Al-Qadisiyah Journal of Pure Science

Volume 26 | Number 4 Article 7

8-15-2021

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Recommended Citation
Khudhur, Nashmeel Saeed; Yassin, Sidra Qubad; Hassan, Ahmed Saman; and Omar, Mortatha Nawzad (2021) "Applying Some Indices For Soil Pollution Assessment In Northern Industrial Area From Erbil Governorate," *Al-Qadisiyah Journal of Pure Science*: Vol. 26: No. 4, Article 7.
DOI: 10.29350/qjps.2021.26.4.1385
Available at: https://qjps.researchcommons.org/home/vol26/iss4/7

Al-Qadisiyah Journal of Pure Science

ISSN(Printed): 1997-2490 ISSN(Online): 2411-3514

DOI: /10.29350/jops.

http://qu.edu.iq/journalsc/index.php/JOPS

Applying Some Indices for Soil Pollution Assessment in Northern Industrial Area from Erbil Governorate

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Article History

Received on: 21/6/2021
Revised on: 4/7/2021
Accepted on: 5/7/2021

Keywords:

Soil pollution, Heavy metals, Industrial area, Pollution indices, Toxicity.

DOI: https://doi.org/10.29350/jops. 2021.26. 4.1385

ABSTRACT

Soil pollution by some heavy metals including: Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Cd and Pb from northern industrial area of Erbil City was assessed. The contamination indices including: geoaccumulation index (I_{geo}), contamination factor (CF), enrichment factor (EF), degree of contamination (C_{deg}), pollution load index (PLI) and element contamination index (ECI) were applied to assess soil pollution in Erbil North Industrial area at three sites (for both surface and sub-surface soils). Maximum Fe value 34243.6 ppm was recorded in sub-surface soil (site 2). Maximum values 265.4, 248.8, 98.23 and 397.45 ppm were recorded for Cr, Ni, Cu and Zn at sub-surface soil (site 3). Whereas, maximum values of 22.52, 5.36, 23.9, 6.12 and 65.67 ppm were recorded for As, Mo, Ag, Cd and Pb at surface soil (site 3). Results of analysed heavy metals for soil Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Ag, Cd and Pb have shown that the studied sites were severely contaminated with Cd, so the maximum detected Cd concentration was 6.12 ppm in surface soil (300 meters away from the industrial area). The soil pollution in the studied area was classified as moderate to strong surface and sub-surface soil contamination. Behavioral toxicity experiment showed slight growth effect on *Lepidium sativum* L.

1. INTRODUCTION

Soil receive a myriad of waste products and chemicals used in modern industrial society. With industrial progress, soil contamination with toxic heavy metals is spreading throughout the world. Huge amounts of toxic heavy metals have released into the environment from various industrial, agricultural and military operations which cause deleterious effects on soils, water and air [14].

Soil contamination by heavy metals like chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), cadmium (Cd) and cupper (Cu) are consequently the most critical environmental problems. It poses significant impacts on human health as well as the ecosystems because they cannot be naturally degraded as organic pollutants and they accumulate in different parts of the food chain [13]. Some activities like smelting and mining of metals, use of fertilizers and pesticides in agriculture, burning of fossil fuels, production of batteries and other metal

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products in industries, sewage sludge and municipal waste disposal release huge amount of heavy metals to the soil [18].

Because of their persistence and toxicity, heavy metals are dangerous. Soil acts as a sink for heavy metals through sorption, complexation, and precipitation reactions. Due to proximity to humans, accumulation of harmful substances in urban soils is of great concern. Heavy metals may transferred to human bodies by ingestion, inhalation and dermal contact, or through food chains [22]. According to the United Nation Environmental Program (UNEP), Percy *et al.* (1997) sited in [6] reported that out of the forty heavy metals in the earth, arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg) and nickel (Ni) are the most common heavy metals that considered as pollutants. In particular the metals arsenic, antimony, lead, mercury, copper, chromium and chromium VI (the soluble compound), can have adverse harmful effects on human health and the environment and thus it should be tested [22].

Plant growth and yield reduction has been recorded as a result of changes in physiological and biochemical processes when they are growing on heavy metal polluted soils which eventually leads to food insecurity [17]. Excessive uptake of metals by plants may produce toxicity in human nutrition, and cause acute and chronic diseases. For instance, Zn and Cd can lead to acute respiratory and gastrointestinal damages as well as cause acute heart, brain and kidney damages. High concentrations of soil heavy metals can negatively affect crop growth, as these metals interfere with metabolic functions in plants, including biochemical and physiological processes, inhibition of photosynthesis, respiration and degeneration of main cell organelles, even leading to death of plants [5]. Heavy metals also affect chlorophyll content, vegetable biomass and antioxidative enzyme activities. Heavy metals are accumulate in crops and result in crop biomass and chlorophyll content decreasing [17].

