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SPATIAL DISTRIBUTION OF SOME OF HEAVY METALS POLLUTION PARAMETERS FOR SOILS SURROUNDING AL- DORA POWER PLANT, SOUTH BAGHDAD, IRAQ

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Abstract

A 24 soil samples were taken from the area surrounding the Dora power plant, south of Baghdad, they were distributed on six transects surrounding the plant to study the concentration of heavy metals Pb, Zn, Ni, Cr and the effect of power plant pollutants on some soil pollution parameters. Furthermore, some physical and chemical properties of soil and concentrations of heavy metals have been studied .The results showed an increase in its concentration in the soil of the sites near the plant and its decrease in an irregular manner with increasing the distance from it and its concentration increased in the soil samples of the second and third transect, which are in the direction and movement of the plant's pollutants. The average concentration of metals was Zn>Pb> Cr> Ni, as for the contamination factor (CF), it was Pb> Zn> Ni> Cr with values of 1.97-1.89-1.86-1.17 and that 56.25% of the samples had a moderate concentration factor. Additionally, the pollution load factor (PLI) was at an average of 1.67 and 41.66% of the samples were the moderate degree of contamination, which was concentrated in the samples of the second and third transect and some of the fourth transects. However, the rest of the percentages were distributed between the nil or low degree of contamination and low degree of contamination .The general average of the Index Geo-accumulation (Igeo) was (0.38 - 0.37 - 0.36 - 0.22), with an arranged Pb> Zn> Ni> Cr, indicating the effect of anthropogenic source in supporting the soil with pollutants and it's affected by the plant's pollutants. In the role of the Potential Ecological Risk Index (RI), it averages were (34.41 - 33.32 - 25.11 - 19.78 - 16.07 - 11.91) indicating that the most ecologically risk sites are the sites of the third transect, then the second, fourth, first, fifth and the least are the sixth transect sites, respectively. Although, it was within the low potential ecological risk. The lowest values of the metals contamination parameters, in general, were at the soil sample sites of the sixth transect, which indicates that the least polluted soil samples to non- polluted with these metals. Pearson's Correlation showed the existence of a strong positive significant correlation for the pairs of metals. As well as, the existence of a weak correlation in general for soil characteristics with the metals concentrations, ranged between a weak positive correlation for the metals with clay, CEC and PH and a weak negative correlation with organic matter OM and positive and significant with salinity ECe and a negative correlation and weak with distance from the plant location.

Key words: *Soil pollution, contamination, heavy metals, pollutants, Al-Dora powerplant*

Introduction

Soil pollution, as an important ecological resource, has received great attention due to its direct and indirect impact on human health, especially its contamination with heavy metals and what increases the risk of these metals is the impossibility of decomposition as well as their stability. The sources of heavy metals vary, but human exposure to them is largely due to mining and industrial activities such as refineries, petrochemicals, electrical plants ,and electronic industries. Furthermore, the World Health Organization has identified 13 heavy metals harmful to the population health that exacerbate diseases (Danielyan and Chailyan, 2019). Heavy metals are present in large quantities and freely in the environment due to human intervention and among the most important sources are fertilizers, pesticides, fuel combustion and emissions of compounds, they can be absorbed and accumulate in the tissues of living organisms and what is called bioaccumulation occurs. Otherwise, it may be transmitted through the food chain, which as long it is, its concentration increased in the final consumer and its concentration and absorption depend on ecological and physiological factors. Also, mineral poisoning can cause health damages such as reduced immune defenses, growth rate, aging diseases, memory loss and diseases of the central nervous system (Santos *et al.*, 2020). Soil pollution means the destruction of the soil horizon or the layer in which the plant's root and living organisms grow. These chemicals are related to soil particles and their effect depends on their forms of existence as well as soil properties and ecological characteristics, the most important sources of which are fuel combustion, car exhaust and factory waste (Watanabe *et al.*, 2000). (Wuana and Okieimen, 2011) described the environmental sources from the total heavy metals by an equation that expresses the sources of their processing entering the environment with the sum of their sources from) parent material, gaseous atmosphere, fertilizers, agrochemicals, organic waste and other inorganic sources) minus the metals resulted from the environment by (heavy metals removed by plants and removed by washing, volatilization and emissions to the atmosphere through human activity). Where high levels of heavy metals Pb, Zn, Ni, Cr, Cu, Cd and Mn was found in surface samples of Lishui River sediments. Their distribution was in specific locations with high levels in zones of industrial activities dump them in various quantities in the form of gas, solid and liquid wastes, but they eventually settle in the soil (Shen *et al.*, 2019). Some pollution parameters were used to study sediment pollution because of industrial wastes along the Turag River and were observed that there is significant pollution in some sites with metals Cr, Pb, Zn, Cu, Cd (Banu *et al.*, 2013). The content of six heavy metals was studied in eight sites of industrial urban areas and it was found that there is a large negative correlation with distance. Besides, this indicates that the concentration of metals decreases with the distance from the pollution source, which was considered to be a source of human pollution except those with a weak correlation (Dimitrijevic *et al.*, 2016). The biological factor, which is specific to humans, which shows the principle of independence and dependability, is among the factors of soil formation, which plays a fundamental role in influencing its diverse characteristics, development and degradation as well, (Jenny, 1994) identified these factors and used them in an equation with an attempt was made to fragment the biological factor in (microbes, vegetation, animal and man) as independent factors that have an effective and distinct role in the soil .The growing population represents the effect of this factor, where the increasing demand for electric power and the expansion of various projects that have led to being one of the most important constant sources of air pollution in Iraq. In addition to the fact that these electrical plants are characterized by their aging and low combustion efficiency and the lack of modern technologies to improve their efficiency and control their emissions, especially gaseous matter, such as heavy metals such as lead Pb (Ministry of Environment, 2013). The power plants distributed in Baghdad result in large quantities of pollutants into the air and with the used water and drainage their various wastes without treatment or partial treatment , Human activity and through its distribution of power plants, uses petrochemical materials harmful to public health and resulted in quantities of air, water and soil pollutants as a result of the burning of poor-quality fuels (Ministry of Environment, 2016). The research aims to determine the concentrations of some heavy metals in the soils of the area surrounding the Dora power plant, which are Pb, Zn, Ni, Cr and study of some physical and chemical soil properties of the study area. As well as, the evaluation of some pollution parameters for these heavy metals and spatial distribution of heavy metals concentrations and pollution parameters.

Materials and Methods

Location and nature of the study area

The study area is the area surrounding Al- Dora thermal power plant located on the side adjacent to the western side of the Tigris River and its right bank south of the Baghdad city and 17 km south of the city center, located between (44.22° - 44.23°)E, (33.15° - 33.16°)N. The area of the study area was estimated at 29.25 km^2. Fig. 1 represents a satellite image of the study area taken from the Compsat- 3A in 29/1/2020 showing the location of the Dora power plant and clearly showing the clouds of hazy white pollutants released by the plant's chimneys and their direction.

The study area is a part of the Iraqi sedimentary plain whose surface is characterized by the flatness of its lands and its slope towards the south. Sediments of the Tigris and Euphrates Rivers cover it, as coarse particles were deposited on the sides of the Tigris River here and by the time the levees of the river were formed, which are among the important secondary physiographics units that formed the Iraqi sedimentary plain. It is characterized by its coarse to medium textures and its relatively high topographical position 2-3 m relative to the soil location of the following river basins, with deep groundwater level and good drainage. According to the data (General Meteorological Authority, 2019) the annual average temperature was 23.4 C°, the average maximum temperature was 33.1 C° and the average minimum temperature was 16.1 C° for the years (1985-2019). It has a dry climate and the annual total rainfall is 97.01 mm, the annual average winds for the same period was 3.2 m/sec. As for the direction of the winds, the percentages of their frequency were as follows: the

