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HYDROCHEMICAL EVALUATION OF THE GROUNDWATER IN FATAH UMAR – HAZAR KANI AREA, NORTHEAST IRAQ

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ABSTRACT

Hydrochemical data are presented to describe the groundwater quality of Fatah Umer – Hazar Kani area, which is located between longitude E 44° 57' – 45° 12' and latitude N 34° 40' – 34° 57', about 100 Km southeast of Kirkuk city in northeast of Iraq. The present study revealed that the Bai Hassan Formation and Quaternary sediments are the main aquifer system, in the studied area, which supplies the region with water, whereas the Injana Formation is the second aquifer system. The hydrochemical properties of the groundwater show the dominance of Ca – HCO_3 type in the aquifer system. The chemical weathering of the rocks is the major mechanism that influences groundwater quality.

The EC values increase towards the central part of the studied area along the groundwater flow direction, because most of the low salinity waters enter the studied area from its northern parts and flows towards the central parts carrying dissolved ions. The low transmissivity of the beds and clogging nature of the sediments permit intermittent flushing and hence the dissolved ions sustain longer and reactions take place within the aquifers. The hydrochemical properties of the groundwater samples are compared with the world standards for drinking, irrigation and livestock, for evaluation purposes. All groundwater samples are suitable for drinking purpose, except the Tapa Sawz, Kanimaran and Simaq samples, because nitrate concentration exceeds the acceptable level and reached the polluted level. All samples are suitable for irrigation and livestock purposes.

التقييم الهيدروكيميائي للمياه الجوفية لمنطقة فتاح عمر – هزار كاني في شمال شرق العراق

قصي ياسين الكبيسي و سركوت غازي سالار

المستخلص

اعتمدت البيانات الهيدروكيميائية لمعرفة نوعية المياه الجوفيةً في منطقة فتاح عمر– هزار كاني، الواقعة بين خطِي الطول '57 °44 – '12 °45 وخطي العرض '40 °34 – '57 °34، حوالي 100 كيلومتر جنوب شرق مدينة كركوك في شمال شرق العراق. وجدت هذه الدراسة إن تكوين باي حسن وترسبات العصر الرباعي يشكلان المكمن الرئيسي للمياه الجوفية في المنطقة المدروسة التي تجهز المنطقةً بالماء وإن تكوين إنجانة يشكل المكمن الثاني للمياه الجوفية. أظهرت التحاليل الهيدروكيميائية للمياه الجوفية في منطقة الدراسة سيادة نوع Ca – HCO_3 في المكامن المائية، وإن التجوية الكيميائية للصخور هي الآلية الرئيسية التي تؤثر على نوعية المياه الجوفية.

بين التوزيع الجغرافي للتوصيلية الكهربائية ازدياد قيمها باتجاه الأجزاء الوسطى لمنطقة الدراسة، لأن أغلب المياه المغذية للمياه الجوفيةً تأتي من الأجزاء الشمالية جارية نحو الأجزاء الوسطى، حاملة أيونات ذائبة. إن النفاذية المنخفضة للطبقات الصخرية والطبيعة المعرقلة للرواسب تسبب عرقلة في جريان المياه الجوفية مسببة زيادة في زمن بقاء الأيونات الذائبة وحدوث تفاعلات داخل المكامن. تم مقارنة الصفات الهيدروكيميائية لعينات المياه الجوفيّةً بالمعايير العالمية لأغراض الشرب والري وتربية الماشية، وأظهرت النتائج بأن كل عينات المياه الجوفيةً مناسبة لأغراض الشرب ماعدا عينات مياه Tapa Sawz و Kanimaran و Simaq لأن تركيز النترات يتجاوز المستوى الموصى به ويصل المستوى الملوث، بينما كل عينات المياه الجوفيةً مناسبة لأغراض الري وتربية الماشية.

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INTRODUCTION

Groundwater is considered one of the basic sources in many countries in the world to supply cities and urban places with water for domestic, agricultural and industrial uses, due to shortage of surface water and rainfall quantities. Therefore, the quality and quantity of the groundwater must be preserved.

The chemical composition of the surface water and groundwater is controlled by many factors that include composition of precipitation, mineralogy of aquifers, climate and topography. These factors combine together to create diverse water types that change spatially and temporally (Güler *et al*., 2002). Therefore, considerable variation can be found, even in the same area, especially where rocks of different compositions and solubility occur. Groundwater quality is influenced by the effects of human activities, which cause pollution to the land surface, because most groundwater originates by recharge of rainwater infiltrating from the surface (WHO, 1996).

The studied area, Fatah Umar – Hazar Kani, is located about 100 Km southeast of Kirkuk city between longitudes E 44° 57' – 45° 12' East and latitudes N 34° 40' – 34° 57' North (Fig.1).

