Hydrochemical Characteristics and Shallow Groundwater Quality in Kirkuk Urban Area, Iraq

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Abstract— *The assessment of hydrochemical characteristics and shallow groundwater quality was carried out in Kirkuk urban area, Iraq. Twenty two water samples were collected systematically at 20 locations for each of high and low water seasons in April and September (2014) and analysed for physical and chemical parameters. Hydrochmical data suggest that contamination of ground water is caused by infiltration of surface water polluted by domestic seepage pits and leakage from local agricultural area. Depending on hydrochemical facies, the type of water that predominates in the urban area is Ca-Mg-SO4 type during both wet and dry seasons. The study found that Kirkuk shallow groundwater is unsuitable for drinking water and industries purposes but some of water samples are suitable for construction and irrigation purposes.*

Keywords— Kirkuk, Urban area, Groundwater Quality, Hydrochemical characteristics.

I. INTRODUCTION

Groundwater quality in Kirkuk urban area is affected by human activities, such as industrial production, transportation and housing, besides, the continued growth of urban population. The population of Kirkuk city is predicted to increase from 1,050,000 in 2008 to 1,445,556 in 2020 (Omer et al, 2014), which contribute to increase the quantity and size of Municipal solid waste that consider as a source of contamination with the ability to transfer pollutants to groundwater (Mustafa et al., 2013).The presence of residential, local agricultural area, industrial sites, and oil industry in Kirkuk city resulted in waste generation. Industrial waste and fertilizer added to the farmland contribute to change the quality of groundwater after the penetration and reach to the reservoir. The shallow groundwater aquifers represent the uppermost water-bearing zones; so they more susceptible to contamination than deeper aquifers. Groundwater bodies in Kirkuk city are fed naturally by direct precipitation and influent seepage from Khassa River, and artificially by seepage from green spaces and from domestic seepage pit, where Kirkuk's water department produces about 350000 m^3 per day of drinking water (Pollus, 2010). Because Kirkuk city is free of sewage disposal projects, some of these waters may enter groundwater through seepage pits. Populations are used the shallow aquifer for public, domestic and irrigation water supply. Therefore, the population will be at risk of water consumption. This paper focuses on studying and discussing the chemistry and quality shallow groundwater in Kirkuk urban area in detail.

1.1 Regional setting of the study area

The urban area of Kirkuk city is located 250 km north of Baghdad, the capital city of Iraq. Geographically, the study area is located in the northwestern part of Lailan sub-basin between latitudes 35˚ 30.162' – 35˚ 30.195' N and longitude 44˚ 26.304' – 44˚ 26.259' E, spreading over an area of 101.14 km². Khassa is Ephemeral River flowing from northeast to southwest across the central of Kirkuk city. The study area is characterized by a humid subtropical climate (Frenken, 2009). Stratigraphically, the northeast part of the study area is covered by the outcrops of Fatha (Middle Miocene), Injana (Upper Miocene) and Al-Mukdadyia (Lower Pliocene) Formations that deposited in shallow marine, continental and fluvial environment respectively. Alluvial Quaternary deposits as a sheet run-off and slope deposits cover the remaining flat areas (Figure 1). Alluvial is commonly consisted of clayey silt, sand and gravel with secondary gypsum (Buday, 1980; Kassab and Jassim, 1980; Jassim et al., 1984; Jassim and Goff, 2006).Shallow groundwater of study area is located in the unconfined aquifer within Quaternary deposits (Al-Naqash et al. 2003). The aquifer consists of gravel, sand, silt, and clay found either as an individual layer or as a mixture with some lenses of secondary gypsum restricted in the southern part of the study area. The general direction of groundwater flow is from the northeast part towards the lower topography in the south-west (Saud, 2009).

