Calculation of Pollution Indicators for Heavy Metals in the Surface Soil of Nasiriyah Oil Field

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Abstract

The study included the assessment of the pollution indicators of heavy metals in the surface soil of the Nasiriyah oil field. Nine soil samples were collected from selective sites of the oil field, and the soil samples were analyzed to find the concentration of heavy metals such as Co, Cr, Cu, Ni, pb, V and Zn. The results are compared with the global standards. Zn, Cr, Ni, V, Co and Pb possess high value which indicate pollution due to the industrial activities. The factor of enrichment is determined to find the saturation factor, processing and converting raw concentrations values and finding the local background for the element's concentration in the local soil. Regarding the values of the enrichment factor (EF)) in the soil samples were at an average between (21.7-0.28) according to the following (Cu > V > pb > Cr > Co > Ni > Zn). The contamination factor (CF) values in the samples of soil study area were at an average between (11.91-0.21) according to (Zn > Ni > Co > Cr > Pb > V >Cu). The highest PLI values at S9, S8, S4 and S3, which are >1 indicate that the soil in these stations is polluted, while soil of the stations S1, S2, S5, S6 and S7 are <1 and thus is not polluted.

Keywords: *Pollution indicators, heavy elements, contaminated soil, Nasiriyah oil field.*

1. Introduction

The existence of heavy metals (HMs) in the soil is interest to researchers due to their harmful effects on human life [1] or damage and toxicity to the surroundings [2]. It is transmitted from the soil to the human body through the mouth or skin, or it can be transmitted by inhaling the droplets emitted from the soil [3].

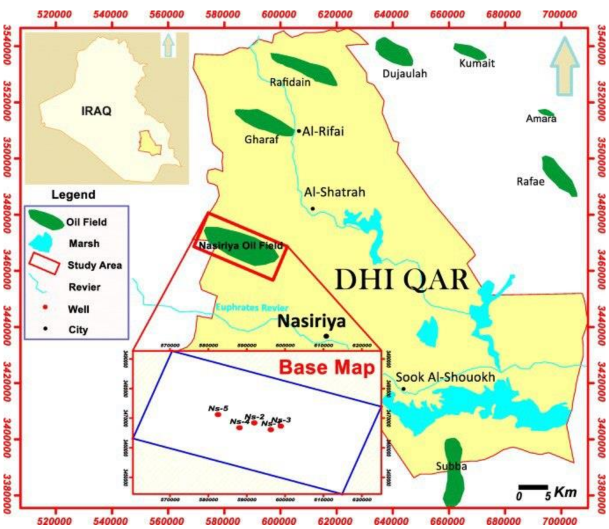
The activities carried out by humans such as industry, mining, oil waste, vehicle waste or factories [4] have a major role in soil contamination and corruption. Therefore, the researchers seek to find the enrichment coefficient (EF) to assess the number of HMs in the soil [5] and to find their sources. Also, the load contamination index (PLI) is used, which depends on the enrichment factor [6]. In addition to finding the contamination factor (CF), by which the amount of soil pollution is estimated [7].

2. Study area

Nasiriyah oil field is located in Dhi Qar governorate, about 38 km northwest of Nasiriyah city (Figure 1-1). It covers an area of 410km2 between (45º59'- 46º00') E and 31º21' - 31º22') N. The field was discovered in 1975 through seismic surveys carried out by the National Oil Company for the area - Nasiriyah - Hilla - Diwaniyah, where the structure appeared as a convex fold of northwest-southeast axis trend and with a structural closure. The exploration well (Nasiriyah 1) was drilled in 1978 at the top of the structure in order to explore the hydrocarbon possibilities.

Weak oil evidence was found in the Zubair Formation. The seismic surveys were interpreted in 1986, where the new seismic maps showed that the structure consist of a convex fold affected by several faults parallel to the axis of the structure, this gave the need to drill a fifth well in 1987. The drilling reached a depth of 3430 meters in the Al-Sulay Formation. A well and the area of the field is 578 square kilometers. The starting date of production is 10/8/2009 and the current production capacity is 86 thousand barrels per day [8].

