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HYDROCHEMICAL ASSESSMENT OF WATER RESOURCES IN AL-TEEB AREA, NE MAISSAN GOVERNORATE, SOUTH IRAQ

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ABSTRACT

Groundwater and seasonal Al-Teeb River are the main sources of water in the study area, which is characterized by arid to semiarid climate. The hydrochemical study involved the analysis of major cations and anions, trace elements and physical properties; the total dissolved solids (TDS) and pH, for 16 groundwater samples and 4 river water samples of the period 2014 – 2015.

Groundwater samples were collected from 14 wells from the Quaternary unconfined aquifer, in addition to 2 well samples from the Tertiary confined aquifer. The water from the river and from the groundwater of the Quaternary aquifer is classified according to the TDS as moderately brackish water, whereas, the groundwater of the Tertiary aquifer is less saline and some wells are classified as fresh water. Moreover, the type of water for most samples is (Na – Sulphate).

Chemical analyses of trace elements of all samples show an increase in the concentration of lead, nickel and cadmium that exceeds their standards limit according to the World Health and the Iraqi Standards, whereas iron and manganese exceed their standard limits in some samples. Piper diagram classification shows that the water type for all samples is earth alkaline with an increase proportion of alkalis ($Na^{2+} + K^{+}$) and prevailing sulfate and chloride ions. These result are the same for both surface and groundwater samples for the two seasons. Such water is mostly unsuitable for human and building uses, but it is suitable for livestock and permissible for irrigation, with the exception of two samples from the Tertiary aquifer which are almost suitable for all purposes other than human consumption.

التقييم الهيدروكيميائي لمصادر المياه في منطقة الطيب، شمال شرق محافظة ميسان، جنوب العراق

قصي الكبيسي و سيماء أكرم الصالح

المستخلص

تهدف الدراسة إلى تقييم نوعية مياه مصادر المياه في مدينة الطيب، شمال شرق محافظة ميسان، جنوب العراق وتحديد مدى ملائمتها للأغراض المختلفة. تمتاز منطقة الدراسة بمناخ جاف إلى شبه جاف وتعتبر المياه الجوفية و مياه نهر الطيب الموسمي المصدرين الرئيسيين للمياه في المنطقة.

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تضمنت الدراسة الهيدروكيميائية تحليل الأيونات الرئيسة الموجبة والسالبة مع بعض العناصر النادره إضافة الى الخصائص الفيزيائية (الأس الهيدروجيني والمواد الصلبة الذائبة) لنماذج المياه التي التقطت للفترة مابين (2014 – 2015) لـ 16 عينة من المياه الجوفية و 4 عينات من مياه نهر الطيب. حيث تم التقاط 14 عينة من الآبار الجوفية التي تخترق المكمن الرباعي، وعينتان من الآبار التي تخترق المكمن الثلاثي (باي حسن – المقدادية).

تم تصنيف المياه في مناطق الدراسة حسب كمية الاملاح الذائبة الكلية الى مياه متوسطة الملوحة لمياه نهر الطيب الموسمي والخزان الجوفي للعصر الرباعي، ومياه عذبه في البئرين الارتوازيين المحفوره في مكمن باي حسن – المقدادية. علاوة على ذلك، بينت نتائج التحاليل الكيميائية إن معظم عينات المياه كانت من نوع كبريتات الصوديوم.

وبينت نتائج التحاليل الكيميائية للعناصر النادرة في جميع عينات المياه السطحية والجوفية زيادة في تركيز أيونات كل من الرصاص، النيكل والكادميوم عن الحد المسموح به وفقا لكل من منظمة الصحة العالمية والحدود القياسية العراقية، في حين كانت تراكيز كل من ايونات الحديد والمنغنيز تتجاوز الحد المسموح في بعض العينات فقط.

يوضح تصنيف بايبر إن نوعية المياه كانت: أرضية قلوية مع زيادة نسبة (الصوديوم + البوتاسيوم) وسيادة كل من ايونات الكبريتات والكلوريدات لنماذج المياه السطحية والجوفية وللموسمين الجاف والرطب.

وبناءاً على النتائج اعلاه فان المياه في منطقة الدراسة غير مناسبة لكل من: الاستهلاك البشري، البناء والصناعة، ولكنها مناسبة للاستخدام الحيواني ومقبولة لغرض الإرواء الزراعي للمحاصيل التي تتحمل الملوحة المتوسطة والعالية. بينما بينت نتائج تحاليل المياه الجوفية لبئرين ارتوازيين يخترقان المكمن الثلاثي صلاحيتهما لجميع الاستخدامات عدا الاستهلاك البشري.

INTRODUCTION

Hydrochemical studies reveals the quality of water in its physical, chemical and biological characteristics to obtain its suitability for human, animal drinking, agriculture and industrial purposes (Davis and DeWiest, 1966).