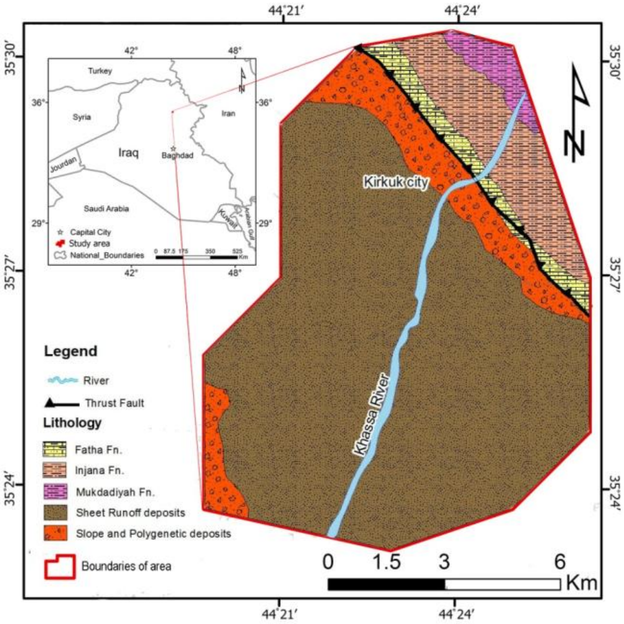

FIGURE 1: LOCATION AND GEOLOGICAL MAP OF THE STUDY AREA (BANDER AND AL-JUMAILY, 1993)

II. MATERIALS AND METHODS

Groundwater samples were collected systematically with a density of one sample per 2 kilometer square to get a uniform coverage of the study area (De Vivo et. al, 2008) observed in the Figure 2.Twenty-two water samples were collected at 20 locations for each high and low water seasons in April and September 2014 respectively. The parameters such as pH and electrical conductivity (EC; µS/ cm) were measured using portable devices immediately after sampling. The groundwater sampled container were labeled, tightly packed and stored in a cooled box at 4°C (with ice packs) until analyzed chemically in the Laboratory using the standard procedures suggested by American Public Health (APHA, 1994). The hydrochemical study of groundwater included measurements of acidity (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), concentration of the cations major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anion major ions (HCO_3^{-}, SO_4^{2-}, Cl^{-}) and minor ion (NO_3^{-}).

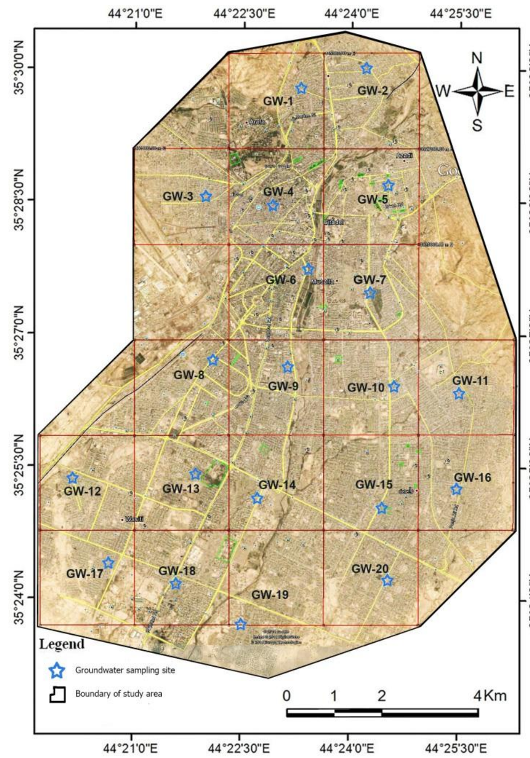

FIGURE 2: GROUNDWATER SAMPLING SITES

III. RESULTS AND DISCUSSION

Results of Hydrochamical parameters were listed in Tables 1a and 1b.The pH of water is a measure of its reactive characteristics (Fitts, 2002; Todd and Mays, 2005; Thompson et al., 2007). The pH mean values of the water samples are6.99 (ranges of 6.77 to 7.43)during wet season and are 7.04(ranges of 6.83 to 7.34) during dry season. Most of the water samples are between neutral in the upper part of the study area and slightly alkaline in the lower part due to the fact when groundwater migrates from recharge toward discharge, alkalinity changes from low to high (Fitts, 2002). The lowest pH value is restricted in the ancient part of the city (Shorja; GW-7) especially during wet season that could be due to hydrogen ions generated from nitrification processes (Stumm and Morgan, 1996). The abundance of cations were arranged in the following order: Ca>Mg > Na > K, whereas the abundance of anions were arranged in order: SO_4>HCO_3>Cl> NO_3during wet season and arranged in order: SO_4>Cl>HCO_3> NO_3during dry season.