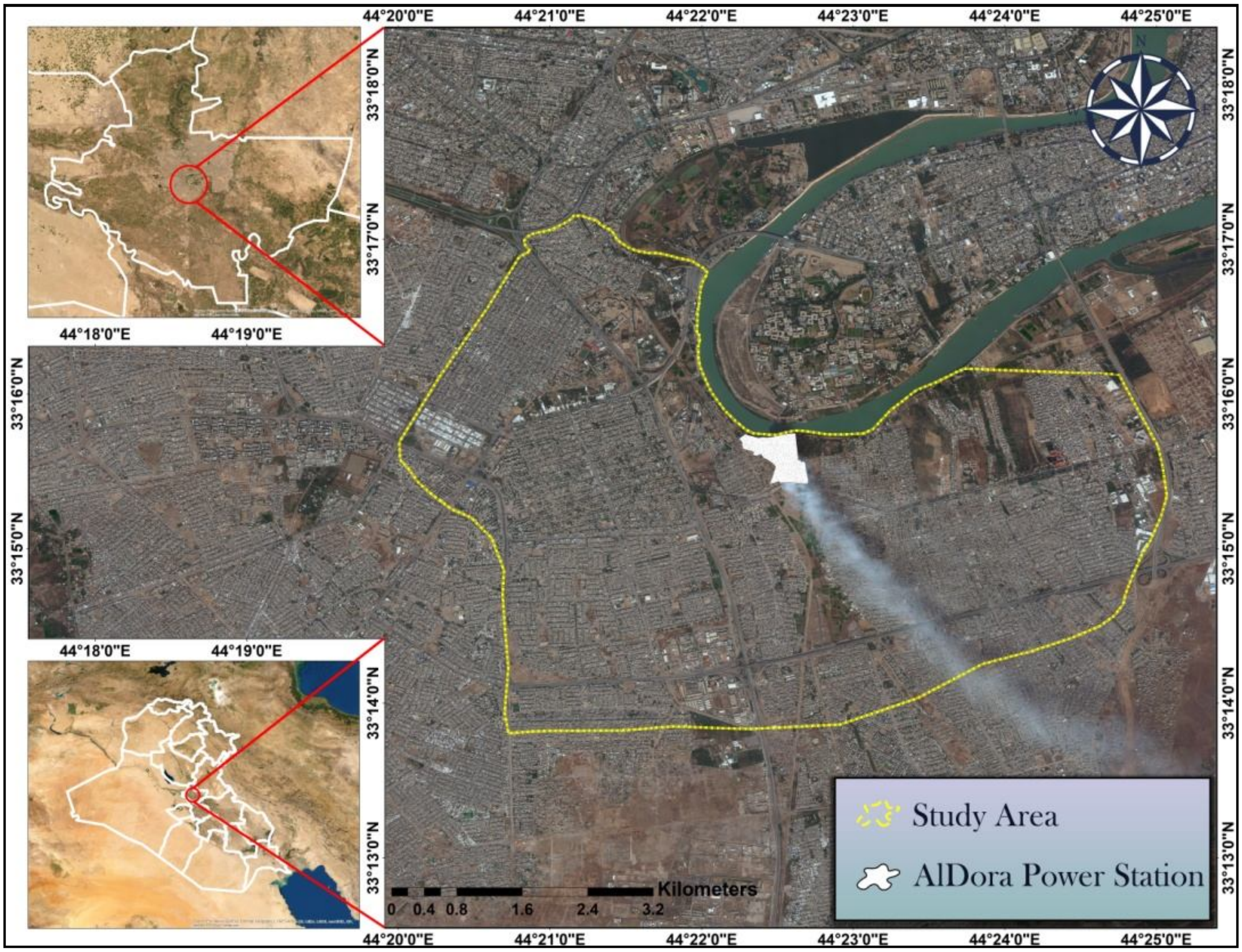

Fig. 1: Satellite of the study area.

prevalent direction is northwest with a percentage of 32.20, stillness by 22.18, westerly by 17.60 and (5.75, 4.30, 5.56, 2.70, 3.50 and 5.60) southwest, south, southeast, east, east, northeast and north, respectively, for the same period. The uses of the lands of the study area were distributed among mostly residential lands, with the spread of some industrial workshops in it and some very small areas that are agricultural use and abandoned unused.

Sampling

A preliminary exploratory survey was conducted in the study area to diagnose the obstacles that may be encountered and the possibility of accessing the sample sites easily. Then soil samples were collected from 24 sites, all at a depth of (0-5) cm, distributed on six transects extending from the boundaries of the power plant in different directions and length ranged between (2005-2106) m by four sample sites along each transect and at different distances .Their sites were determined using the GPS of WGS 1984. These samples covered the area of study area approximately and according to the possibility of access to the specified sites, moreover, a comparative or background soil sample was also obtained to calculate the pollution parameters that were a distance of (4034) m from the boundaries of the plant. The sample location and the comparison sample, their distribution and their coordinates were shown in Fig. 2 and table 1.

Soil samples were air-dried and passed through a 2 mm diameter sieve and were saved for laboratory analysis to measure some physical and chemical properties and concentrations of heavy metals.

Soil Characteristics

2. The relative distribution of soil separates was estimatedusing a hydrometer method (Richards, 1954).

3. The electrical conductivity EC in a soil paste extractor was estimated (Richards, 1954).

4. The pH in a soil paste extract was estimated (Richards, 1954).

5. Calcium carbonate was estimated by the weight

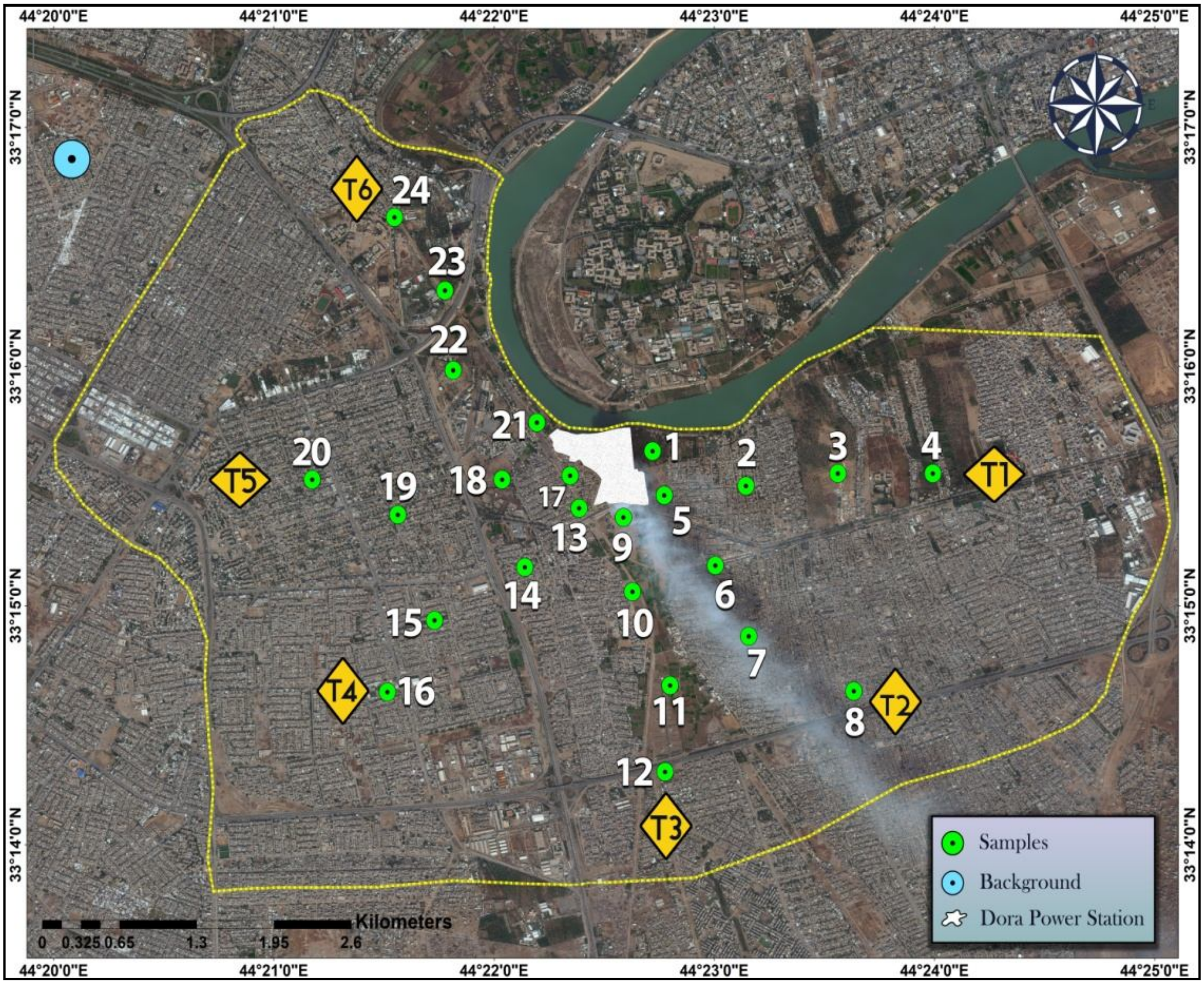

Fig. 2: The locations of soil samples and their distribution on the six transects in the study area.

loss method for CO_2 gas as in 23b in (Richards, 1954).

6. Organic matter was estimated according to Walkley and Black (Jackson, 1958).

7. Estimation of the cation exchange capacity CEC

Table 1: Coordinates of the soil samples sites and their distance from the plant site.

