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Evaluation of Water Quality of Koi Sanjaq Basin, Erbil Governorate Northern Iraq

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Abstract

Thirty water sample of wells, and three samples of springs from the upper most aquifer, as well as four samples from Lesser Zab River in Koi Sanjaq Basin, Erbil governorate of northern Iraq was collected and physically and chemically were analyzed. Physical analysis includes temperature, hydrogen ion concentration (pH), Electrical Conductivity (EC), Total Dissolved Solid (TDS), and Turbidity, whereas the geochemical analysis included concentration determines of the major, minor and trace elements. Chemical classification of the present samples using of chadha diagram explain that (95%) of them located within field 5 and 6 whereas the rest (5%) are located in the field 8. According to Iraqi [9] and WHO [10] standers, most of the samples are unsuitable for human drinking purpose. For livestock purpose, all the groundwater and surface water samples are very good samples, while Sodium Adsorption Ratio (SAR) and Na% values show that these samples are suitable for irrigation purposes. High ions concentrations make the present samples unsuitable for all industries.

Keywords: groundwater, surface water, spatial analyses, water suitability, Koi, Sanjaq, Erbil.

تقييم نوعية المياه لحوض كويسنجق ، محافظة اربيل ،شمال العراق

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الخلاصة

تم تجميع و تحليل الخواص الفيزيائية و الكيميائية لثلاثة نماذج من العيون، ثلاثين نموذجا من الابار من الخزان العلوى و اربعة نماذج من نهرالزاب الاسفل فى حوض كويسنجق محافظة اربيل شمال العراق. ضم تحليل الخواص الفيزيائية درجة الحرارة ، الاس الهايدروجيني. التوصيلية الكهربائية ، مجموع الاملاح الذائبة و العكورة بينما تضمن التحليل الكيميائي قياس تركيز العناصر الرئيسة ، الثانوية و النادرة، بين تصنيف جادا لنوعية المياه ان 95% من نماذج الدراسة الحالية تقع فى حقلين 5,6 بينما باقى النماذج (5%) وقعت فى حقل 8 . اعتمادا على مقياسي منظمة الصحة العالمية 2008 و العراقية 2009 ، لصلاحية شرب المياه للانسان تبين ان معظم النماذج كانت غير صالحة. اما لشرب الدواجن فكانت معظم النماذج المياه السطحية و الجوفية جيدة جدا بينما اعتمادا على قيم نسبة امتصاص الصوديوم و نسبة المئوية للصوديوم فان هذه النماذج صالحة للري . التراكيز العالية للايونات جعلت هذه النماذج غير صالحة لكل الصناعات.

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Introduction:

Koi Sanjaq City is located at 75 km to the east of Erbil City, and 20 km north of Lesser Zab River, tributary of Tigris River. While Haibat Sultan Mountain bound the area from the east, northeast to the north, which represents a limb of Safeen anticline, and koya seasonal streams are bounded the area from west direction It has a coordinates of UTM (3967555) and (4001000) northing and (446000) and (496700) easting, with an area around 1000 square kilometers Figure-1, Geographically the study area is undulated and contain hills and mountains in the north part , while in the south and south west the area is undulated contains hills only. Tectonically the study area is located at boundary between high folded zone and foothill zone of chamchamal butma subzone, the structural feature of the area is trending NW-SE as general trend of Zagros [1]. Five geological formations are exposed; they range in age from middle Eocene to Pleistocene, with Quaternary deposits, the exposed formations are from older to younger:

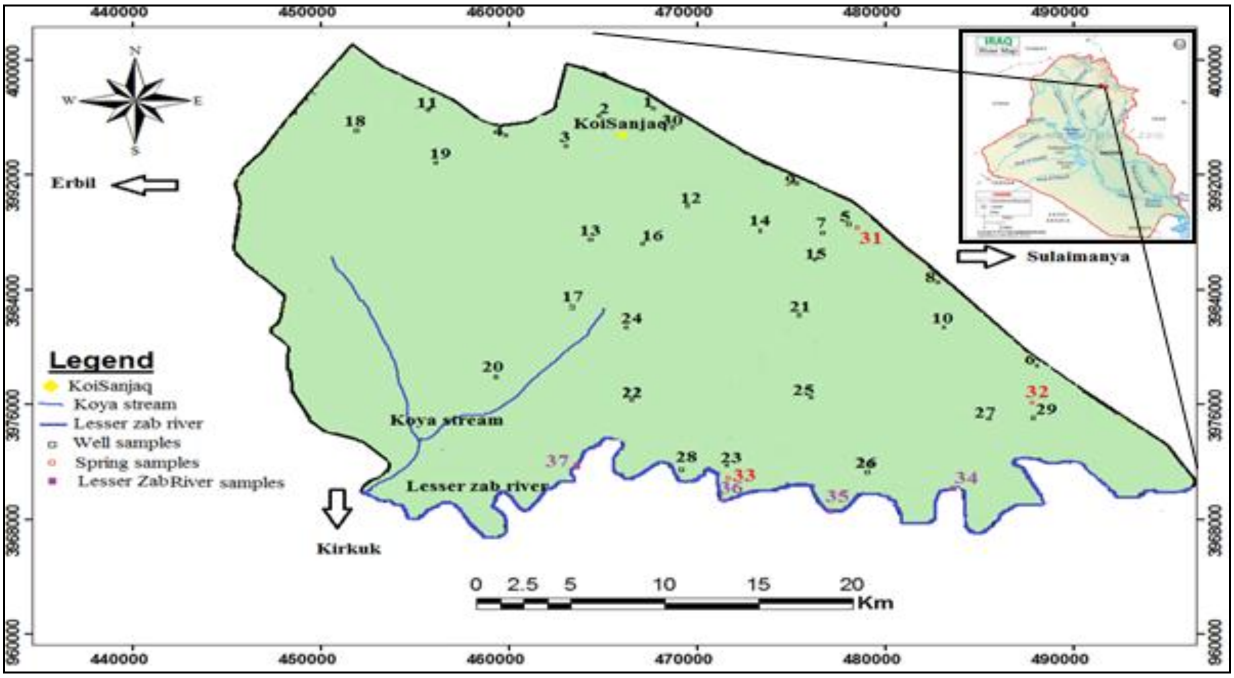

Figure 1- Location Map with sample locations of the study area.

Pila Spi Formation: This formation is of Middle – Late Eocene [2], it is composed mainly of light gray and yellowish white color, well bedded limestone and marly limestone, the thickness is 100-200 m.. the depositional environment is marine, lagoon. Fatha Formation: This formation is of Middle Miocene age it is composed of cyclic deposits of mudstone and thin layers of limestone and gypsum, The thickness is 100 - 200 m The depositional environment is marine and lagoon [3]. Injana Formation: This Formation is of upper Miocene age [2], it is composed of fine grained molasse sediments, which includes sandstone, red or grey colored siltstone and claystone. The thickness is 150 – 200 m [3], the depositional environment is continental, fluvio - lacustrine. Muqdadiya Formation: The formation is of Late Miocene – Pliocene age, it composed of pebbly sandstone, siltstone and claystone, all are mainly grey in color**,** the thickness is 400 -1000 m [3], the depositional environment is continental, fluvio - lacustrine. Bai Hassan Formation: This formation is Pliocene – Pleistocene in age [2], it composed of thick conglomerate alternated with red claystone and grey sandstone, the thickness is 1000 – 2500 m [3], the depositional environment is continental, fresh water molasses. Quaternary Sediments, the Quaternary sediments are mainly of alluvial type and of Pleistocene - Holocene age, characterized by heterogeneous deposits and consist of alternation of gravel, sand, silt and clay. Figure-2.Several studies have been carried out for this area; Stevanovic [4] studied the climate, hydrology, geomorphology and regional geology of three governorates "Sulaimani, Erbil and Duhok"**.** Bapeer [5] was studied the infiltration rates and Atterberg Limits of soils in Koi Sanjaq City, and Heedan & Bapeer [6] perform an evaluation of the water wells in Haibat Sultan mountain, Koisanjaq area [6].

