اتجاه الرياح، ومن خلال اختباره بتطبيق مؤشرات التلوث الكيميائي والتي شملت مؤشر التراكم الجغرافي او الجيوكيميائيIgeo و مؤشر حمل التلوث PLI و عامل التلوث CF .في موقع الدراسة،كان تصنيف مؤشر التراكم الجغرافي ل Pb, Cr, Co ضمن الفئة رقم 1 والتي تدل على ان هناك تلوث طفيف لمنطقة الدراسة

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بهذه العناصر ، اماالتصنيف بالنسبة لعنصر Zn فكان ضمن الفئة رقم 2 والتي تدل على ان هناك تلوث متوسط لمنطقة الدراسة بهذا العنصر. اما عنصر Ni فكان ضمن الفئة رقم 6 والتي تدل على ان اعلى مستوى تلوث في المنطقة كان بهذا العنصر.اما مؤشر حمل التلوث فكان تصنيفه لجميع العناصر ضمن الفئة رقم 1 والتي تدل على لا يوجد تلوث او ما يسمى ب (تلوث الكمال) ، وان توزيع نسب نمط المعادن تأثر بالغازات المنبعثه واتجاه الرياح السائد.

1. Introduction

Soil pollution occurs when hazardous substances, chemicals, salts, radioactive substances, or pathogenic agents accumulate in the soil, harming plant growth and animal health [1]. Exploration and production activities can have severe negative consequences in oil field locations [2]. Sediment chemistry data is an important part of sediment assessment processes for determining the effects of hazardous and bioaccumulative compounds [3].Contaminants in soil can come from a variety of sources, some of which are human (primarily fertilisers and petroleum removal wastes), while others are natural [4]. The metal concentration charts, in general, show variations in heavy metal concentrations that can be linked to human activity[5][6][7][8]. The most frequent methods for assessing soil enrichment with metals are the index of geo-accumulation (I-geo), the contamination factor (Cf) and the pollutant load index (PLI). The geo accumulation index (Igeo) can be used to measure soil pollution. This index determines if anthropogenic contaminants have been deposited on surface soil and how heavily they have been present [9]. The pollution load index (PLI) is a summative indicator of the overall amount of heavy metal toxicity in a specific sample and measures the number of times that the concentration of heavy metals in the sediment exceeds the background value [10]. The contamination factor (Cf) is a single index that is thought to be a straightforward and efficient approach for tracking heavy metal contamination [11]. The present study aims to study the concentration of selected heavy metals pollution in the soil of the Al-Najaf refinery area using environmental pollution indicators and their impact on the surrounding areas.

2. Location of study area

Al-Najaf refinery is located in the middle part of Iraq, It is about 30 km from the centre of Al-Najaf Governorate towards Karbala Governorate between the longitudes in the east (44° 08′ 43″- 44° 15′ 40″) and latitudes north (32° 08′01" - 32° 14′ 20″), (Figure 1). The refinery and its surrounding area cover about 378 dunm of area. The daily production reached 750,000 gallons [12].