Calcium is the dominant cation found in the groundwater of the study area. Its mean concentrations during wet season are303.6 mg/L (variesof115 to 613mg/L), and 314.1 mg/L (varies of 123 to 656mg/L) during dry season. It is clear, calcium ion is restricted in the ancient residential area in Kirkuk city particularly in Shorja quarter (Figure 1; GW-7), in which domestic seepage pits is predominant. Consequently, the nitrification process in unsaturated zone is prevalent and leads to enhance acidity that may be buffered by the dissolution of carbonate mineral from the surrounding aquifer materials. This finding corresponds with the fact that there must be some buffer mechanism in ground water, which keeps the pH approximately constant (Miotlinski, 2008).Magnesium concentrations during dry season were higher due to the dilution by rainwater making concentration during wet season relatively low. Mg^{2+}average content during wet seasons are146.5 mg/L (rangesof35to 422 mg/L) and 148.6 mg/L (ranges of 40to428mg/L) during dry season.

The mean concentrations of Na^+are143.1 mg/L (rangesof44to418mg/L) during wet season, but are 147.8 mg/L (ranges of 42to412 mg/L) during dry season. The high values of Na in urban area reflect that groundwater polluted by the sewage from seepage pits of surrounding residential area. This result corresponds with the results of many researchers (Eisena and Anderson, 1979; Naftz and Spangler, 1994; Eiswirth and Hoetzl, 1997; Mason et al. 1999; Buttle and Labadia, 1999).

Potassium mean concentrations are5.1 mg/L (ranges of 2 to17) during wet season, while the mean concentrations of K^+ are 5.25 mg/L (ranges of 2 to17mg/L) during dry season. The similarity between two seasons indicates that the source of K^+ is constant and may be derived from domestic wastewater especially when potassium concentrations increases in the oldest residential districts (Shatarlu; GW-4, Shorja; GW-7 and Granada; GW-9) compared with other regions in Kirkuk city. This result is supported by the results of many researchers (Ambily and Jisha, 2012; Zheng, 2013; El-Nahhal et al., 2014) they found that many surfactants, soups and cosmetics, are containing potassium in their chemical structure. These products may be degraded during sludge formation resulting in transferring potassium into inorganic form, thus contribute significantly to the pollution of sewage.

The elevated sulfate concentrations with calcium reflect the presence of secondary gypsum in the Quaternary deposits, where the mean concentrations of sulfate are 1428 mg/L (varies of 456 to 3050) during wet season and 1421 mg/L (variesof475 to 3121) during dry season. The artificial sources of sulfate derived from wastewater of residential, local agricultural and industrial areas in the Shorja (GW-7), Musala and Panja Ali (GW-20) was clear evidence of urbanization. This result is proved by many researchers (Long and Saleem, 1974; Schicht , 1977; Eisena and Anderson, 1979).

The average concentrations of HCO_3^- are 180.8 mg/L(rangesof67to450 mg/L) during wet season and 105.9 mg/L (ranges of 15to268 mg/L) during dry season. The highest concentration of HCO_3^- in groundwater during the wet season may be derived from the dissolution of carbonate minerals from the surrounding surface soil by CO_2^- rich rainwater. The high bicarbonate value in groundwater sample (GW-7) present in ancient residential neighborhoods (Shorja and Musala) in Kiukuk city might be due to seepage from local agricultural area and domestic sewage from seepage pits. Decomposition of organic matter in sewage by microbes leads to formation of CO_2 in water that increases the concentration of carbonate and bicarbonate in groundwater (Vyas and Sawant, 2008).

Chloride mean concentrations are91.3 mg/L(ranges of 31 to304mg/L) during wet season and 107.2 mg/L (rangesof40 to 497mg/L) during dry season. The special fluctuation of chloride concentration is not related with the direction of groundwater movement in spite of chloride is conservative component. This result enhances the fact that chloride represents the major products of urbanization that change groundwater chemistry (Eisena and Anderson, 1979). The high concentration of chloride observed near Shorja and Musalla quarters (Figure 1; GW-7) could be due to organic waste from domestic sewage of seepage pits from surrounding residential area. The similar finding was obtained by other workers (Yogendra and Puttaiah, 2008; Singh and Khan 2011).

Nitrate is one of the most common contaminants existed in urban groundwater (Martı´nez et al., 2014).Therefore, the nitrate mean concentrations are 73.1 mg/L (rangesof12 to 208 mg/L)during wet season and 70.1 mg/L (rangesof13to 202 mg/L) during dry season. The high value of NO_3 in ancient residential areas in Kirkuk city (Tesin quarter; GW-8)may be generated from oxidation of ammonium formed from sewage of seepage pits through unsaturated zone, where sufficient O_2 diffuses from atmosphere causing most oxidation of the reduced wastewater components (Stumm and Morgan 1996).

