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Enrichment Factor and Geo-accumulation Index for Heavy Metals at Industrial Zone in Iraq

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***Abstract*:** *This field study was conducted in Al Anbar Province in Iraq in order to identify the level of contamination inlarge industrial zones, 8samples soil had been collected with depth (0-2)cm, were analyzed by X-ray Fluorescence for 6 metals (Pb, Ni, Cd, Co, Cr, Cu).calculated Enrichment Factor and Geo-accumulation Index to assess quantitatively the influences of human activities by these heavy metals.*
Keyword: *Heavy metal, Soil , Enrichment Factor , Geo accumulation Index , Pollutant.*

I. Introduction

The problem of pollution is one of the most urgent environmental problems Which began to take a serious environmental dimensions, economically and socially with large expansion supported by modern technology [1]. The pollution extends to include even air and soilis addition to water and food caused by intense and unplanned industrial activity and absence treatment of industrial waste[2].

The researchers such as Adel MashaanRabeeand others studied (Using Pollution Load Index (PlI) and Geo-accumulation Index (I-Geo) six stations along Tigris river in Baghdad region; 2011)they have collected samples from six stations along Tigris river to assess level of pollution by (Mn , Ni , Pb, Cu and Cd).Indicating that the studied stations in Tigris river were unpolluted by total studied heavy metals [3].

The researchers such as RashidaNazir and others during their studies of (Indoor/outdoor relationship of trace metals in the atmospheric particulate matter of an industrial area; 2011) collected samples of aerosols inside and outside homes in industrial areas using a high volume air sampler on glass fiber filters and through the analysis of these samples chemically and measured device atomic absorption spectrometry have proved the presence of some of the heavy elements[4]

The researchers such asJingliang Mei with others studied (Assessment of Heavy Metals in the Urban River Sediments in Suzhou City, Northern Anhui Province, China; 2011) they collected 12 samples were analyzed by X-ray Fluorescence for metals (Fe, Cu, Zn, As and Pb) Enrichment Factor (EF) and Geo-accumulation index (Igeo) were used to quantitatively assess the influences of human activities , they found that the sediments in urban river were polluted by Cu, Zn, and Pb [5] .

The researchers such as M.chakravarty and others studied (Metal Pollution Assessment in Sediment of the Dikrong River, N.E. India ;2009) for metals (Al, Fe, Ti, Mn, Zn, Cu, Cr, Ni and Pb) have been studied and assessed by using Enrichment Factor, Pollution Load Index and Geo-accumulation Index. They have achieved that sediment have been contaminated by Cu and Pb.[6]

Based on the above method researches, it is necessary to investigate and assess concentration by heavy metals in industrial .

II. Background and sample collection

Study region: Study region is located at industrial zone at Al-anbarprovince which is located in the western part of Iraq at the longitude and latitude (41° 36' 0" E, 32° 54' 0" N). Anbar provincehas mineral resources which encourage province and public sectors to establish many factories such as cement, phosphate,fertilizers, glass, ceramics and many of Construction materials factories [7].

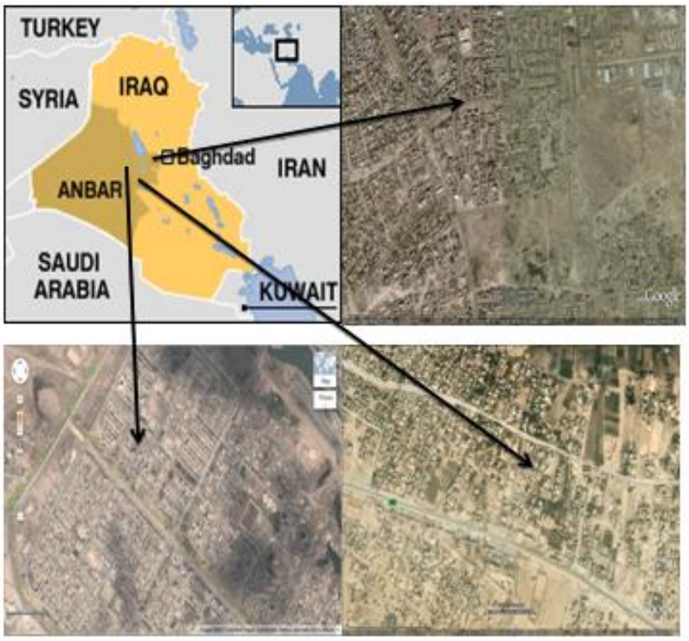

Fig1: show study area

Sampling: Only soil samples had been collected with depth (0-2) by using a homemade soil sampler.. Soil sampling was carried out from October to December 2013.All the samples were taken from industrial zone except one sample which has been taken from far away from any industrial zone activity. First of all samples were air-dried in natural condition, and the debris of animals and plants had been removed by hands. Then grinded and passed through a sieve (2mm) .
Analysis of samples: the samples had been analyzed by X-Ray Fluorescence and SPECTRO XEPOS device from AMETEK was used for this purpose. The charts were drawn by using STATISTICA software (StatSoft, 1999).