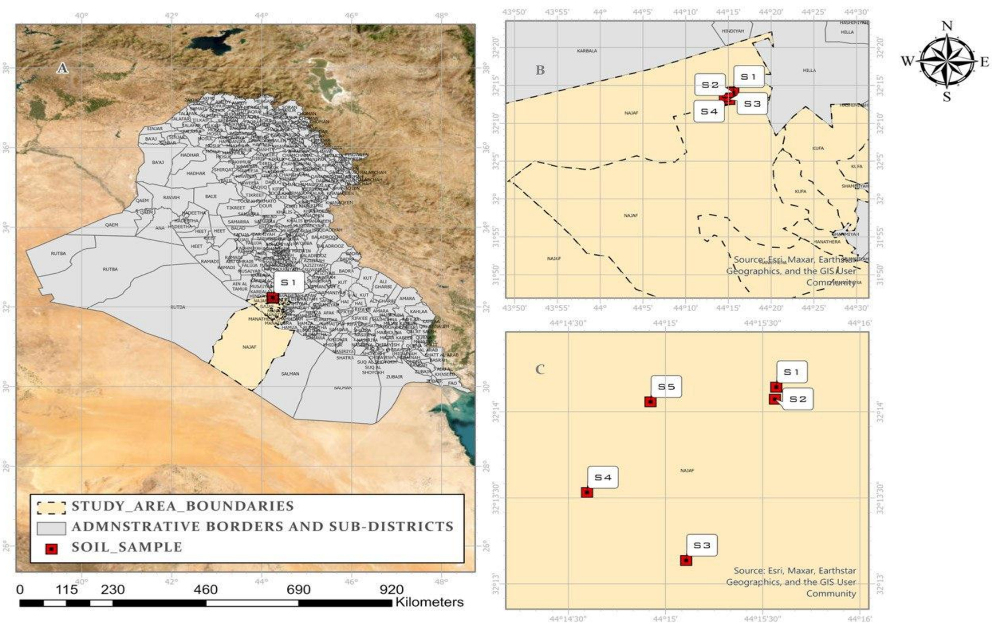

Figure 1: A: Study Area Relative to The Map of Iraq
B: Study Area Relative to Najaf Governorate
C: Zoom in Study Area

3. Climate of study area

Summers in Najaf are long, hot, arid, and clear, while winters are cold, dry, and mostly clear. For the period (2012-2022), temperatures ranged from 6°C to 45°C, with temperatures rarely falling below 2°C or exceeding 49°C. July is the hottest month in Najaf, with average temperatures of 45°C and lows of 30°C. The cold season lasts three months, and daily maximum temperatures average less than 22°C. January is the coldest month in Najaf, with an average temperature of 6°F and a high of 17°F. From January 18 to February 6, the rainy season lasts 2.7 weeks, with an average 31-day rainfall of at least 13 mm. January is Najaf's wettest month, with an average rainfall of 13 mm. The rainless season lasts 11 months, from February 6 to January 18. July has the least rain in Najaf, with an average rainfall of 0 mm. The perceived humidity level in Najaf, as assessed by the proportion of time the humidity comfort level is muggy, oppressive, or terrible, does not change significantly throughout the year, remaining within 1% of 1%. The wind in any particular area is heavily influenced by local terrain and other variables. July is the windiest month in Najaf, with an average hourly wind speed of 11.2 miles per hour. December is the calmest month in Najaf, with an average hourly wind speed of 7.2 miles per hour(5).

4. Methodology

Five sample locations were chosen, and GPS was used to locate sampling sites precisely (Figure 2). The soil samples were collected by scraping the surface layer at a depth of 5 cm using a clean plastic scoop and stored in polyethene bags [13] (Table 4). The concentrations of heavy metals were analysed in the University of Al-Ameed, Central Laboratory for Consultation of Scientific Research by the atomic absorption device.

2.1 Contamination assessment

Three indices were used to assess heavy metal contamination in the soil. These include (PLI), (I-geo)and (CF).

1. Index of geo-accumulation (I geo)

The geo-accumulation index (Igeo) determines the metal contamination in the soil by comparing the current concentrations with the background and is a common criterion for assessing heavy metal pollution in sediments. It can be determined using the equation that follows [14].

$$I_{geo} = log2\left[\frac{Cn}{1.5Bn}\right] \qquad (1)$$

Where:

- **Cn** is the element 'n' concentrations, and Bn is the background of geochemical value [In this investigation, take Bn=world surface soil average provided by [15].

A factor of 1.5 is included in the connection to allow for any variations in the background data caused by the lithogenic effect [16].

This index ranges from zero to five with seven classes (Table- 1). The greatest grade, (6), corresponds to a 100-fold enrichment, while the lowest grade, (0), corresponds to the background concentration.

