



Some heavy Metal pollution investigation in Sulaimani province groundwater.

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Abstract

The paper aims to go into the impact of some heavy metal contamination in the Sulaimani province groundwater for irrigation purpose. Water samples were collected from (36) locations in the study area that not the same and the heavy metals such as (Iron, Zinc, Copper and Manganese) were finding out by using Atomic Absorption Spectrophotometer. Heavy metal contamination appraisal in ground water required cognition of pre anthropogenic metal concentrations to act as a reference against which measured values can be compared. Groundwater taint by heavy metal was accomplished using Enrichment Factor (*EF*), Metal Contamination Index (*MCI*), Contamination Factor (*CF*), Pollution Index (*PI*), Contamination degree (*Cd*), modified Contamination Degree (*mCd*), Pollution load Index (*PLI*) and Index of geo accumulation (*Igeo*). Established on the above exponents, the results indicate the study groundwater resources to be very low degree of contamination.

Introduction

Groundwater that is in contact with bedrock for a prolonged period is enriched with many ions including trace elements and heavy metals due to the interaction between water and rock [1, 2, 3 and 4]. Heavy metals in natural water system are generally present in small amount concentration. Also, as micronutrients iron, zinc, copper and manganese are required by the body in small amounts for metabolic activities [5]. Their natural event in groundwater and surface water can be due to natural sources such as dissolution of minerals containing trace elements in the aquifer material. As well the natural processes, due to anthropogenic factors such as mining operations, disposal of industrial wastes and applications of biocides for pest metals may enter into the aquatic system. Anthropogenic sources of elemental contamination and pollution released into the environment have been summarized by many researchers [6]. Through the disposal materials, globalization and economic activity, heavy metals are continuing to be introduced to waters and soils via

several pathways, including fertilization, irrigation, rivers, runoff, and atmospheric deposition [7]. However, these anthropogenic activities can contribute to the environmental impacts of aquatic habitat. The pollution of water by heavy metals is a problem in the world because these metals are permanent and most of them have toxic effects on plant when they surpass a sealed concentration [8]. But day by day the quality of available water is declining due to natural and anthropogenic activities. Besides many other pollutants, it is severely foul due to the mien of heavy metals. For the sake of a better world and sustainability of life the chemists and researchers all over the world are trying very hard to address this big problem. Removal of these heavy metals is becoming a growing global concern. Bioremediation, phytoremediation and photocatalytic processes are many green techniques use for removing metals, use of industrial and agricultural waste have been developed. Shallow groundwater and soils are irrigated with water contain high concentrations of trace elements have a threat to agricultural production and humanity. They do so in three ways: (1) trace elements can accumulate in plants to levels that cause phytotoxicity; (2) trace elements in plants can adversely affect humans and animals that consume those plants; and (3) trace elements can migrate with seepage through the root zone and into groundwater, possibly re-emerging with subsurface drainage in surface waters, thereby affecting wildlife, or with groundwater pumped for domestic use, thereby threatening the health of humans. Therefore, this research work was aimed at assessing the concentrations of Fe, Zn, Cu, and Mn in several water sources from different locations and distinguishing between natural and anthropogenic sources of the studied metals.

II. MATERIALS AND METHODS

A-Study area

The study area is located between Latitude 35°06'51" - 35°36'08" North and Longitude 45°07'46" - 45°42'16" East covered an area (290) Km², with an elevation ranged between (525-952) meters as shown in (Table 1). It lies in Sulaimani Governorate north east of Iraq. The objective of this study is agriculture. The groundwater samples were collected which included springs, kahrezes and wells. The precipitation which is the main source of ground water recharges in the study area is moderate and the mean annual precipitation of 650 - 750 mm. For assessment the heavy metal contamination, (36) sites were chosen for sample collection in this study area. The underground water samples of the study area are given in (Figure 1).

B-Field sampling, laboratory methods and Data analysis

Water samples were collected at (November, 2008 and May, 2009) from different sampling sites have been analyzed for various heavy metals such as (Fe, Zn, Cu and Mn) as per the suggestions given by APHA [9], than the mean of concentrations metals for two periods are given in (Table 1). Clean polypropylene bottles were used for collected the samples rinsed with acid; the samples were filtered and decreased the pH of water below 2.0 with adding concentrated nitric acid to prevent precipitation and adsorption of metals on container walls. For detecting the concentrations of heavy metals in water samples were using an Atomic Absorption Spectrophotometer (PerkinElmer model AA200) with a specific lamp for particular metal. The world surface rock average of individual metal has been taken to be the background following the recent works of some authors. Mean concentration of metals at selected sampling stations and their world surface rock average is given in (Table 2) [10].

With the help of following parameters we can estimate the levels of contamination of those water recourses from those: Enrichment Factor (*EF*), Metal Contamination Index (*MCI*), Contamination Factor (*CF*), Pollution Index (*PI*), Contamination degree (*Cd*), modified Contamination Degree (*mCd*), Pollution load Index (*PLI*) and Geo accumulation Index (*Igeo*).