The main objective of this study is to evaluate water quality and its suitability for different uses, by study the physical and chemical properties of the surface and groundwater samples.

Hydrology and hydrogeology of study area:

The Lesser Zab River originates from the Zagros Mountains which are about 3000 m height in Iran and joins the Tigris River in Iraq, considered as a main source of surface water in the study area. Also ground water is another main source for water. Some villages in Koi Sanjaq City are completely depended on the ground water as a main source of water in their water supply systems. The main hydrological units includes: Fissure karstic aquifer, which consist of limestone, dolomitic limestone and chalky limestone which considered as a very good aquifer in the study area. Intergranular aquifer, this type of aquifer considered as a good aquifer for ground water accumulation, which consist of both unconsolidated materials and consolidated rocks represented by Bihassan and Muqdadiya formations with Quaternary deposits. Complex (intergranular and fissured multi - layered aquifer) this aquifer represented by Fatha and Injana formations, which are characterized by low production, due to heterogeneous lithology [7], Figure-3.

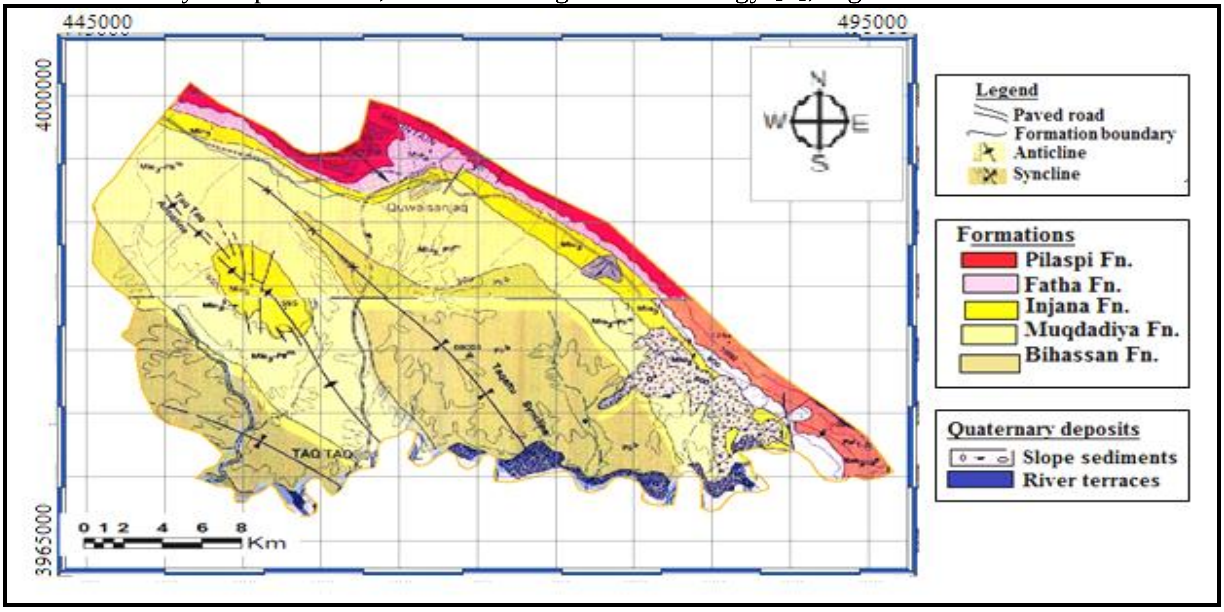

Figure 2- Geological map of the study area

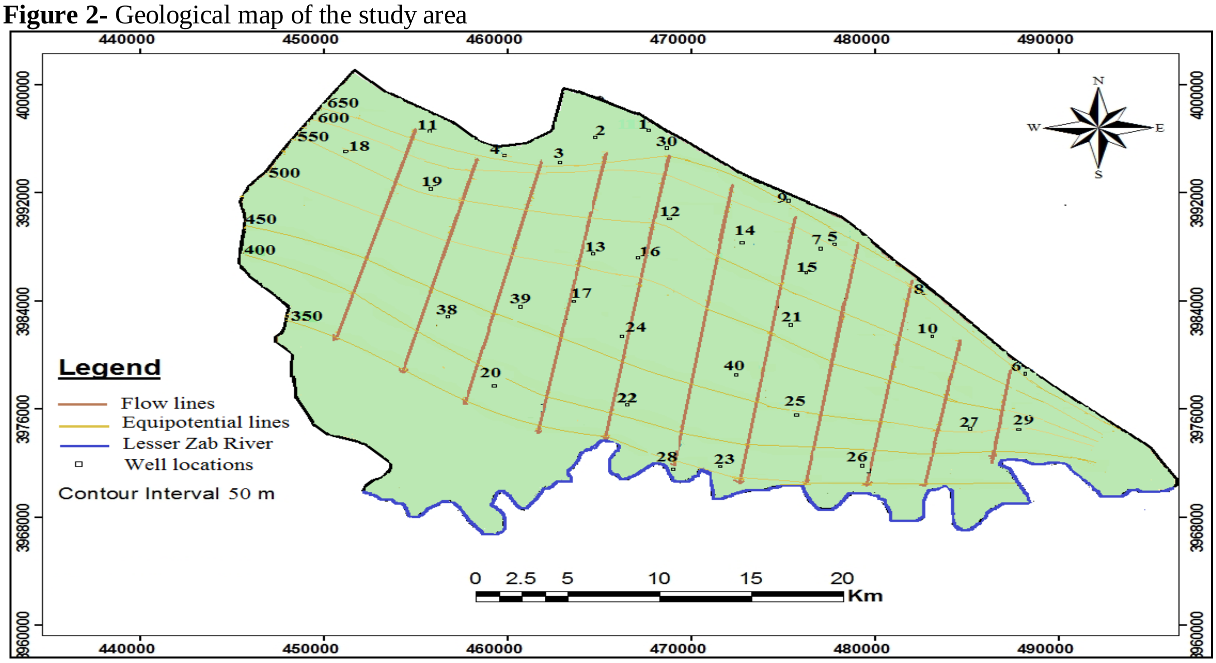

Figure 3- Groundwater flow map (meter above sea level) of the study area.

Material and methods:

Thirty well water, three spring water samples and four Lesser Zab River samples were collected to study the physical and chemical properties Figure-1, temperature, pH ,TDS and EC, were measured in the field using a waterproof portable meter, The other physical and chemical parameters of the water samples were analyzed in the laboratory of chemical department, Education College ,University of Salahaddin, , using the routine methods suggested by Andrew [8], as described in Table1. Samples for trace elements analysis were filtered and acidified to pH less than 2 using high-purity HNO_3 acid and sent to the laboratory of Hall Environmental Analysis Laboratory (EPA) in USA. Wells and springs samples were taken for one period (high flow period, from 5/4/2014 to 13/4/2014), whereas for Lesser Zab River, the water samples were taken for two periods (high flow period during 5/4/2014to 13/4/2014, and low flow period from 3/10/2014 to 10/10/2014).

Table 1- Shows the examined hydro geochemical parameters of the studied area samples.