III. Result anddiscussion

Heavy metals can produce complex compoundswhich are very harmful for human health . The following tables shows the value of heavy metals [Pb, Ni, Cd, Co, Cr, Cu] concentration.

Table 1: Heavy metals concentration (ppm) of soil samples at industrial zone

Zone	Pb	Ni	Cd	Co	Cr	Cu
A1	11	127.3	2	3.9	716.5	19.7
A2	19.4	86.9	2	8.5	214.2	8.5
A3	27	176.9	2	8.5	432.3	8.5
A4	244.6	98.9	2	3.9	450.1	3131
A5	34.7	141.3	2	9.2	529.6	48.9
A6	12.3	127.	2	3.9	781	28.3
A7	16.4	130.9	2	3.9	804.1	30.3
A8	56.1	96	2	14.6	386.8	49.6

Table 2: shows the minimum, maximum ,mean, with global average and zero level concentration

	Mean	**Minimum**	**Maximum**	**global average**	**zero level**
Pb	52.68750	11	244.6	10	9
Ni	123.15	86.9	176.9	40	91.8
Cd	2	2	2	0.06	2
Co	7.05	3.9	14.6	8	3.9
Cr	539.3250	214.2	804.1	100	169.3
Cu	415.6	8.5	3131	30	16.5

Zero level: means the concentrations of heavy metals at area far away from any industrial zone.
The concentration of Pb ranging from (11 ppm ~ 244.6 ppm)with mean value(52.68750)has exceeded the global average [8], zero level and mean value five time and at A4 zone Pb concentration exceeded more than 200% of global average. Ni concentration began from 86.9 ppm ~ 176.9 ppm with mean value (123.15) ppm which is more than global average and zero level . Cd in all zones had same concentration even at zero level but hasexceeded global average. While Co was from 3.9 ppm to 14.6 ppm which is more than global average 8 ppm

and zero level 3.9 ppm ,more than mean value 7.05 ppm about 100% . minimum value of Cr was exceeded the global average one time , and the mean value wasexceededmore five times compare with global average, while the maximum value was exceeded eight times compare with global average value, finally Cu record concentration value from 8.5 ppm to 3131 ppm with mean value 415.6 ppm which more than global average 30 ppm about 1300% . and more than zero level 16.5 about 2600% . the value of four heavy metal (Pb, Ni, Cr, Cu) recorded peaked at measurement zone A4, A3, A7 and A4 respectively.

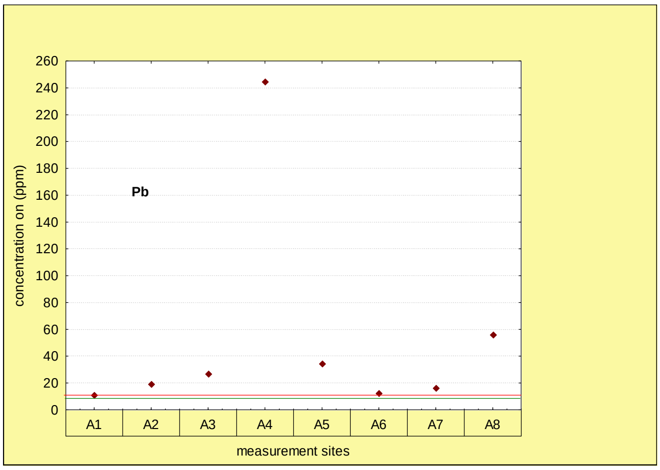

Fig 2: shows the concentration of Pb element at all measurement sites in comparison with global average value and zero level.

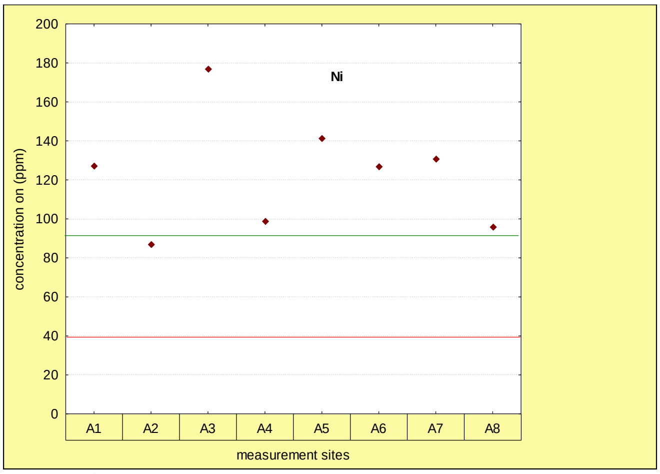

Fig 3: shows the concentration of Ni element at all measurement sites in comparison with global average value and zero level.