Pollution index is a powerful tool for ecological geochemistry assessment. Widely, they are considered as a useful tool for the comprehensive evaluation of the degree of contamination. Furthermore, particularly in the case of farmlands, pollution indices can be very useful in assessing soil quality and predicting future ecosystem sustainability [16].

The aim of this study is to:

1. Assess heavy metal pollution of surface and sub-surface soil in North industrial area.
2. Predict the effect of heavy metals on vegetation growth around this area by applying a toxicity experiment.
3. Assess the degree of contamination using different pollution indices including: Geoaccumulation Index (I_{geo}), Enrichment Factor (EF), Contamination Factor (CF), Degree of Contamination (C_{deg}), Pollution Load Index (PLI) and Element Contamination Index (ECI) on the base of different local geochemical backgrounds for the studied total concentrations of heavy metals Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Cd, Pb and Al.

2. MATEREAL AND METHODS

2.1. Study area

Erbil governorate is the capital of Iraqi Kurdistan Region. It is one of the oldest continuously inhabited communities in the world that founded before 2300 B.C. [2]. Geographically, Erbil is elevates 414 m a.s.l. and it locates on longitude 43° 15' E and latitude 35° 11' N to 37° 24 N'. It covers a total of 16484 km^2 with population of 1300000 [29]. The city is situates within recent sediment that belongs to palaeocin age and represents old river sedimentation which came from Backtaric formation. Their stones are composed of lentical and stratigraphs from stone, sand, silt and alluvial [10].

Because it is originates from limestone and dolomite of different formation, the soil of Erbil is calcareous [7] and contain 1-2% organic matter and this type of soil occurs in areas with hot-dry summers and cold-rainy winters. Erbil climate is most closely approaches Irano-Turanian type which characterized by cold winters, mild-growing period of springs and hot summers and locates in semi-arid zone [8].

North industrial area situates in north of Erbil City (Figure 1), that compromised as the major center for automobile repairing, auto-mechanics, panel beaters, spraying painters and servicing and in some cases, car wash personnel [14]. In February 2021, and by using core sampler (10 cm height and 5 cm diameter), triplicate soil samples from two different depths (0 and 5 cm depth) were taken into polyethylene bags in three different distances away from the center of the area which were: 200, 300 and 400 meters away from the industry. The soil samples were then taken to the laboratory for analysis. Soils were air-dried at room temperature (25°C), crushed and then sieved through 2 mm stainless sieve to remove debris [21]. The amount of heavy metal in the soils were determined by XRF device (Genius 5000 XRF) [26].

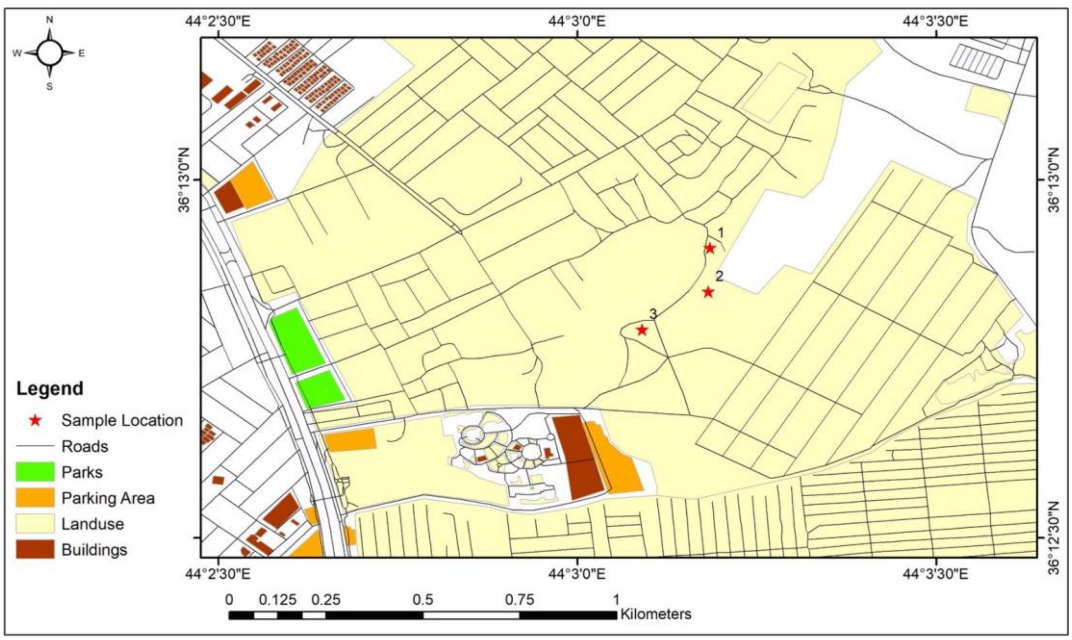

Figure 1: North industrial area of Erbil City showing the studied sites.