The controlling factors on the hydrogeochemical evolution of the groundwater are aquifer mineralogy, water rock interactions, flow velocity, distance along flow paths, residence time, and mixing (Hudak, 2000). Water often consists of major cations and anion as; Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-} and $SO_4^{=}$.

Chemical parameters of water are used in classifying and assessing water quality. A number of techniques and methods have been developed to interpret the chemical data. In this study, the method proposed by piper (1944), has been used.

The objective of the present study is to assess the physical and chemical properties of water for both groundwater and Al-Teeb River in the study area; to determine water quality, water salinity and possible usages of the water resources.

The study area is located northeast of Maissan Governorate, and lies between 32° 15′ 00″ – 32° 30′ 00″ N and 46° 55′ 00″ – 47° 25′ 00″ E. It occupies (1191 Km^2) of near flat terrain. Al-Teeb River comes from the Iranian territory and flows into Al-Sannaf marsh beyond the study area (Fig.1).

Some previous work, related to the present study, include: Hassan *et al*. (1977) study of the floodplain fans that extend from Mandali and Badra to Al-Teeb area and include two layers of clay, acting as a regional extension barrier near Badra area. One of these two layers separates the Quaternary sediments from the Tertiary sediments; the second layer acts as a boundary dividing the Quaternary aquifer into two parts. Krasny (1982) carried out hydrochemical and hydrogeological study of Al-Kut, Ali Al-Gharby and Al-Teeb area and found that the water depth ranges (10 – 20 m), and that the amount of total dissolved solids increases towards the southwest with a range of (2000 – 3500) mg/L. Al-Jiburi (2005) focused on the hydrochemical and hydrogeological characteristic of Ali Al-Gharby area. He reported that Bai-Hassan and Muqdadiyah formations are the main upper groundwater aquifers in the eastern and northern parts of the area, while Quaternary sediments represent the main aquifer for most parts of the area. Al-Kaabi (2009) found, through hydrochemical modeling of Al-Teeb area, that the ionic strength of groundwater samples increases with increasing of total dissolved solids, which ranges from a low value of (0.0163 ppm) in Mukdadiyah and Bai-Hassan wells at the hills of Himreen structure to high value of (0.2086 ppm) at the south and southwest of the study area. Al-Abadi (2011) reported that the aquifer systems in Maissan are subdivided into: shallow aquifer and semi-confined aquifer in the Quaternary sediment, and confined aquifer in Mukdadiyah and Bai-Hassan formations.