Samples	Dist. (m)	Geographic		Samples	Dist.(m)	Geographic	
		X	Y			X	Y
1	141	33.26075300N	44.37867000E	14	684	33.25266600N	44.36899400E
2	700	33.25833000N	44.38573900E	15	1474	33.24896600N	44.36216800E
3	1360	33.25920600N	44.39269700E	16	2075	33.24397400N	44.35860100E
4	2106	33.25920600N	44.39988400E	17	207	33.25904500N	44.37242100E
5	117	33.25768400N	44.37955200E	18	700	33.25878300N	44.36727800E
6	668	33.25279000N	44.38341800E	19	1436	33.25632800N	44.35938500E
7	1249	33.24786200N	44.38594400E	20	2039	33.25878300N	44.35289900E
8	2098	33.24403000N	44.39389400E	21	151	33.26275100N	44.36990800E
9	113	33.25614000N	44.37646300E	22	841	33.26638700N	44.36356900E
10	657	33.25096900N	44.37714100E	23	1331	33.27195300N	44.36295100E
11	1387	33.24444000N	44.37998800E	24	2005	33.27704600N	44.35913300E
12	2080	33.23786400N	44.37981800E	Back-ground	4034	33.28297300N	44.33554400E
13	104	33.25678600N	44.37310600E				

(Savant 1994).

8. The AAS Atomic Adsorption Spectrometer was implemented to estimate the total concentration of heavy metals Pb , Zn, Ni and Cr and then several pollution parameters were calculated.

Heavy metals pollution parameters

Contamination Factor (CF)

It indicates the level of one soil contamination with specific heavy metals and that its high value gives an indication of the polluted state on that site. As it increases as it is close to the source of pollution, that is, it is an expression of the contamination level of any soil in the form of contamination factor CF (Adamu *et al.,* 2014) and as follows :

$$CF = \frac{Cm\,Sample}{Cm\,Background}$$

Cm sample = Concentration of the studied metal in the soil,Cm Background = Concentration of the metal in the comparison soil.

The contamination factor was divided into four classes, which are according to table 2.

Pollution Load Index (PLI)

It expresses the state of soil pollution in a specific location and is calculated by the (CF) for each metal according to the mentioned equation, as it is divided into seven classes (Abraham and Parker, 2008) as shown in table 3.

$$PLI = \left[CF_1 \times CF_2 \times CF_3 \times .... \times CF_n\right]^{1/n}$$

Where: n = number of metals

Table 2: Classification of contamination factor and level of contamination.

Contamination factor	Level of Contamination
$C_f < 1$	Low Contamination
$1 \le C_f < 3$	Moderate Contamination
$3 \ge C_f < 6$	Considerable Contamination
$C_f > 6$	Very High Contamination

Table 3: The classification of Potential Load Index (PLI).

PLI	Contamination Degree
PLI < 1.5	Nil to Very Low degree of contamination
1.5 ≤ PLI < 2	Low degree of contamination
2 ≤ PLI < 4	A moderate degree of contamination
4 ≤ PLI < 8	A high degree of contamination
8 ≤ PLI < 16	A very high degree of contamination
16 ≤ PLI < 32	The extremely high degree of contamination
PLI eH 32	Ultra-High degree of contamination

Geo-accumulation Index (Igeo)

It expresses the contribution of the land source in supplying the soil with heavy metals and it is used to determine human pollution in sediments (Adamu *et al.,* 2014) according to the following:

$$I_{geo} = \log_2 \frac{C_n\,Sample}{1.5\,B_n\,background}$$

C_n sample = metal concentration in the soil sample

B_n background = metal concentration in the background sample and it is related to soil rock variances.

1.5 = a corrective constant for the activity of the human factor or for calculating any possible variance in the background sample.This indicator was divided into seven classes as shown in table 4.

Table 4: Classification of Geo-accumulation Index (Igeo).

Igeo Value	Grade	Classification
≤0	0	Unpolluted
0 – 1	1	Unpolluted to Moderately Polluted
1 – 2	2	Moderately Polluted
2 – 3	3	Moderately Polluted to Strongly Polluted
3 – 4	4	Strongly Polluted
4 – 5	5	Strongly Polluted to Extremely Polluted
> 6	6	Extremely Polluted

Potential Ecological Risk Index (RI)

This indicator is used to show the potential for ecological risks of pollution in soils or sediments based on the toxicity of heavy metals and the ecological response to them (Hakanson, 1980).

$$Cr^i = \frac{Cf^i}{Cn^i}, Er^i = Tr^i \times Cr^i, RI = \sum Er^i$$

Cr^i = Contamination factor for heavy metal.

Cf and Cn = concentration measurement of the measured metal in the studied sample and the background sample, respectively.

Er^i = potential ecological risk index of the metal

Tr^i = the toxic response for a given substance (Cr = 2, Zn = 1, Ni = Pb = 5)

Table 5: The classes of Potential Ecological Risk.

E_r^i	RI	Potential Ecological Risk
$E_r^i < 40$	RI < 150	Low
$40 = E_r^i < 80$	150 = RI < 300	Moderate
$80 = E_r^i < 160$	300 = RI < 600	Considerable
$160 = E_r^i < 320$		High
$E_r^i = 320$	RI = 600	Very High

RI = The potential ecological risk index of all heavy metals for a region which is the sum of individual potential factor.

Results and Discussion

Soil characteristics analysis

Table 6 shows the results of the laboratory analysis of some characteristics of the area's physical and chemical soil samples, which were distributed over the six transects.

Soil textures varied between (coarse, moderately coarse, moderate and moderately fine) with variation in the values of their separates between high and low depending on the nature of the sedimentation and the physiographic location (Gerrard, 1981). This is also a result of the sequence of sedimentation processes over time and the difference in the factor momentum of the carrier of sediments, which is the water of the Tigris River. This contributed to the formation of sedimentary soils on both sides of the river, starting from the rivers' levees of coarse, moderately coarse and moderate texture, to the fine textures the further we move from it. Soil separates values ranged between (11.3-38.2, 18.9-62.5 and 6.5-60.1) g.kg^{-1} for clay, silt and sand, respectively. As for soil salinity, its values ranged between (3.14 - 11.02) dsm^{-1} and the high salinity in most samples is one of the common phenomena in areas with dry and semi-dry climates, due to higher rates of evaporation during periods of drought and the lack of precipitation. As a characteristic of the PH reaction, the soils were between neutral and moderately alkaline, its values ranged between (7.0-8.1) and it is within the range of reaction degrees of calcareous soils due to the buffering capacity of those soils. As well as, the preservation of the reaction value in that range due to the presence of calcium resulting from carbonate minerals found in soils. In addition to low precipitation, high level of evapotranspiration and little or no leaching process of the bases to the subsurface horizons. While the values of CEC of the cationic ions were low, ranged between (12.3-23.3) Cmole.kg^{-1} and this characteristic is generally related to the content of the clay (Hepper *et al.*, 2006). The values of carbonate minerals ranged between (17.11 - 33.71%), which are very calcareous soils, the percentage of calcium carbonate in them is more than 15% that characterizes Iraqi sedimentary soils. The report of (FAO, 1973) indicated that soils in areas affected by the Mediterranean climate and desert climate contain carbonate minerals that are inherited from the parent material and the soils prevalent in dry and semi-dry regions are calcareous soils due to climatic factors and the long dry season (Ryan *et al.,* 2006). Most soil samples were very low in its content of organic matter, which ranged between (0.30 - 1.76%) and only (8.33%) was low, according to soil and water analysis laboratories of the University of Chile (Rodríguez *et al.,* 1993). As in sample No. 1 and 4 as their content of organic matter was more than 1, this is because the first sample was within the area of palm groves and trees and sample No. 4 was covered with vegetation and weeds.

Table 6: physical and chemical characteristics of soil samples in the study area

Transect	Samples	Clayg m.kg^{-1}	Siltg m.kg^{-1}	Sand gm.kg^{-1}	texture	Eced sm^{-1}	PH	CEC Cmole.kg^{-1}	$CaCO_3$ %	O.M %
T1	1	17.6	21.3	60.1	SL	3.14	7.4	20.3	17.11	1.76
	2	27.7	41.1	30.7	L	6.18	7.6	19.8	26.51	0.41
	3	25.9	62.5	11.2	SiL	7.43	7.7	16.4	32.13	0.70
	4	20.7	55.3	23.2	SiL	5.42	7.5	22.1	21.50	1.25
T2	5	26.8	53.3	19.2	SiL	9.30	7.6	19.9	29.42	0.22
	6	36.2	37.4	25.5	CL	8.11	8.1	20.7	33.71	0.50
	7	28.6	39.2	31.5	CL	7.63	7.8	16.3	28.10	0.61
	8	31.9	18.9	48.7	SCL	9.02	7.6	20.5	29.82	0.42
T3	9	15.4	55.2	28.3	SiL	7.94	7.3	15.1	25.70	0.42
	10	20.1	42.2	36.7	L	8.13	7.6	17.3	19.21	0.61
	11	29.4	40.3	29.8	CL	6.40	7.7	20.5	21.72	0.90
	12	31.1	60.2	8.4	SiCL	9.51	7.9	22.4	18.14	0.32
T4	13	16.5	35.2	47.6	L	9.73	7.5	18.4	28.22	0.30
	14	27.2	38.2	33.8	L	11.02	7.1	20.1	31.71	0.51
	15	33.1	52.5	13.4	SiCL	8.41	7.4	21.4	32.20	0.43
	16	30.7	44.6	24.1	SiCL	9.60	7.5	20.3	29.41	0.50
T5	17	16.8	56.6	25.4	SiL	5.62	7.0	18.5	24.31	0.43
	18	35.2	57.4	6.5	SiCL	6.80	7.1	20.2	28.50	0.61
	19	32.1	29.5	37.3	CL	3.41	7.3	19.6	30.22	0.52
	20	38.2	46.5	11.4	SiCL	8.55	7.5	23.3	27.41	0.61
T6	21	15.1	38.2	46.3	SL	3.09	7.0	12.3	20.62	0.41
	22	21.2	57.1	20.8	SiL	4.37	7.5	17.7	29.90	0.33
	23	18.8	48.5	31.9	SiL	6.15	7.7	15.3	26.71	0.31
	24	11.3	60.2	27.7	SiL	5.21	7.5	17.4	24.12	0.52