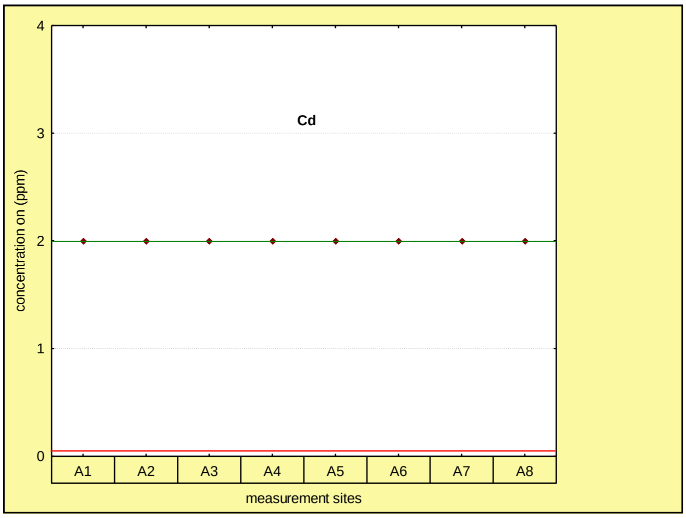

Fig 4: shows the concentration of Cd element at all measurement sites in comparison global average value and zero level.

Red line: represent global average value.**Green lin**e: represent zero level value.

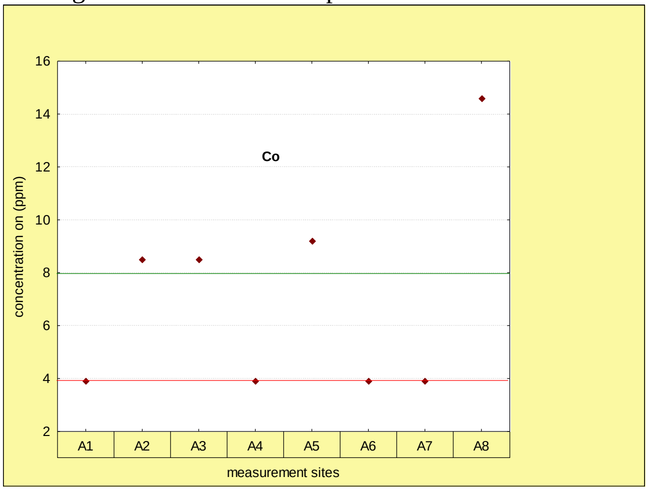

Fig 5: show the concentration of Co element at all measurement sites campier with global average value and zero level.

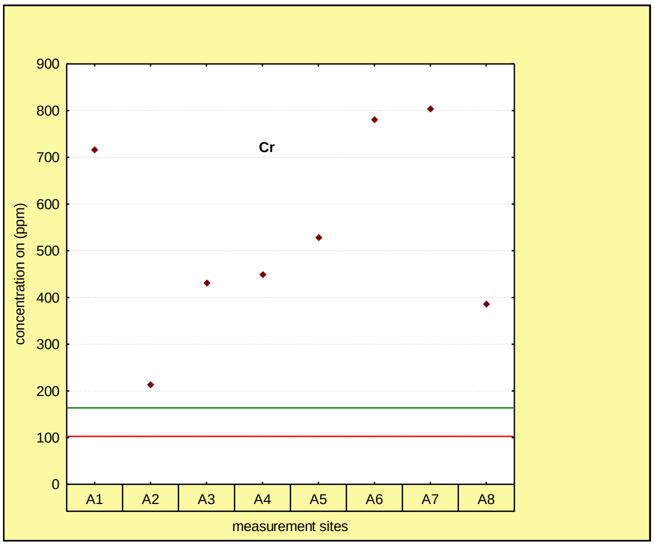

Fig 6: shows the concentration of Cr element at all measurement sites in comparison with global average value and zero level.