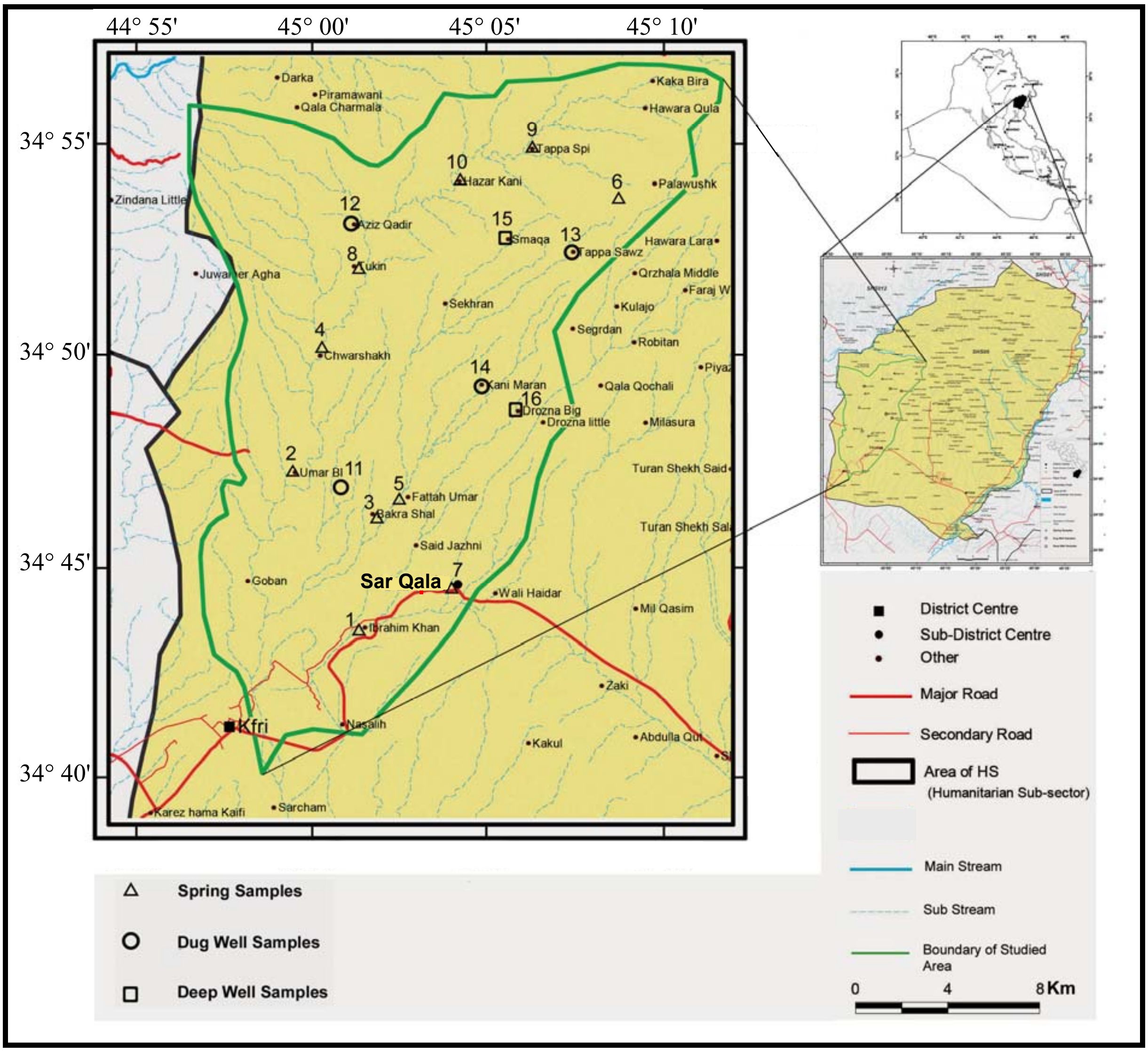

Fig.1: Location of the studied area with samples location

The studied area has semi arid climate. Rainfall is of short duration and its mean annual is about 320 mm (Salar, 2006). Because of the semi arid climate, surface water is rare in the area and the groundwater is the main source for drinking and household uses, hence, the surface water became less significant and the demand for water draws attention to the importance of the groundwater resources. People, in the studied area mainly depend on the groundwater for domestic, livestock and local irrigation purposes, through drawing water from hand dug wells, springs and few drilled deep well.

The objectives of this study are; to evaluate and to trace the groundwater quality trends in the studied area; to identify chemical types of the groundwater and to evaluate the groundwater quality for domestic, livestock and irrigation uses. Moreover, to show the impact of the above mentioned factors on the groundwater quality.

GEOLOGICAL SETTING

Geological setting of Fatah Umar – Hazar Kani area is quoted mainly from Bellen *et al.* (1959); Buday (1980); Sissakian (2000) and Jassim and Buday in Jassim and Goff (2006). The studied area includes different rock units, which are shown in Fig. (2), these are:

- **Fat'ha Formation**

Fat'ha Formation is characterized by the prevalence of evaporites. The rocks of the formation consist of anhydrite, gypsum, inter bedded with limestone, marl and relatively fine grained clastics. The thickness of the formation is highly variable. The age of the formation is Middle Miocene.