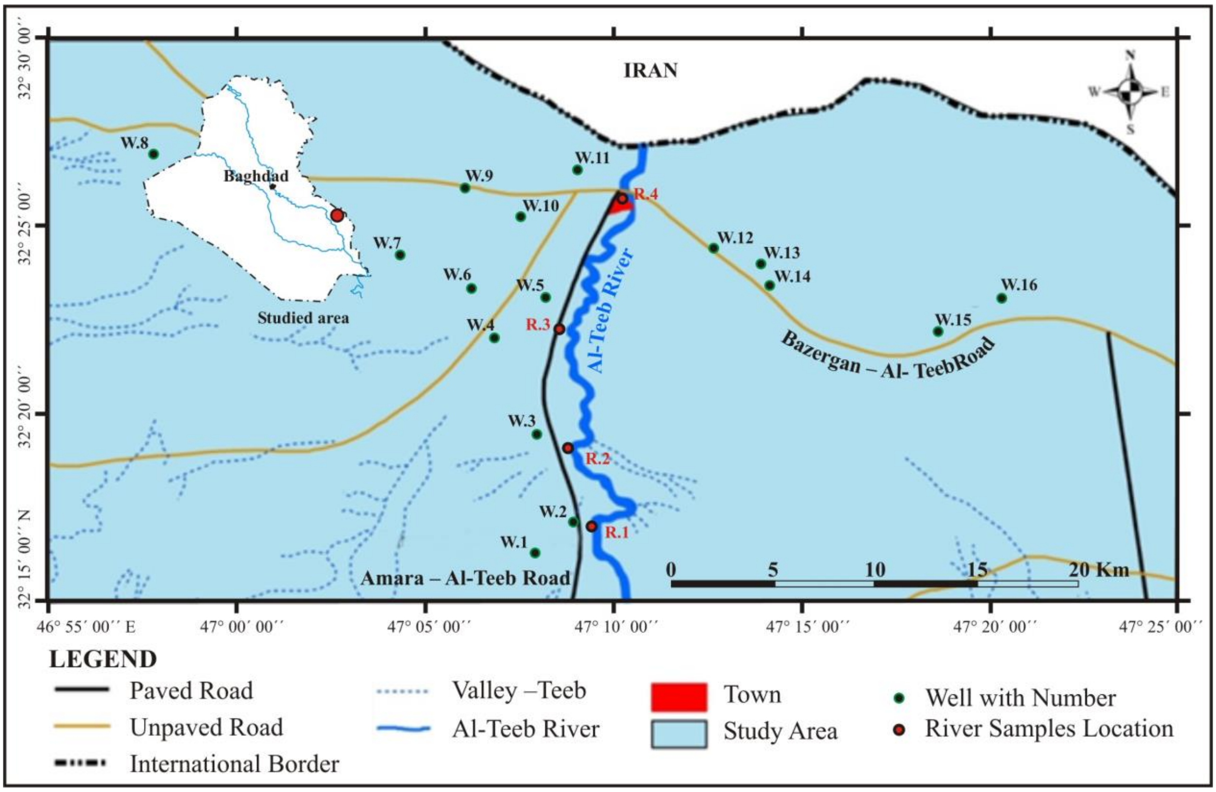

Fig.1: Location map of the study area showing distribution of surface and groundwater samples

▪ Geological Setting

The Mesopotamian Plain forms most of the area, while higher topography lies in the east and northeast of the area. The maximum elevation is (200 m) above sea level and the minimum elevation is 14 m (Barwary, 1992).

Startigraphically, most of the study area is characterized by Quaternary sediments cover. Pre-Quaternary rocks are exposed at the east and northeast of Al-Teeb town and consist of Mukdadiyah and Bai-Hassan formations (Pliocene) (Barwary, 1992). The Quaternary sediments consist of clay with sea and river sediments as well as aeolian sands. The Mukdadiyah Formation (Lower Pliocene) consists of sandstone, claystone and silty sand. Sandstone beds very often contain pebbles of (0.5 – 2.0 cm) size with different shape and lithology. The Bai-Hassan Formation is characterized by interbedding of conglomerate, claystone and sandstone with the grain size becoming coarser vertically, which represent the boundary between Bai-Hassan and the underlying Mukdadiyah Formation. The environment of both formations is fresh water fluvial environment (Fig.2). Most important minerals of the gravel of Bai-Hassan and Mukdadiyah formations are silicate minerals of quartz and chalcedony, as well as carbonate minerals such as calcite, aragonite and dolomite, and some evaporate minerals such as gypsum and anhydrite found in the veins between the sandstone and claystone layers, Al-Adol (1982).

Structurally the study area lies within the secondary Tigris zone (Jassim and Goff, 2006). Moreover, according to Al-Kadhimi (1996) the study area lies within the Tikirt – Amara secondary belt, which represents the main portion of the Mesopotamian Plain and it is characterized by shallow subsurface longitudinal anticlines separated by synclines trending NNW – SSE direction with a number of associated faults.