Table 1: Classified grades of I- geo

Igeo	Classes	Classification
Igeo≤0	Class 0	Practically unpolluted
$0< Igeo \leq 1$	Class 1	Slightly polluted
$1< Igeo \leq 2$	Class 2	Moderately polluted
$2< Igeo \leq 3$	Class 3	Moderately severely polluted
$3< Igeo \leq 4$	Class 4	Severely polluted
$4< Igeo \leq 5$	Class 5	Severely extremely polluted
Igeo> 5	Class 6	Extremely polluted

2. Contamination Factor (CF)

This CF is used to classify the amount of metal pollution in soil samples [17]:

$$CF = C\ metal / C\ background\ value \qquad (2)$$

Where:

Metal C is the average substance content of at least 5 sample sites.

Background C is the pre-industrial reference level of the material.

Table 2: Classified grades of CF

CF	Classes	Classification
CF< 1	Class 1	Low contamination
$1 \leq CF <3$	Class 2	Moderate contamination
$3 \leq CF <6$	Class 3	Considerable contamination
CF> 6	Class 4	Very high contamination

3. Pollution load index (PLI): The pollution load index represents the degree of pollution of all heavy metals in a sample site and is composed of pollution from a range of heavy metals[18]. Progressively getting the pollutant load index (PLI), created by [19] is as follows:

$$PLI = n\sqrt{(CF1 * CF2 * CF3 * \ldots CFn)} \qquad (3)$$

Where
CF is the single contamination index factor
n is the heavy metals count of the species.

Table 3: Classified grades of PLI

PLI	Class	Classification
PLI< 1	Class 0	Perfection
PLI=1	Class 1	Baseline level
PLI> 1	Class 2	Deterioration on-site quality

Figure 2: Satellite map of soil sample locations

Table 4: Locations and Coordinates of Soil Samples

Sample NO.	Location	Coordinate	
		X	Y
S1	Checkpoint of Najaf refinery	44°15'35''	32°14'10''
S2	Outside the refinery / main street near the entrance door	44°15'33''	32°14'4''
S3	Near the flare	44°15'7''	32°12'8''
S4	Near to the store	44°14'37''	32°13'32''
S5	Near the loading door of the refinery	44°14'56''	32°14'3''

Table 5: Heavy Metals Concentration in (ppm) for Soil Samples

Sample NO.	Co	Ni	Cr	Zn	Pb
s1	0.1	1.7572	1.5243	0.0995	0.0122
s2	0.02	2.1323	1.2311	0.0574	0.04
s3	7.081	3.1392	0.4	0.1189	0.08
s4	0.07	2.1126	0.5276	0.0628	0.06
s5	0.15	2.5074	0.2	0.1468	0.1231
mean	1.4842	2.472875	0.7766	0.09708	0.06306
Range	0.02-7.081	1.7572-3.1392	0.2-1.5243	0.0574-0.1468	0.0122-0.1231
Kabata-Pendias, 2011	6.9	18	42	62	25
Al-Saady , 2019	30.3	28.9	18.2	77.3	32

Table 6: Pollution Indices of Soil Samples

Sample .No	Co		Ni		Cr		Zn		Pb		
--	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	PLI
1	0.014	0.0002	0.097	6.347	0.036	0.016	0.001	1.238	0.0004	0.0002	4.02×10^{-11}
2	0.002899	0.00005	0.118461	7.702635	0.029312	0.013236	0.000926	0.714204	0.0016	0.00003	1.49×10^{-11}
3	1.026232	9.80533	0.1744	11.33992	0.009524	0.00019	0.001918	1.479422	0.0032	0.00006	1.04×10^{-8}
4	0.010145	0.0002	0.117367	7.631472	0.012562	0.005672	0.001013	0.781394	0.0024	0.00004	3.63×10^{-11}
5	0.021739	0.00043	0.1393	9.057631	0.004762	0.00009	0.002368	1.82657	0.004924	0.002223	1.68×10^{-10}
mean	0.215102	1.96126	0.12943	8.415859	0.018491	0.007115	0.001566	1.207925	0.002522	0.000515	2.372×10^{-10}