- **Injana Formation**

Injana Formation consists of calcareous sandstone and red and green mudstones with one thin gypsum bed (20 cm thick) and a purple siltstone horizon. The calcareous sandstone contains oscillation ripple marks; they are overlain by fining upward cycles of siltstone and red mudstone.

The thickness of the formation is variable, due to subsequent erosion over major folds (Jassim and Buday in Jassim and Goff, 2006). The age of the formation is usually accepted as Late Miocene.

- **Mukdadiya Formation**

Mukdadiya Formation usually starts with pebbly sandstone. The alternation of thickly bedded sandstones, siltstones and claystones is characteristic feature of the formation. A general trend of decreasing grain size can be partly observed along the axis of the main deposition area (Buday, 1980). The age of the formation is Late Miocene – Pliocene.

- **Bai Hassan Formation**

Bai Hassan Formation consists of alternation of conglomerates and claystones with sandstones and siltstones. These constituents show variations both laterally and vertically. The age of the formation is Late Pliocene – Pleistocene.

- **Quaternary Sediments**

Quaternary sediments consist of a mixture of various sediment sizes, which include gravels, pebbles, sands, silts and clays. The pebbles are mainly carbonates, which are derived from Bai Hassan Formation. These sediments are overlying the Bai Hassan Formation and the differentiation between them is extremely difficult, due to the similarity in their lithology and absence of fossils in both units. The thickness of Quaternary sediments is variable in the studied area. The age of these sediments is Pleistocene – Holocene.

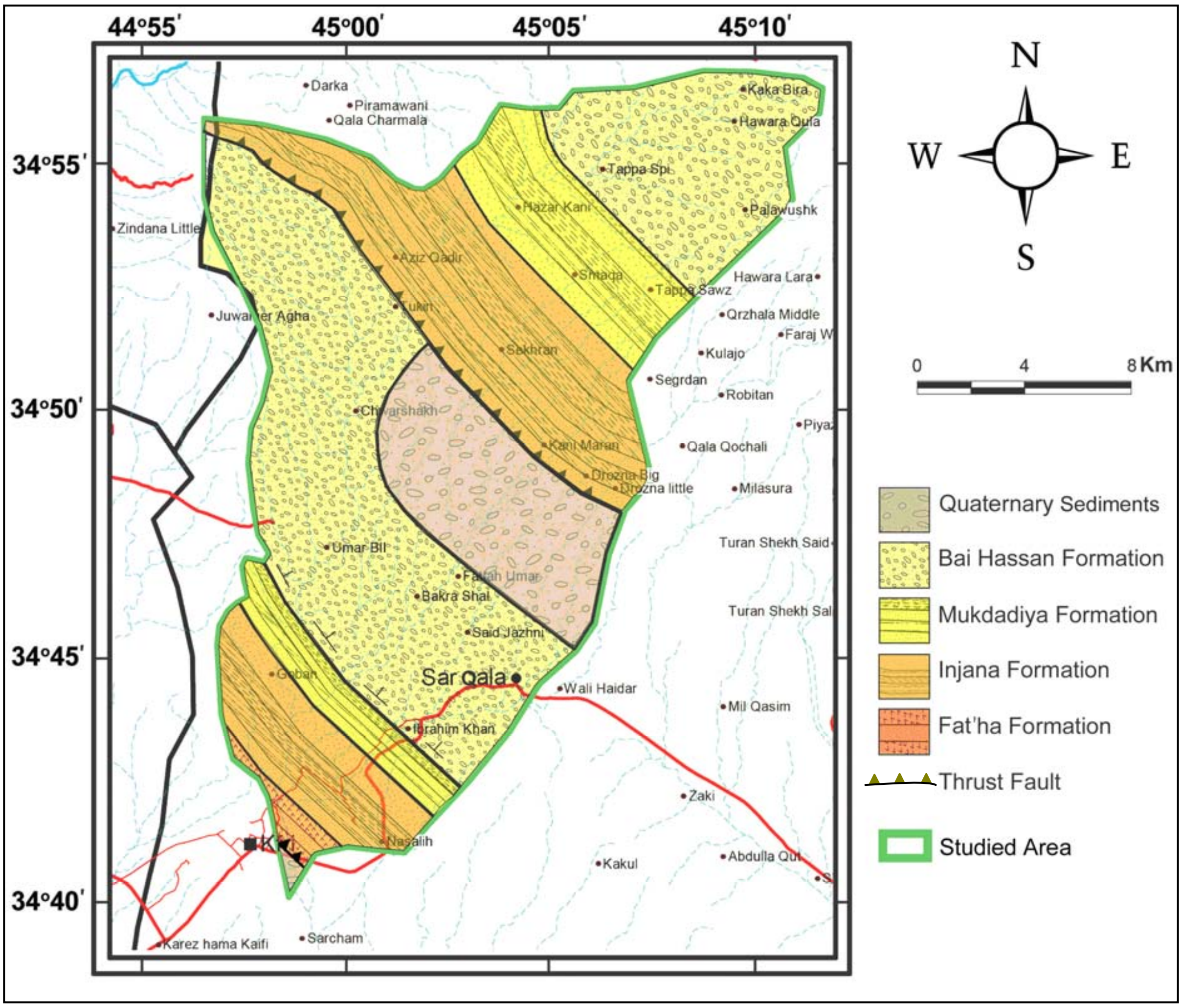

Fig.2: Geological map of the studied area (after Sissakian, 2000)