Parameter	Methods of analysis
Calcium (Ca^{+2}), Magnesium (Mg^{+2})	Flame Atomic Emission Photometric (F-AES) method.
Potassium (k^{+}) and Sodium (Na^{+})	Flame Atomic Emission Photometric (F-AES) method.
Chloride (Cl^{-})	Argenometric method (Moher Method).
Sulfate (SO_4^{-2})	Turbidimetric method (FGI-SSI-1103).
Bicarbonate (HCO_3^{-})	Potentiometric method
Phosphate (PO_4^{-3})	Spectrophotometric method (JENWAY-6300) Ascorbic acid method.
Cu, Cr,B, Cd, Co, Zn, Ni, Mn, and Fe)	EPA method 200.7
As, Pb	EPA method 200.8
Turbidity	Measured by Nephelometer

Results and discussion:

1. Hydrogeochemical parameters:

Hydrogeochemial parameters of the study area are presented in Tables-2, 3, 4, the results of these data were presented statistically in form of mean, median and range in Tables-5,6. Significant differences of temperature degrees are observed in the samples of wells due to the difference in the depth of these aquifers, but for the river samples there is no such difference. Water in the study area is slightly alkaline with pH values ranging from (7.33 - 8.25) and (7.53-7.81) for well and spring samples respectively, and (7.72-7.90) for the river samples, water well samples no. (6,8,19) and spring sample no. (32) which are located with Fatha and Injana Formations are characterized by high value of TDS according to IQS (2009) [9] and WHO (2008) [10] standers, due to the presences of gypsum in Fatha formation and the thick beds of claystone in Injana Formation which prevent vertical movement of water or decrease the rate of infiltration**,** According to the classification of Derver,1997 in [11], the majority of the present samples fall in fresh to slightly fresh water class. The turbidity of Lesser Zab River samples exceeded the limits of WHO,(2008) standard except the sample 34 and the concentration of turbidity increase with the direction of river flow.

The source of Calcium and Magnesium in the water of the study area comes from weathering of carbonate rocks of Pilaspi formation. Calcium in sample no.(12) , and Magnesium in samples no.(6,8,32) are out of range of both (IQS and WHO) standers , both Sodium and Potassium are within standards limit of IQS (2009) and WHO (2008) . In the study area Bicarbonate ions formed as a result of reaction between carbonate rocks of pilaspi formation with CO_2 gas in atmosphere and water from rainfall, the value of Bicarbonate and Chloride are within the limits IQS and WHO standras. The natural source of Sulfate ions (SO_4^{2-}) in the groundwater comes from dissolution of sulfate minerals such as gypsum which are dominant in Koy Sanjaq basin. Also some fertilizers considered as a source of sulfate, samples (6,8,9,12,18,19,32) are out of limits of the IQS (2009) and WHO (2008) standards.

Minor compounds include Nitrate (NO_3^{-}), Phosphate (PO_4^{3-}) and Boron (B). Boron was not detected in the river samples. The values of nitrate and boron lies within the standards limit, while Phosphate not detected in water wells and springs in the study area. (PO_4^{3-}) present only in Lesser Zab waters with low values ranges between (0.17-0.25ppm).

Spatial distribution of TDS, pH and the concentrations of the cations and anions in the studied water samples are presented in Figures -4,5 and 6 for groundwater samples, and Figures-7 and 8 for surface water. For groundwater the changes occur due to the lithological variations in the study area, no significant changes were noticed in surface water. As shown in the figures the values of TDS are increased with flow direction.

Heavy metals are a special group of trace elements, which have been shown to create definite health hazards when taken up by plants [12]. Also for human drinking a contamination by heavy metals may causes a very potentially harmful disease. The elements like (B,Cd,Cr,Co,Cu, Ni, Pb) are not detected in the water samples of the study area Table-7. The values of Fe, Mn, As, and Zn are within the range of limits according to IQS [9] and WHO [10] standards.

Presentation of geochemical data in the form of graphical charts such as chadha diagram , helps us in recognizing hydrogeochemical types of water samples based on the ionic composition of different water samples. The eight fields that are mentioned by chadha [13] is given below. 1. Alkaline earths exceed alkali metals. 2. Alkali metals exceed alkaline earths. 3. Weak acidic anions exceed strong acidic anions. 4. Strong acidic anions exceed weak acidic anions. 5. Alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions, respectively. 6. Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. 7. Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. 8. Alkali metals exceed alkaline earths and weak acidic anions exceed strong acidic anions. all water samples of the study area were plotted in this diagram, the results indicated that more than 95% of these samples are within field 5 and 6 , whereas the rest (5%) are located in the field 8 Figure-9.

Table 2- Hydrochemical parameters of wells and springs samples of the study area.

Sample. NO.	T°C	pH	EC μs/cm	TDS mg/l	Ca^{2+} ppm	Mg^{2+} ppm	Na^{+} ppm	K^{+} ppm	SO_4^{2-} ppm	Cl^{-} ppm	HCO_3^{-} ppm	NO_3^{-} ppm	B ppm
W1	20	7.49	770	492.8	51	17.2	7.6	1.32	37	13	173	0.08	N.D.
W2	20	7.58	403	258	43.8	20.7	2.48	0.4	59.3	8.4	130.8	1.21	N.D.
W3	23	8.1	603	385.9	59	27.6	4.38	0.85	65.3	25.5	178	1.02	N.D.
W4	23	7.72	271	173.4	30.1	11.2	9.1	0.85	16.25	15.2	124.3	0.09	N.D.
W5	21	7.47	995	636.8	104.5	31.4	16.11	2.72	141	52.3	205	0.07	N.D.
W6	22	7.63	1605	1027.2	130.5	105.6	30.03	2.0	650	59.3	145.2	1.72	N.D.
W7	21	7.33	265	169.6	18.5	12.3	8.5	1.29	32.4	23.7	49.1	2.92	N.D.
W8	21	7.4	1940	1241	139.7	119.1	31.72	2.37	716	61.7	150.4	1.85	N.D.
W9	21	7.45	1180	755	107.5	39.9	29.5	1.92	254	39.9	162.8	1.51	N.D.
W10	23	7.5	529	338.5	60.3	21.4	12.93	1.02	70.3	37.2	143.6	1.04	0.04
W11	19	8.25	486	311	48.8	21.1	7.95	0.13	39.5	16.9	173.3	3.08	0.03
W12	20	7.5	1521	973.4	183.2	55.2	24.75	1.92	510.7	35.3	158.6	1.1	0.3
W13	19	7.93	777	497.2	33.1	8.54	108	1.21	100.5	45	190	1.84	0.22
W14	22	7.81	577	369.2	61.4	22.6	1.61	0.31	95.2	10.1	148.8	1.9	0.29
W15	21	7.82	485	310.4	48.3	22.2	8.03	0.39	58.2	23.1	148.6	1.05	0.23
W16	20	7.78	526	336.6	67.4	20.8	11.5	0.31	48.4	35.5	192.9	1.03	0.04
W17	17	7.72	836	535	32.6	9.53	99.65	1.11	75	85	173.2	1.74	0.16
W18	16	7.81	1329	850.5	101.9	42.7	56.51	1.29	260.5	92.9	205	0.09	0.19
W19	16	8.09	1927	1233.2	145.9	43.8	105	1.38	485	123.6	173.3	1.83	0.07
W20	20	8.13	603	385.9	44.2	8.9	28.3	1.8	30.7	61	125.9	0.05	0.1
W21	22	7.63	751	480.6	53.7	29.0	10.11	0.58	64.3	10.1	206	1.15	N.D.
W22	23	7.69	989	632.9	90.8	48.7	25.29	0.67	189.7	57.51	197.9	1.03	N.D.
W23	21	7.59	566	362.2	62.8	20.4	8.4	0.93	75.2	16.9	156.3	1.73	0.06
W24	21	7.84	1011	647	23.8	9.4	160	1.92	145.6	98	173	0.09	N.D.
W25	20	7.82	681	435.8	54.6	38.4	1.44	0.76	130	13.5	156.7	1.82	N.D.
W26	22	7.78	1270	812.8	43.8	18.2	1.26	0.31	95.2	10.1	112.8	1.41	0.05
W27	22	7.62	675	432	65.9	28.9	9.02	0.49	70.8	34.6	210.9	1.34	N.D.
W28	23	7.75	440	281.6	27.2	23.3	22.6	1.38	46.4	21.1	142.6	0.09	N.D.
W29	21	7.62	814	520.9	30.4	30.4	0.85	0.85	103.7	62.2	196.2	0.06	0.06
W30	21	7.91	396	253.44	39.5	19.6	1.44	0.31	28.8	19.3	134.5	2.1	N.D.
S31	14	7.76	633	380	55	13	10	0.5	40	16	178	1.9	0.03
S32	21	7.53	1777	1066	120	106	29.8	2	620	53	127	2.03	0.18
S33	14.5	7.81	453	272	51	17.2	7.1	1.32	39	13	173	2.71	0.25

N.D. = Not detected.