3. Result and Discussion

five main heavy metals are discussed: Nickel, zinc, copper, cobalt, lead, and cobalt were found in the soil of the study region (Table 5 **)**. Several elements, such as temperature, wind direction and speed, rainfall, and an exposed open channel, influence the research region. The Iraqi Meteorological Organization and Seismology report that, between 2012 and 2022, the average annual temperature was 25 ˚C, the average annual rainfall was 1045 mm, and the average annual wind speed was 1.6 m/s in a northwesterly direction. These heavy metals are discussed as follows:

Table 5 shows these heavy metals are discussed as follows:

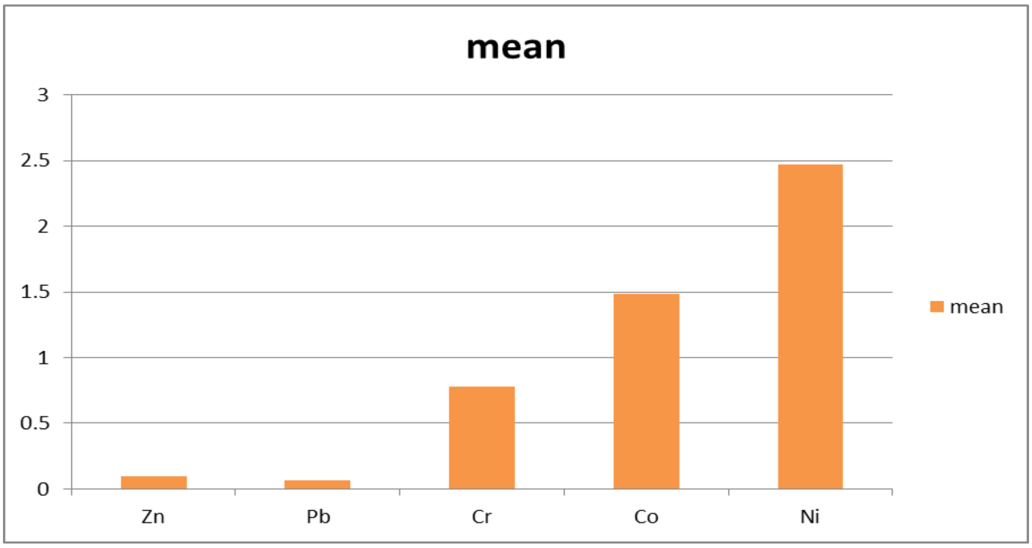

Figure-3 Mean of Heavy Metals of Najaf Refinery

1. Zinc (Zn)

The average concentrations of Zn in the soil of the Najaf refinery selected locations ranged from 0.05 ppm in location No. 2 to 0.14 ppm in location No. 5 with a mean value of 0.09 ppm, according to [15][20] values, the mean value of Zn is lowest than the background values.

2. Nickel (Ni)

The concentrations of Ni averages in the soil of the Najaf refinery selected locations ranging from 1.75 ppm in location No. 1 to 3.13 ppm in location No. 3 with a mean value of 2.47 ppm, according to [15][20] values, the mean value of Ni is lowest than the background values.

3. Lead (Pb)

The concentrations of Pb averages in the soil of the Najaf refinery selected locations ranging from 0.012 ppm in location No. 1 to 0.12 ppm in location No. 5 with a mean value of 0.063 ppm, according to [15][20] values, the mean value of Pb is lowest than the background values.

4. Chromium (Cr)

The concentrations of Cr averages in the soil of the Najaf refinery selected locations ranging from 0.2 ppm in location No. 5 to 1.5 ppm in location No. 1 with a mean value of 0.77 ppm, according to [15][20] values, the mean value of Cr is lowest than the background values.

5. Cobalt (Co)

The average concentrations of Co in the soil of the Najaf refinery selected locations ranged from 0.02 ppm in location No. 2 to 7.08 ppm in location No. 3 with a mean value of 1.48 ppm, according to [15][20] values, the mean value of Co is lowest than the background values.

B. Contamination assessment:

1. Index of geo-accumulation (I geo):

The I-geo of Co, Zn, Cr, Ni and Pb is calculated in (Table 6).