METHODOLOGY

Groundwater samples have been collected from 16 locations during high water season (4/ 2005) from stations, as shown in Fig. (1). During the sampling operation, two types of bottles were prepared and used for storing the water samples. Polyethylene bottles of 1.5 liter, and 0.450 liter, which have been used for indicating inorganic constituents (major and minor ions) and for nitrate analysis, respectively. All water samples were stored in cool box until were analyzed in the laboratories of University of Sulaimaniyah and Sulaimaniyah Health and Environmental Protection Office.

The techniques and methods followed for collection, preservation, analysis and interpretation are those given by APHA (1995). The E.C. and temperature were measured in the site by field electrode meter device (Consort), whereas the pH, concentration of major cations and anions were analyzed in the laboratory as per the standard analytical procedures. Sodium and potassium, in groundwater samples were analyzed using Flamephotometer method. Calcium and magnesium were estimated by EDTA titrimetric method, whereas chloride was determined by argentometric titration using standard silver nitrate; as reagent. Bicarbonate concentrations of the groundwater were determined titrimetrically. Sulfate concentration was carried out following gravimetric method.

HYDROGEOLOGIC SETTING

The studied area comprises long narrow anticlines trending NW – SE of different amplitudes. These anticlines are separated by broad synclines containing thick molasses of the Mukdadiya and Bai Hassan formations and Quaternary sediments. These geological setting strongly influences the hydrogeology of the area (Krashni in Jassim and Goff, 2006).

The major part of the aquifer system is characterized by a plain controlled by the broad synclinal structure and linear hilly belts, following anticlines and dissected by stream valleys of Bakrashal and Umar Bil. The hydraulic parameters differ due to variations in lithology and aquifer thickness. According to Krashni in Jassim and Goff (2006) the transmissivity of Bai Hassan Formation and Quaternary sediments, in synclines reaches (200 – 300) m^3/day, while the transmissivity of Injana Formation is only (1 – 10) m^3/day. Hence, the hydrogeology of the studied area is characterized by the presence of two aquifer systems: The first is Bai Hassan Formation and Quaternary sediments aquifer system, which is the main aquifer in the studied area with unconfined type and characterized by high productivity that enables it to supply the Fatah Umar and Umar Bil streams with water. The second consists of Injana Formation in which the effective and productive beds are sandstone that alternate with claystones and siltstones. The productivity of Injana Formation is less significant than that of the first aquifer system. Therefore, most of the good productive springs and drilled wells are located within the first aquifer system, e.g. Sarqala, Fatah Umar, Bakrashal and Umar Bil springs.

RESULTS AND DISCUSSION

In order to understand the groundwater hydrochemistry of the studied area and its evaluation for different purposes, analyses of groundwater samples from selected locations were conducted (Table 1). The following observations were acquired for different parameters:

- **pH**

The pH values of the groundwater varies from 6.78 – 7.30, indicating very weak acidic nature. The desirable Ph limit range of water prescribed for drinking purpose (WHO, 2004) is 6.5 – 8.5, while that of EEC (Lloyd and Heathcote, 1985) is 6.5 – 9.0. The analyzed groundwater samples are within the limits prescribed by WHO (2004). There are no much distinct variations of pH in different samples, collected in the present study.

- **Electrical Conductance and Total Dissolved Solids**

Electrical Conductance is an approximate measure for total dissolved ions (Allan and Castillo, 2007) therefore, the differences in electronic conductivity results are mainly from the differences in concentrations of the TDS, therefore the EC and TDS are concordance.

In the present study, the EC measurements of the first main aquifer (Bai Hassan Formation and Quaternary sediments), at southern central part of the studied area, range from (385 – 1199) µs/cm, with average value of 692 µs/cm, while the EC of the second aquifer system (Injana Formation), at northern central part, range from (597 – 1115) µs/cm, with average value of 851.14 µs/cm (Table 1).

The spatial distribution of EC is shown in Fig. (3). The EC values increase toward the central part of the studied area along the groundwater flow direction, because the low salinity waters enter the studied area from northern parts, where groundwater receives most of its meteoric recharge, and flows towards the central parts carrying dissolved ions. The low transmissivity of the beds and clogging nature of the sediments permit intermittent flushing and hence the dissolved ions sustain longer, which increases the residence time, and reactions take place within the aquifer.