2.2. Analysis of pollution indices

2.2.1. Index of Geoaccumulation (I_{geo})

The index of geoaccumulation (I_{geo}) was calculated by the proposed formula by Muller (1969) and is given by [19] using the following mathematical relation:

$$I_{geo} = \log_2 [C_n/1.5B_n] \quad \text{................} \quad (1)$$

Where: C_n is the measured total concentration in the soil with the metal n, B_n is the background value for the metal n, the factor 1.5 (correction factor) is used because of possible variations of the background data due to lithological variations.

2.2.2. Enrichment Factor

The Enrichment Factor (EF) is a normalization method proposed by Simex and Helz (1981) to assess the concentration of the metals as given by [15]. For the present study, EF has been chosen to normalize metal concentrations using Al. The EF is defined as follows:

$$EF = (M/Al)_{\text{Sample}} / (M/Al)_{\text{Background}} \text{ .... (2)}$$

Where: $(M/Al)_{\text{Sample}}$ is the ratio of metal and Al concentrations in the sample $(M/Al)_{\text{Background}}$ is the ratio of metal and Al concentrations of the background.

2.2.3. Contamination Factor (CF)

The contamination Factor (CF) is the concentration of each metal in the soil divided by the background concentration of the metal (concentration in unpolluted soil).

$$CF = C_{\text{Heavy metal}} / C_{\text{Background}} \text{ .... (3)}$$

The background concentrations were calculated from the heavy metal concentration in unaffected soils of the studied area [15].

2.2.4. Pollution Load Index (PLI)

The Pollution load index (PLI) provides an empirical index that comparatively assesses the level of heavy metal pollution. The PLI for the various sampling areas were determined as the geometric mean of all assessed CF of a sampling site [1].

$$PLI = (CF_1 \times CF_2 \times CF_3 \times .... \times CF_n)^{1/n} \text{ .... (5)}$$

$_n$ is the number of metal index providing a simple, comparative means for assessing the level of heavy metal pollution. A value of PLI < 1 denotes perfection. PLI = 1 indicates that only baseline levels of pollutants are present, and PLI > 1 would indicate deterioration of the site quality.

2.2.5. Degree of Contamination (C_{deg})

It is a modified and generalized form of the degree of contamination (C_{deg}) formula proposed by Hakanson, 1980 and given by [15]. It is calculated by the following equation:

$$C_{deg} = \sum (C_m / B_m)^i \text{ .... (4)}$$

Where: i represents the respective metals (i.e. K, Ca, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Cd, Pb and Al), C_m is the measured concentration in the soil, and B_m is the background concentration value of metal (m) within the area of study. For the C_{deg}, Hakanson recognized four descriptive classes, where by $C_{deg} < 8$ implies a low degree of contamination, C_{deg} 8-16 means a moderate degree of contamination, C_{deg} 16-32 indicates a considerable degree of contamination and $C_{deg} \geq 32$ implies a very high degree of contamination.

2.2.6. Element Contamination Index (ECI)

Element contamination index (ECI) is an expression of a single metal contamination within a sample or combined metal contamination for a sample relative to the background values of the respective metal [23]. They are expressed as:

$$ECI = (C_m - B_m / B_m) \text{ .... (6)}$$

Where i C_m and B_m are as defined earlier. MCI was designed to describe general trace elements contamination. MCI of < 5 implies a very low contamination; MCI = 5-10 means low contamination; MCI = 10-25 denotes medium contamination; MCI = 25-50 means high contamination; MCI = 50-100 implies a very high contamination and MCI > 100 implies an extremely high contamination.

2.3. Toxicity experiment

A pot experiment was conducted to detect the growth of garden cress seeds (*Lepidium sativum* L.) in the polluted soil taken form the industrial area. Pots were sown with seeds of garden cress and control pots of unpolluted soil were used for comparison of results. Behavioral toxicity was studied during a period of two weeks inside the pots. The scientific classification of *L. sativum* is given in Table 1.

Table 1: Scientific classification of garden cress seeds (*Lepidium sativum* L.).

Kingdom:	Plantae
Order:	Brassicales
Family:	Brassicaceae
Genus:	*Lepidium*
Species:	L. *sativum*

Taken from: [11].

2.4. Statistical analysis

The obtained data during the present study was statistically analysed using SPSS version 23 and Microsoft Excel 2019. All data expressed as mean values, the difference among the means of heavy metals were compared by one-way ANOVA analysis with applying Duncan multiple comparison tests at level of significant 5%. Heatmaps were made by Gnuplot version 5.4.

3. RESULT AND DISCUSSION

3.1. Soil heavy metal values

The analytical results for the studied soil samples are summarized in Table 2. The metals Cr, Mn, Fe, Ni, Cd, Cu, Pb, As, Mo, Ag, and Zn occur as anthropogenic activity in the soil at a level which depends initially on the location from the center and subsequently on redistributive processes such as leaching.

Table 2: Summary of heavy metal values (ppm) in the study area.