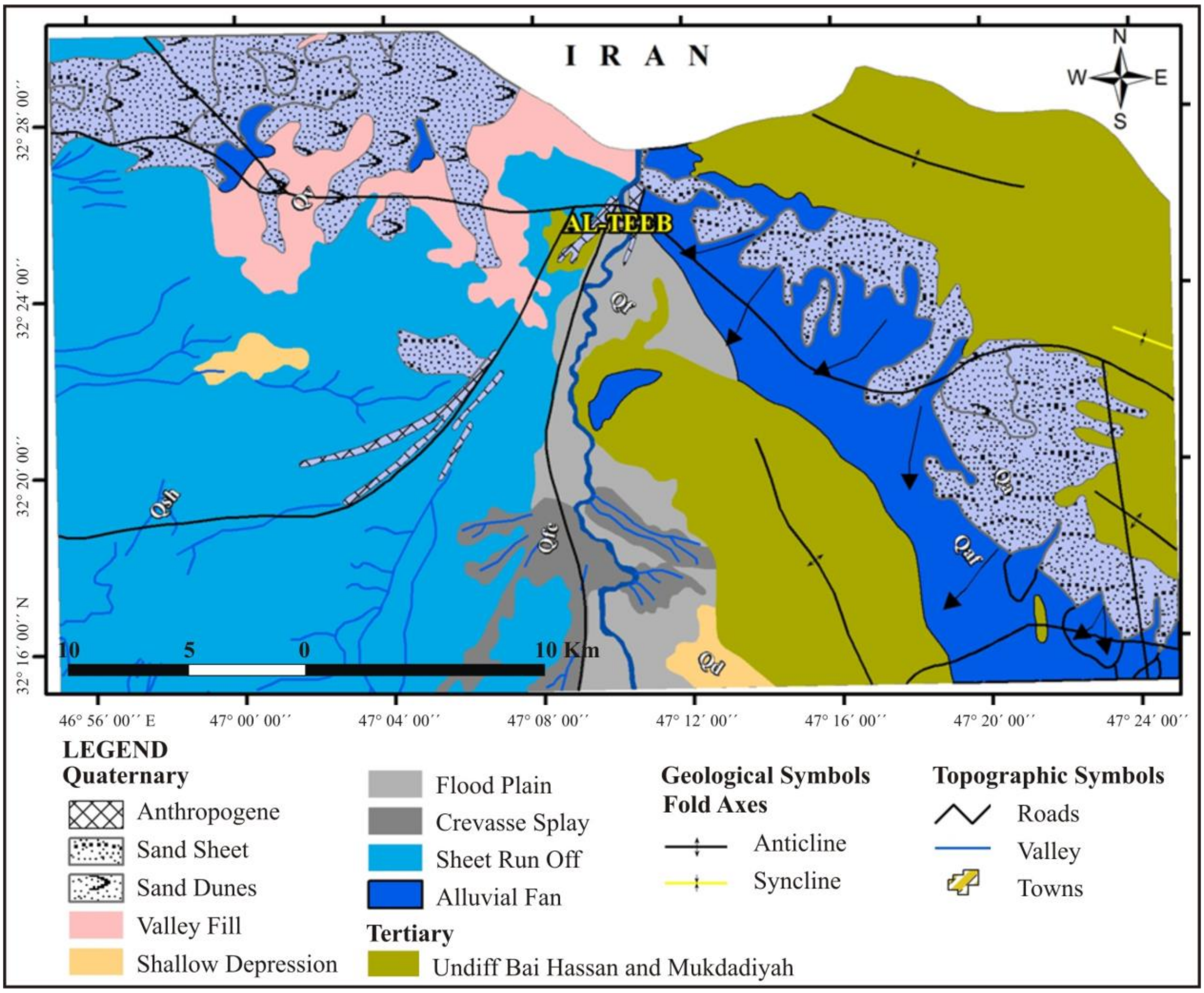

Fig.2: Geological map of the study area modified after (Barwary, 1992)

- **Hydrological and Hydrogeological Setting**

Al-Teeb River, a seasonal river, flows from the Iranian territory. Its total length is about (500 Km) and its width is about (50 m), while the maximum depth is (30 m). It flows for about (50 Km) inside Iraq and ends in Hor Al-Sennaf. The average discharge is variable, the surface drainage has a low flow regime because of long drought period, where the quantity of water depends on: amount of precipitation in the recharge area; and on the amount of water released by dams in Iran (The General Commission of Dams and Reservoirs, 2002).

The aquifer systems within the study area are of three types: the first is Quaternary unconfined (shallow) aquifer, has limited extent, penetrated by only few dug wells. The second is the main aquifer, which is (semi-confined), where most of the operating wells penetrate it. Its thickness ranges between (20 – 42 m). The third is a deep confined aquifer, made up of the Bai-Hassan and Mukdadiyah formations. These aquifers are separated by two low permeable aquitards, the hydraulic characteristics of which are unknown. The hydraulic connection between the aquifer units is possible and the confined portion of aquifer system is not fully separated (Al-Abadi, 2011). The groundwater flow in the study area is from northeast toward southwest.

- **Methods and Sampling**

Sixteen groundwater samples have been collected for two seasons. The first set was collected during the dry season of October 2014; and the second set was collected during the wet season of April 2015. 14 well samples represent the Quaternary aquifer and 2 samples of artesian well reflect the confined Tertiary aquifer. In addition, 4 surface water samples were collected from Al-Teeb River in October 2014, and only one sample from one site in April 2015, as the river became dry (Fig.1). For sampling purposes, one-liter volume bottles were prepared for anions and cations analysis, and a bottle of 30 milliliter volume for trace elements analyses after adding one drop of HNO_3 acid; in order to acidify the water sample to pH value less than 2. Laboratory tests included measurement of pH; electrical conductivity (EC); total dissolved solids (TDS); as well as chemical analyses of the major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-} and HCO_3^-). Also, the analyses of some trace elements (Fe, Mn, Pb, Ni, Cd, Zn and Cu) have been carried out. The analytical data are used to assess the chemical composition of groundwater and surface water.

RESULTS AND DISCUSSION

- **Physical Properties of the Water Samples**

The physical analysis of water samples are shown in Table (1). Water samples in the study area are odorless, colorless and have salty taste; except a sample from (well 16) which has a very good and acceptable taste. The pH average values of the groundwater samples are (7.22) and (7.25) in dry and wet seasons respectively. This shows that all the samples taken from all locations have low spatial variations of pH; indicating the stability of the water. The TDS average value of the Quaternary aquifer is (3868 ppm) and (3906 ppm) in wet and dry seasons respectively. Whereas, the two artesian wells (W.15 and W.16) of the Tertiary confined aquifer, have lower values of (588), (1486) and (540), (1438) ppm in wet and dry seasons respectively. All the samples are classified as brackish water, except W.16, which is classified as fresh water according to the classification of Klimentove (1983) and Tood (1980).