Table 1: Major chemical constituents of groundwater samples

No.	Sampl Name	pH	Temp. C°	E.C. µs/cm	Unit	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Sum epm	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}	Cl^{-}	Sum epm	TH	NO_3^{2-}	Aquifer System	Sample from
1	Mam Hatam	7.00	22.4	1005	ppm	41.14	14.86	72.54	1.65		219.17	0	55.41	89.22		163.87	8.05	Second	Spring
					epm	2.06	1.24	3.16	0.04	6.49	3.59	0	1.15	2.52	7.26				
2	Umar Bil Gawra	7.01	23.5	542	ppm	28.35	10.75	28.75	0.56		131.10	0	27.78	35.71		115.03	24.2	First	Spring
					epm	1.42	0.90	1.25	0.01	3.58	2.15	0	0.58	1.01	3.74				
3	Bakra Shal	7.28	24.0	644	ppm	26.48	10.88	47.97	0.86		134.94	0	42.27	49.61		110.89	14.38	First	Spring
					epm	1.32	0.91	2.09	0.02	4.34	2.21	0	0.88	1.40	4.49				
4	Chwar Shakh	7.30	23.7	385	ppm	25.92	9.51	13.64	0.61		102.52	0	4.02	30.79		103.83	25.1	First	Spring
					epm	1.30	0.79	0.59	0.02	2.70	1.68	0	0.08	0.87	2.63				
5	Fatah Umar	7.10	24.0	610	ppm	33.45	10.01	43.38	0.83		153.46	0	16.46	39.42		124.71	28.7	First	Spring
					epm	1.67	0.83	1.89	0.02	4.41	2.52	0	0.34	1.11	3.97				
6	Tula Bi	6.90	23.0	465	ppm	25.88	9.14	22.29	0.87		125.54	0	9.04	32.25		102.23	30.7	First	Spring
					epm	1.29	0.76	0.97	0.02	3.05	2.06	0	0.19	0.91	3.16				
7	Sar Qala	6.80	22.0	991	ppm	46.81	17.11	63.22	1.38		238.07	0	46.04	74.37		187.31	47.8	First	Spring
					epm	2.34	1.43	2.75	0.04	6.55	3.90	0	0.96	2.10	6.96				
8	Tuken	7.00	23.2	499	ppm	32.18	9.60	19.70	0.54		134.38	0	12.02	32.59		119.85	39	First	Spring
					epm	1.61	0.80	0.86	0.01	3.28	2.20	0	0.25	0.92	3.37				
9	Tapa Spi	7.10	24.0	893	ppm	33.37	13.02	72.72	1.57		157.45	0	58.55	101.32		136.89	18.42	First	Spring
					epm	1.67	1.08	3.16	0.04	5.96	2.58	0	1.22	2.86	6.66				
10	Hazar Kani	7.16	22.5	710	ppm	29.16	11.12	50.08	0.98		139.72	0	53.59	61.35		118.57	32.95	Second	Spring
					epm	1.46	0.93	2.18	0.03	4.59	2.29	0	1.12	1.73	5.14				
11	Umar Bil Bchuk	6.85	22.5	1199	ppm	70.41	22.32	79.86	1.48		263.99	0	83.24	70.69		179.98	26.3	First	Dug Well
					epm	3.52	1.86	3.47	0.04	8.89	4.33	0	1.73	1.99	8.06				
12	Aziz Qadr	7.28	22.0	876	ppm	44.35	16.82	50.85	1.10		186.94	0	58.04	70.88		115.03	38.45	Second	Dug Well
					epm	2.22	1.40	2.21	0.03	5.86	3.06	0	1.21	2.00	6.27				
13	Tapasawz	6.80	22.0	644	ppm	28.61	11.12	42.62	0.89		140.37	0	37.95	52.44		117.18	56.6	Second	Dug Well
					epm	1.43	0.93	1.85	0.02	4.23	2.30	0	0.79	1.48	4.57				
14	Kani Maran	6.78	22.1	1011	ppm	46.65	14.72	73.03	1.63		200.89	0	43.88	116.20		177.07	63	Second	Dug Well
					epm	2.33	1.23	3.18	0.04	6.78	3.29	0	0.91	3.28	7.49				
15	Smaq	6.88	22.8	1115	ppm	43.83	16.56	98.78	1.64		210.70	0	94.77	85.71		177.60	59	Second	Deep Well
					epm	2.19	1.38	4.30	0.04	7.91	3.45	0	1.97	2.42	7.85				
16	Drozna	7.00	22.4	597	ppm	29.50	10.61	33.82	0.73		149.85	0	15.46	50.03		117.32	37.8	Second	Deep Well
					epm	1.48	0.88	1.47	0.02	3.58	2.46	0	0.32	1.41	4.19				
Min.		6.78	22.00	385	ppm	25.88	9.14	13.64	0.54		102.52	0	4.02	30.79		102.23	8.05		
Max.		7.30	24.00	1199	ppm	70.41	22.32	98.78	1.65		263.99	0	94.77	116.20		267.67	63.00		
Average		7.02	22.89	765	ppm	37.91	13.31	51.43	1.08		169.76	0	42.07	63.31		149.44	34.53		
WHO Standard (2004)		6.5 – 8.5	---	---		100 – 300	---	200	---		---		250	200 – 300		500	50		