Table 3- Hydrochemical parameters of the Lesser Zab River samples for high flow period

S. No.	T°C	pH	EC µs/cm	TDS mg/l	Turb-idity NTU	Ca^{2+} ppm	Mg^{2+} ppm	Na^{+} ppm	K^{+} ppm	SO_4^{2-} ppm	Cl^{-} ppm	HCO_3^{-} ppm	NO_3^{-} ppm	PO_4^{3-} ppm
34	19.9	7.74	361	231	0.31	53	15.87	6.99	1.47	30	12	170	1.4	0.19
35	19.3	7.72	361	231	43.7	45	11	8	1.3	36	14	180	2.09	0.25
36	19.4	7.76	368.7	236	50.3	52	12	8	1.3	42.3	12	179	2.1	0.25
37	19.3	7.8	434.3	278	48.6	56	12	9	1.1	42	14	180	2.04	0.29

Table 4- Hydrochemical parameters of the Lesser Zab River samples for low flow period.

S. No.	T°C	pH	EC µs/cm	TDS mg/l	Turb. NTU	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SO_4^{2-}	Cl^{-}	HCO_3^{-}	NO_3^{-}	PO_4^{3-}
34	22.3	7.76	314	201	0. 29	50 .2	15.1	6.0	0.98	34	13	140	1.4	0.22
35	22.3	7.84	335.9	215	20.1	42	11	7	0.9	40	12	145	1.9	0.25
36	22.6	7.81	339	217	22	46	14	7	0.9	40	11	145	1.92	0.17
37	22.3	7.9	404.6	259	25.8	50	10	7.5	1.0	40	11	145	2.09	0.3

Table 5- Statistical characteristics of hydrochemical parameters of the wells and springs samples.

Units	Parameter	Location	Mean	Range	Med.	IQS, 2009	WHO, 2008
˚C	Temp.	Well	20.7	16 - 23	21	-	-
		Spring	16.5	14 - 21	14.5		
	pH	Well	7.74	7.33 - 8.25	7.74	6.8-8.5	6.5-8.5
		Spring	7.7	7.53 - 7.81	7.76		
Ms/cm	EC	Well	840.5	265 - 1940	716	-	-
		Spring	1061	453 – 1777	633		
ppm	TDS	Well	538.05	169.6- 1241	458.24	1000	1000
		Spring	636.8	272 - 1066	380		
ppm	Ca^{2+}	Well	67.3	18.5-183.21	56.53	150	100
		Spring	75.3	51 -120	55		
ppm	Mg^{2+}	Well	30.74	8.54-119.13	22.42	100	125
		Spring	45.4	13 -106	17.2		
ppm	Na^{+}	Well	28.63	1.26- 159.9	12.22	200	200
		Spring	15.6	7.1 -29.8	10		
ppm	K^{+}	Well	1.09	0.13 - 2.72	0.98	-	12
		Spring	1.27	0.5 - 2	1.32		
ppm	Cl^{-}	Well	39.61	8.44-123.6	32.28	350	250
		Spring	27.3	13 -53.00	16		
ppm	$SO4^{2-}$	Well	154.4	16.25-716	75.11	400	250
		Spring	229.6	29 -620	40		
ppm	HCO_3^{-}	Well	161.12	49.05-210.9	160.7	-	-
		Spring	159.3	127-178	173		
ppm	NO_3^{-}	Well	1.2	0.05-3.08	1.18	50	50
		Spring	2.21	1.9-2.75	2.03		
ppm	PO_4^{3-}	Well	ND	ND	ND	-	-
		Spring	ND	ND	ND		
ppm	B	Well	0.15	0.03-0.3	0.061	0.5	-
		Spring	0.16	0.09-0.23	0.18		

Table 6- Statistical characteristics of hydrochemical parameters of the Lesser Zab River samples

Units	Parameter	Low flow period			High flow period			IQS, 2009	WHO, 2008
		Mean	Range	Medium	Mean	Range	Medium		
˚C	Temp.	22.37	22.3 -22.6	22.45	19.4	19.3-19.9	19.35	-	-
	pH	7.82	7.76 -7.90	7.78	7.75	7.72-7.8	7.5	6.8-8.5	6.5-8.5
µs/cm	Ec	348.3	314 – 404.6	337.4	381..2	361-434.3	364.5	-	-
ppm	TDS	223	201 - 259	216	244	231-278	233.5	1000	1000
NTU	Turbidity	17.07	0.29-25.8	21.05	35.7	0.31- 50.3	46.15	-	5.0
ppm	Ca^{2+}	47.05	42-50.2	44	51.5	45 - 56	52.5	150	100
ppm	Mg^{2+}	8.7	10-15.1	12.5	12.71	11-15.87	12	100	120
ppm	Na^{+}	7	6-7.5	6.87	7.99	6.99 -9.0	8	200	200
ppm	K^{+}	0.94	0.9-1	0.9	1.29	1.1- 1.47	1.3	-	12
ppm	Cl^{-}	11.7	11-13	11.5	13	12- 14	13	350	250
ppm	SO_4^{2-}	37.5	34-40	40	37.57	30-42.3	42.1	400	240
ppm	HCO_3^{-}	141	140-145	142	177.2	170-180	180	-	-
ppm	NO_3^{-}	1.5	1.4-2.09	1.45	1.91	1.4-2.1	1.82	50	50
ppm	PO_4^{3-}	0.2	0.17-0.3	0.19	0.25	0.19-0.29	0.25	-	-
ppm	B	ND	ND	ND	ND	ND	ND	0.5	-

Table 7- Trace element concentration in the water samples of the study area.

Units	Parameter	Location	Range	Mean	Med.	IQS, 2009	WHO, 2008
ppm	Cd	Well	ND	ND	ND	0.003	0.003
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		
ppm	Cr	Well	ND	ND	ND	0.05	0.05
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		
ppm	Co	Well	ND	ND	ND	-	-
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		
ppm	Cu	Well	ND	ND	ND	2	1
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		
ppm	Fe	Well	0.020 – 0.11	0.061	0.07	< 3	0.3
		Spring	ND	ND	ND		
		Lesser Zab	0.058- 0.1	0.07	0.063		
ppm	Mn	Well	0,0032-0.25	0.026	0.006	0.4	0.1
		Spring	0.0061-0.0071	0.0066	0.003		
		Lesser Zab	0.023-0.089	0.063	0.071		
ppm	Ni	Well	ND	ND	ND	0.07	0.02
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		
ppm	As	Well	0.001-0.0019	0.001	0.001	0.01	0.01
		Spring	ND	ND	ND		
		Lesser Zab	0.0018-0.0019	0.001	0.001		
ppm	Zn	Well	0.01-0.078	0.033	0.019	3	3
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		
ppm	Pb	Well	ND	ND	ND	0.01	0.01
		Spring	ND	ND	ND		
		Lesser Zab	ND	ND	ND		