The EC average values of groundwater samples are (5239) and (5402) μmohs/cm in wet and dry seasons respectively. The TDS values are (1445 ppm) and (1569 ppm) in wet and dry season respectively. According to the classification of Letterman (1999), the values of TDS in all samples indicate very high water hardness, except sample (W.16) which is classified as hard water.

With regard to Al-Teeb River, all the water samples are also odorless, colorless and have salty taste, reflecting the brackish nature of this class, where the TDS average values are

(3300) and (3773) ppm in wet and dry season respectively, (The General Commission of Dams and Reservoirs, 2002). The EC average values were (5120) and (5432) µmohs/cm in wet and dry seasons respectively. According to the classifications of Letterman (1999) the results indicate very high hardness in the river samples.

The increase in TDS is generally due to high evaporation rate, solution of salty deposits by groundwater, slow circulation of groundwater that slows flushing of connate water and blown fine dust derived from surrounding playas (Davis and DeWiest, 1966).

Table 1: Physical parameters of water samples in the two seasons

No. of Water Samples	Dry season				Wet season			
	TDS (mg/L)	TH (mg/L)	EC mho/cmµ	pH	TDS (mg/L)	TH (mg/L)	EC mho/cmµ	pH
Groundwater samples								
W.1	4080	1574.2	5510	7.5	4000	1545.1	5050	7.3
W.2	4350	1688.6	5590	7.2	4300	1582.7	5550	7.3
W.3	3870	1408.4	5500	7.2	3800	1368.5	5320	7.1
W.4	3950	1300.7	5450	7.2	3577	1103.9	5240	7
W.5	4200	1652.8	6010	7.1	4085	1607.3	5990	7.4
W.6	3940	1532.8	5910	7.4	3890	1371.1	5500	7.2
W.7	3400	1175.2	4100	7.2	3220	1100.4	4270	7.3
W.8	3600	1679.9	4750	7.4	4505	1475	5530	7.3
W.9	4200	1608	5650	7.1	4150	1495.9	5600	7
W.10	4010	1450	5620	7.2	3910	1401	5454	7.3
W.11	3690	1515.7	5180	7.4	3660	1325.3	5080	7.7
W.12	4100	1917.6	5800	7.15	4000	1789	5545	7
W.13	3405	1382.4	5010	7.17	3363	1280.7	4898	7.13
W.14	3900	1524.9	5550	7.5	3700	1445.2	5320	7.6
W.15	1486	690.36	2140	7.1	1438	603.76	2100	7
W.16	588	299.81	866	7.25	540	293.2	836	7
River samples								
R.1	4250	1566	5920	7.5	–	–	–	–
R.2	3650	1350.3	5310	7.2	–	–	–	–
R.3	3700	1379.4	5320	7.2	–	–	–	–
R.4	3500	1556	5180	7.3	3300	1525.8	5120	7.2
WHO (2011)	1000	500	–	6.5 – 8.5	1000	500	–	6.5 – 8.5
IQS (2009)	1000	500	1500	6.5 – 8.5	1000	500	1500	6.5 – 8.5

- **Chemical Properties of Water Samples**

The results of hydrochemical analysis of the water samples in the study area, for the two seasons, are shown in Tables (2 and 3). The results show high concentrations of major ions where the anion SO_4^{2-} is dominating while the Na^{2+} cation is dominating in both seasons, and for both river and groundwater samples.

Depending on the equation of Ivanov *et al*. (1968), all the river water samples and most of the groundwater samples are (Na – Sulphate) type, except samples number (W.7 and W.16) where the water type is (Na – Chloride), and samples number (W.15) is (Ca – Sulphate) type, in both seasons. These results indicate the similarity of the hydrogeochemical processes. High concentration of sodium is attributed to halit, which dissolves easily in water. It is an abundant mineral in the study area. It could be also related to the ion exchanges between calcium and magnesium ions with sodium in clay minerals, which is another source of sodium ion in water.