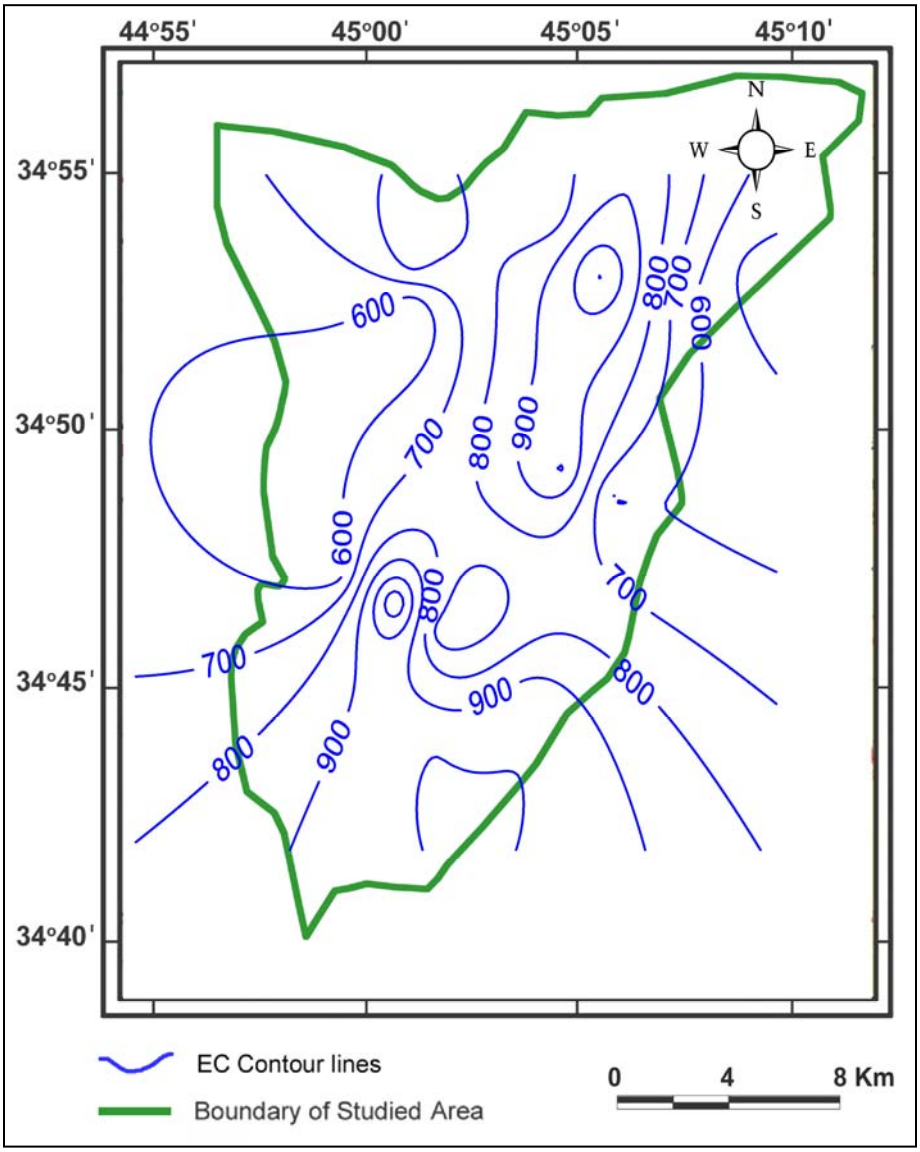

Fig.3: Spatial distribution of E.C. values

▪ **Major Cations and Anions**

Major cations and anions, such as Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^- , CO_3^{2-}, SO_4^{2-} and Cl^- (Table 1) were plotted in hydrochemical trilinear diagram (Fig.4). The groundwater samples can be classified into three hydrogeochemical facies: The groundwater samples of Tapa Spi and Smaq samples represent area No.7 (Non-carbonate alkali exceeds 50%, primary salinity), while those of Aziz Qadir, Hazar Kani, Tapa Sawz, Bakra Shal, Mam Hatam and Kani Maran samples represent area No.9 (Non of the cation and anion pairs exceeds 50%) and those of Umar Bil Bchuk, Umar Bil Gawra, Fatah Umar, Chwar Shakh, Tulabi, Sar Qala, Tuken and Drozna samples represent area No.5 (Carbonate hardness exceeds 50%, secondary alkalinity).

The trilinear diagram (Fig.4) representation of the groundwater samples reflects hydrochemical process from Non-Carbonate hardness to Carbonate hardness. The hydrochemical properties of the groundwater show the dominance of $Ca - HCO_3$ type in the aquifer systems of the studied area. According to Gibbs (1970) the chemical weathering of rocks is the major mechanism that influences groundwater quality (Fig.5).