III. Enrichment Factor (EF):

Enrichment factor analysis, a method proposed by Simex and Helz [11] to assess trace element concentration, is mathematically expressed as:

$$EF = (C_n/C_{ref})_{sample} / (B_n/B_{ref})_{background} \dots\dots\dots (1)$$

Where C_n (sample) is the concentration of the element in the enriched samples, C_{ref} (sample) is the concentration of the examined chemical element in the reference environment, B_n is the background or pristine value of the element and B_{ref} is the concentration of the reference element in the reference environment. In this work, the background value is that of the world surface rock average [10] given in (Table 2). According to (Forstner and Wittmann) [12] in case of Fe, particularly the redox sensitive iron-hydroxide and oxide under oxidation condition constitute significant sink of heavy metals in aquatic system. Even a low percentage of Fe(OH)₃, in aquatic system, has a controlling influence on heavy metal distribution. Fe is used as the normalized metal as it is an acceptable normalization element to be used in the calculation of enrichment factor since Fe distribution was not related to other heavy metals [13]. Fe is taken as a normalization element while determining enrichment factor (EF). Five contaminant categories based on the EF value [14] is given in (Table 3).

IV. ECI (Elemental contamination index) and MCI (overall Metal Contamination Index)

ECI and MCI are expression of single metal contamination within a sample or combined metal contamination for a sample relative to the back-ground values of the respective metal and are expressed as

$$ECI = (C_x - B) / B \dots\dots\dots (2)$$

$$MCI = \Sigma [(C_x - B) / B] \dots\dots\dots (3)$$

Where, C_x is metal concentration, and B background value of the metal. According to Meybeck [15] MCI was designed to describe general trace elements contamination on a scale from (0 to 100) as shown (Table 4).

V. Contamination Factor (CF) and pollution index (PI):

Contamination factor (CF) or pollution index (PI) is the ratio obtained by

$$CF = (C_m \text{ Sample}) / (C_m \text{ Background}) \dots\dots\dots (4)$$

A scale ranging contamination levels of CF and PI from (1 to 6) based on their intensities (Table 5), presents the Contamination factor (CF) based on Hakonson [16], and the pollution index (PI) depended on [17 and 18].

VI. Contamination degree (Cd):

The (Cd) for each site was calculated as sum of all contamination factors (Table 6) Ahdy and Khaled [19] using the following formula.

$$Contamination \ degree \ (Cd) = \sum_{i=1}^N CF_i \dots\dots\dots (5)$$

VII. Modified Degree of Contamination (mCd):

The modified formula is generalized by defining the degree of contamination (*mCd*) as the sum of all the contamination factors (*Cf*) for a given set of pollutants divided by the number of analyzed pollutants. The modified equation for a generalized approach to calculating the degree of contamination is given below Abraham [20].

$$\text{Modified Degree of Contamination (mCd)} = \frac{1}{N} \sum_{i=1}^N CF_i \dots\dots\dots (6)$$

For the classification and description of the modified degree of contamination (*mCd*) are proposed in (Table 7).

VIII. Pollution Load Index (PLI):

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_N)^{1/N} \dots\dots\dots (7)$$

This empirical index provides a simple, comparative means for assessing the level of heavy metal pollution [21].

Where, *N* is the number of metals (four in the present study) and *CF* is the contamination factor calculated as described in (4).

IX. Geo accumulation index (Igeo)

A common approach to estimate the enrichment of metal concentrations above background or baseline concentrations is to calculate the geo accumulation index (*Igeo*) [22]. The method assesses the degree of metal pollution in terms of seven enrichment classes based on the increasing numerical values of the index. This index is calculated as follows:

$$I_{geo} = \log_2 [C_m \text{ Sample}] / [1.5 \times C_m \text{ Back ground}] \dots\dots\dots (8)$$

Where *C_m Sample* is the concentration of the element in the enriched samples, and the *C_m back ground* is the background or pristine value of the element. The factor 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithological variations in the sediments.

Therefore, if the concentration of element in a sample be five times greater than the concentration of it in the background the sample is extremely polluted. The degree of metal pollution is assessed in terms of seven contamination classes based on the increasing numerical value of the index as shown in (Table 8), [23].