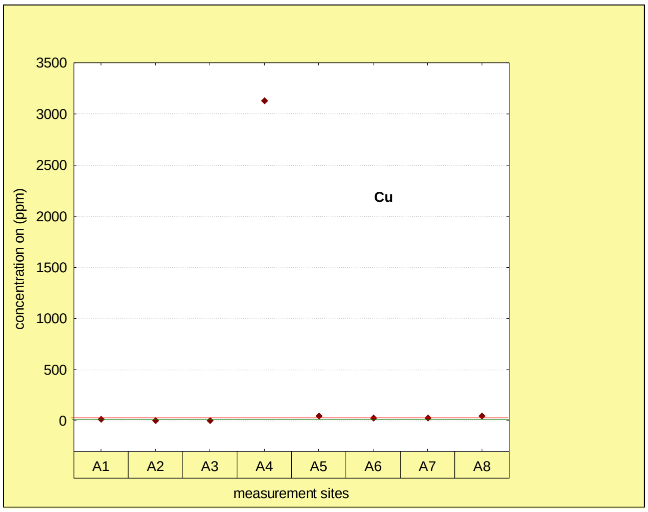

Fig 7: shows the concentration of Cu element at all measurement sites in comparison with global average value and zero level.

IV. Estimation pollution level

A. Enrichment Factor (EF):

Enrichment factor which put forward by zoller [9], is method to estimating the anthropogenic impact on sediments by calculating differentiate between the metals originating from human activities and those from natural provenance or the mixed source of the metals [9]. The EF calculation seeks to reduce the metal variability associated with variations in sediment ratios. The EF method normalizes the measured heavy metal content with respect to a sample reference metal such as Fe or Al [10]. In this study we use Fe as a sample reference metal to calculating the enrichment factor since Fe was considered that the distribution of Fe was not related to other heavy metals, and usually has a relatively high concentration in the earth, The FE is calculated by the following equation:

$$EF=(C_i/C_{ie})s/(C_i/C_{ie})\ RS$$

Where C_i is the content of elementiin the sample of interest or the selected reference sample, and C_{ie} is content of immobile element in the sample or the selected reference sample. So(C_i/C_{ie})s is the heavy metal to immobile element ratio in the samples of interest, and (C_i/C_{ie})RS is the heavy metal to immobile element ratio in the selected reference sample[9].

five contamination categories are generally recognized on the basis of the enrichment factor : EF<2,depletion to mineral enrichment; 2≤EF<5, moderate enrichment; 5 ≤EF<20, significant enrichment;20≤EF<40, very high enrichment; and EF>40, extremely high enrichment.

B. Index of geo-accumulation

Index of geo – accumulation (I_{geo}) was originally defined by Müller in 1969, in order to determine and define metal contamination in sediments, by comparing current concentration with pre- industrial levels[11]. It can be calculated by the following equation

$$I_{geo} = \log 2\,[Ci/1.5\ C_{ri}]$$

Where C_i is the measured concentration of the examined metal i in the sediment , and C_{ri} is the geochemical background concentration or reference value of the metal i . Factor 1.5 is used because of possible variations in background values for a given metal in the environment as well as very small anthropogenic influences. The geo-accumulation index (I_{geo}) was distinguished into seven classes by Muller:

Table 3:represent seven classes of geo-accumulation index by Muller.

I_{geo}	I_{geo} class	Sediment Quality
0-0	0	Unpolluted
0-1	1	Unpolluted to moderately polluted
1-2	2	moderately polluted
2-3	3	moderately polluted to highly polluted
3-4	4	Highly polluted
4-5	5	Highly polluted to very highly polluted
5-6	>5	very highly polluted

5. Result of estimation pollution level

5.1 A1 zone: Table 4: Enrichment factor and geo- accumulation index at A1 industrial zone.

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation(Igeo)	Degree of (I geo)
Pb	1.332913264	Depletion	-0.447458977	Unpolluted
Ni	3.85636042	Moderate	1.085198013	moderately
Cd	40.39131102	Extremely	4.473931188	High to very high polluted
Co	0.590722924	Depletion	-1.621488377	Unpolluted
Cr	8.682112304	Significant	2.256004204	moderately to high
Cu	0.795708827	Depletion	-1.191729372	Unpolluted

5.2 A2 zone: Table 5: Enrichment factor and geo- accumulation index at A2 industrial zone.

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	2.04721252	Moderate	0.371094152	unpolluted to moderately
Ni	2.292561443	moderate	0.534393676	unpolluted to moderately
Cd	35.17547285	very high	4.473931188	High to very high polluted
Co	11.21218197	significant	-0.497499659	Unpolluted
Cr	2.260375885	Moderate	0.513995979	unpolluted to moderately
Cu	0.337330903	Depletion	-1.541893779	Unpolluted