Concentrations of heavy metals and estimation of pollution

The concentration of heavy metals

Table 7 showed a comparison between the concentrations of heavy metals in the control sample in the study area, with their natural abundance of different studies. Which was (33.5-45.6-17.1-37.7) mg.kg^{-1} for Pb, Zn, Ni and Cr respectively.

Table 7: The concentrations of heavy metals in the background sample and their comparison with other natural abundance.

	Pb	Zn	Ni	Cr
Lindsay,1979	10	50	40	100
Schacklette and Boerngen,1984	16	48	13	37
Moon *etal.*2006	15	35	17	45
Rose *etal.*1987	17	36	17	43
WHO. 2003	50-300	150-300	30-75	1-5
Our new study	35.5	45.6	17.1	37.7

Table 8 showed that 71.88% of the samples were at concentrations higher than those of the elements in the background sample. The major damage caused by the location of the power plant in a residential area is shown here.

Table 8: Heavy metal concentrations in the soil samples of study.

Tran sect	Sam- ples	Heavy Metal Concentration (mg/kg)			
		Pb	Zn	Ni	Cr
T1	1	35.1	80.1	18.2	46.0
	2	71.1	101.5	32.1	50.2
	3	62.2	93.8	28.6	41.4
	4	54.3	69.7	21.3	37.1
Mean		55.67	86.27	25.05	43.67
T2	5	115.3	138.1	54.0	63.3
	6	87.0	119.7	39.3	46.7
	7	91.4	122.3	42.2	51.9
	8	98.2	110.5	45.4	54.1
Mean		97.97	122.56	45.22	54.00
T3	9	119.2	140.1	60.3	57.3
	10	92.1	146.2	55.1	63.1
	11	73.3	112.5	41.2	48.3
	12	88.9	118.2	45.8	52.6
Mean		93.37	129.25	50.60	55.32
T4	13	97.2	115.2	45.9	55.1
	14	65.4	102.1	40.1	61.3
	15	51.5	80.2	32.3	47.6
	16	42.2	66.3	30.2	44.8
Mean		64.07	90.95	37.12	52.20
T5	17	65.3	56.5	27.2	38.2
	18	53.4	53.6	18.4	35.0
	19	48.2	49.2	16.1	30.6
	20	41.7	45.3	14.1	24.0
Mean		52.15	51.15	18.95	31.95
T6	21	39.1	42.5	15.0	33.5
	22	33.4	37.3	14.7	28.1
	23	35.2	43.3	16.2	31.5
	24	30.6	40.1	13.6	26.5
Mean		34.57	40.77	14.87	29.90
Mean of all samples		66.30	86.84	31.96	44.50

The concentrations of the metals ranged between (30.6-119.2) and (37.3-146.) and (13.6-60.3) and (24.0-63.3) mg.kg^{-1} for each of Pb-Zn-Ni-Cr, respectively. In general, high values of metal concentrations are observed in samples of soils close to the plant site as in samples (5, 9, 13, 17, 21) and their concentrations decrease, but not regularly, in samples of soils far from it. They ranged between increases and decreases, especially in soil samples from transects 2-3-4, samples close to the pollution source are affected by gases and pollutants by the plant more than other samples. Furthermore, the location of the sample of these transects was in the direction of northwestern wind's movement prevailing in the region, that its speed varies between low and high. As well as, the stillness percentage of wind that helps in the descent and falling of pollutants and collecting them on the soil surface, or taking them away when increasing its speed to fall again in other locations when its speed drops .It was also observed that the concentrations of metals increase in sites close to traffic routes for vehicles, as in samples 5, 8, 9, 12, 13, as the combustion of vehicle fuel and the volume of its passage leads to an increase in heavy metal pollutants, especially Pb (Yan *et al.,* 2013). There is also a big and noticeable increase in the number of vehicles that use leaded gasoline and lead-acid batteries and many sites in Iraq can be considered as high-density traffic sites, especially in the capital, Baghdad, which contributed to an increase in ecological pollutants (Jassim *et al.,* 2015). However, it can observe the decrease in the concentrations of these metals in the sites of soils covered by vegetation and used agriculturally, as in samples 1, 4, as these metals condense on the vegetative parts (Yan *et al.,* 2012). Otherwise, the plant's root and trees can adsorb heavy metals, so their concentrations in them are reduced (Chojnacka *et al.,* 2005). The average metals concentrations of the samples for each transect for Pb (97.97 - 93.37 - 64.07 - 55.67 - 52.15 - 34.57) mg.kg^{-1} for transect (2 - 3 - 4 - 1 - 5 – 6), respectively and the average concentration of Zn in the transects was (129.25 - 122.56 - 90.95 - 86.27 - 51.15 - 40.77) mg.kg^{-1}. The average concentration of the Ni in the transect soils samples was arranged from (50.60 - 45.22 - 37.12 - 25.05 - .18.95 - 14.87) mg.kg^{-1}. Furthermore, the average concentration of Cr was arranged (55.32 - 54.00 -52.20 - 43.67 - 31.95 - 29.90) mg.kg^{-1} for transects (2-3 - 4 - 1 - 5 – 6) respectively and for each of these transects .It was observed that the metals concentration increases in soils of the second and third transect more than the rest transects, the direction and passage of the power plant pollutants towards it and parallel to the direction of the

Table 9: The value of contamination factor (CF).

Tran-sect	Sam-ples	Contamination Factor (CF)			
		Pb	**Zn**	**Ni**	**Cr**
T1	1	1.04	1.75	1.06	1.22
	2	2.12	2.22	1.87	1.33
	3	1.85	2.05	1.67	1.09
	4	1.62	1.52	1.24	0.98
Mean		1.65	1.88	1.46	1.15
T2	5	3.44	3.02	3.15	1.67
	6	2.59	2.62	2.29	1.23
	7	2.72	2.68	2.46	1.37
	8	2.93	2.42	2.65	1.43
Mean		2.92	2.68	2.63	1.42
T3	9	3.55	3.07	3.52	1.51
	10	2.74	3.20	3.22	1.67
	11	2.18	2.46	2.40	1.28
	12	2.65	2.59	2.67	1.39
Mean		2.78	2.83	2.95	1.46
T4	13	2.90	2.52	2.68	1.46
	14	1.95	2.23	2.34	1.62
	15	1.53	1.75	1.88	1.26
	16	1.25	1.45	1.76	1.18
Mean		1.90	1.98	2.16	1.38
T5	17	1.94	1.23	1.59	1.01
	18	1.59	1.17	1.07	0.92
	19	1.43	1.07	0.94	0.81
	20	1.24	0.99	0.82	0.63
Mean		1.55	1.11	1.10	0.84
T6	21	1.16	0.93	0.87	0.88
	22	0.99	0.81	0.85	0.74
	23	1.05	0.94	0.94	0.83
	24	0.91	0.87	0.79	0.70
Mean		1.02	0.88	0.86	0.78
Mean of total samples		1.97	1.89	1.86	1.17

winds may have the effect of increasing their concentration .As for the lowest concentrations of the metals, they were in the sixth transect soil samples, which were far from the transect and direction of the pollutants, but rather opposite to their direction .The increase in the concentration of the metal in soils near the plant and their decrease by moving away from it, even randomly, indicates that the pollution source is the same for all these metals, which is the power plant. Besides that, these metals accumulate over time in soil samples and according to their correlation to their physical and chemical characteristics and the direction and speed of wind in the study area .In general, the general average of metals concentrations in all samples of the study soil was Zn < Pb< Cr <Ni (86.84 - 66.30 - 44.50 - 31.96) respectively.

Table 10: The value of Pollution Load Index (PLI).