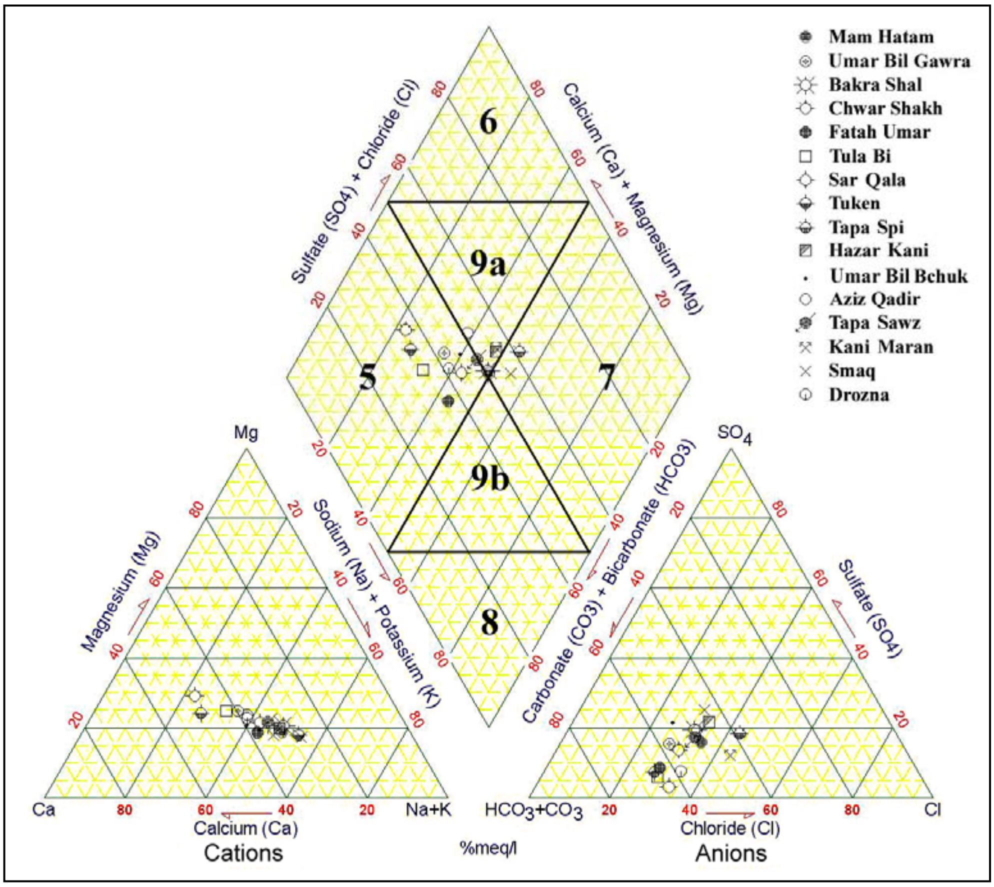

Fig.4: Piper diagram of the ground water samples

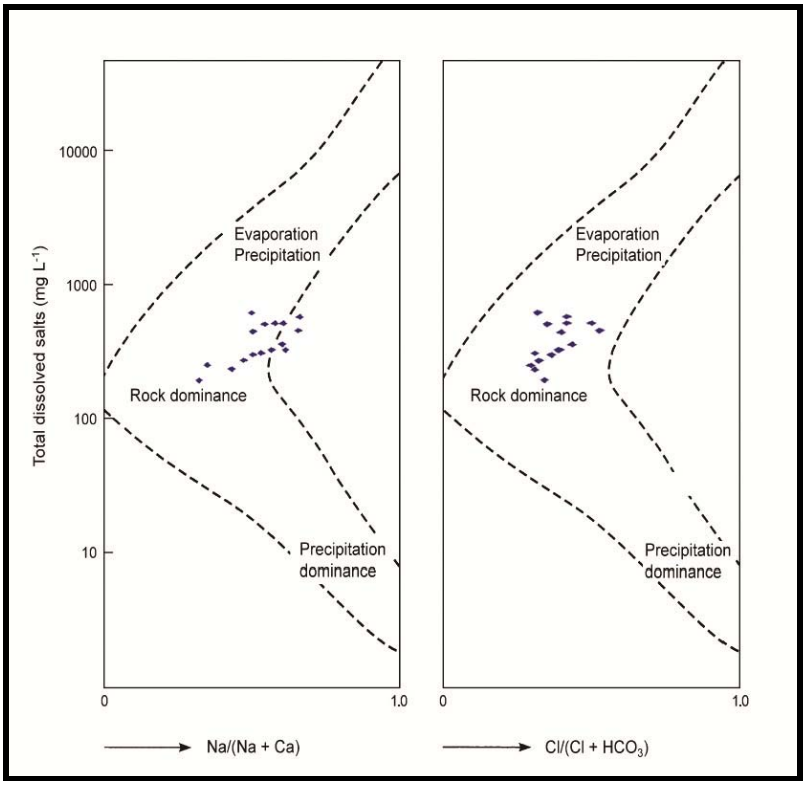

Fig.5: Mechanism controlling the quality of groundwater (after Gibbs, 1970)