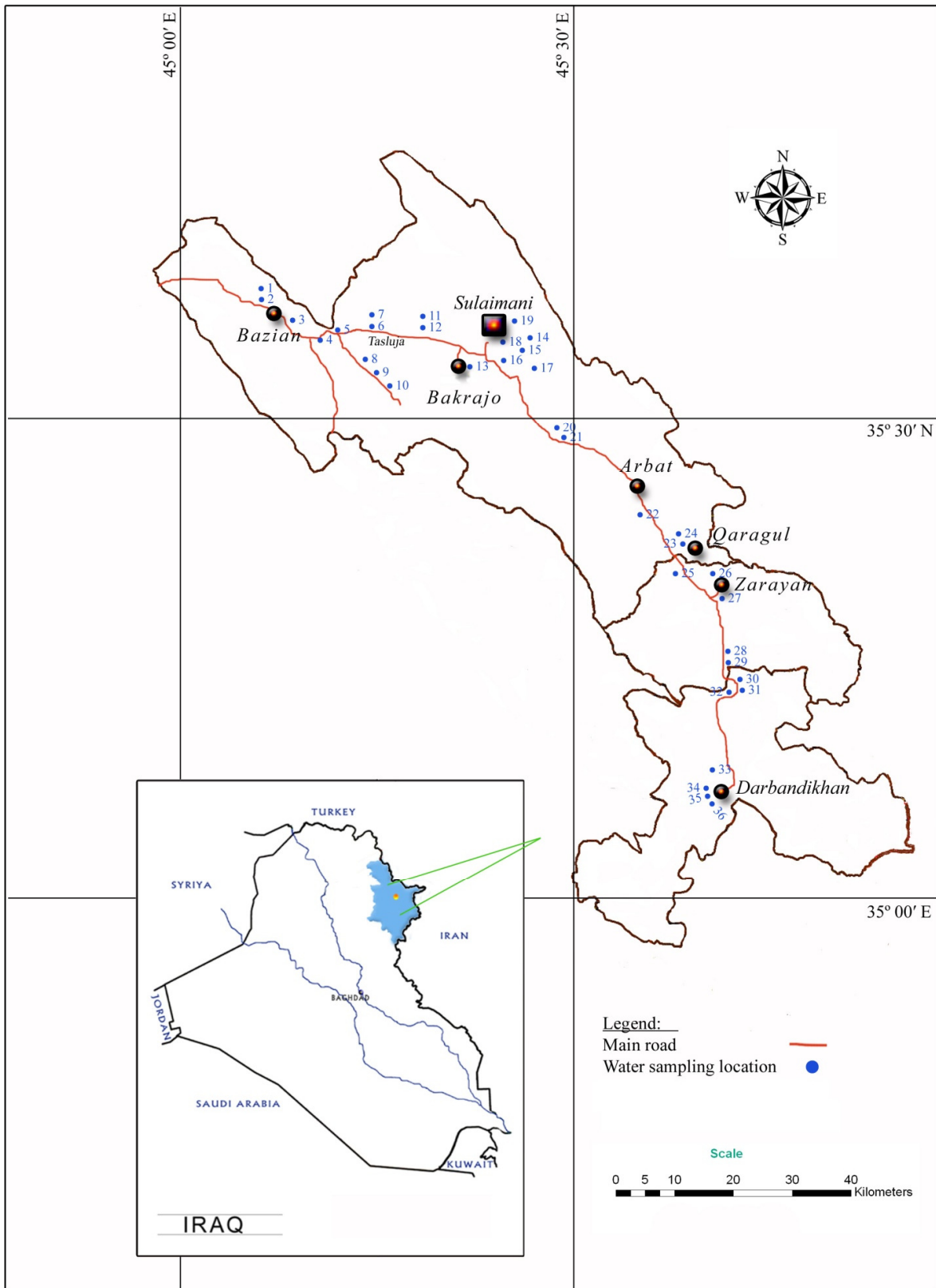


Figure1: Map of the study area.

Table 1: The Global Position System (GPS) reading and the mean of concentrations metals for the selected ground water locations for (November, 2008 and May, 2009).

Sample ID	Locations	Coordinates		Elevation in meter	The mean concentration in ppm			
		Latitude	Longitude		Fe	Zn	Cu	Mn
1	Bazian1	35°36'08"	45°07'46"	834	0.145	0.051	0.032	0.045
2	Bazian2	35°35'34"	45°08'33"	835	0.176	0.584	0.035	0.028
3	Suraqan	35°35'02"	45°10'41"	857	0.109	0.243	0.023	0.036
4	Qucha	35°34'51"	45°11'53"	952	0.183	0.046	0.009	0.032
5	Hars	35°35'25"	45°13'06"	877	0.259	0.044	0.016	0.030
6	Kanakawa1	35°35'12"	45°15'40"	750	0.174	0.102	0.049	0.046
7	Kanakawa2	35°35'33"	45°15'37"	779	0.103	0.016	0.017	0.018
8	Kealasy1	35°34'40"	45°17'16"	763	0.223	0.057	0.025	0.047
9	Kealasy2	35°34'19"	45°17'01"	761	0.180	0.023	0.027	0.046
10	Kealasy3	35°34'06"	45°16'54"	759	0.138	0.011	0.030	0.035
11	Bakhy Bamoky1	35°34'23"	45°21'14"	798	0.512	0.108	0.048	0.050
12	Bakhy Bamoky2	35°34'19"	45°21'09"	788	0.234	0.107	0.045	0.167
13	Bakrajo	35°32'04"	45°22'08"	750	0.230	0.035	0.045	0.052
14	Bntabaq	35°33'25"	45°26'44"	862	0.178	0.080	0.055	0.054
15	Mzgauly Gaura	35°33'20"	45°26'39"	852	1.018	0.418	0.049	0.086
16	Khumkhana	35°33'07"	45°26'36"	805	0.332	0.207	0.468	0.068
17	Qamishaka	35°32'43"	45°26'16"	777	0.196	0.293	0.063	0.063
18	Sheakh Mstafa	35°33'17"	45°26'33"	820	0.216	0.091	0.046	0.061
19	Parky Azady	35°33'36"	45°26'20"	862	0.266	0.049	0.039	0.056
20	Razyana1	35°28'14"	45°29'21"	702	0.359	0.023	0.019	0.026
21	Razyana2	35°28'12"	45°29'20"	702	0.121	0.015	0.018	0.011
22	Braiaty	35°22'48"	45°36'39"	610	0.108	0.037	0.039	0.033
23	Qaragul1	35°20'50"	45°38'22"	558	0.230	0.041	0.050	0.055
24	Qaragul2	35°20'56"	45°38'25"	550	0.234	0.019	0.040	0.049
25	Nasr	35°20'31"	45°38'47"	562	0.132	0.021	0.042	0.052
26	Zarayan1	35°18'52"	45°40'22"	552	0.150	0.598	0.036	0.034
27	Zarayan2	35°18'39"	45°40'38"	568	0.163	0.035	0.033	0.061
28	Miradea1	35°14'12"	45°41'31"	555	0.197	0.538	0.047	0.043
29	Miradea2	35°14'10"	45°41'37"	697	0.117	0.107	0.025	0.053
30	Chnara1	35°12'43"	45°42'16"	723	0.122	0.095	0.036	0.031
31	Chnara2	35°12'38"	45°42'13"	727	0.163	0.079	0.034	0.043
32	Chnara3	35°12'27"	45°41'46"	760	0.121	0.028	0.023	0.022
33	Emamahmad	35°07'41"	45°41'07"	671	0.116	0.141	0.022	0.011
34	Hawarabarza	35°07'05"	45°41'19"	548	0.148	0.102	0.061	0.057
35	Salimpirk1	35°06'51"	45°41'36"	531	0.167	0.020	0.061	0.058
36	Salimpirk2	35°06'50"	45°41'39"	525	0.163	0.031	0.053	0.036