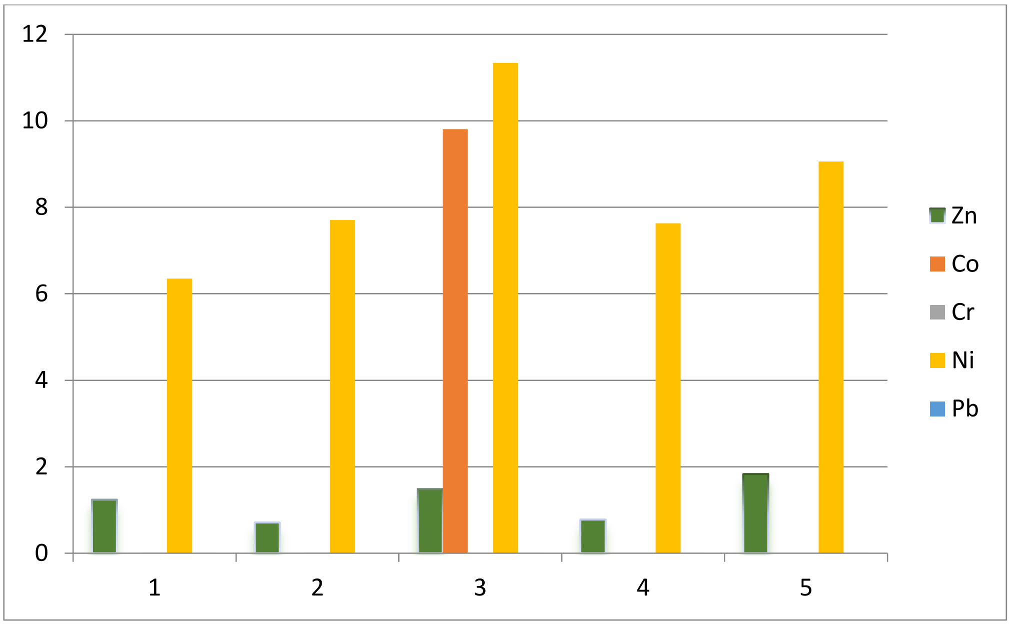

Figure 4: Igeo Values of Heavy Metals in Najaf Refinery

- The I-geo values of **Zn** greater than 1 were found at most sites and ranged from 1.23 to 1.82 (Table 6), and these results are from (class 2), which indicates that zinc concentrations in the soils of the studied sites are medium contaminated sites (Table 1). Samples from sites No. 2 and No. 4 showed I-Geo at 0.71 and 0.78, respectively, which (Class 1) reflects the slightly contaminated sites
- The I-geo values of **Co** are greater than zero at most sites, ranging from 0.00043 to 0.00005 (Table 6), and these results from (Class 1) indicate that Co concentrations in the soil of the studied sites are slightly contaminated (Table 1). The sample from site No. 3 showed an I-Geo of 9.8, respectively, reflecting (Class 6) of highly contaminated sites.
- The I-geo values of **Cr** \ greater than zero were found at all studied sites and ranged from 0.00009 to 0.016 (Table 6), and these results from (Class 1) indicate that the concentrations of vines in the soil of the studied sites are slightly contaminated (Table 1).
- The I-geo values of **Ni** greater than five were found at all sites studied, ranging from 6.34 to 11.3 (Table 6). These results are from (class 6), which indicated that the concentrations of nickel in the studied sites' soil are highly contaminated (Table 1).
-The I-geo values of **Pb** greater than zero were found at all sites studied, ranging from 0.00003 to 0.0022 (Table 6); these results from (Class 1) indicated that lead concentrations in the soil of the studied sites were slightly contaminated (Table 1).

2. Contamination Factor (CF):

The Cf of Co, Zn, Cr, Ni and Pb is calculated in (Table 6).