5.3 A3 zone: Table 6: Enrichment factor and geo- accumulation index at A3 industrial zone.

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	2.150948807	Moderate	0.847996907	unpolluted to moderately
Ni	3.523174482	moderate	1.559899642	Moderately
Cd	26.55492355	very high	4.473931188	High to very high polluted
Co	0.846438188	depletion	-0.497499659	Unpolluted
Cr	3.443908035	Moderate	1.527070336	Moderately
Cu	0.22571685	depletion	-2.404390255	Unpolluted

5.4 A4 zone: Table 7: Enrichment factor and geo- accumulation index at A4 industrial zone.

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	30.31579991	very high	4.027389998	high to very high
Ni	3.064424173	moderate	0.72100802	unpolluted to moderately
Cd	41.31343678	Extremely	4.473931188	High to very high polluted
Co	0.604209013	depletion	-1.621488377	Unpolluted
Cr	5.578553369	Significant	1.585283064	Moderately
Cu	129.3523706	Extremely	6.120554697	very high polluted

5.5 A5 zone: Table 8: Enrichment factor and geo- accumulation index at A5 industrial zone.

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	2.570884547	Moderate	1.209973162	Moderately
Ni	2.617190105	moderate	1.23572706	moderately
Cd	24.69629728	very high	4.473931188	High to very high polluted
Co	0.852022256	depletion	-0.38332864	unpolluted
Cr	3.923747713	Moderate	1.819940621	Moderately
Cu	1.207648937	depletion	0.119909464	unpolluted to moderately

5.6 A6 zone: Table 9: Enrichment factor and geo- accumulation index at A6 industrial zone.

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	1.487123685	Depletion	-0.286304185	Unpolluted
Ni	3.847781405	Moderate	1.085198013	moderately
Cd	40.30145488	Extremely	4.473931188	High to very high polluted
Co	0.589408778	Depletion	-1.621488377	unpolluted
Cr	9.442630879	Significant	2.380360048	moderately to high
Cu	1.140531173	depletion	-0.669122948	Unpolluted

5.7 result A7 zone: Table 10: Enrichment factor and geo- accumulation index at A7 industrial zone

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	1.737398563	Depletion	0.128733314	unpolluted to moderately
Ni	3.466851707	Moderate	1.125430691	moderately
Cd	35.31297893	very high	4.473931188	High to very high polluted
Co	5.164523169	significant	-1.621488377	unpolluted
Cr	8.518549908	Significant	2.422412429	moderately to high
Cu	1.069983262	Depletion	-0.570607208	Unpolluted

.

5.8 result A8 zone: Table 11: Enrichment factor and geo- accumulation index at A8 industrial zone

Heavy metal	Enrichment Factor (EF)	Degree of enrichment	geo-accumulation (I geo)	Degree of (I geo)
Pb	6.626740848	Significant	1.90303827	Moderately
Ni	2.834969347	Moderate	0.678071905	unpolluted to moderately
Cd	39.37457426	very high	4.473931188	High to very high polluted
Co	2.155757941	Moderate	0.282933963	unpolluted to moderately
Cr	4.569025597	Moderate	1.366625294	Moderately
Cu	1.952978883	depletion	0.140415119	unpolluted to moderately

V. Conclusions

1. Mean value of heavy metals Pb, Ni, Cr and Cu are 52.6 , 123.1 , 539.3 , 415.6 ppmwith global average value 10, 40, 100, 30 ppm respectively , the soil is seriously polluted by these heavy metals.
2. According to the Enrichment factor A1 zone is extremely enriched by Cd (40.3) with significantly enriched by Cr (8.6),A2 zone is very high enriched by Cd(35.1) withsignificantly enriched by Co (11.2) , A3 zone is very high enriched by Cd (26.5). A4 is extremely enriched by Cu (129.3) and Cd (41.3) with very high enrichment by Pb (30.3) and significantly enrichment by Cr (5.57) .A5 is very high enrichment by Cd

(24.6). A6 is extremely enrichment by Cd (40.3) and significantly enrichment by Cr (9.4), A7 is very high enrichment by Cd (35.3) with significantly enriched by Cr (8.5) and Co (5.1), A8 is very high enrichment by Cd(39.3) with significantly enrichment by Pb (6.6).

3. According to the geo- accumulation index all zones are polluted by Cd with degree high to very high polluted . A4 zone is polluted by Pb (4.02)and Cu (6.12) with high to very high polluted degree. A1, A6,A7 are polluted by Cr with moderately to high polluted degree. While A1, A3,A5,A6,A7 are polluted by Ni with moderately polluted degree.

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