TABLE 1A
RESULT OF PHYSICO CHEMICAL ANALYSIS OF GROUNDWATER SAMPLES IN STUDY AREA DURING WET SEASON

Sample ID	pH	EC (µs/cm)	TDS (mg/L)	TH (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO3 (mg/L)	SO4 (mg/L)	Cl (mg/L)	NO3 (mg/L)
GW-1	6.91	2350	1682	1617	486	98	98	4	203	1585	68	12
GW-2	7.09	2200	1563	1250	305	119	135	3	166	1236	80	139
GW-3	6.85	1049	704	587	124	67	46	3	91	513	38	56
GW-4	6.85	1361	928	801	200	74	49	13	109	761	40	72
GW-5	6.91	2390	1714	1756	489	130	86	2	440	1683	48	62
GW-6	7.06	877	583	431	115	35	44	8	67	456	31	13
GW-7	6.90	4820	3856	2082	613	134	261	13	450	2011	304	108
GW-8	6.84	1546	1064	792	166	92	94	2	233	525	88	208
GW-9	6.81	1651	1142	947	233	89	75	17	110	955	65	86
GW-10	6.77	1930	1353	1251	340	98	81	3	86	1257	66	63
GW-11	6.83	1932	1355	1153	342	73	113	3	166	1159	116	85
GW-12	7.425	2320	1658	1473	230	218	122	3	134	1578	46	22
GW-13	7.11	3610	2739	2347	483	277	348	3	310	2882	97	42
GW-14	7.09	1539	1059	933	157	131	88	2	69	959	37	73
GW-15	7.11	3460	2607	2192	435	269	289	4	325	2481	127	77
GW-16	7.08	2220	1579	1222	260	139	159	3	163	1410	104	119
GW-17	6.863	1633	1129	917	205	99	105	3	72	1011	65	38
GW-18	7.06	1815	1266	1152	256	125	87	6	91	1188	50	67
GW-19	7.06	2680	1948	1677	275	241	163	2	147	1862	84	34
GW-20	7.23	4480	3532	2630	358	422	418	5	184	3050	272	86
Min	6.77	877	583	431	115	35	44	2	67	456	31	12
Max	7.43	4820	3856	2630	613	422	418	17	450	3050	304	208
Avg	6.99	2293	1673	1361	303.6	146.5	143.1	5.1	180.8	1428	91.3	73.1

TABLE 1B
RESULT OF PHYSICO CHEMICAL ANALYSIS OF GROUNDWATER SAMPLES IN STUDY AREA DURING DRY SEASON

Sample ID	pH	EC (µs/cm)	TDS (mg/L)	TH (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO3 (mg/L)	SO4 (mg/L)	Cl (mg/L)	NO3 (mg/L)
GW-1	6.90	2750	2006	1656	495	102	190	4	155	1625	184	13
GW-2	7.05	2010	1415	1135	277	108	111	3	84	1120	66	106
GW-3	6.95	1071	720	566	123	63	42	3	63	508	46	61
GW-4	6.95	1351	921	792	201	70	48	13	22	749	45	74
GW-5	6.92	2350	1682	1648	458	122	79	2	168	1504	53	61
GW-6	7.11	963	644	498	134	40	47	10	15	503	43	24
GW-7	7.20	4200	3271	2256	656	150	386	14	267	2142	497	97
GW-8	6.83	1284	872	660	137	77	68	2	146	475	70	202
GW-9	6.83	1666	1153	1008	250	93	76	17	49	965	69	98
GW-10	6.92	1914	1341	1281	353	97	81	3	84	1229	66	55
GW-11	6.84	1960	1377	1244	375	74	113	3	68	1185	113	83
GW-12	7.20	2350	1682	1528	246	222	123	3	95	1613	44	26
GW-13	6.98	3500	2642	2354	469	288	305	3	142	2710	95	24
GW-14	7.3	1653	1144	1026	176	142	87	2	62	1046	40	60
GW-15	7.125	3370	2529	2260	461	269	266	4	178	2407	128	76
GW-16	7.22	2190	1555	1336	299	143	167	3	51	1393	103	111
GW-17	6.841	1636	1131	955	217	100	103	3	79	1013	68	28
GW-18	7.07	1775	1235	1180	267	125	84	5	61	1167	49	65
GW-19	7.13	2670	1940	1826	304	259	168	2	61	1939	85	41
GW-20	7.34	4530	3579	2721	384	428	412	6	268	3121	280	97
Min	6.83	963	644	498	123	40	42	2	15	475	40	13
Max	7.34	4530	3579	2721	656	428	412	17	268	3121	497	202
Avg	7.04	2260	1642	1397	314.1	148.6	147.8	5.25	105.9	1421	107.2	70.1

3.1 Classification of groundwater

Total hardness is expressed by its equivalent from calcium carbonate (Todd, 1980). Total hardness is an important parameter used in domestic purpose. Based on Todd classification (1980) for water hardness was classified into four types (Table 2). It is clear that all samples are of very hard type.