Figure -1 Location map of the study area (Al – Nasiriyah oil field) [9].



3. Methodology

Nine samples of soil were collected from the area of study at different locations on December 2021. The samples were classified and put in the bags for preparation to analysis in the laboratories. Soil samples were- analyzed in Central Lab, Tehran University, and the analysis include: 1. XRD technique 2. XRF technique and 3, pH measurement.

4. Trace elements

Soil is an incubating pollutant, and the environment surrounding the soil, whether it is air, rocks, or water are all directly or indirectly affected by the pollutants of this soil. These pollutants are considered to be the result of human activity such as agriculture, industry, or even transport operations or other activities that have a negative impact on the soil and the surrounding environment.

Therefore, determination of heavy metals distribution of contamination is of prime importance, due to its dangerous to humans, animals, or even plant [3].

The concentration of HMs in the surface of the soil in the area of the study are shown in Table-1 and compared to [10-11], because many types of soil had been used, including the virgin soil, where the ratio of most elements are within their normal proportions.

The mean concentration of HMs in the soil surface were coming as Zn<Cr < Ni < V < Co < Pb <Cu.

Industrial activities of oil production are one of the most important causes of excess zinc, lead, nickel and copper [10] Flying ash during oil exploration is highly responsible for increasing the Zn concentration in the surface soil around the oil field site [12].The content of Zn in the surface soil in the area of the study ranged between (110ppm - 2732ppm) with an average value of (834ppm).

Chromium concentration in the surface soil is mainly due to the parent material. Cr possess a concentration ranged between (246ppm - 370 ppm) in the surface soil in the area of the study with an average value of (288.88ppm). Cr is possess a high concentration in the soil surface in the area of the study is mainly due to fuel combustion [13]. Nickel in soil is mostly associated with the existence of iron and manganese oxides, and with clay minerals as well, where montmorillonite had the ability of binding this metal [12]. Ni is possess a concentration ranged between (124ppm- 244 ppm) in the surface soil of the study area with an average value of (197.33ppm). The increased concentration of nickel is related to oil combustion [13]. Increased vanadium (V) in urban and industrial soils, especially around oil refineries and areas with high levels of residual fuel oil consumption [13]. The concentration of (V) in the surface soil in the area of the study ranged from (91ppm -124ppm) with a mean value (102.88ppm). The content of cobalt (Co) in soils is inherited mainly from parent materials, being high in loamy soil and low in sandy and organic soils [13]. Co is possess a concentration ranged from (43ppm -75ppm) with a mean value (57.44ppm), where the high cobalt value in the area is related with the fuel combustion. Lead (Pb) had toxic effect on plants, animals and humans, where the increase in the content of lead in the soil results from activities of the industrial and the use of products containing Pb such as agrochemicals, oil and mining [14]. The content of (Pb) in the surface soil ranged from (22ppm - 127ppm) with a mean value (32.22 ppm).

Several significant resources for copper (Cu); such as fertilizers, sewage sludge, agrochemicals, petroleum refineries, and industrial byproducts waste [13]. Cu is possess a concentration ranged from (1ppm - 35ppm) with a mean value (11.88ppm).

Table -1: Heavy metals concentration (in ppm) for surface soil samples of the area study.

Sample No.	**Cr**	**Co**	**Ni**	**Cu**	**Zn**	**Pb**	**V**
S1	294	60	189	24	950	0.0	99
S2	246	43	124	0.0	2732	0.0	91
S3	285	56	209	16	187	22	98
S4	264	54	244	1	110	102	110
S5	280	58	197	14	578	0.0	101
S6	293	57	244	15	236	0.0	105
S7	370	58	148	0.0	175	0.0	94
S8	262	56	223	2	346	127	104
S9	306	75	198	35	2192	40	124
Mean	288.88	57.44	197.33	11.88	834	32.33	102.88
Al Saady, 2016	68.17	12.02	71.95	17.73	36.14	5.35	------
Al Bassam,2014							71

5. Enrichment Factor (EF)

EF is a reliable factor in processing, conveying and analyzing the environmental reality to decision managers, manufacturers, technicians and the public [15].