Transect	Samples	PLI	Transect	Samples	PLI
T1	1	1.23	T4	13	2.31
	2	1.84		14	2.01
	3	1.62		15	1.58
	4	1.31		16	1.39
Mean		1.50	Mean		1.82
T2	5	2.17	T5	17	1.39
	6	2.09		18	1.16
	7	2.22		19	1.03
	8	2.27		20	0.89
Mean		2.32	Mean		1.11
T3	9	2.75	T6	21	0.95
	10	2.62		22	0.84
	11	2.01		23	0.93
	12	2.24		24	0.81
Mean		2.40	Mean		0.88
Mean of all samples			1.67		

Contamination Factor (CF)

It is considered an effective and simple tool for monitoring heavy metals contamination and its high value gives an indication of the pollution status at that site. Table 9 showed the values of this factor for the samples of the studied soils, which ranged between (0.70 - 3.55) and its value has increased in soil samples (5, 9, 13, 17, 21) that close to the power plant and this indicates the pollution level that occurs due to the influence of human activities (anthropogenic effect). The product from the combustion of plant's fuel that increases the concentrations of Pb, Zn in particular, as well as pollutants in small industrial workshops and car plumbing workshops that distributed over public roads, which led to an increase in Cr concentrations, for example, as in site 5, the second transect. In addition to the combustion of vehicle, fuel and gases emitted from their exhausts in soil samples close to vehicle passage routes, which contain Pb in particular, which is exacerbated by increased traffic, which increased pollution levels in the air and soil (Chen et al., 2010). The average CF values for Pb were (2.92 - 2.78 - 1.90 - 1.65 - 1.55 - 0.91) for the transects (2 - 3 - 4 - 1 - 5 – 6), respectively, as for the Zn, the average CF values were (2.83 - 2.68 - 1.98 - 1.88 - 1.11 - 0.88) for the transects (3-2-4-1-5-6). The average CF values for Ni were (3.52 - 2.95 - 2.16 - 1.46 - 1.10 - 0.86) for the transects (2 - 3 - 4 - 1 - 5 – 6) respectively and the average CF values for Cr (1.46 - 1.42 - 1.38 - 1.15 - 0.84 - 0.78) for the transects (3 - 2 - 4 - 1 - 5 – 6), respectively .In general, the average CF values of all study samples were 1.97 - 1.89 - 1.86 - 1.17 and were arranged as Pb> Zn> Ni> Cr and that 10.93% of the samples with a

Table 11: Value of Index Geo-accumulation (Igeo).

Transect	Samples	Pb	Zn	Ni	Cr
T1	1	0.20	0.35	0.21	0.24
	2	0.42	0.44	0.37	0.26
	3	0.37	0.41	0.33	0.21
	4	0.32	0.30	0.24	0.19
Mean		0.32	0.37	0.28	0.22
T2	5	0.68	0.60	0.63	0.33
	6	0.52	0.52	0.46	0.24
	7	0.54	0.53	0.49	0.27
	8	0.58	0.48	0.52	0.28
Mean		0.58	0.53	0.52	0.28
T3	9	0.71	0.61	0.70	0.30
	10	0.55	0.64	0.64	0.33
	11	0.43	0.49	0.48	0.25
	12	0.52	0.51	0.53	0.27
Mean		0.55	0.56	0.58	0.28
T4	13	0.58	0.50	0.53	0.29
	14	0.39	0.44	0.46	0.32
	15	0.30	0.35	0.37	0.25
	16	0.24	0.28	0.35	0.23
Mean		0.37	0.39	0.42	0.27
T5	17	0.38	0.24	0.31	0.20
	18	0.31	0.23	0.21	0.18
	19	0.28	0.21	0.18	0.16
	20	0.24	0.19	0.16	0.12
Mean		0.30	0.21	0.21	0.16
T6	21	0.23	0.18	0.17	0.17
	22	0.19	0.16	0.17	0.14
	23	0.21	0.18	0.18	0.16
	24	0.18	0.17	0.15	0.13
Mean		0.20	0.17	0.16	0.15
Mean of total sample		0.38	0.37	0.36	0.22

Table 12: The value of Potential Ecological Risk (Er^i) of the metals and (RI).

Transect	Samples	Er^i				RI
		Pb	Zn	Ni	Cr	
T1	1	5.20	1.75	5.30	2.44	14.69
	2	10.60	2.22	9.35	2.66	24.83
	3	9.25	2.05	8.35	2.18	21.83
	4	8.10	1.52	6.20	1.96	17.78
Mean		8.28	1.88	7.30	2.31	19.78
T2	5	17.20	3.02	15.75	3.34	39.31
	6	12.95	2.62	11.45	2.46	29.48
	7	13.6	2.68	12.30	2.74	31.32
	8	14.65	2.42	13.25	2.86	33.18
Mean		14.60	2.68	13.18	2.85	33.32
T3	9	17.75	3.07	17.60	3.02	41.44
	10	13.70	3.20	16.10	3.34	36.34
	11	10.90	2.46	12.00	2.56	27.92
	12	13.25	2.59	13.35	2.78	31.97
Mean		13.90	2.83	14.76	2.92	34.41
T4	13	14.50	2.52	13.40	2.92	33.34
	14	9.75	2.23	11.70	3.24	26.92
	15	6.65	1.75	9.40	2.52	21.32
	16	6.25	1.45	8.80	2.36	18.86
Mean		9.53	1.98	10.82	2.76	25.11
T5	17	9.70	1.23	7.95	2.02	20.90
	18	7.95	1.17	5.35	1.84	16.31
	19	7.15	1.07	4.70	1.62	14.54
	20	6.20	0.99	4.10	1.26	12.55
Mean		7.75	1.11	5.52	1.68	16.07
T6	21	5.80	0.93	4.35	1.76	12.84
	22	4.95	0.81	4.25	1.48	11.49
	23	5.25	0.94	4.70	1.66	12.55
	24	4.55	0.87	3.95	1.40	10.77
Mean		5.13	0.88	4.13	1.57	11.91
Mean of total samples		9.86	1.89	9.28	2.34	23.43

considerable concentration factor were concentrated in the samples of the second and third transect .They were in the same direction as the plant's pollutants and with the direction of the northwest wind movement. As for 32.81% of samples, they had a low concentration factor, which was concentrated in soil samples of the sixth and fifth transect, which indicates the lack contamination of their soils samples with heavy metals, while the largest percentage of samples, which is 56.25% had a moderate concentration factor.

Pollution Load Index (PLI)

This index gives a comprehensive assessment of the level of heavy metals contamination for each site, taking into account the CF for each of the four heavy metals in that site. Table 10 showed the values of this index, which ranged from (0.81 - 2.75). The average PLI values were 2.40 -2.32 - 1.82 - 1.50 -1.11- 0.88 for transects 3 - 2 - 4 - 1 - 5 - 6 respectively. This indicates the high contamination of the sample sites for second, third and fourth transects than in the other transects, its overall mean was 1.67, which means a moderate degree of contamination .This index gives a clearer image of site soil pollution and it was observed that 45.83% of the sites were nil to a low degree of contamination concentrated in the fifth and sixth transect and that 41.66% were the moderate degree of contamination concentrated at the sample sites of the second and third transect and some of the fourth transect. As for the lowest percentage, which is 12.50%, it had a low degree of contamination, most of which were concentrated in the sample sites of the first transect, which were the least polluted sites as they were far from the path and direction of the plant's pollutants.