TABLE 2
CLASSIFICATION OF WATER DEPENDING ON TH.

Water Class	Total Hardness TH (mg/L)	Water points Classification	
	Todd (1980)	Wet season	Dry season
Soft	7-75		
Moderately Hard	75-150		
Hard	150-300		
Very Hard	> 300	All samples	All samples

According to Altoviski (1962)and Heath (1998), total dissolved solids (TDS) values in the water samples were classified as shown in Table 3.It is clear that the samples GW-7 and GW-20were of brackish water type; Samples (GW-3, GW-4 and GW-6) were of fresh water type; the remainder were slightly brackish during wet and dry seasons.

TABLE 3
CLASSIFICATION OF WATER CLASS DEPENDING ON TDS VALUES (PPM)

Altoviski (1962)		Heath (1998)		Wet season	Dry season
Fresh water	0 - 1000	Fresh	<1000	GW-3, GW-4, GW-6	GW-3, GW-4, GW-6, GW-8
Slightly brackish water	1000-3000	Slightly saline	1000_ 3000	GW-1, GW-2, GW-5, GW-8, GW-9, GW-10, GW-11, GW-12, GW-13, GW-14, GW-15, GW-16, GW-17, GW-18, GW-19	GW-1, GW-2, GW-5, GW-9, GW-10, GW-11, GW-12, GW-13, GW-14, GW-15, GW-16, GW-17, GW-18, GW-19
Brackish water	3000-10000	Moderately saline	3000_10000	GW-7, GW-20	GW-7, GW-20
Salty water	10000-100000	Very saline	10000_35000		
		Briny	>35000		

3.2 Hydrochemical indices and Facies

The ionic relationships Mg/Ca, Cl/HCO_3, and the Cationic Exchange Value (CEV) = {Cl – (Na+ K)}/ Cl) (Table 4) were studied to identify the origin of the groundwater in the study area. Value of Mg/Ca given for inland water is less than 2.0, and for seawater is about five (Sarma and Krishnaiah 1976). The Mg/Ca values for groundwater in the area are below 2.0 ranging from 0.33 to 1.95 during wet season and ranging from 0.33 to 1.84 during dry season indicating that the groundwater is inland with respect to origin. Cl/HCO_3 values measured were all less than 7.0 ranging from 0.19 to 2.54 during wet season and ranging from 0.55 to 4.88 during dry season. The water in the area appears to be of inland origin because waters under marine origin would have values from 20 to 50 (Custodio, 1987). Values of CEV specified for inland waters are close to zero, and for seawater are from +1.2 to +1.3 (Custodio, 1983). The CEV values in the study area are generally below 1.0 fluctuating from -5.07 to -0.44 during wet season and fluctuating from -4.07 to -0.24 during dry season indicating that the groundwater is in inland water origin.

TABLE 4
HYDROGEOCHEMICAL INDICES Mg/Ca, Cl/HCO$_3$, AND CEV IN WATER SAMPLES.

Hydrochemical indices	Mg/Ca		Cl/HCO3		CEV = [Cl – (Na + K)]/Cl	
Sample ID	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
GW-1	0.33	0.34	0.57	2.04	-1.39	-0.61
GW-2	0.64	0.64	0.83	1.36	-1.61	-1.53
GW-3	0.89	0.85	0.71	1.25	-0.89	-0.44
GW-4	0.61	0.57	1.31	3.52	-1.1	-0.79
GW-5	0.44	0.44	0.19	0.55	-2.17	-1.25
GW-6	0.5	0.49	0.79	4.88	-1.61	-0.87
GW-7	0.36	0.38	1.16	3.2	-0.48	-0.24
GW-8	0.91	0.93	0.65	0.83	-0.44	-0.34
GW-9	0.63	0.61	1.01	2.43	-1.1	-0.84
GW-10	0.47	0.46	1.31	1.35	-1.01	-0.92
GW-11	0.35	0.33	1.2	2.87	-0.63	-0.53
GW-12	1.57	1.49	0.59	0.79	-3.31	-3.45
GW-13	0.95	1.01	0.54	1.15	-5.07	-4.07
GW-14	1.38	1.33	0.92	1.1	-2.69	-2.38
GW-15	1.02	0.96	0.67	1.23	-2.81	-2.24
GW-16	0.88	0.79	1.1	3.48	-1.65	-1.42
GW-17	0.8	0.76	1.57	1.48	-1.64	-1.44
GW-18	0.8	0.77	0.95	1.37	-1.84	-1.69
GW-19	1.45	1.4	0.98	2.4	-2.23	-2.06
GW-20	1.95	1.84	2.54	1.8	-1.5	-1.44
Minimum	0.33	0.33	0.19	0.55	-5.07	-4.07
Maximum	1.95	1.84	2.54	4.88	-0.44	-0.24
Inland water	< 2		0.1 - 5		Close to zero	
Marine water	5		20 - 50		+1.2 to +1.3	