Metals	Site 1 (200 m)		Site 2 (300 m)		Site 3 (400 m)	
	Surface	Depth	Surface	Depth	Surface	Depth
Cr	201.5^{a}	102.8^{c}	193.1^{b}	155.8^{b}	142.7^{c}	265.5^{a}
Mn	765.7^{b}	741.7^{b}	534.1^{c}	721.9^{c}	790.3^{a}	845.1^{a}
Fe	30572.8^{b}	25771.0^{c}	30870.9^{a}	32352.0^{b}	29559.3^{c}	34243.6^{a}
Ni	214.5^{b}	243.2^{b}	136.1^{c}	111.9^{c}	217.4^{a}	248.8^{a}
Cu	41.6^{b}	7.01^{c}	35.07^{c}	68.26^{a}	98.23^{a}	39.03^{b}
Zn	134.3^{b}	60.11^{c}	51.37^{c}	310.4^{a}	397.5^{a}	101.3^{b}
As	12.7^{b}	8.18^{b}	3.63^{c}	5.62^{c}	22.52^{a}	15.45^{a}
Mo	0^{c}	0^{b}	5.36^{a}	1.39^{a}	4.47^{b}	0^{b}
Ag	20.15^{a}	12.68^{b}	17.42^{b}	12.35^{c}	4.58^{c}	23.95^{a}
Cd	4.89^{c}	1.97^{c}	6.12^{a}	2.81^{a}	1.54^{b}	1.65^{b}
Pb	25.29^{b}	0^{c}	3.24^{c}	7.61^{b}	65.68^{a}	17.22^{a}

The maximum values of Fe, Cr and Ni were 34243.6, 265.4 and 248.8 ppm observed in sub-surface soil at site 3, while surface soil at the same showed the highest Cu and Zn concentrations (98.23 and 397.5 ppm) respectively (Figure 2).

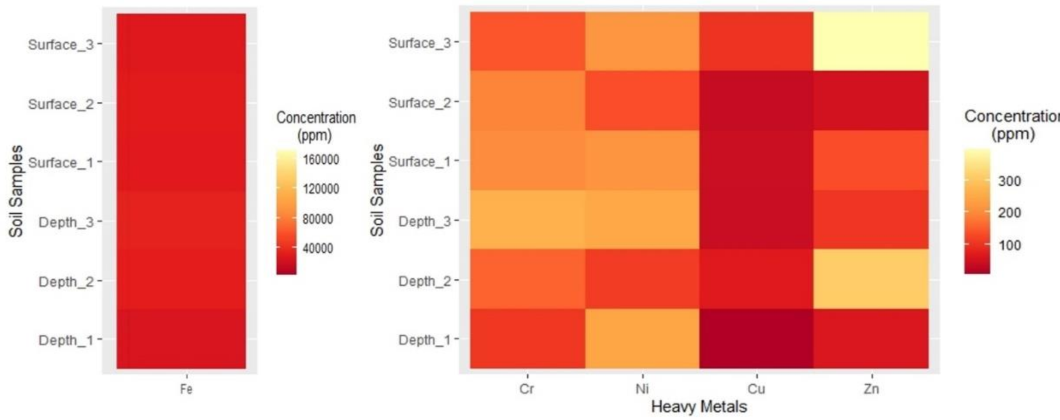

Figure 2: Heatmap of Fe, Cr, Ni, Cu and Zn values in the studied area.

Surface soil at site 3 showed the highest values of As (22.52 ppm) and Pb (65.67 ppm), whereas maximum values of Mo (5.36 ppm) and Cd (6.12 ppm) were observed in surface soil at site 2 and the maximum Ag (23.9 ppm) value was detected in subsurface soil at site 2 (Figure 3). It was assumed that the main source of the contaminating metals was loss of metal-rich materials during industrial activity and scraps and other possible sources, e.g., long distance atmospheric transport of metals or Pb in vehicle exhausts.

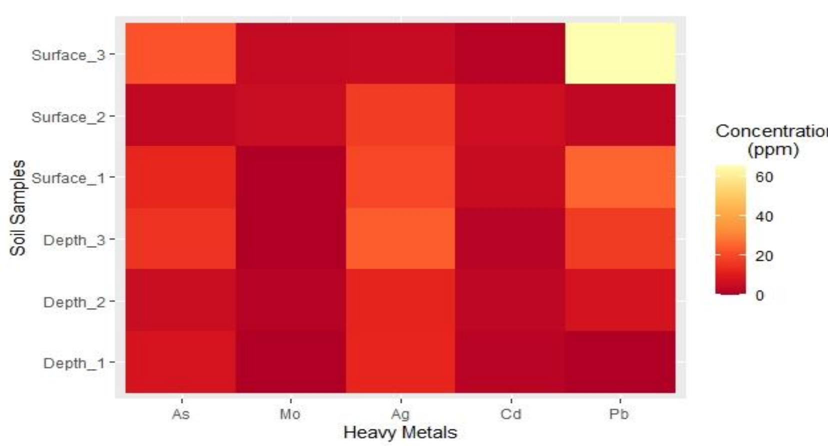

Figure 3: Heatmap of As, Mo, Ag, Cd and Pb values in the studied area.