$$\mathbf{EF = (C_x/C_{ref})_{sample} / (B_x/B_{ref})_{Background} \quad \ldots\ldots \quad (1)}$$

Table -2 Values of EF for soil samples

Elements	EF_{S1}	EF_{S2}	EF_{S3}	EF_{S4}	EF_{S5}	EF_{S6}	EF_{S7}	EF_{S8}	EF_{S9}	Local Geochemical	Mean
Cr	4.65	6.30	4.69	3.87	4.57	6.15	7.07	4.96	2.92	100	5.02
Co	12	14	12	10	12	15.5	14	13.5	9	10	12.44
Ni	15.6	16.4	18	18.6	13.4	26.6	14.6	22	9.8	20	17.22
Cu	0.64	0.0	0.42	0.0	0.35	0.57	0.0	0.0	0.57	55	0.28
Zn	21.77	101.16	4.44	2.27	13.72	7.11	4.83	9.5	30.5	70	21.7
Pb	0.0	0.0	3	12.66	0.0	0.0	0.0	20.66	3.33	14	4.40
V	1.11	1.66	1.16	1.13	1.19	1.58	1.27	1.41	0.86	135	1.26

Where:

Cx, Cref, Bx, and Bref are the content of the element studied in the tested environment, studied element in the environment reference, element reference in the studied environment, and element reference in the reference environment respectively.

When EF < 2 displays shortage to low enrichment can be consideration as natural variability, when 2 < EF < 5, this means low enrichment (i.e. some enrichment due to anthropogenic input), and when 5 < EF < 20 indicates the human activity (considerable an enrichment because of anthropogenic inputs). If EF between 20 and 40 shows a very high enrichment, when EF > 40 displays extremely high enrichment [4, 16]. The average values of EF elements in the soil surface coming as Zn>Ni>Co>Cr>Pb>V>Cu. Values of EF for soil are shown in Table -2Range and mean of EF value for elements in surface soil are tabulated in Table-3

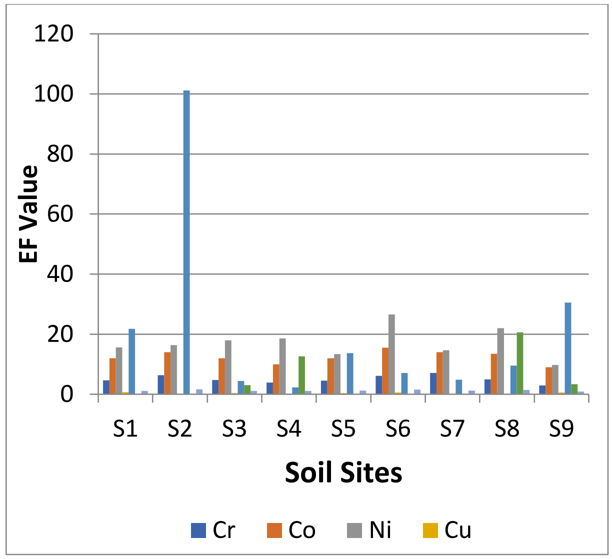
Table -3 Range and Mean of EF value of Elements in the Surface Soil

Trace Element	EF Value Range	Mean	EF category
Cr	2.92-7.07	5.02	Major enrichment
Co	9-15.5	12.44	Major enrichment
Ni	9.8-26.6	17.22	Significant enrichment
Cu	0-0.64	0.28	shortage to minimal enrichment
Zn	2.27-101.16	21.7	Significant enrichment
Pb	0-20.66	4.40	moderate enrichment
V	0.86-1.66	1.26	shortage to minimal enrichment

When EF <2 shortage to minimal enrichment, while 2<EF<5, enrichment is moderate and 5<EF<20, major enrichment.