Table 2: Mean concentration of metals at selected sampling stations and their world surface rock average [10].

Metals	Mean concentration of metals in ppm	World surface rock average
Fe	0.213	4.72
Zn	0.125	95
Cu	0.049	45
Mn	0.047	850

Table 3: Five contaminant categories based on EF value [14].

Enrichment factor (EF) value	Contamination degree
EF < 2	Deficiency to low enrichment
2 < EF < 5	Moderate enrichment
5 < EF < 20	Significant enrichment
20 < EF < 40	Very high enrichment
EF ≥ 40	Extremely high enrichment

Table 4: Meybeck classification of MCI (Metal Contamination Index) [15].

Metal Contamination Index (MCI)	Contamination degree
MCI <5	<i>Very low contamination</i>
5 < MCI <10	<i>low contamination</i>
10 < MCI <25	<i>Medium contamination</i>
25 < MCI <50	<i>High contamination</i>
50 < MCI <100	<i>Very high contamination</i>
MCI ≥100	<i>Extremely high contamination</i>

Table 5: Contamination factor (Cf) and pollution index (PI) based on [16 and (17 and 18)].

Contamination factor (CF) or (PI)	Classification
CF < 1	<i>Low contamination factor or pollution index</i>
1 < CF <3	<i>Moderate contamination factor or pollution index</i>
3 < CF <6	<i>Considerable contamination factor or pollution index</i>
CF ≥ 6	<i>Very high contamination factor or pollution index</i>

Table 6: Contamination degree (Cd) based on Ahdy and Khaled classification [19].

Contamination degree (Cd)	Classification
Cd <6	<i>Low contamination degree</i>
6 < Cd <12	<i>Moderate contamination degree</i>
12 < Cd < 24	<i>Considerable contamination degree</i>
Cd ≥ 24	<i>Very high contamination degree</i>

Table 7: Abraham classification of the modified degree of contamination [20].

Modified contamination degree (mCd)	Classification
mCd <1.5	<i>Nil to very Low degree of contamination</i>
1.5 < mCd <2	<i>Low degree of contamination</i>
2 < mCd <4	<i>Moderate degree of contamination</i>
4 < mCd <8	<i>High degree of contamination</i>
8 < mCd <16	<i>Very high degree of contamination</i>
16 < mCd <32	<i>Extremely degree of contamination</i>
mCd ≥ 32	<i>Ultra degree of contamination</i>

Table 8: contamination classes of the geo accumulation index (Igeo) based on [23].

I-geo value	I- geo class	Pollution intensity
$I_{geo} \leq 0$	0	<i>unpolluted</i>
$0 < I_{geo} \leq 1$	1	<i>unpolluted to moderately polluted</i>
$1 < I_{geo} \leq 2$	2	<i>moderately polluted</i>
$2 < I_{geo} \leq 3$	3	<i>moderately to strongly polluted</i>
$3 < I_{geo} \leq 4$	4	<i>strongly polluted</i>
$4 < I_{geo} \leq 5$	5	<i>strongly to very strongly polluted</i>
$I_{geo} > 5$	6	<i>very strongly polluted.</i>

X.RESULTS AND DISCUSSIONS

For estimating anthropogenic impact on groundwater quality is to calculate a normalized enrichment factor (EF) for metal concentrations above uncontaminated background levels. Enrichment factors were calculated from the mean concentrations of two period's heavy metals for the sampling sits in this study area (Table 9). The normalizing element used in this study was Fe due to low occurrence variability. Deely and Fergusson [13] proposed Fe as an acceptable normalization element to be used for calculating the enrichment factor since they consider the Fe distribution which was not related to other heavy metals. According to [24], EF values varied between 0.5 and 1.5 indicate that the metal is entirely from crustal

materials or natural processes, where *EF* values greater than 1.5 suggest that the sources are more likely to be anthropogenic.