3.2. Soil contamination assessment results

3.2.1. Index of geoaccumulation (Igeo)

The calculated I_{geo} values for the studied heavy metals are shown in Table 3, and compared to the Index of Geoaccumulation (I_{geo}) for contamination levels in the soil (Table 4). The I_{geo} values indicated uncontaminated to moderately contaminated soils in many of the studied sites (Figure 4). Surface soil from site 1 (100 m away from the industrial area) was strongly contaminated with Cd (I_{geo} = 3.72), and surface soil from site 2 (200 m away from the industrial area) was strongly to extremely contaminated with Cd (I_{geo} = 4.05). Elevated Cd concentrations are largely the result of the metallurgical industry, bearing and brushing wear, moving engine parts, corrosion of Cd plumbing, fungicides and insecticides, phosphate fertilizers, concrete and asphalt, rubber and sewage sludge [4]; hence, concentrations found in Erbil Industrial area have been significantly influenced by anthropogenic activities.

Table 3: Index of Geoaccumulation (I_{geo}) for different sites.

Studied metals	**Index of Geoaccumulation (I_{geo})**					
	Site 1 (200 m)		**Site 2 (300 m)**		**Site 3 (400 m)**	
	Surface	**Depth**	**Surface**	**Depth**	**Surface**	**Depth**
Cr	0.94	-0.03	0.88	0.57	0.44	1.34
Mn	-0.21	-0.26	-0.73	-0.30	-0.17	-0.07
Fe	-0.25	-0.50	-0.24	-0.17	-0.30	-0.09
Ni	0.41	0.60	-0.25	-0.53	0.43	0.63
Cu	0.29	-2.29	0.04	1.00	1.53	0.19
Zn	0.77	-0.40	-0.63	1.98	2.34	0.36
As	0.45	-0.19	-1.37	-0.74	1.27	0.73
Mo	0.00	0.00	2.61	0.65	2.35	0.00
Cd	3.72	2.41	4.05	2.92	2.05	2.15
Pb	1.02	0.00	-1.96	-0.72	2.40	0.46

Table 4: Index of geoaccumulation (I_{geo}) for contamination levels in the soils.

I_{geo} Class	***I_{geo} Value***	***Contamination Level***
0	*$I_{geo} \leq 0$*	*Uncontaminated*
1	*$0 < I_{geo} < 1$*	*Uncontaminated/moderately contaminated*
2	*$1 < I_{geo} < 2$*	*Moderately contaminated*
3	*$2 < I_{geo} < 3$*	*Moderately/strongly contaminated*
4	*$3 < I_{geo} < 4$*	*Strongly contaminated*
5	*$4 < I_{geo} < 5$*	*Strongly/extremely contaminated*
6	*$5 < I_{geo}$*	*Extremely contaminated*

* Taken from [15].

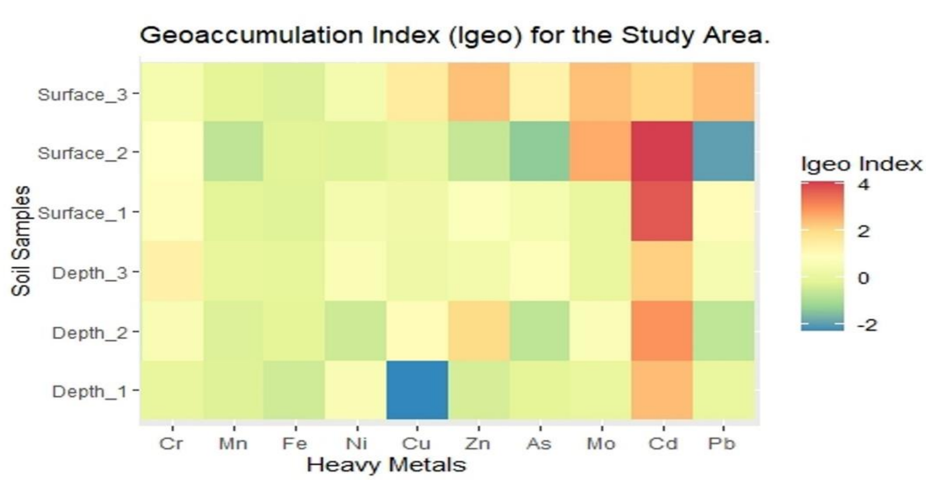

Figure 4: Heatmap of geoaccumulation index of the studied soils.

However, some of the studied sites were moderately to strongly contaminated with Zn, Mo, Cd and Pb. Moreover, there were no contamination with Fe in all of the studied sites.