Table 2: Chemical analysis of water samples in dry season

No. of Water Samples	**Ca^{2+}**	**Mg^{2}**	**Na^{+}**	**K^{+}**	**HCO_3^{-}**	**SO_4^{2-}**	**Cl^{-}**	**Aquifer Type**
	(ppm)							
	Groundwater samples							
W.1	350	170	441	10	529	1190	738	Quaternary
W.2	366	188	550	11.7	548	1370	751	
W.3	320	148	556	10	491	1296	687	
W.4	290	140	640	8	515	1184	631	
W.5	360	183	470	10	522	1163	788	
W.6	360	160	520	10	500	1233	684	
W.7	235	143	533	9	453	751	740	
W.8	386	174	590	11	500	1278	724	
W.9	380	160	530	9.6	539	1240	767	
W.10	330	152	550	11	548	1210	802	
W.11	335	165	465	9	489	1078	671	
W.12	410	217	500	9.5	480	1330	760	
W.13	290	160	360	9	421	1079	650	
W.14	332	169	472	9	418	1413	655	
W.15	150	77	130	9	87	611	190	Bai-Hassan, Mukdadiyah
W.16	61	36	75	1.8	24	171	188	
River samples								
R.1	345	171	608	11.1	510	1545	706	
R.2	310	140	512	10	482	1186	706	
R.3	320	141	512	9.3	481	1185	680	
R.4	310	190	520	10.5	462	1200	705	
WHO (2011)	100	125	200	12	–	250	250	
IQS (2009)	150	100	200	–	–	400	350	

Table 3: Chemical analysis of water samples in wet season

No. of Water Samples	**Ca^{2+}**	**Mg^{2}**	**Na^{+}**	**K^{+}**	**HCO_3^{-}**	**SO_4^{2-}**	**Cl^{-}**	**Aquifer Type**
	(ppm)							
	Groundwater samples							
W.1	345	166	420	9.3	513	1166	730	Quaternary
W.2	350	172	536	11	530	1363	731	
W.3	309	145	518	9.6	489	1230	667	
W.4	241	122	589	8	480	1179	610	
W.5	355	175	454	10	510	1150	752	
W.6	310	145	516	7	512	1205	675	
W.7	215	137	516	8.5	416	730	710	
W.8	360	140	565	11	500	1270	700	
W.9	345	154	518	9	518	1230	780	
W.10	317	148	536	7.5	505	1190	740	
W.11	300	140	450	8	460	1061	640	
W.12	380	204	480	8	466	1309	740	
W.13	274	145	346	8	405	1005	636	
W.14	315	160	467	9	397	1290	640	
W.15	140	62	105	9	66	582	165	Bai-Hassan, Mukdadiyah
W.16	60	35	75	1.5	23	168	185	
River samples								
R.1	–	–	–	–	–	–	–	
R.2	–	–	–	–	–	–	–	
R.3	–	–	–	–	–	–	–	
R.4	298	190	473	10.1	459	1150	739	
WHO (2011)	100	125	200	12	–	250	250	
IQS (2009)	150	100	200	–	–	400	350	

Analysis of trace elements showed a high level of lead (Pb), nickel (Ni) and cadmium (Cd) in all selected samples according to WHO (2011) and IQS (2009) standards, while iron (Fe) and manganese (Mn) are high in some samples only. Whereas the concentration level of zinc (Zn) and Cupper (Cu) are below the recommended level (Table 4).

Table 4: Trace elements concentration for water samples on October 2014

No. of Water Samples	**Fe**	**Mn**	**Pb**	**Ni**	**Cd**	**Zn**	**Cu**
	(ppm)						
W.1	0.204	0.492	0.394	1.139	1.4	1.715	0.033
W.2	0.203	0.396	0.268	1.075	0.39	0.148	0.027
W.3	0.077	0.103	0.335	1.132	0.232	1.746	0.011
W.4	0.364	0.129	0.374	1.313	1.407	0.932	0.097
W.5	0.044	0.059	0.409	0.846	0.034	0.065	0.017
W.6	0.856	0.115	0.35	0.804	0.04	0.275	0.023
W.7	0.734	0.568	0.258	0.661	0.024	0.082	0.025
W.8	0.446	0.443	0.514	1.078	0.046	0.185	0.016
W.9	0.132	0.251	0.344	0.705	0.02	0.168	0.028
W.10	0.405	0.232	0.313	0.737	0.004	0.096	0.017
W.11	0.198	0.065	0.382	0.99	0.046	0.213	0.021
W.12	0.152	0.225	0.237	0.795	0.05	0.259	0.014
W.13	0.414	0.171	0.459	0.685	0.048	0.242	0.048
W.14	0.735	0.235	0.375	0.761	0.08	0.115	0.076
W.15	0.171	0.031	0.171	0.008	0.015	0.044	0.016
W.16	0	0.051	0.085	0.238	0.01	0.038	0.013
River samples							
R.1	0.418	0.039	0.361	0.257	0.015	0.638	0.024
R.2	0.818	0.081	0.294	0.375	0.02	0.205	0.021
R.3	0.768	0.055	0.224	0.161	0.018	0.082	0.034
R.4	0.412	0.032	0.149	0.078	0.021	0.049	0.014
WHO (2011)	0.3	0.4	0.01	0.07	0.003	3	2
IQS (2009)	0.3	0.1	0.01	0.02	0.003	3	1

CLASSIFICATION OF WATER SAMPLES

Piper diagram is used to infer the hydrogeochemical facies (Piper, 1944). The cations and anion fields are combined to show a single point in a diamond shaped field, from which inference is drawn on the basis of hydrogeochemical facies concept. These trianglar diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods (Sadashivaiah *et al*., 2008). Distinct group of water quality types can quickly be discriminated by their plotting on certain subarea of diamond shaped field (Walton, 1970). According to Langguth (1966), the plotted water samples on the Piper diagram shows that the type of water is: Earth alkaline water with increased proportion of alkalis and prevailing sulphate and chloride ions, as shown in Fig.3. The results are the same for the two seasons, and there is no significant changes in the hydrochemical facies during the study period, indicating that most of the major ions are of natural origin, because the groundwater movement is through similar rocks and dissolves specific mineral matters.