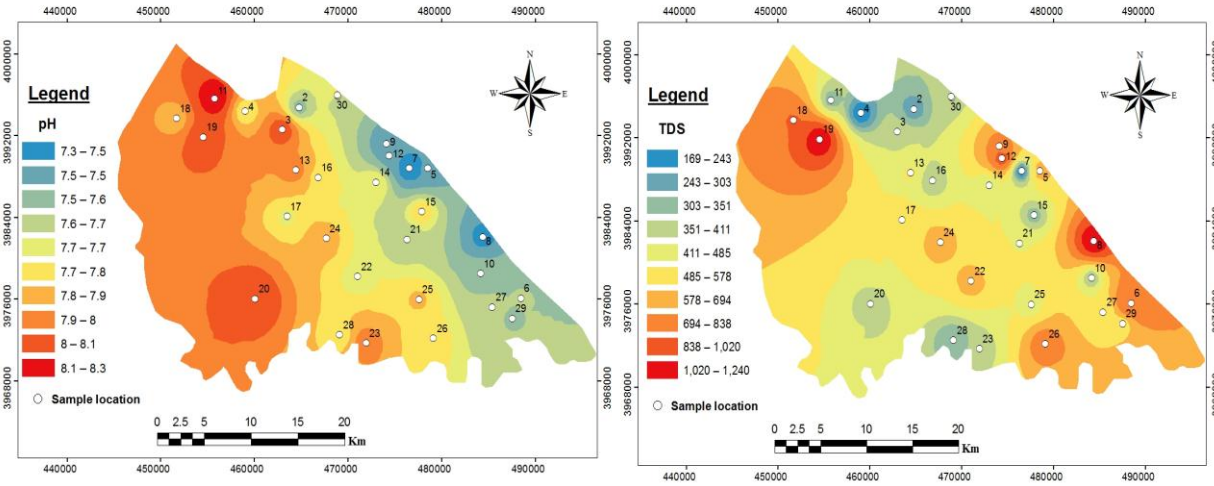

Figure 4- Spatial distribution of pH and TDS values of the study area.