Pb I_{geo} values found indicate moderate contamination in the soil samples, but the maximum value of I_{geo} (2.40) denotes moderate to strong contamination. Automobile emissions have contributed significant amounts of Pb to the environment. The legacy of automobile pollution remains even though the current contribution of Pb from vehicle emissions is negligible. The high Pb fluxes associated with past emissions have been stored in the soil and are now being remobilized by surface erosion processes, contributing to soil dust contamination. The accumulation of metals in the soil is a long-term process and it is difficult to remove these substances in a short period. The sources of Cr, Co, Cu, and Zn are come from industrial emissions and the practice of using mixed sewerage to irrigate croplands [30]. [24] pointed out that potential anthropogenic sources of Ni include vehicle exhaust, diesel fuel, metal plating, lubricating oil, brushing wear, asphalt paving, brake lining wear, phosphate fertilizers and storage batteries. Clear signs of pollution are present for Cd, Mo, Zn and Pb (Figure 4).

3.2.2. Enrichment factor (EF)

The enrichment factor (EF) is indicator used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil and it is a convenient measure of geochemical trends which applied for speculating on lithogenic or anthropogenic origin of heavy metals [24, 31].

The results of the Enrichment Factor of the studied metals are tabulated in Table 5. EF values for the studied metals were ranged from 0 to 24.48, indicating minimal to very high enrichment soil when the values were compared with Table 6.

Table 5: Enrichment Factor (EF) for different sites.

Heavy Metals	Enrichment Factor (EF)					
	Site 1 (200 m)		Site 2 (300 m)		Site 3 (400 m)	
	Surface	Depth	Surface	Depth	Surface	Depth
Cr	2.88	1.47	2.76	2.23	2.04	3.79
Mn	1.30	1.25	0.90	1.22	1.34	1.43
Fe	1.26	1.06	1.27	1.33	1.22	1.41
Ni	2.00	2.26	1.27	1.04	2.02	2.31
Cu	1.83	0.31	1.54	3.00	4.32	1.72
Zn	2.55	1.14	0.97	5.88	7.53	1.92
As	2.04	1.31	0.58	0.90	3.61	2.48
Mo	0.00	0.00	9.09	2.36	7.57	0.00
Cd	19.56	7.89	24.48	11.25	6.16	6.60
Pb	3.03	0.00	0.39	0.91	7.87	2.06

Table 6: Soil contamination categories based on enrichment factor (EF). *

EF Value	***Contamination Level***
EF < 2	*Minimal enrichment*
EF = 2-5	*Moderate enrichment*
EF = 5-20	*Significant enrichment*
EF = 20-40	*Very high enrichment*
EF > 40	*Extremely high enrichment*

* Taken from [15].

Surface soils from all of the studied sites showed greater enrichment in comparing with the sub-surface soil indicating their anthropogenic sources. Surface soil from site 3 (400 m away from the industrial area) showed significant enrichment by EF values of 7.53 for Zn, 7.57 for Mo, 6.16 for Cd and 7.87 for Pb. Moreover, significant enrichments were observed with Zn, Mo, Cd and Pb in sites 1, 2 and 3 (Figure 5). Whereas most of the studied soils showed moderate to minimal enrichment as some researchers suggest that heavy metals with EF values less than 2 were not a major concern contaminant [31, 9].

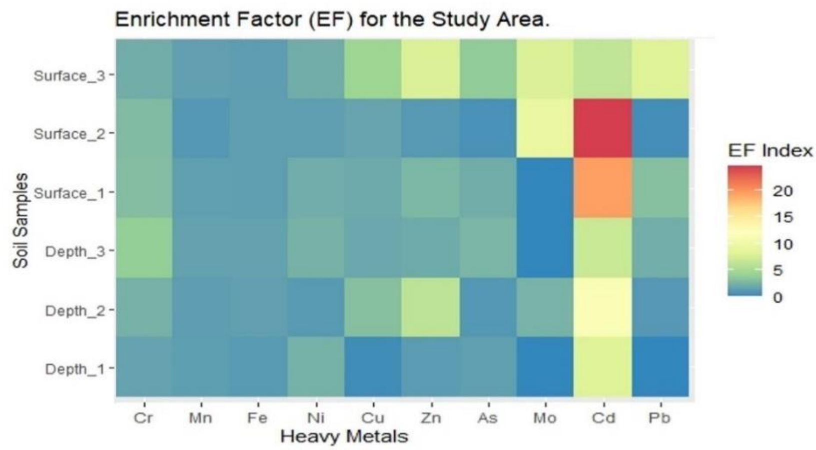

Figure 5: Heatmap of enrichment factor (EF) of the studied soils.