The *EF* for (Zn, Cu and Mn) remain in the value < 2 in all stations indicates deficiency to low enrichment according to [14]. Therefore, the heavy metal pollution of this study area wasn't likely to originate from anthropogenic activities, as shown in (Figure 2).

Elemental contamination index (ECI) and overall metal contamination index (MCI)

According to [15], MCI of all the sampling sites less than 5 implies very low contamination and it is presented in (Table 9).

Table 9: Enrichment factor and Metal contamination index values of heavy metals in selected sampling stations.

Sample ID	Enrichment Factors (EF)			MCI	Classification
	Zn	Cu	Mn		
1	0.017	0.023	0.002	3.968	Very low contamination
2	0.165	0.021	0.001	3.956	Very low contamination
3	0.111	0.022	0.002	3.974	Very low contamination
4	0.012	0.005	0.001	3.961	Very low contamination
5	0.008	0.006	0.001	3.944	Very low contamination
6	0.029	0.029	0.001	3.961	Very low contamination
7	0.008	0.017	0.001	3.978	Very low contamination
8	0.013	0.012	0.001	3.952	Very low contamination
9	0.006	0.015	0.001	3.961	Very low contamination
10	0.004	0.022	0.001	3.970	Very low contamination
11	0.010	0.010	0.001	3.889	Very low contamination
12	0.023	0.020	0.004	3.948	Very low contamination
13	0.008	0.020	0.001	3.950	Very low contamination
14	0.022	0.033	0.002	3.960	Very low contamination
15	0.020	0.005	0.000	3.779	Very low contamination
16	0.031	0.148	0.001	3.917	Very low contamination
17	0.074	0.034	0.002	3.954	Very low contamination
18	0.021	0.022	0.002	3.952	Very low contamination
19	0.009	0.015	0.001	3.942	Very low contamination
20	0.003	0.006	0.000	3.923	Very low contamination
21	0.006	0.016	0.001	3.974	Very low contamination
22	0.017	0.038	0.002	3.976	Very low contamination
23	0.009	0.023	0.001	3.950	Very low contamination
24	0.004	0.018	0.001	3.949	Very low contamination
25	0.008	0.033	0.002	3.971	Very low contamination
26	0.198	0.025	0.001	3.961	Very low contamination
27	0.011	0.021	0.002	3.964	Very low contamination
28	0.136	0.025	0.001	3.952	Very low contamination
29	0.046	0.023	0.003	3.974	Very low contamination
30	0.039	0.031	0.001	3.972	Very low contamination
31	0.024	0.022	0.001	3.964	Very low contamination
32	0.011	0.020	0.001	3.974	Very low contamination
33	0.060	0.020	0.001	3.973	Very low contamination
34	0.034	0.043	0.002	3.966	Very low contamination
35	0.006	0.038	0.002	3.963	Very low contamination
36	0.009	0.034	0.001	3.964	Very low contamination

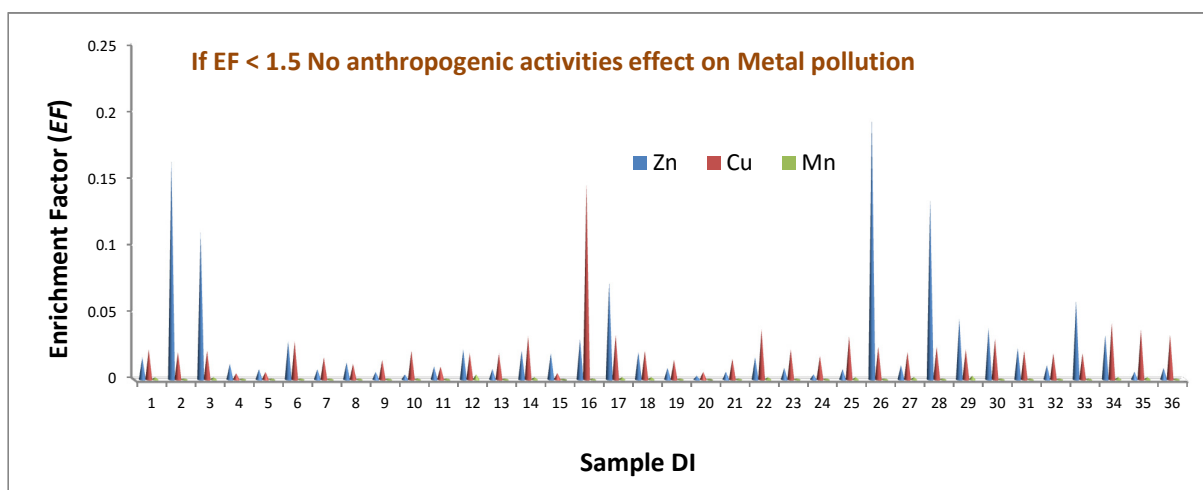


Figure2: Enrichment factor at all the sampling sites.