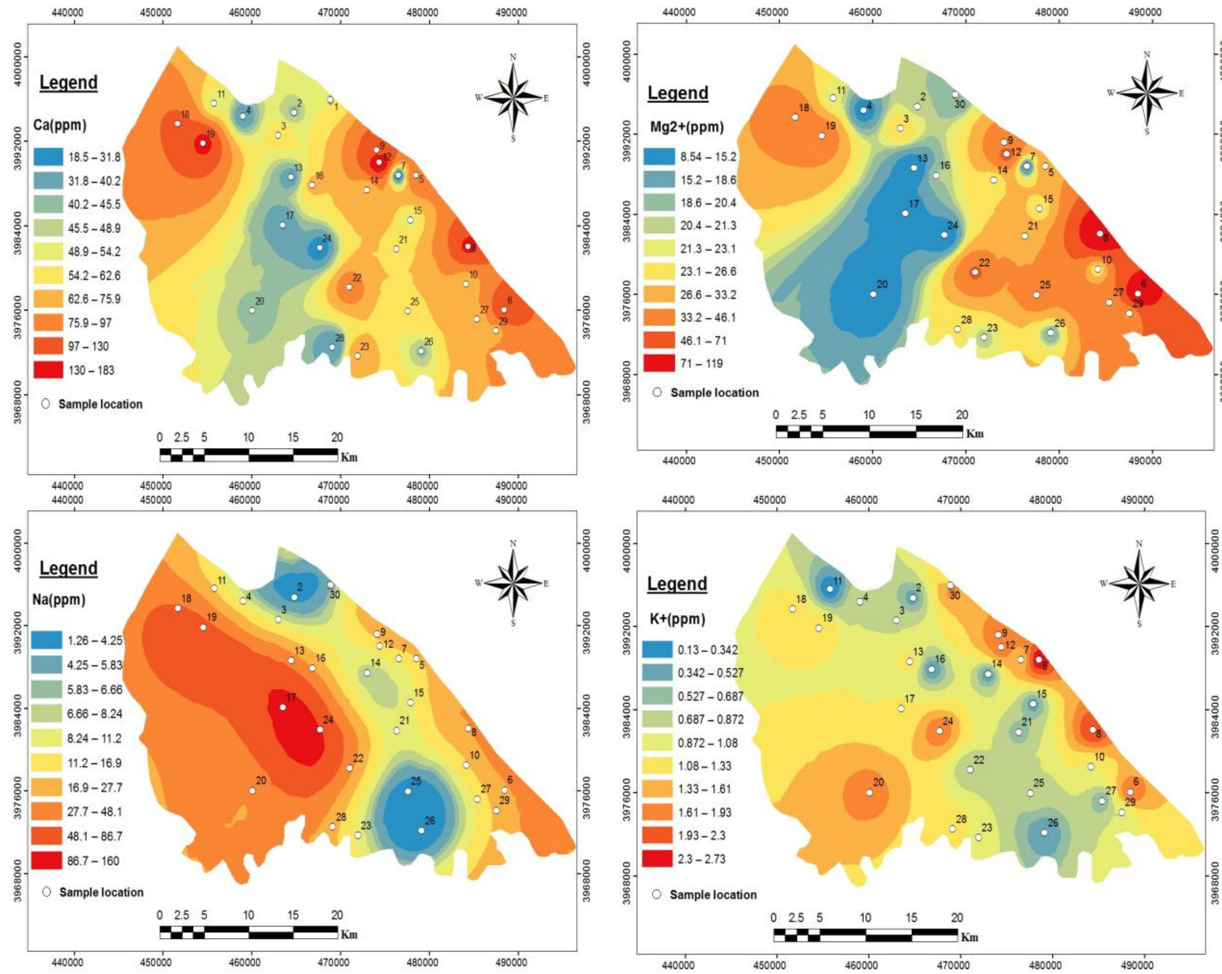

Figure 5- Spatial distribution of Ca, Mg, Na and K values of the study area

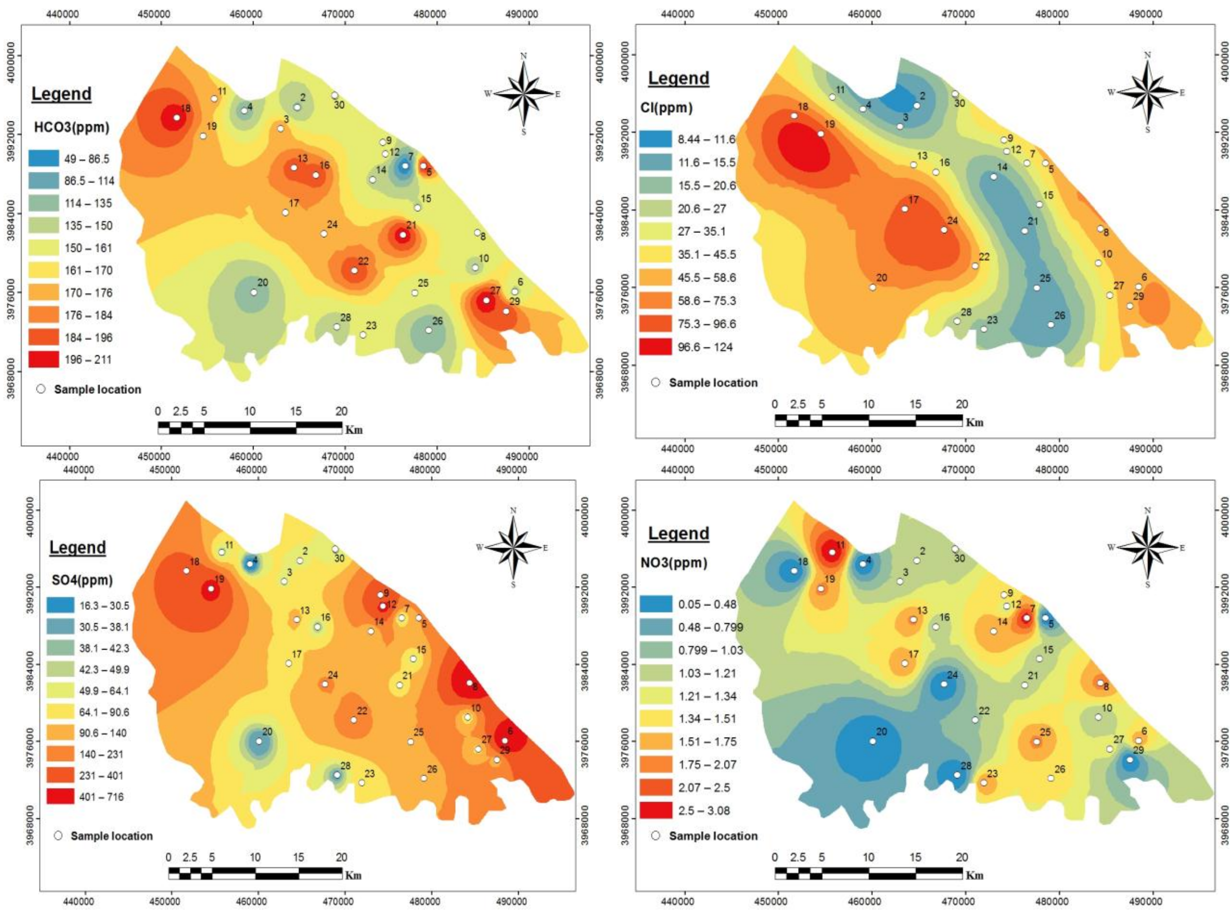

Figure 6- Spatial distribution of HCO_3, Cl, SO_4, and NO_3 values of the study area.

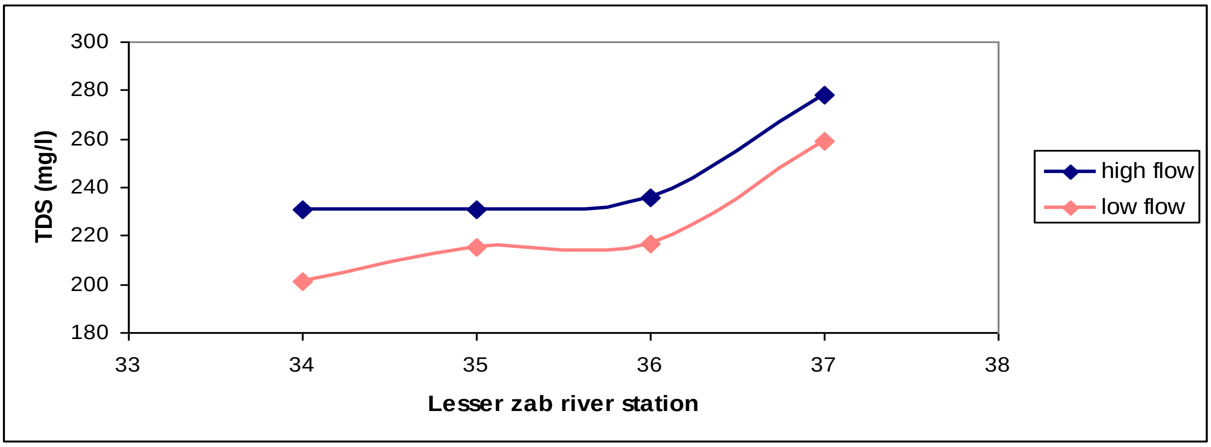

Figure 7- TDS concentration (ppm) of Lesser Zab River for high and low flow conditions

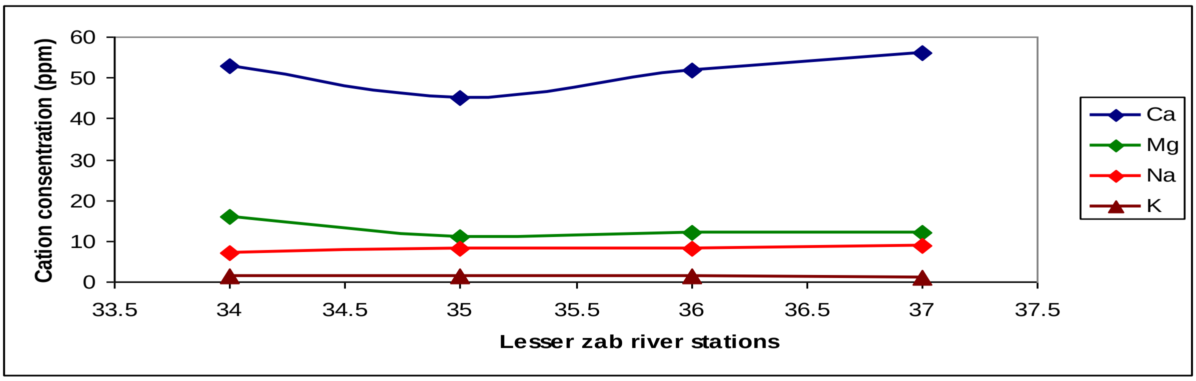

Figure 8a- Cations concentration (ppm) of Lesser Zab River samples for high flow condition.

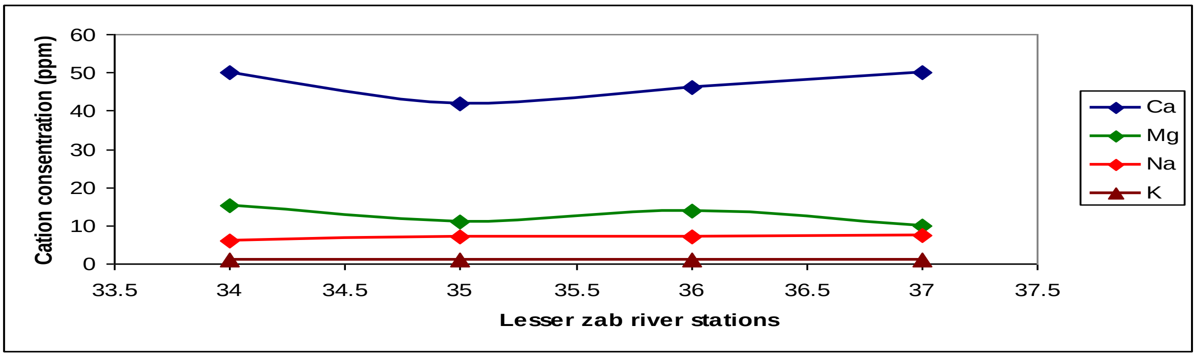

Figure 8b- Cations concentration (ppm) of Lesser Zab River samples for low flow condition.

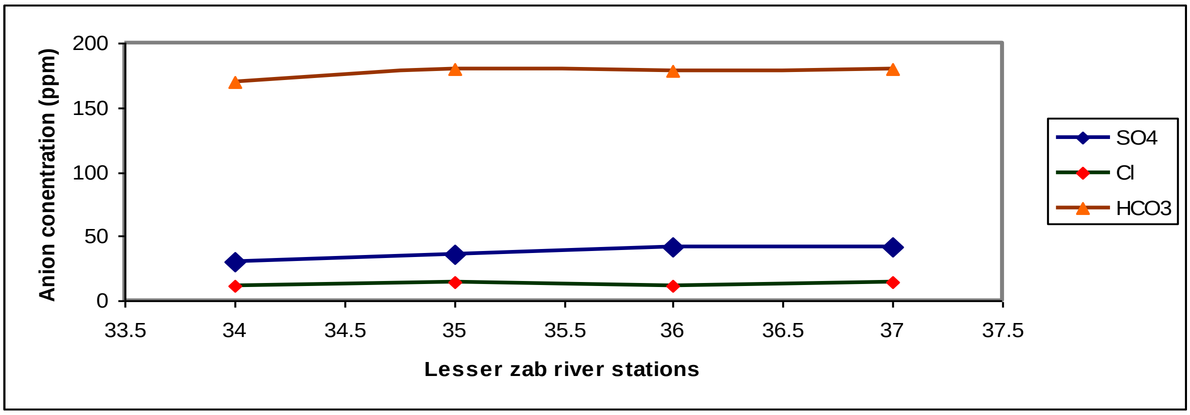

Figure 8c- Anions concentration (ppm) of Lesser Zab River samples for high flow condition.