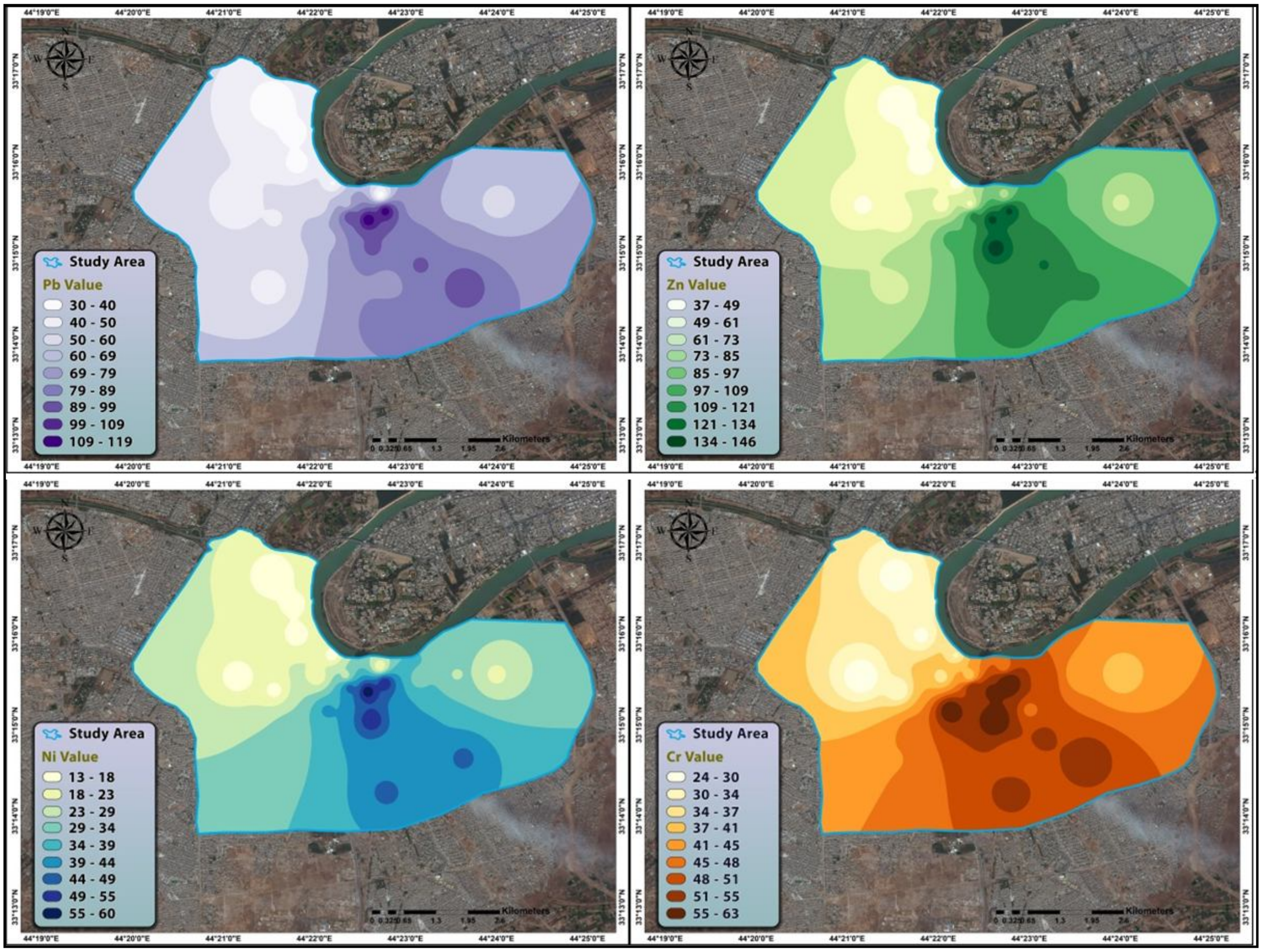

Fig. 3: The spatial distribution of the heavy metals concentrations in the soil samples of the study area.

Additionally, high PLI values are observed in some sites close to vehicle traffic routes as at sites 8, 9, 12, 13, 23 and that may be due to the vehicle fuel combustion pollutants that led to increase the values of this index to be within the moderate degree of contamination.

Geo-accumulation Index (Igeo)

Igeo expresses the expected source of pollutants and the contribution of the Lithogenic Sourse in supplying the soil with heavy metals. Table 11 showed that the values of this indicator range between (0.71- 0.12).

All Igeo values for soil samples in the study area were less than 1 and within class 1 with a range of (1-0), which indicates that it is unpolluted to moderately polluted. The overall mean of the Igeo values was 0.38 - 0.37 - 0.36 - 0.22 for Pb > Zn > Ni > Cr respectively. Whenever the values are less than (1), it supports the assumption that pollutants from human activity, such as industrial activity or vehicles, affect these soils. That is, the anthropogenic source here contributed to supporting soils with pollutants and its exposure to emissions and materials resulting from industrial activity resulting from the combustion of plant fuel to generate electric power, as well as vehicle pollutants and any other human activity that may be present in the study area. This indicates that the contribution of the land source in supplying soils with heavy metals was at weak levels.

Potential Ecological Risk Index (RI)

This indicator is used to show the potential ecological risks of pollution in soils based on the toxicity of heavy metals and the ecological response to them. First, the (Er^i) must be calculated, which is an indicator of the potential ecological risk for each of the heavy metals. Table 12 showed the potential ecological risk values for each metal and for the sites as well.

The values of Er ranged between (0.81 - 17.75) and the rates of this indicator were arranged for Pb (14.60 - 13.90 - 9.53 - 8.28 - 7.75 - 5.13) for soils samples of transects (2 - 3 - 4 - 1 - 5 – 6), respectively. Moreover, the mean values of Er for Zn were (2.83 - 2.68 - 1.98 - 1.88 - 1.11 - 0.88), whereas the rates of this indicator

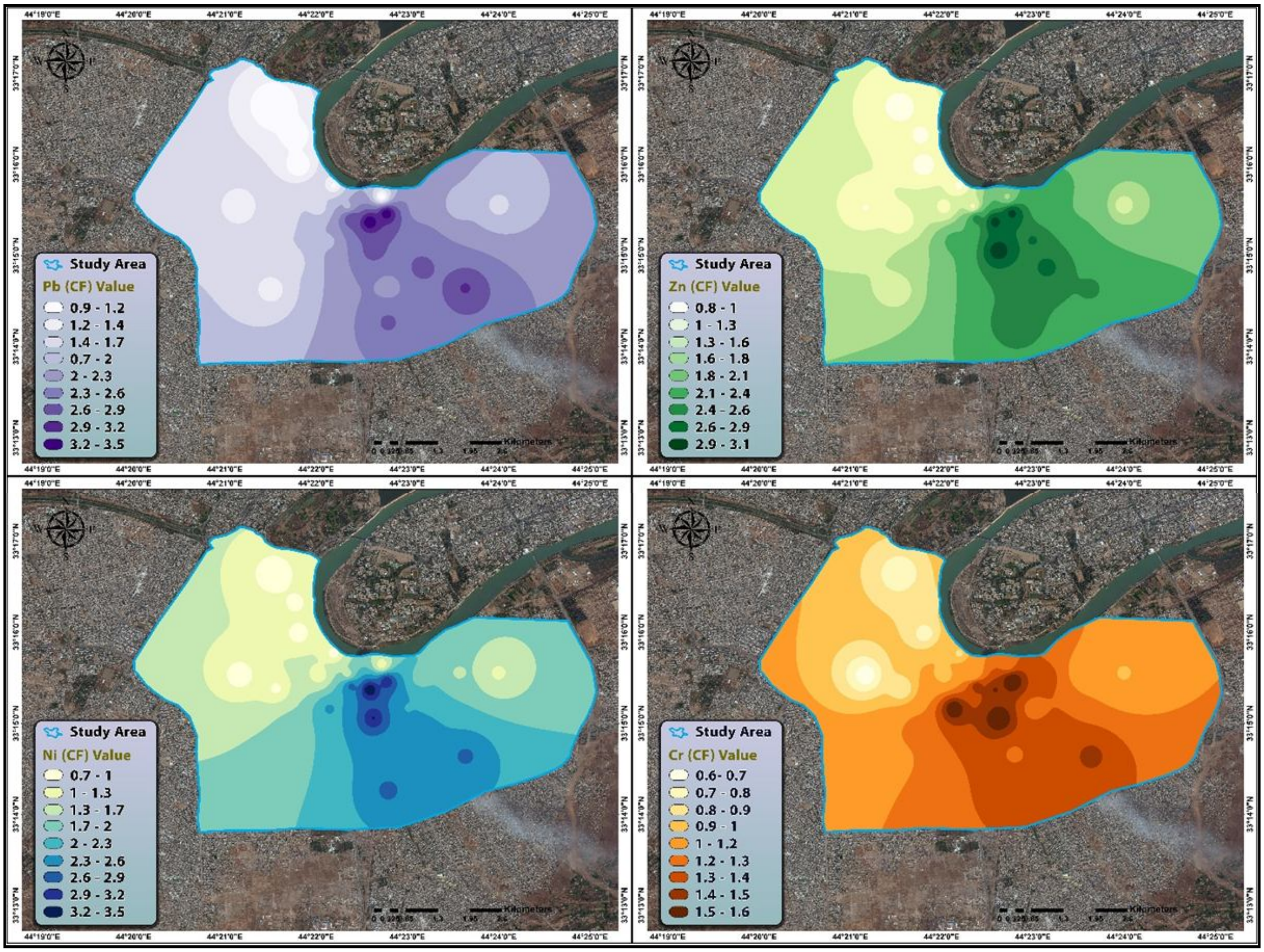

Fig. 4: The spatial distribution of CF values for the soil samples of the study area.

and its ecological risk values for Ni were (14.76 - 13.18 - 10.82 - 7.30 - 5.52 - 4.13) and its values for the Cr were (2.92 - 2.85 - 2.76 - 2.31 - 1.68 - 1.57) for the transects (3 - 2 - 4 - 1 - 5 – 6), respectively. In general, the general average of this indicator was (9.86 - 9.28 - 2.34 - 1.89) for the Pb > Ni > Cr > Zn, respectively. All these values indicated that the ecological risk for each metal was within the Low Potential Ecological Risk because its value was less than 40. In case of collecting the ecological risk values for all the metals in each site, it can obtain an RI that indicates the potential ecological risk for each site, as its value of the sites ranged between (10.77 -41.44). The average values of this indicator were (34.41 - 33.32 - 25.11 - 19.78 - 16.07 - 11.91) indicating that the most ecological risk sites are the sites of the third transect and the least is the sixth transect sites, then the remaining values are arranged for the transects (2-4-1-5), respectively. The general average of the values of this indicator for all study sites was 23.43. All these values remain within the Low Potential Ecological Risk because the sum of the ecological risk values for all metals for each site was less than 150.