CF, Cd and mCd of analyzed metals

(Table 10) shows the contamination factor (*C_f*) of each element the degree of contamination (*C_d*) and also modified degree of contamination for each sampling site. The contamination factor for all the studied waters falls under low contamination factor according to Hakanson classification and on the basis of contamination degree values that ranged between (0.0224-0.2211) indicates low degree of contamination (Table 10).

The *mCd* values for all sites are less than 1.5, it lies in the range (0.0056-0.0553) for the individual metal, which shows nil to very low degree of contamination (Table 10). The *mCd* data indicates non-anthropogenic impact in the entire sites (Figure 3).

Pollution Load Index (PLI)

The PLI does not show much fluctuation. Lower values of PLI imply no appreciable input from anthropogenic sources. The PLI value of >1 is polluted where as <1 indicates no pollution according to the classification of [25]. The values of PLI for all sites <1 were summarized in (Table 10).

Table 10: Contamination factor, contamination degree, modified contamination degree and Pollution load index for selected sampling stations

Sample ID	Contamination factor (<i>C_f</i>)				Contamination degree (<i>C_d</i>)	Modified contamination degree (<i>mCd</i>)	PLI
	Fe	Zn	Cu	Mn			
1	0.0306	0.0005	0.0007	0.0001	0.0319	0.0080	0.0009
2	0.0372	0.0061	0.0008	0.0000	0.0441	0.0110	0.0015
3	0.0230	0.0026	0.0005	0.0000	0.0261	0.0065	0.0011
4	0.0387	0.0005	0.0002	0.0000	0.0394	0.0098	0.0006
5	0.0549	0.0005	0.0003	0.0000	0.0557	0.0139	0.0007
6	0.0369	0.0011	0.0011	0.0001	0.0391	0.0098	0.0012
7	0.0218	0.0002	0.0004	0.0000	0.0224	0.0056	0.0004
8	0.0471	0.0006	0.0005	0.0001	0.0483	0.0121	0.0010
9	0.0381	0.0002	0.0006	0.0001	0.0390	0.0098	0.0007
10	0.0292	0.0001	0.0007	0.0000	0.0300	0.0075	0.0005
11	0.1084	0.0011	0.0011	0.0001	0.1106	0.0277	0.0017
12	0.0496	0.0011	0.0010	0.0002	0.0519	0.0130	0.0018
13	0.0487	0.0004	0.0010	0.0001	0.0501	0.0125	0.0010

14	0.0376	0.0008	0.0012	0.0001	0.0397	0.0099	0.0013
15	0.2156	0.0044	0.0011	0.0001	0.2211	0.0553	0.0032
16	0.0702	0.0022	0.0104	0.0001	0.0829	0.0207	0.0034
17	0.0415	0.0031	0.0014	0.0001	0.0461	0.0115	0.0019
18	0.0457	0.0010	0.0010	0.0001	0.0477	0.0119	0.0013
19	0.0563	0.0005	0.0009	0.0001	0.0577	0.0144	0.0011
20	0.0761	0.0002	0.0004	0.0000	0.0767	0.0192	0.0007
21	0.0255	0.0002	0.0004	0.0000	0.0261	0.0065	0.0004
22	0.0228	0.0004	0.0009	0.0000	0.0241	0.0060	0.0007
23	0.0486	0.0004	0.0011	0.0001	0.0502	0.0126	0.0011
24	0.0496	0.0002	0.0009	0.0001	0.0507	0.0127	0.0008
25	0.0280	0.0002	0.0009	0.0001	0.0292	0.0073	0.0008
26	0.0318	0.0063	0.0008	0.0000	0.0389	0.0097	0.0016
27	0.0344	0.0004	0.0007	0.0001	0.0356	0.0089	0.0009
28	0.0417	0.0057	0.0010	0.0001	0.0485	0.0121	0.0019
29	0.0247	0.0011	0.0006	0.0001	0.0264	0.0066	0.0010
30	0.0257	0.0010	0.0008	0.0000	0.0276	0.0069	0.0009
31	0.0345	0.0008	0.0008	0.0001	0.0362	0.0090	0.0010
32	0.0255	0.0003	0.0005	0.0000	0.0264	0.0066	0.0006
33	0.0246	0.0015	0.0005	0.0000	0.0266	0.0066	0.0007
34	0.0313	0.0011	0.0014	0.0001	0.0337	0.0084	0.0013
35	0.0353	0.0002	0.0013	0.0001	0.0369	0.0092	0.0009
36	0.0344	0.0003	0.0012	0.0000	0.0360	0.0090	0.0009