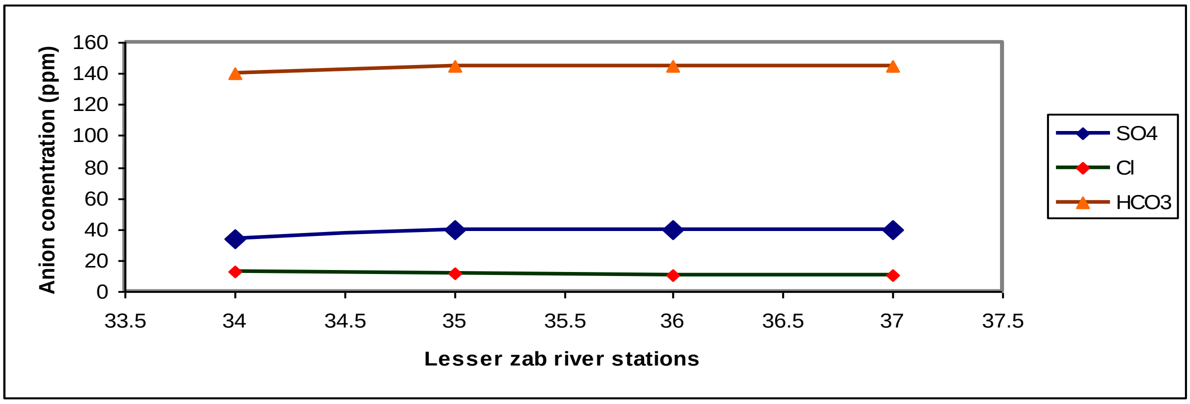

Figure 8d- Anions concentration (ppm) of Lesser Zab River samples for low flow condition.

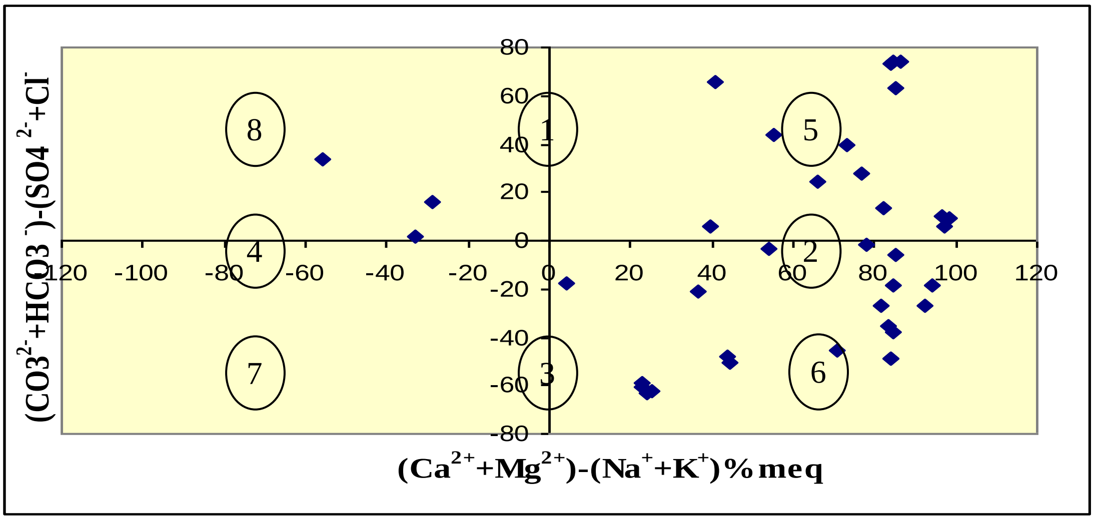

Figure 9- Chadha's diagram of wells, springs and Lesser Zab River samples for the study area.

2. Surface and groundwater suitability for different purposes:

Water suitability for any purpose is related to its physical, chemical and biological properties. Water is mainly used for drinking, irrigation or for industrial purposes if it fulfills the criteria or standards of certain limits.

Water uses for drinking purpose

In general there are several standers to determine the suitability of water for drinking, in this study the WHO [10] and IQS [9] standards were used. According to these two standards, all of the surface water for the two sampling periods were suitable for drinking with reference to major ions and TDS values, however, samples exceeded the recommended limit of turbidity values, all of the selected samples for groundwater and spring were found to be suitable for human drinking except the spring sample 32 and well samples (6, 7,8, 9,12,18 19,22 and 29) were exceed the permissible limits for drinking water.

Water uses for Livestock

According to Altoviski [14], all the groundwater and surface water samples have ranged as very good samples for both livestock and poultry uses as shown in Table-8.

Table 8- Water quality parameters (ppm) guide for the livestock uses [14]

Parameters	Very good	Good	Permissible	Can be used	Maximum Limit
Na	800	1500	2000	2500	4000
Ca^{+}	350	700	800	900	1000
Mg^{+}	150	350	500	600	700
Cl^{-}	900	2000	3000	4000	6000
SO_4^{2-}	1000	2500	3000	4000	6000
T.D.S	3000	5000	7000	10000	15000

Water uses for irrigation purpose:

The suitability of irrigation water is mainly depends on the amounts and type of salts present in water. The main soluble constituents are calcium, magnesium, sodium as cations and chloride, sulphate, bicarbonate as anions. The other ions are present in minute quantities. Quality of irrigation is judged with three parameters:

a. Total salt concentration (EC).
b. Sodium Adsorption Ratio (SAR).
c. Na%

Salt concentration of irrigation water is measured as electrical conductivity (EC). Conventionally saline waters are those which have sodium chloride as the predominant salt. SAR is a measurement of the ratio of sodium (Na^{+}) ions to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, expressed in meq/1. The following formula was used to evaluate SAR and Na% values [15] :

$$\mathbf{SAR = Na^{+} / \{\sqrt{\ } Ca^{2+} + Mg^{2+}) / 2\}} \quad \mathbf{(1)}$$

$$\mathbf{Na\% = [rNa + rk] \times 100 / [rCa + rMg + rNa + rK]} \quad \mathbf{(2)}$$

The values of SAR in excess of 9 mg/l indicate that there is a medium or high sodium or low calcium plus magnesium content in the groundwater. If this kind of water is used in irrigation, it can cause the dispersion of soil colloids, destroying soil texture and permeability [16]. For the study area SAR and Na% were calculated Tables -9 and 10 and the data is plotted on the US Salinity Laboratory diagram Figure-10. According to this classification all the water samples are suitable for irrigation purpose. Because the water samples located in classes (C2S1) which is relatively good for irrigation purpose, and (C3S1) which is suitable for irrigation purpose. According to Don classification [17], Table-11, all water samples are suitable for irrigation purpose.

Table 9- SAR and Na% values for water well and spring samples

Wells No.	SAR	Na%	Wells No.	SAR	Na%
1	0.21	7.9	18	0.84	22.3
2	0.05	2.9	19	1.38	29.5
3	0.08	3.8	20	0.72	30.1
4	0.25	14.6	21	0.19	8.1
5	0.25	8.9	22	0.37	11.4
6	0.33	8.13	23	0.12	5.3
7	0.26	17.1	24	4.95	78
8	0.34	7.8	25	0.03	1.3
9	0.43	13.2	26	0.03	1.6
10	0.26	10.9	27	0.16	6.6
11	0.17	7.6	28	0.54	23.6
12	0.29	7.2	29	0.32	11.6
13	3.05	66.6	30	0.03	1.91
14	0.03	1.5	31	0.03	10.2
15	0.17	7.7	32	0.03	8.3
16	0.22	9	33	0.12	7.9
17	2.78	64.2			

Table 10- SAR and Na% values for Lesser Zab River samples.