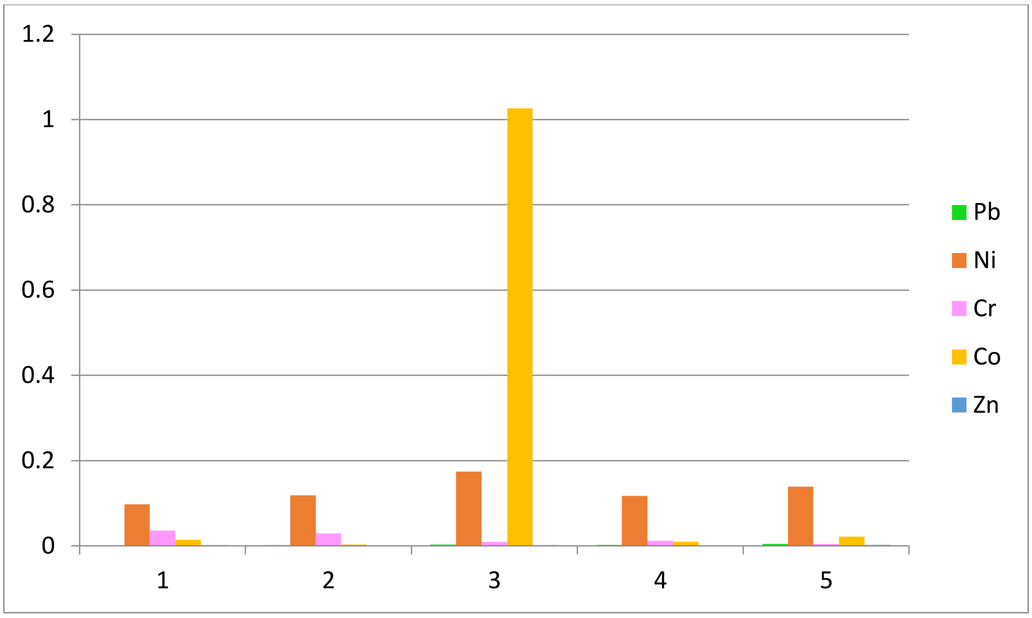

Figure 5: Contamination Factor of Najaf Refinery

-The CF values of **Pb** are classified as (Class 1) and represent low pollution ranging from 0.0004 to 0.0049 for all studied sites. The CF values of **Ni** are classified as (Class 1) in all sites studied and range from 0.09 to 0.17, and it is believed that a large part of Pb and Ni finds its way into the environment due to the combustion of diesel oil and oil. The spill led to an increase in both nickel in the soil.

- The Cf values of **Cr** are classified as (class 1), indicating low pollution ranging from 0.004 to 0.03 at all sites studied.

-The Cf values of **Zn** are classified as (class 1) and represent low pollution ranging from 0.0009 to 0.002, and Zn comes from toxic waste from industrial sources.

-The Cf values of **Co** are Classified as (class 1), representing low pollution ranging from 0.002 to 0.02, except for one site No. 3 with 1.02 respectively, classified as class 2 and meaning moderate pollution

3. Pollution load index (PLI):

The PLI of Co, Zn, Cr, Ni and Pb is calculated in (Table 6).

The (PLI) Co, Zn, Cr, Ni and Pb were rated class 0 with no complete contamination at all sites studied.

A variety of sources produces heavy metals, and soils are thought to be their final sink[21]. Heavy metal contamination in the soil poses a significant risk to agricultural goods and human health, so determining the spread of heavy metal pollution is critical.[22].Furthermore, this heavy metal enters the environment and interacts with soil or water, potentially harming plants and animals[23].

4. conclusion

In the soil of the Najaf oil refinery, the concentrations of Co, Ni, Cu, Zn, and Pb in soil samples were determined and employed as indicators for pollution. The findings from the comparison between this study and the studies of [10] [11] show that the concentrations of heavy metals are very low, based on CF, PLI, and Igeo. It was found that I-geo for Co and Zn showed relative amounts of class 2, indicating very contaminated, and I-geo for Cr and Pb in the analysed locations showed relative values of class 1, which indicated somewhat polluted. Co, Zn, Pb, Cr, and Ni have class 1 contamination factors, representing low contamination. PLI results in all investigated locations were categorised as class 0, indicating class 0, meaning no pollution. The direction of the wind and the gases released impacted the metal percentages' dispersion pattern.

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