Piper diagram was used to define ionic species depending on the major cations (Ca^{2+}, Mg^{2+} and Na^{+}+K^{+}) and anions (HCO_3^{2-} +CO_3^{2-}, SO_4^{2-} and Cl^{-}). Piper diagram (1944) was divided into seven types of water class according to Langguth(1966)as shown in Figure 3.

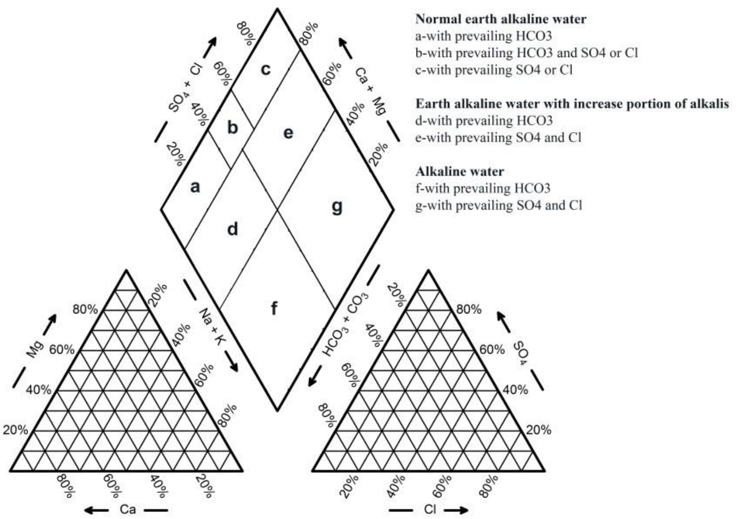

FIGURE 3: PIPER TRILINEAR DIAGRAM WITH LANGGUTH DESCRIPTION

The water samples of study area were plotted on the Piper diagram as shown in the Figures 4a and 4b and were described to determine the main species of water as listed in Table 5. It is evident that the most water types of samples (75%) were earth alkaline water with prevailing sulfate, whereas the other water samples were earth alkaline water with increase portion of Na and prevailing SO_4 and Cl for both two seasons.