No.	Low flow period		High flow period	
	SAR	Na%	SAR	Na%
34	0.07	7.8	0.15	7.01
35	0.1	10.7	0.20	9.8
36	0.09	9.7	0.18	9.2
37	0.09	9.9	0.20	9.7

Table 11- Classification of Don [17] for irrigation waters.

EC µs\cm	TDS ppm	SAR	Na%	pH	Water Quality
250	175	3	20	6.5	Excellent
250-750	175-525	3-5	20-40	6.5-6.8	Good
750-2000	525-1400	5-10	40-60	608-7.0	Permissible
2000-3000	1400-2100	10-15	60-80	7-8	Doubtful
More than 3000	>2100	>15	>80	>8	Unsuitable

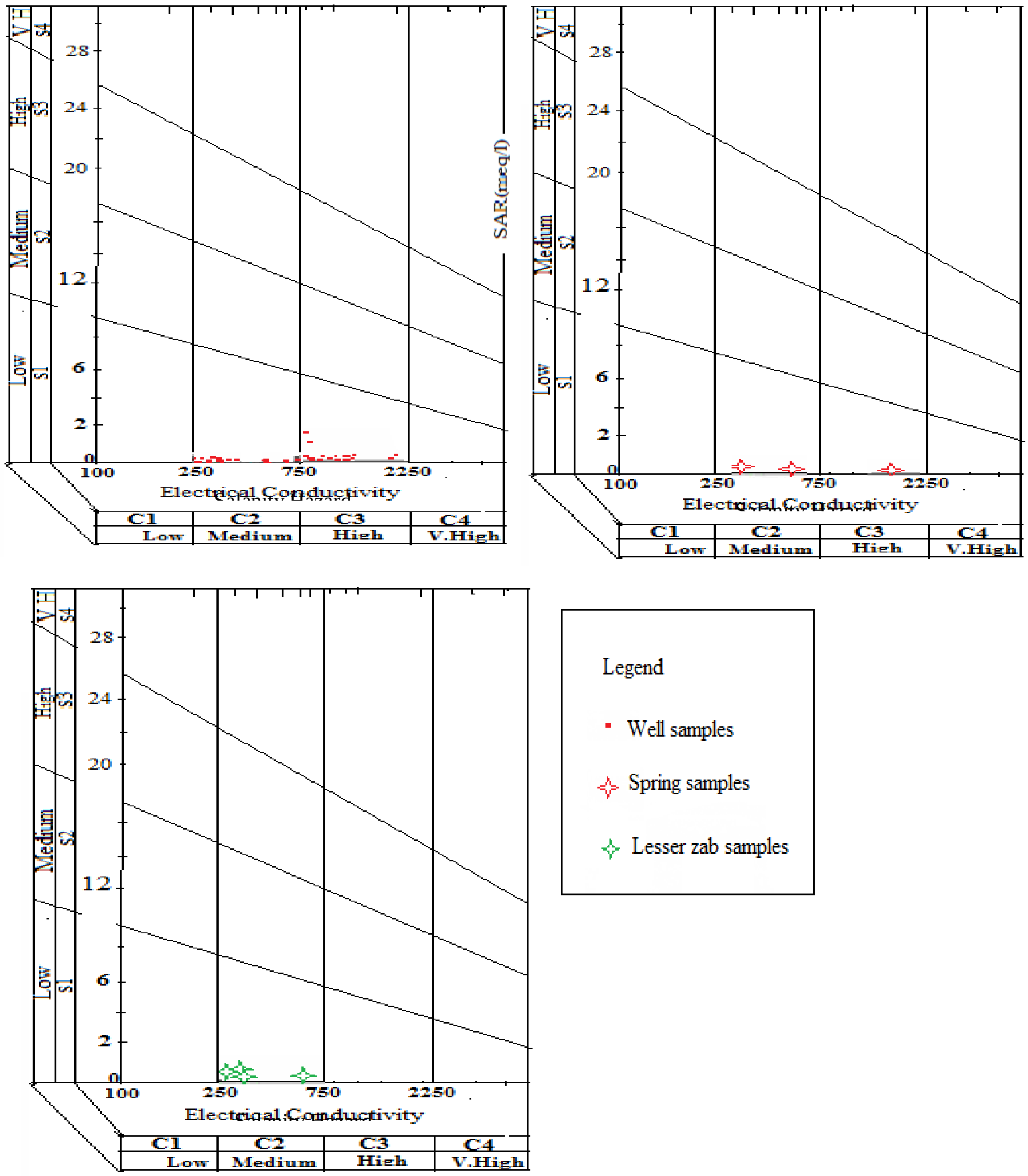

Figure 10- Diagram for use in interpreting the analysis of irrigation water. Adapted by U.S. Salinity Laboratory staff (1954) in Hem [18]

Water uses for industry purpose

According to Hem [18], all surface and groundwater samples are not suitable for all types of industries, due to high ions concentrations Table-12.

Table 12- Suitability of water for industrial purposes [18]

Parameter	Chemical pulp and paper		Wood chemicals	Synthetic rubber	Petroleum products	Canned, dried frozen fruits and vegetables	Soft-drinks bottling	leather tanninsg	Hydraulic cement manufacture
	Unbleached	Bleached							
Fe	1	0.1	0.5	0.1	1	0.2	0.5	0.3	25
Mn	0.5	0.05	0.2	0.1	-	0.2	0.05	0.2	0.5
Ca	20	20	100	80	75	-	100	--	-
Mg	12	12	50	36	30	-	-	--	-
Cl	200	200	500	-	300	250	500	250	250
HCO_3	-	-	250	-	-	-	-	---	-
SO_4	-	-	100	-	-	250	500	250	250
NO_3	-	-	5	-	-	10		---	-
Cu	-	-	-	-	-	-	-	---	-
Zn	-	-	-	-	-	-	---	---	-
HCO_3	-	-	250	-	-	-	-	-	-
SO_4	-	-	100	-	-	250	500	250	250
TDS	-	-	1000	-	1000	500	--	---	600
pH	6 - 10	6 - 10	6.5-8	6.5-8.5	6-9	6.5-8.5		6-8	6.5-8.5
TH	100	100	900	350	350	250	-	Soft	-

Water uses for Building purpose:

Study the suitability of water for building purposes is based on [14] classification, according to this classification, all surface and groundwater samples are suitable for building purpose Table-13.

Table 13- Suitability of water samples of the study area for building purposes [14]

Parameters (ppm)	Na^+	Ca^{+2}	Mg^{+2}	Cl^-	SO_4^{-2}	HCO_3^-
Permissible limit	1160	437	271	2187	1460	350

Conclusions:

Several conclusions can be drawn from the present study as follows:

1. The high values of EC and TDS of the groundwater samples indicated that these samples located on Fatha and Injana Formations. These Formations are characterized by presences of gypsum in Fatha formation, and thick beds of claystone in Injana Formation which causes to prevent of vertical movement of water or decrease the rate of infiltration.
2. Spatial distribution of TDS, cations and anions values through the studied area revealed that the groundwater properties are considerably differs from site to another mainly due to the lithological variations in the area.
3. For surface water samples the value of TDS and turbidity increases with the flow direction.
4. Groundwater and surface water of the study area shown to be suitable in general for drinking purpose according to IQS [9], and WHO [10], standards, except few places are unsuitable for drinking , whereas it is suitable, for irrigation and building purposes.

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