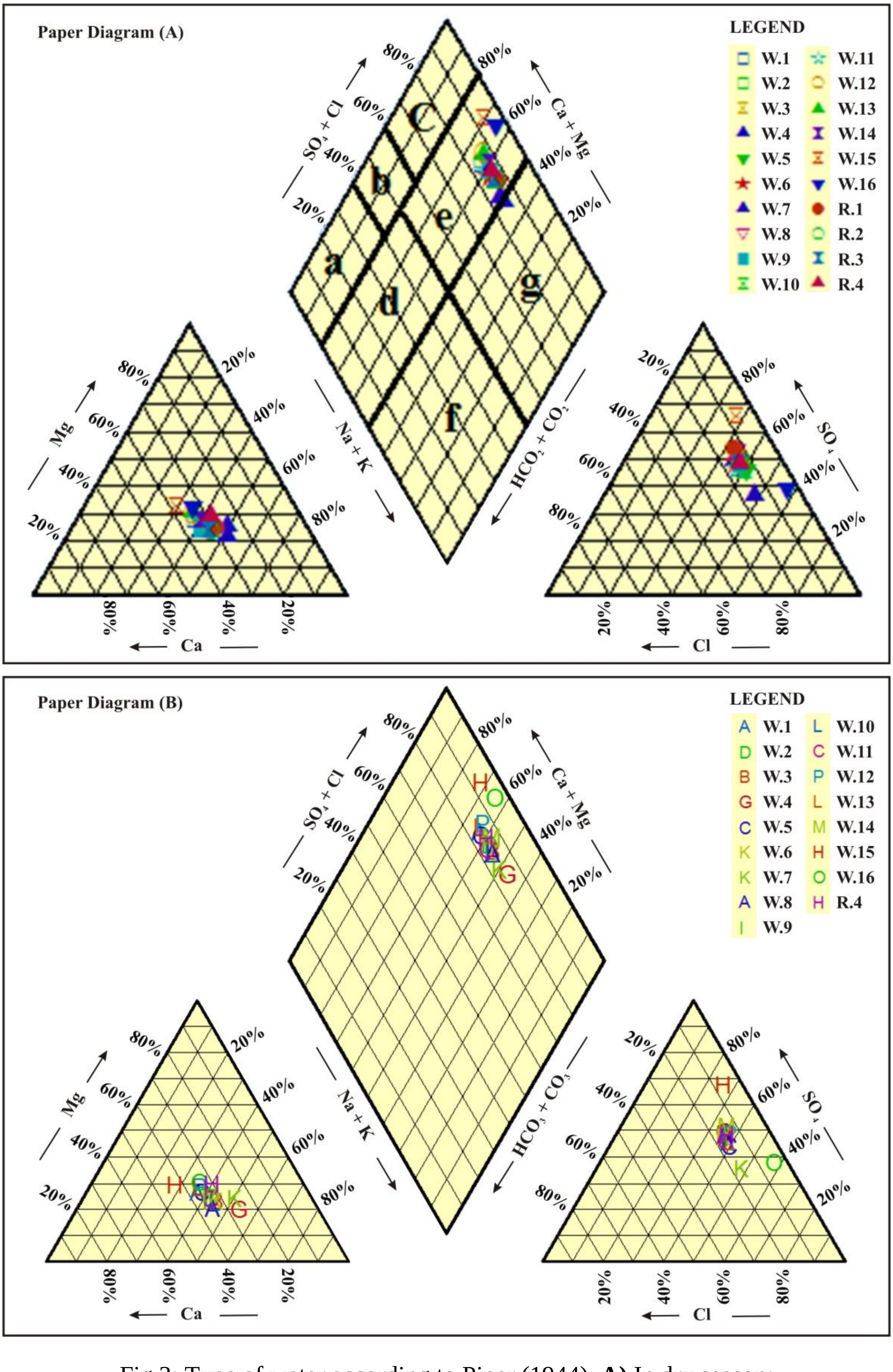

Fig.3: Type of water according to Piper (1944). **A)** In dry season;
B) In wet season