Some heavy metals has EF values 2 – 5 for Cr, Ni, Cu and As indicating moderate enrichment. By contrast, the collected soil samples in the surface and sub-surface layers has relatively higher EF values 5–20 for Cd. This indicates that a severe degree of Cd contamination may be possible in the study area. The obtained variations in EF values may due to the differences in the magnitude of input for each metal in the soil. Generally, it has observed that the maximum EF values of heavy metals in the studied soils out of the center zone (200 m) were higher than those found in the peripheral zone, suggesting that the soil samples located farthest away from the center of industries may have high potential to be enriched soil with such heavy metals. Previously, it has been reported that heavy metals such as Cd, Pb, Cr, and As are the most abundant metals found in soils around industrial sites [12], mainly due burning of residual oils as well as the steel factory [15]. Overall, it is possible that the industrial areas can be polluted with heavy metals, attributing to the industrial and human activities [3, 32, 28].

3.2.3. Contamination factor (CF), pollution load index (PLI) and degree of contamination (C_{deg})

The determined values of contamination factor (CF) and pollution load index (PLI) are shown in Table 7 and Figure 6. The contamination factor was used to determine the contamination status of the soils. Generally, according to CF values in the studied soils, most of the elements were categorized as low to moderate contamination (1 < CF < 3). Whereas, Cd showed very high contamination since it has CF > 6 that ranged between 6.16 and 24.48.

Table 7: Contamination Factor (CF) for different sites.

Heavy Metals	Contamination Factor (CF)					
	Site 1 (200 m)		Site 2 (300 m)		Site 3 (400 m)	
	Surface	Depth	Surface	Depth	Surface	Depth
Cr	2.88	1.47	2.76	2.23	2.04	3.79
Mn	1.30	1.25	0.90	1.22	1.34	1.43
Fe	1.26	1.06	1.27	1.33	1.22	1.41
Ni	2.00	2.26	1.27	1.04	2.02	2.31
Cu	1.83	0.31	1.54	3.00	4.32	1.72

Zn	2.55	1.14	0.97	5.88	7.53	1.92
As	2.04	1.31	0.58	0.90	3.61	2.48
Mo	0.00	0.00	9.09	2.36	7.57	0.00
Cd	19.56	7.89	24.48	11.25	6.16	6.60
Pb	3.03	0.00	0.39	0.91	7.87	2.06
PLI	**5.18**	**4.48**				
C_{deg}	**38.81**	**21.82**	**47.93**	**38.97**	**52.10**	**20.07**

Table 8: Soil contamination categories based on contamination factor (CF). *

CF Value	***Contamination Level***
CF<1	*Low contamination*
1<CF<3	*Moderate contamination*
3<CF<6	*Considerable contamination*
CF>6	*Very high contamination*

* Taken from [15].

Considerable contaminations with Cr at site 3 (CF = 3.79), Cu at site 3 (CF = 4.32), Zn at site 2 (CF = 5.88), As at site 3 (CF = 3.61) and Pb (CF = 3.03) as tabulated in Table 7. In addition to Cd, Zn, Mo and Pb showed very high contamination with CF > 6 (Figure 6).

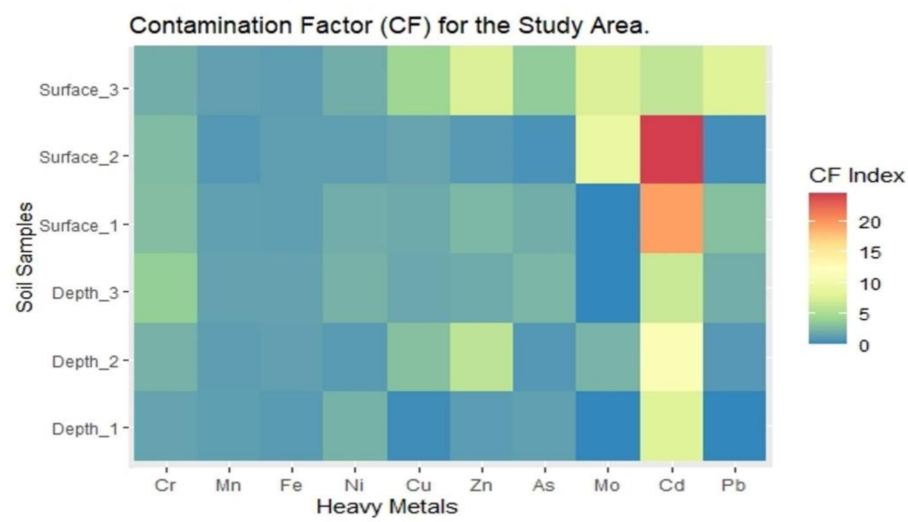

Figure 6: Heatmap of contamination factor (CF) of the studied soils.

Pollution load index (PLI) is used to evaluate the extent of pollution by heavy metals in the environment. If PLI < 1, there is no heavy metal pollution [25]. The values of PLI > 1 imply that heavy metal pollution exists in the study areas. The calculated pollution load index (PLI) from CF values showed that the soils undergo medium to strong contamination by the investigated heavy metals. PLI for the surface soils was 5.18 and for the sub-surface soils was 4.48.

The highest degree of contamination (C_{deg}) was 52.10 observed in surface soil at site 3 (Table 7) indicating that surface soil from this site has a very high degree of contamination, whereas sub-urface soil from the same site has lowest C_{deg} of 20.07 indicating a considerable degree of contamination.