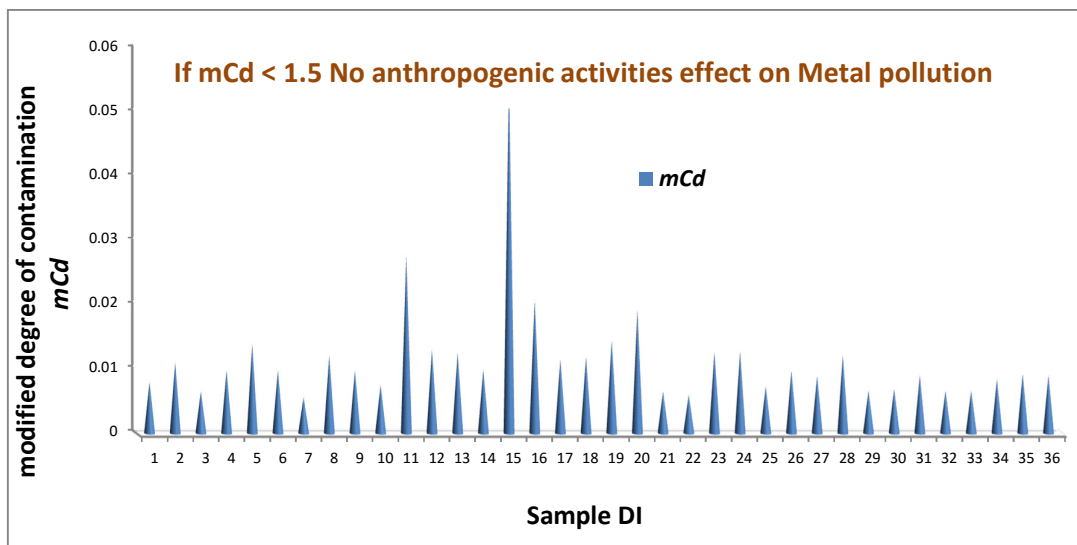


Figure3: modified degree of contamination at all the sampling sites.

Index of geo accumulation (I-geo)

The *I-geo* method was used to calculate the heavy metal contamination levels for study area. The geo accumulation index (*I-geo*) scale consists of seven grades (0-6) ranging from unpolluted to highly pollute according to (Table 8). According to, Geo-accumulation index all stations are unpolluted for (Fe, Cu, Zn and Mn) the average *I-geo* < 0, such given in (Figure 4).

The *I-geo* factor is not readily comparable with *EF* due to the nature of *I-geo* calculation which involves a logarithm function and a background multiplication factor of 1.5. The result of geo accumulation indices for the sampling sites as given in (Table 11).

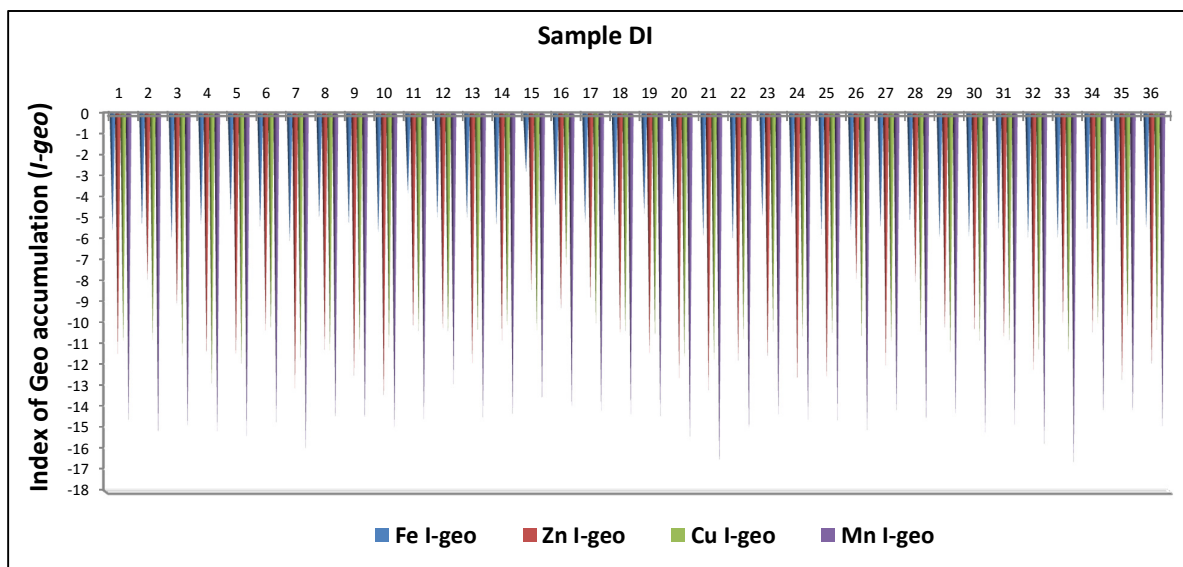


Figure 4: Geo accumulation index at all the sampling sites.

Table 11: Index of Geo accumulation (*I-geo*) in the sampling sites.