THE USABILITY OF SURFACE AND GROUNDWATER IN THE AREA

Evaluation of the chemical analyses of surface and groundwater has shown that:

- For human drinking: Evaluation was made by comparing the chemical analyses of water samples in the area with the maximum acceptable concentration according to the World Health Organization (WHO, 2011), and Iraqi Standards (IQS, 2009). Results show that all water parameters are above the maximum acceptable limits, indicating that it is unsuitable for human drinking, except the artesian well (W.16), where most of its parameters are within the recommended guide levels, as shown in Tables (2 and 3).
- For industrial and building purposes: Comparing the ions concentration analyses with Altoviski standards (1962) for building uses, showed that all water samples are unsuitable for building, because the bicarbonate concentration exceeds the recommended limit, except wells number (W.15 and W.16) that are suitable for building purposes.
- For livestock purpose: Using the suggested standards of Crist and Lowry (1972), it is shown that all of the water samples are suitable for livestock.
- For irrigation uses: Water for agricultural purposes depends on the types of plants and its tolerance for salt concentration, the amount of irrigation water, soil, and climate (Davis and DeWiest, 1966). To assess water quality for irrigation, there are four most popular criteria, these are: TDS or EC, sodium adsorption ratio (SAR), chemical concentration of elements such as (Na^+, Cl^-) and residual sodium carbonate (RSC) (Karanth, 2008). According to classification for water irrigation by Done (1995), the results showed no harmful effects from soluble sodium percentage (Na%), and the groundwater samples of the wells were good for irrigation water class. Whereas, classification of irrigation water based on SAR values were good to permissible. On the other hand, the salinity hazard was high and generally acceptable for irrigating very salt-tolerant plants only (Table 5).

Table 5: The calculated values of SAR, Na%, RSC and salinity of samples

No. of Water Samples	Dry season				Wet season			
	SAR	Na%	RSC	Salinity	SAR	Na%	RSC	Salinity
W.1	4.84	38.2	– 22.79	Very high	4.65	37.1	– 23.05	Very high
W.2	5.83	34.6	– 24.81		5.86	43.3	– 22.03	
W.3	6.45	46.5	– 20.1		6.09	45.5	– 19.33	
W.4	7.72	51.9	– 17.55		7.71	53.9	– 14.19	
W.5	5.03	47.4	– 24.47		4.93	36.8	– 23.76	
W.6	5.78	42.7	– 22.12		6.06	45.2	– 19.01	
W.7	6.76	48	– 17.55		6.77	50.7	– 15.17	
W.8	6.26	43.6	– 25.12		6.4	45.8	– 21.29	
W.9	5.75	42	– 23.3		5.83	43.2	– 21.4	
W.10	6.29	45.5	– 20		6.23	45.6	– 19.72	
W.11	5.2	40.3	– 22.26		5.38	42.7	– 18.95	
W.12	4.97	36.5	– 30.43		4.94	37.1	– 28.06	
W.13	4.21	36.5	– 20.73		4.21	37.3	– 18.96	
W.14	5.26	40.5	– 23.63		5.34	41.6	– 22.38	
W.15	2.15	29.9	– 12.37	High	1.86	28.7	– 10.98	High
W.16	1.88	35.5	– 5.59		1.9	35.9	– 5.48	
River samples								
R.1	6.69	46.07	– 22.92	Very high	–	–	–	Very high
R.2	6.06	45.49	– 19.08		–	–	–	
R.3	6	44.950	– 19.68		–	–	–	
R.4	5.73	42.39	– 23.52		5.27	40.58	– 22.98	

CONCLUSIONS

- The water sources of this area is from the seasonal Al-Teeb River, and groundwater from the confined aquifer of the upper main aquifer in the northeast part of the area, represented by Bai-Hassan and Mukdadiyah formations, and the unconfined aquifer of the upper main aquifer in the remaining parts of the study area, represented by the Quaternary sediments.
- In dry and wet seasons calcium, sodium, magnesium, sulphate and chloride, are the abundant ions in the groundwater samples. The concentration of cation and anions shows high values in general, where sodium ion is a predominant cation, and sulphate is a predominant anion. The general type of the water is (Na – Sulphate) for the both seasons, which indicates the similarity of the hydrogeochemical processes in both seasons, reflecting the presence the evaporate minerals, which are the main source of these ions. From the concentrations of the major ions of the groundwater samples, it is believed that Bai-Hassan and Mukdadiyah aquifer has better quality water than the Quaternary aquifer.
- All water samples are unsuitable for human drinking, either because of the high salinity or because of elevated concentrations of trace elements above the standard limit for human consumption. Besides, water samples are not suitable for industrial and building purposes because each sample has a certain elevated chemical constituent, while, it is suitable for livestock uses. For irrigation purposes, it is suitable for salt-tolerant and very salt tolerant plants.

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