The highest EF value of (Cr) were 7.07 and 6.30 and 6.15 at S7,S2 and S6 respectively (Table-2), indicating significant enrichment ,while all other values were moderate enrichment .All EF values of (Co) are indicating significant enrichment ,and the highest EF value of (Co) were 15.5 at S6 (Table-2).The highest EF value of (Ni) were 26.6 and 22 at S6 and S8 respectively (Table-2), indicating very high enrichment due to industrial activities ,while all other values are of significant enrichment, with a mean value of 17.22 (Table-3). All EF values of (Cu) are indicating shortage to minimal enrichment, the greatest values of EF of (Cu) were 0.64, 0.57, 0.42 at S1,S6,S9 and S3 respectively (Table-2).The highest EF value of (Zn) were 101.16, 30.5 and 21.77 at S2,S9 and S1 respectively (Table-2) indicating very high enrichment due to high industrial activities, while at S5,S6 and S8, implying significant enrichment , whereas S3, S4 and S7, implying moderate enrichment. The highest values of EF (Pb) were 20.66 and 12.66 at S8 and S4 respectively (Table-2) indicating very high enrichment due to industrial activities, while at S3 and S9, EF values of (Pb) were 3 and 3.33 respectively, implying moderate enrichment, while all other values are (0) at S1,S2,S5,S6,S7. All EF values of (V) are representing deficiency to minimal enrichment, with an average value of (1.26) as represented in Table-3. Spatial variation values of EF of the measured HMs for the surface soil in the study area is illustrated in figure-2.

Figure -2: Spatial variation of EF values for Cr, Co, Ni, Cu, Zn, Pb and V in the Surface Soil.



6. Contamination Factor (CF)

CF is used to assess the level of the contamination of metals in soil residue samples via divided the concentration of each mineral in the soil or sediment by its value of the background [17-20]. Contamination factor is calculated by eq. (2):

$$CF = (C_m)_{Sample} / (C_m)_{Background} \ldots\ldots\ldots\ldots \quad (2)$$

Where (Cm) Sample is given metal concentration in soil sediment, and (Cm) Background is content'sof trace elements in the continental crust.

Table-4: CF values for surface soil samples

Element	CF_{S1}	CF_{S2}	CF_{S3}	CF_{S4}	CF_{S5}	CF_{S6}	CF_{S7}	CF_{S8}	CF_{S9}	Local Geochemical	Mean
Cr	2.94	2.46	2.85	2.64	2.8	2.93	2.7	2.62	3.06	100	2.77
Co	6	4.3	5.6	5.4	5.8	5.7	5.8	5.6	7.5	10	5.74
Ni	9.45	6.2	10.45	12.2	9.85	12.2	7.4	11.5	9.9	20	9.86
Cu	0.43	0.0	0.29	0.01	0.25	0.27	0.0	0.03	0.63	55	0.21
Zn	13.57	39.02	2.67	1.57	8.25	3.37	2.5	4.94	31.31	70	11.91
Pb	0.0	0.0	1.46	6.8	0.0	0.0	0.0	8.46	2.66	15	2.15
V	0.73	0.67	0.72	0.81	0.74	0.77	0.69	0.77	0.91	135	0.75

If CF < 1 is low when 1< CF< 3, is medium, while 3< CF< 6 is considerable, and if CF> 6 is very high. [1, 7, 21, 22]. Average values CF elements in the surface soil were coming as Zn > Ni > Co > Cr > Pb > V >Cu. All CF values of in soil are represented in Table-4 while the range and average values of CF of elements in surface soil are represented in Table-5.

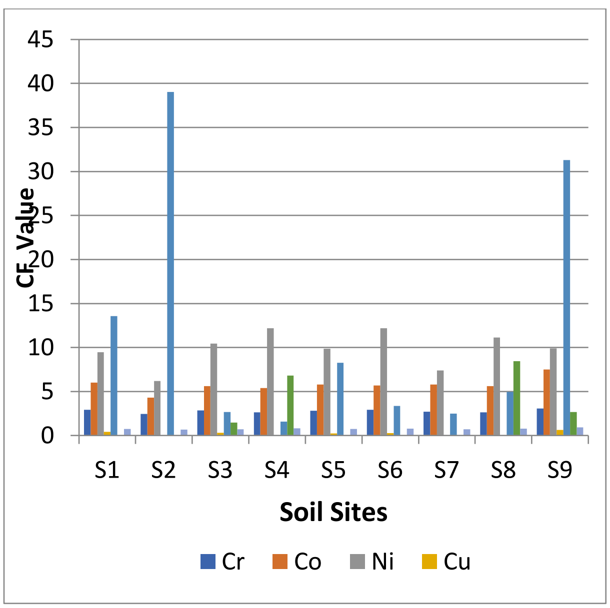
Table -5: Range and average values of CF of elements in the soil surface.