Spatial Distribution (Inverse Distance Weighting IDW)

This method, which is one of the spatial analysis methods, was used to help clarify unknown values from several known values. The concentrations of heavy metals under study and the indices values of pollution were obtained from the previous calculations and were distributed spatially distributed in maps using Arc GIS 10.8 software. The IDW method is considered one of the most appropriate methods of classification and evaluation and it contributed to determining the spatial distribution of the concentration values of heavy metals, indicators and contamination factor and determining their concentration and dispersion. It is one of the appropriate ways to deal with the Raster surface using a statistical, mathematical method, which used the inverse distance weighting to create new data points based on a set of specific graphical points known as geographic coordinates represented by longitude X and Y latitudes, as shown in Figs. 3, 4, 5, 6, 7 and 8.

Correlation Coefficients

The statistical package for the social sciences SPSS application was used to obtain Pearson's Correlation Coefficients between the concentration values of heavy metals understudy with the physical and chemical characteristics and the distance from the pollution source as shown in table 13. It was observed that there is a significant positive correlation for each of the heavy metals pairs in the soil: Zn - Ni, Pb - Ni, Zn - Cr, Ni-Cr, Pb- Zn, Pb-Cr (r = o.953), (r = 0.937), (r = 0.922), (r = 0.920), (r = 0.908), (r = 0.812), respectively .As for the coefficient of correlation (r) of the metals with the clay, it was weakly positive and ranged between (0.045- 0.107), meaning that there is slight adsorption of these elements on the clay surfaces. Besides, the type of clay minerals may have an effect on that, which indicates the possibility of the presence of the chlorite, which is one of the clay minerals spread in Iraqi soils with Montmorillonite and Calcite as mentioned by (Buringh 1960). It has a very low or no CEC ranged between 20-30 Cmole.kg^{-1} and this is reflected in small values of a positive r correlation with the concentration of heavy metals .This indicates that the clay minerals in soil samples of the type of smectites or montmorillonite with high CEC ranged between 80-150 Cmole.kg^{-1}, in a small percentage in the soils of the study area. The correlation was positive and

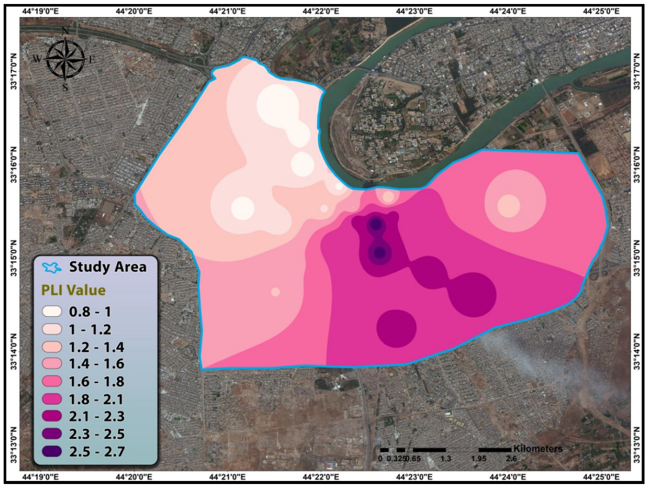

Fig. 5: The spatial distribution of PLI values for the soil samples of study area.

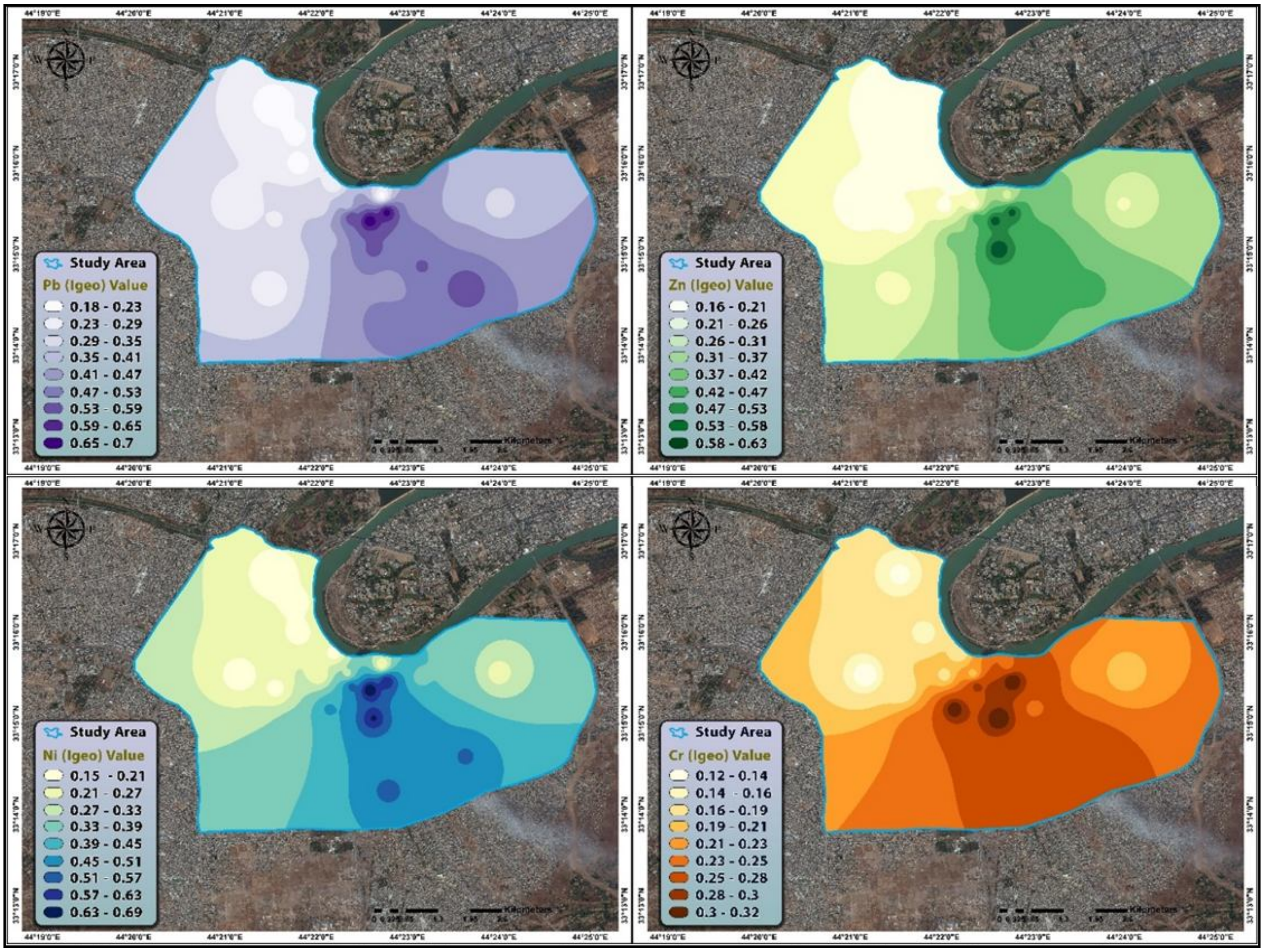

Fig. 6: The spatial distribution of Igeo values for the soil samples of study area.

Table 13: Pearson's Correlation Coefficients between determining soil parameters and distance from the main pollution source.