<i>Sample DI</i>	<i>Fe I-geo</i>	<i>Zn I-geo</i>	<i>Cu I-geo</i>	<i>Mn I-geo</i>
1	-5.6146	-11.4624	-11.0426	-14.8063
2	-5.3342	-7.9320	-10.9133	-15.5007
3	-6.0280	-9.1958	-11.5507	-15.1323
4	-5.2778	-11.6128	-12.9551	-15.3048
5	-4.7727	-11.6612	-12.0884	-15.3994
6	-5.3466	-10.4482	-10.4427	-14.7585
7	-6.1030	-13.1206	-11.9982	-16.1528
8	-4.9919	-11.2877	-11.4279	-14.7275
9	-5.2977	-12.6287	-11.3147	-14.7743
10	-5.6810	-13.6612	-11.1600	-15.1528
11	-3.7909	-10.3724	-10.4727	-14.6527
12	-4.9192	-10.3791	-10.5669	-12.8984
13	-4.9440	-11.9913	-10.5669	-14.5956
14	-5.3179	-10.8077	-10.2612	-14.5272
15	-2.7987	-8.4150	-10.4427	-13.8642
16	-4.4167	-9.4306	-7.1722	-14.1946
17	-5.1748	-8.9283	-10.0653	-14.3163
18	-5.0380	-10.6208	-10.5190	-14.3632
19	-4.7370	-11.5207	-10.7572	-14.4747
20	-4.3017	-12.6287	-11.7947	-15.5816
21	-5.8766	-13.2137	-11.8727	-16.8226
22	-6.0413	-11.9111	-10.7758	-15.2597
23	-4.9472	-11.7808	-10.3987	-14.5139
24	-4.9192	-12.9111	-10.7207	-14.6674
25	-5.7451	-12.7283	-10.6503	-14.5956
26	-5.5607	-7.8978	-10.8727	-15.1946
27	-5.4452	-12.0121	-11.0202	-14.3513

28	-5.1675	-8.0491	-10.5034	-14.8558
29	-5.9253	-10.3791	-11.3987	-14.5541
30	-5.8647	-10.5507	-10.8929	-15.3513
31	-5.4408	-10.8168	-10.9551	-14.8558
32	-5.8766	-12.3392	-11.5190	-15.8226
33	-5.9316	-9.9811	-11.5832	-16.8226
34	-5.5850	-10.4482	-10.1119	-14.4492
35	-5.4102	-12.8352	-10.1237	-14.4366
36	-5.4452	-12.1664	-10.3284	-15.1121

The (integration or conjunction) of the factors and Indexes as shown in (figure 5), the result indicated that it has more conjunction of the factors and (EF and CF).

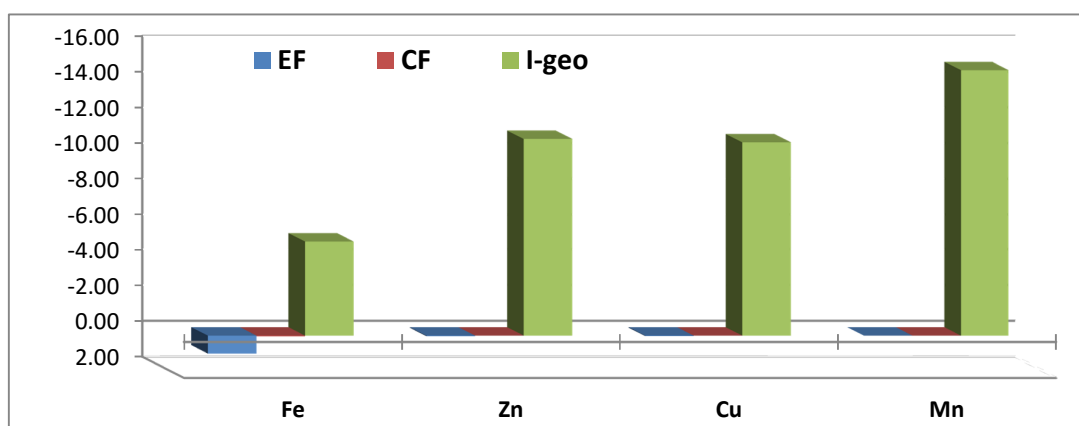


Figure 5: The integration between factors and indexes

XI. CONCLUSION

The results showed that groundwater in the present study area was unpolluted due to low anthropogenic activity, the impact of anthropogenic heavy metal pollution in the sampling sites was evaluated using Enrichment Factor (*EF*), Metal Contamination Index (*MCI*), Contamination Factor (*CF*) and Pollution Index (*PI*), Contamination degree (*Cd*), modified Contamination degree (*mCd*), Pollution load Index (*PLI*) and Index of geo accumulation (*I-geo*) at 36 sampling sites of Sulaimani province. The results show that all sampling sites were found falls in the class of deficiency to low enrichment because *EF* less than 2. The results of Contamination Factor (*Cf*), Contamination degree (*Cd*), and modified Contamination Degree (*mCd*) show that the study area falls under nil to very low contamination, Calculation of Pollution load Index (*PLI*), Metal Contamination Index (*MCI*) and Index of geo accumulation (*I-geo*) indicates the study area is regarded as non-polluted. The present study suggests that these indices are useful tools for identification of anthropogenic source of contamination of ground water.

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