Trace Element	CF value of surface soil		CF category
	Range	Mean	
Cr	2.46-3.06	2.77	Moderate
Co	4.3-7.5	5.74	Considerable
Ni	6.2-12.2	9.86	Very high
Cu	0.0-0.63	0.21	Low
Zn	1.57-39.02	11.91	Very high
Pb	0.0-8.46	2.15	Moderate
V	0.67-0.91	0.75	Low

If CF<1 is low, 1< CF< 3 is medium, if 3< CF< 6 is considerable, and CF> 6 is very high. All values of CF of (Cr) are moderate contamination as shown in Table-4, except S9 are of considerable contamination (Table-5). CF values of (Co) are very high contamination at S1 and S9, while all other values are of considerable contamination (Table-4). All CF values of (Ni) are very high contamination due to industrial activities (Table-4). All values CF

(Cu) are of low contamination, where the highest CF values of (Cu) are 0.63 at S9 (Table-4). The highest values CF of (Zn) were 39.02, 31.31, 13.57 and 8.25 at S2 , S9 ,S1 and S5 respectively are considered of very high contamination due to industrial activities, while at S6 and S8 are considerable contamination and for S3, S4 and S7 are of moderate contamination (Table-5).The greatest CF values of (Pb) were 8.46 and 6.8 at S8 and S4 respectively, representing a very high contamination due to the industrial activities, while at S3 and S9, the CF values of (Pb) are 1.46 and 2.66 respectively, and are considered of moderate contamination. All CF values of (V) are indicating low contamination (Table-5), where highest CF values of (V) are 0.91 at S9, with a mean value 0.75 (Table-5). Spatial variation values CF of the measured HMs for the soil surface in the area of the study is illustrated in figure-3.

Figure -3 Spatial variation in values of CF of Cr, Co, Ni, Cu, Zn, Pb and V in the Surface Soil of the study area.



7. Pollution Load Index (PLI)

PLI is used to evaluate metal pollution and the required action to be taken. PLI is introduced by [23]. If PLI >1 is polluted whereas if PLI <1 represents no pollution [20, 24, 25] and shown by eq. (3).

$PLI = (CF1*CF2*CF3*\ldots CF_n)^{1/n}$ ………….. (3)

n is number of metals.

PLI value for soil sediments are listed in table-6

Table -6: PLI values for surface soil samples of the study area.

$PLI_{S1}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S1}=(2.94*6*9.45*0.43*13.57*0.0*0.73)^{1/7}$

$PLI_{S1}=0.0$

$PLI_{S2}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S2}=(2.46*4.3*6.2*0.0*39.02*0.0*0.67)^{1/7}$

$PLI_{S2}=0.0$

$PLI_{S3}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S3}=(2.85*5.6*10.45*0.29*2.67*1.46*0.72)^{1/7}$

$PLI_{S3}=1.98$

$PLI_{S4}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S4}=(2.64*5.4*12.2*0.01*1.57*6.8*0.81)^{1/7}$

$PLI_{S4}=1.46$

$PLI_{S5}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S5}=(2.8*5.8*9.85*0.25*8.25*0.0*074)^{1/7}$

$PLI_{S5}=0.0$

$PLI_{S6}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S6}=(2.93*5.7*12.2*0.27*3.37*0.0*0.77)^{1/7}$

$PLI_{S6}=0.0$

$PLI_{S7}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S7}=(2.7*5.8*7.4*0.0*2.5*0.0*0.69)^{1/7}$

$PLI_{S7}=0.0$

$PLI_{S8}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S8}=(2.62*5.6*11.15*0.03*4.94*8.46*0.77)^{1/7}$