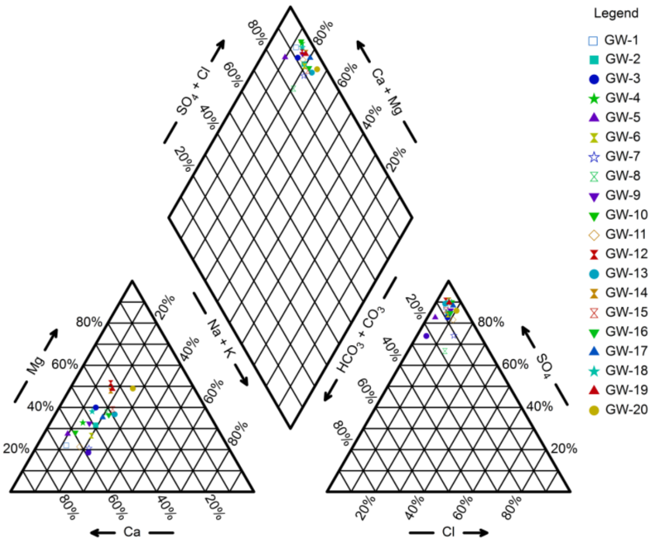

FIGURE 4A: PIPER CLASSIFICATION FOR SAMPLES IN WET SEASON

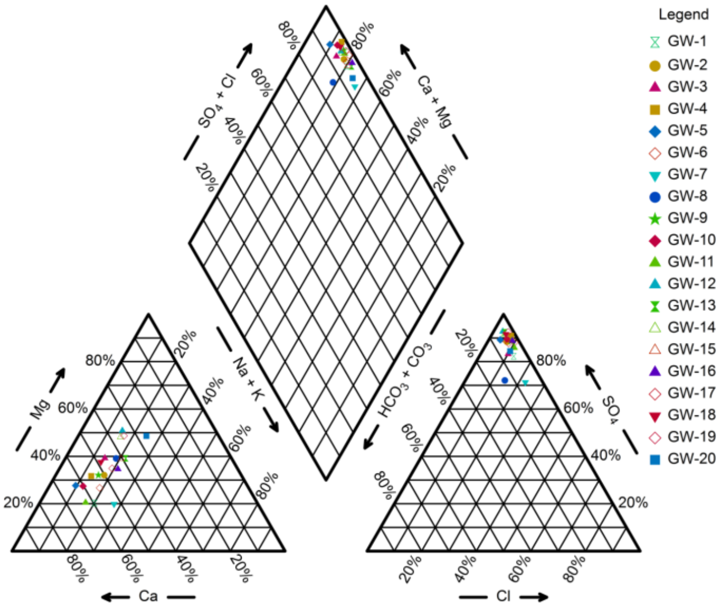

FIGURE 4B: PIPER CLASSIFICATION FOR SAMPLES DURING DRY SEASON

TABLE 5
EXPLANATION OF WATER SPECIES ACCORDING TO LANGGUTH DESCRIPTION (1966).

Water Class	Wet Season	Dry Season	Species
c	GW-1, GW-2, GW-3, GW-4, GW-5, GW-6, GW-8, GW-9, GW-10, GW-11, GW-12, GW-14, GW-17, GW-18, GW-19	GW-1, GW-2, GW-3, GW-4,GW-5, GW-6, GW-8, GW-9, GW-10, GW-11, GW-12, GW-14, GW-17, GW-18, GW-19	Ca-Mg-SO_4
e	GW-7,GW-13,GW-15,GW-16,GW-20	GW-7,GW-13,GW-15,GW-16,GW-20	Ca-Mg-Na-Cl-SO_4

3.3 Groundwater uses for different purposes

The Iraqi (IQS, 2001) standards have been used as guides for the water quality evaluation for drinking purpose (Table 6). It is evident that the shallow groundwater of Kirkuk city is unsuitable for drinking water, because it is affected by TDS, calcium, magnesium, sodium, sulfate and nitrate.

TABLE 6
MEASURED VALUES OF PRESENT STUDY COMPARED WITH IQS, 2009 AND WHO, 2008, PERMISSIBLE LIMITS FOR DRINKING WATER

Parameters	IQS, 2009	WHO, 2008	The suitability of water samples during wet season	The suitability of water samples during dry season
pH	6.5 – 8.5	6.5 – 8.5	Suitable	Suitable
TDS	1000	1000	GW-3, GW-4, GW-6	GW-3, GW-4, GW-6, GW-8
Ca	150	100		
Mg	100	125	GW-1, GW-3, GW-4, GW-6, GW-8, GW-9, GW-10, GW-11, GW-17	GW-3, GW-4, GW-6, GW-8, GW-9, GW-10, GW-11
Na	200	200	Suitable except GW-7, GW-13, GW-15, GW-20	Suitable except GW-7, GW-13, GW-15, GW-20
K	-	12	Suitable except GW-4, GW-7, GW-9	Suitable except GW-4, GW-7, GW-9
Cl	350	250	Suitable except GW-7, GW-20	Suitable except GW-7, GW-20
SO4	400	250		
NO3	50	50	GW-1, GW-6, GW-12, GW-13, GW-17, GW-19	GW-1, GW-6, GW-12, GW-13, GW-17, GW-19

According to Hem (1985) water samples of Kirkuk city are unsuitable for an industry that appears in Table 7.