	Pb	**Zn**	**Ni**	**Cr**	**Clay gm.kg^{-1}**	**Silt gm.kg^{-1}**	**Sand gm.kg^{-1}**	**Eced sm^{-1}**	**PH**	**CECCmole.kg^{-1}**	**CaCO$_3$%**	**O.M %**	**Dist-ance**
Pb	1												
Zn	.908**	1											
Ni	.937**	.953**	1										
Cr	.812**	.922**	.920**	1									
Claygm.kg^{-1}	.092	.107	.063	.045	1								
Siltgm.kg^{-1}	-.083-	-.171-	-.087-	-.244-	-.137-	1							
Sandgm.kg^{-1}	.033	.106	.056	.212	-.458-*	-.817-**	1						
Ecedsm^{-1}	.577**	.586**	.674**	.629**	.404	.075	-.298-	1					
PH	.309	.442*	.314	.204	.319	-.018-	-.159-	.290	1				
CECCmole.kg^{-1}	.008	.065	.019	.064	.651**	-.072-	-.322-	.344	.230	1			
CaCO$_3$%	.076	-.027-	.027	-.011-	.475*	.022	-.292-	.381	.085	.081	1		
O.M%	-.302-	-.069-	-.265-	-.092-	-.102-	-.278-	.302	-.407-*	-.029-	.248	-.466-*	1	
Distancem	-.293	-.259-	-.245-	-.336-	.403	.128	-.350-	.149	.365	.443*	.055	.046	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

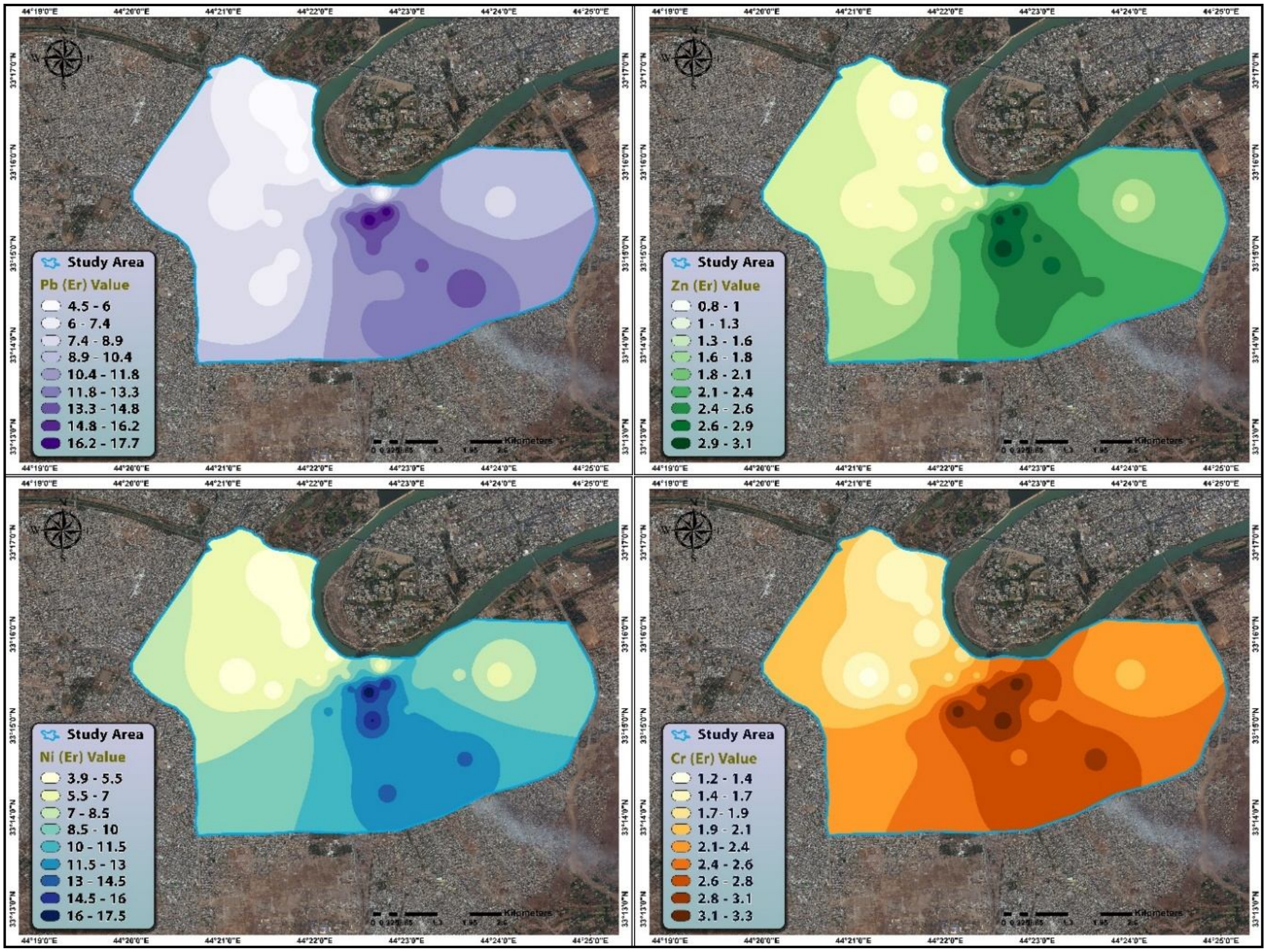

Fig. 7: The spatial distribution of Er values for the soil samples of study area.

significant with salinity and it ranged between (o.577 - 0.674) and positive with pH, ranged between (0.204 - 0.442). As for the correlation with the CEC, it was a very weak positive ranged between (0.008 - 0.065) and this reflects the correlation of this trait with the type of clay minerals that were minerals of slight CEC, as well

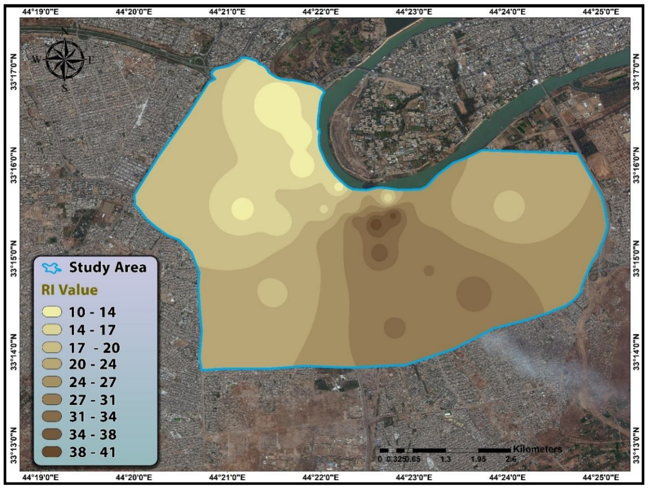

Fig. 8: The spatial distribution of RI values for the sample of study area.

as a small amount of organic matter, with which the correlation with it was negative and weak ranged between (-0.302_-0.069). The values of its correlation with $CaCo_3$ ranged between positive and negative and all of them were very weak values that ranged between (-0.027_ 0.076) and this is due to the fact that these compounds are present in the coarse and inactive separates of the soil that do not help the metals to correlate with it. It was also observed that the values of the metals' correlation with the organic matter were all negative and weak correlation values that ranged between (-0.302_-0.069), that the quantity and quality of the organic matter plays an important role in evaluating the movement and behavior of each of the heavy metals in the environment. Also, their correlation with the organic matter components it is associated with Humic components, especially Humic acid as some metals tend to correlate not only as complexes with organic matter, but also to preserve them in exchangeable forms .Some are constrained and are not available through the formation of complexes, while others are in the form of exchangeable and available (Baranèíková and Makovníková, 2003). The negative and even positive weak correlations indicate that these metals have a slight correlation and adsorption to the soil components, which makes them present in the soil in an unconstrained manner. The metals' correlation values with distance, they were negative and weak values ranged between (-0.336_-0.245). Whereas the metal concentrations decreased with the distance from the plant or the pollution source, but in an irregular manner, which is considered an anthropogenic source .Most of the correlations were with a low values and this indicates that the coefficient of determination (r^2) will lead to explain that other factors can have a great influence on heavy metals concentrations in the study area, such as the speed and direction of the winds carrying gaseous. As well as, not- gaseous pollutants prevailing in the study area, otherwise the physiography of the area that affects the type and severity of soil characteristics and the type of fuel used in the plant.

Conclusions

1. The results showed that there was an increase in the concentration of heavy metals Pb –Zn-Ni-Cr at the samples' soil sites close to the power plant and their concentration decreased irregularly in the farthest sites from it, most of which were less than their concentrations in the comparison sample.

2. The values of (CF) Contamination Factor were (1.97-1.89 - 1.86 - 1.17) for Pb, then Zn, Ni and Cr. Besides, the largest percentage of the samples were moderately contaminated, while the values of considerable concentration factor were concentrated in samples of the second and third transect parallel to the movement and direction of the gas plant pollutants and parallel to the movement and direction of prevailing winds.

3. The values of the PLI (Pollution Load Index) of moderate degree appeared in the soil samples for the second and third transect and that the low or absence degree of this criterion was distributed to the rest of the other transect sites.

4. Through the Igeo (Geo-accumulation index), the results showed that there is an effect of pollution from the anthropogenic source in supporting soils and supplying them with these metals with a weak land supply to them.

5. The Potential Ecological Risk (Er) was 9.86 - 9.28 -2.34-1.89 for Pb> Ni> Cr> Zn, respectively and for the low type. As for the (RI) for the sites, it was also of the low Potential Ecological Risk for all sites.

6. The results also showed that the values of the pollution parameters increased in the samples of the second, third and fourth transect soils and it was observed that the samples of the sixth transect were the least affected and polluted than the others.

Pearson's correlation showed that there was a weak correlation in general for soil characteristics with concentrations of heavy metals ranged between a weak positive correlation for the metals with clay, CEC and pH and a weak negative correlation with organic matter and positive, significant correlation with salinity and a negative, weak correlation with the distance from the plant site.

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