3.2.4. Element Contamination Index (ECI)

Element contamination index (ECI) of the studied soils were 18.56, 23.48 and 10.25 (Table 9) for surface soil in site 1 and both surface and sub-surface soils in site 2 respectively, indicating moderate contamination with Cd by referring to Table 10. Moreover, there were low contamination with Zn, Mo and Pb in surface soil of site 2 and 3 (Figure 7).

Table 9: Element contamination index (ECI) for different sites.

Heavy Metals	Element contamination index (ECI)					
	Site 1 (200 m)		Site 2 (300 m)		Site 3 (400 m)	
	Surface	Depth	Surface	Depth	Surface	Depth
Cr	1.88	0.47	1.76	1.23	1.04	2.79
Mn	0.30	0.25	-0.10	0.22	0.34	0.43
Fe	0.26	0.06	0.27	0.33	0.22	0.41
Ni	1.00	1.26	0.27	0.04	1.02	1.31
Cu	0.83	-0.69	0.54	2.00	3.32	0.72
Zn	1.55	0.14	-0.03	4.88	6.53	0.92
As	1.04	0.31	-0.42	-0.10	2.61	1.48
Mo	-1.00	-1.00	8.09	1.36	6.57	-1.00
Cd	18.56	6.89	23.48	10.25	5.16	5.60
Pb	2.03	-1.00	-0.61	-0.09	6.87	1.06

Table 10: Soil contamination categories based on metal contamination index (MCI). *

CF Value	*Contamination Level*
MCI<5	*Very low contamination*
MCI=5-10	*Low contamination*
MCI=10-25	*Moderate contamination*
MCI=25-50	*High contamination*
MCI=50-100	*Very high contamination*
MCI>100	*Extremely high contamination*

* Taken from [15].

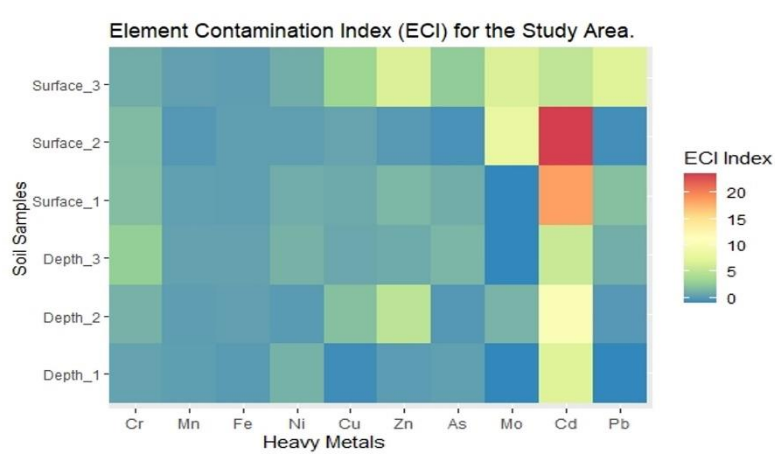

Figure 7: Heatmap of element contamination index (ECI) for the studied soils.

3.3. Result of the toxicity experiment

Ecotoxicity tests evaluate the effect of environmental contamination on organisms through assessment of survival, growth, reproduction and behavior. These tests help to determine whether the contaminant concentration at remediated sites is high enough to cause adverse effects on organisms [27]. Behavioral toxicity of polluted soil from the industrial area on *L. sativum* was monitored for two weeks inside the pots. The polluted soil was slightly affected the growth of *L. sativum* when compared to control pots (Figure 8).

Figure 8: Ecotoxicity experiment of pots cultivated with *L. sativum*.

4. CONCLUSION AND RECOMMENDATION

Industrial and anthropogenic activities bring about serious heavy metal pollution. Results of metal occurrence indicated that Cd was the most dominant metal; however, Ag and Mo were the least dominants. According to U.S. EPA, Cd, Zn, Ni, Cr and Cu have exceeded the acceptable limit for soil. The studied index classify the sites as follow: Geoaccumulation index showed strong to extreme contamination with Cd in surface soil at site 2. Enrichment factor showed very high-enriched soil with Cd at site 2. Very high soil contamination with Cd, Zn, Mo and Pb were observed in the studied sites. Surface soils showed greater pollution load index in comparing with the sub-surface soils. The greatest degree of contamination was observed in surface soil at site 3. Finally and according to element contamination index values, surface soils at sites 1 and 2 have moderate contamination with Cd. *L. sativum* revealed slightly lower growth in polluted soil indicating that the heavy metals affecting its growth. Thus, for the contaminated sites more detailed follow-up work is recommended to identify and explain the origin and source of soil contamination. More toxicity experiments are required to clarify the effects of metal contamination of living organisms in such sites.

Conflict of Interest: The authors declare that they have no conflict of interest.

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