TABLE 7
WATER-QUALITY REQUIREMENTS FOR SELECTED INDUSTRIES WITH EXPLAIN SUITABILITY OF WATER SAMPLES IN STUDY AREA (HEM, 1985)

Industries		Constituents								
		Ca^{2+}	Mg^{2+}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	TH	pH	TDS
Textiles		-	-	-	-	-	-	25	-	100
Chemical pulp and paper	Unbleached	20	12	-	-	200	-	100	6-10	-
	Bleached	20	12	-	-	200	-	100	6-10	-
Wood chemicals		100	50	250	100	500	5	900	6.5-8.0	1000
synthetic rubber		80	36	-	-	-	-	350	6.2-8.3	-
Petroleum products		75	30	-	-	350		350	6.0-9.0	1000
Canned, dried, and frozen fruits and vegetables		-	-	-	250	250	10	250	6.5-8.5	500
Soft-drinks bottling		100	-	-	500	500	-	-	-	-
Leather tanning		-	-	-	250	250	-	75	6.0-8.0	-
Hydraulic cement manufacture		-	-	-	250	250	-	-	6.5-8.5	600

The suitability of groundwater for building purposes was used depending on Altoviski (1962) classification as shown in the Table 8. It is evident that the 60% of water samples can be used for building purposes. The other water samples (GW-1, GW-5, GW-7, GW-12, GW-13, GW-15, GW-19 and GW-20) were unsuitable due to increase the concentration of Ca^{2+}, Mg^{2+}, SO_4^{2-} and HCO_3^- over the limit.

TABLE 8
EVALUATION OF WATER FOR CONSTRUCTION PURPOSE USES (ALTOVISKI, 1962).

Ions	Permissible Limit	Wet season	Dry season
Na^+	1160	all samples	all samples
Ca^{2+}	437	all except GW-1, GW-5, GW-7, GW-13, GW-15	all except GW-1, GW-5, GW-7, GW-13, GW-15
Mg^{2+}	271	all except GW-13, GW-20	all except GW-13, GW-20
Cl^-	2187	all samples	all samples
SO_4^{2-}	1460	all except GW-1, GW-5, GW-7, GW-12, GW-13, GW-15, GW-19, GW-20	all except GW-1, GW-5, GW-7, GW-12, GW-13, GW-15, GW-19, GW-20
HCO_3^-	350	all except GW-5, GW-7	all samples
suitable samples		all except GW-1, GW-5, GW-7, GW-12, GW-13, GW-15, GW-20	all except GW-1, GW-5, GW-7, GW-12, GW-13, GW-15, GW-19, GW-20

Based on the EC values, irrigation water can be classified into four categories (Turgeon, 2000) as shown in Table 9. It is clear that the water samples GW-3, GW-4, GW-6, GW-8, GW-9, GW-14, GW-17, and GW-18were of class C3 type, the other water samples were generally unacceptable for irrigation purposes.

TABLE 9
CLASSIFICATION OF IRRIGATION WATER BASED ON SALINITY (EC) VALUES (TURGEON, 2000)

Level	EC (μS/cm)	Hazard and limitations	Wet season	Dry season
C1	< 250	Low hazard		
C2	250 - 750	Sensitive plants may show stress; moderate leaching prevents salt accumulation in soil.		
C3	750 - 2250	Salinity will adversely affect most plants; requires selection of salt-tolerant plants, careful irrigation, good drainage, and leaching.	GW-2, GW-3, GW-4, GW-6, GW-8, GW-9, GW-10, GW-11, GW-14, GW-16, GW-17, GW-18	GW-3, GW-4, GW-6, GW-8, GW-9, GW-14, GW-17, GW-18
C4	> 2250	Generally unacceptable for irrigation, except for very salt-tolerant plants, excellent drainage, frequent leaching, and intensive management.	GW-1, GW-5, GW-7, GW-12, GW-13, GW-15, GW-19, GW-20	GW-1, GW-2, GW-5, GW-7, GW-10, GW-11, GW-12, GW-13, GW-15, GW-16, GW-19, GW-20

IV. CONCLUSION

The results of the study show that the main products of urbanization that alter ground-water chemistry were sulfate, nitrate, and chloride generated mainly from seepage of domestic seepage pit in the ancient residential areas and local agricultural sites. Moreover, the elevated sulfate concentrations with calcium reflect the presence of secondary gypsum in the Quaternary deposits. The groundwater quality of the Kirkuk urban area is very hard, fresh to slightly brackish and neutral to slightly alkaline. The results of the hydrochemical indices (Mg/Ca, Cl/HCO_3, and CEV) indicating that the groundwater was inland with respect to origin. The main hydrochemical species in the study area was Ca-Mg-SO_4 that pose 75% of water samples, whereas the other water samples was Ca-Mg-Na-Cl-SO_4 with percentage of 25% for both wet and dry seasons. The suitability of waters for different purposes indicate that all water samples were unsuitable for domestic and industrial uses, but 60% and 40% of water samples were suitable for building and irrigation purposes respectively.

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