$PLI_{S8}=2.03$

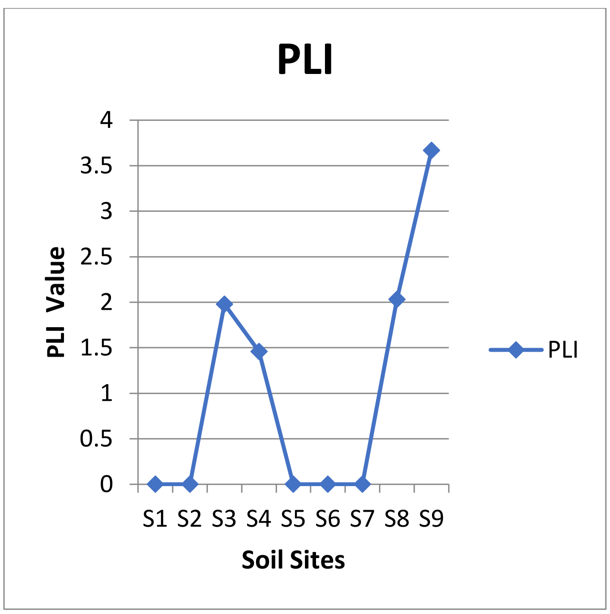
$PLI_{S9}=(CF1*CF2*CF3*CF4*CF5*CF6*CF7)^{1/7}$

$PLI_{S9}=(3.06*7.5*9.9*0.63*31.31*2.66*2.91)^{1/7}$

$PLI_{S9}=3.67$

The highest PLI values are 3.06 , 2.03 , 1.46 and 1.98 at S9 ,S8 ,S4 , and S3 respectively, which are >1, therefore it is considered to be polluted, while S1 , S2 ,S5 ,S6 and S7 are < 1therefore ,it is not polluted (Figure-4).

Figure -4 PLI values of the surface soil of the study area.



8. Conclusion and discussion

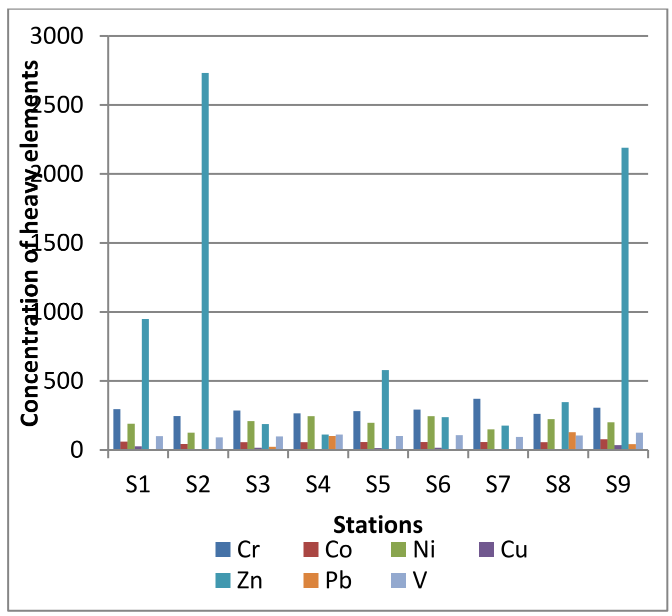
1. The concentration of HMs in the surface soil of the area of the study (Cr, Co, Ni , Zn ,Pb ,V) have high values when comparing them with [26,11]. The increasing of HMs in the soil surface of the area of study may come from air pollution and from the waste of the oil field which float on the soil surface .Rain in winter cause the pollutants to percolate through the soil and increase the concentration of heavy metals .

2. EF values of soil samples of the area of the study are between (0.28-21.7) according to the following (Zn > Ni > Co > Cr > Pb > V >Cu).

3. CF values of soil samples range between (0.21-11.91) according to the following (Cu < V < Pb < Cr < Co < Ni < Zn).

4. Highest PLI values were at S9,S8,S4 and S3, which they are > 1 pointed that the soil in these stations are polluted , whereas the soil stations S1 , S2 , S5 , S6 and S7 are < 1 and hence are not polluted .

Figure -5 Distribution of heavy elements in the soil surface samples of the study area.



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