- **Nitrate (NO_3^{2-})**

Nitrate is the main form of N in the groundwater. Several authors (Hill, 1982; Pacheco and Cabrera, 1997; Steinich *et al.*, 1998; Daskalaki *et al.*, 1998; Antonakos and Lambrakis, 2000) have related groundwater nitrates to different sources, such as leaching of organic and inorganic fertilizers, animal waste, domestic effluents and industry. Nitrate is a common surface water and groundwater contaminant that can cause health problems in infants and animals, as well as the eutrophication of water bodies (Fennesy and Cronk, 1997).

As shown in Table (1), the nitrate concentrations, in the studied area, range from (8.05 – 63) mg/l, with mean value of 34.4 mg/l. The main sources of the nitrate in the studied area are from the human wastes, animal's wastes and fertilizers. This is because in the rural areas, the industrial activities are absent and it is common for people to keep farm animals for consumption and/ or for commercialization. Moreover, part of the animals dung have been collected and used as fertilizer. These nitrate sources, in the studied area, have caused extremely high nitrate concentrations at Sar Qala, Tapa Sawz, Kani Maran and Smaq groundwater samples and nitrate concentrations exceeded the acceptable level by WHO (2004). At Tapa Sawz, Kani Maran and Smaq groundwater samples, the nitrate concentration was found to be 56.6, 63 and 59 mg/l, respectively (Fig.6).

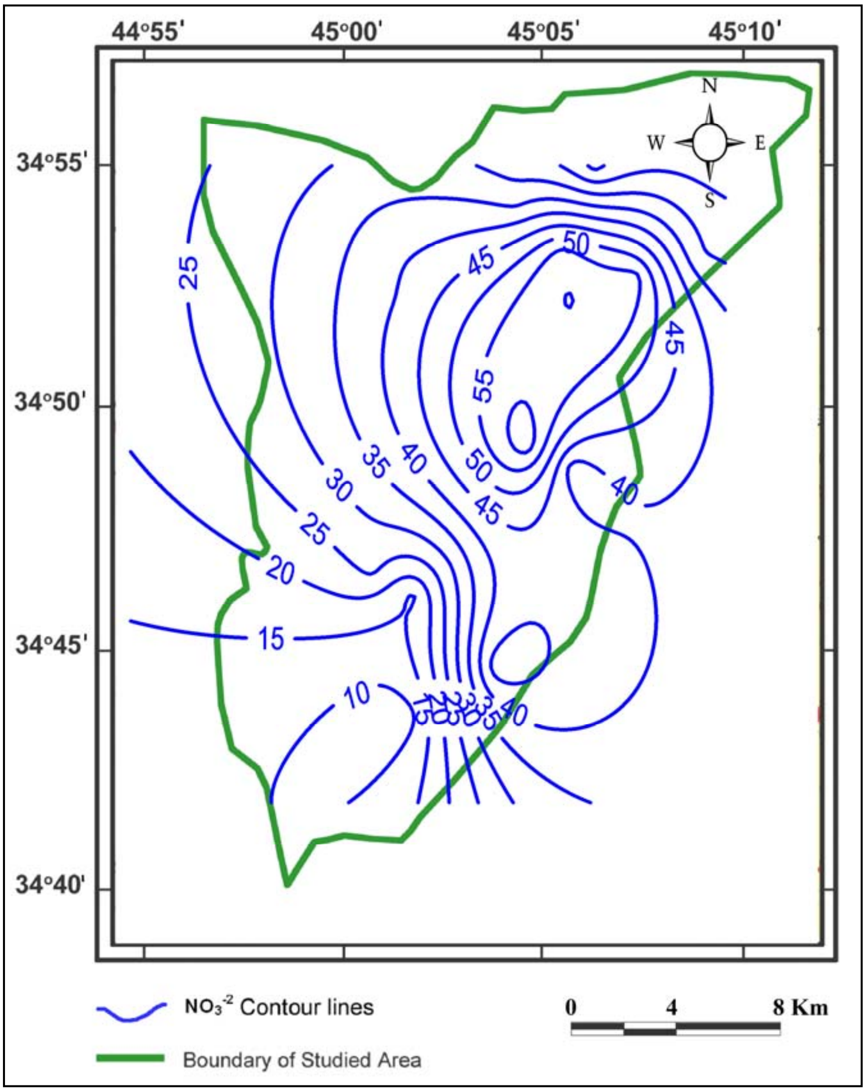

Fig.6: Nitrate concentration

- **Usability of the Groundwater in the Studied Area**

According to the WHO (2004) standard for drinking water quality, all of the collected groundwater samples are suitable for drinking, except the samples of Kani Maran, Sar Qala and Smaq, because the nitrate concentrations exceeded the recommended level (50 mg/l) in each of them (Table 1). In order to evaluate the groundwater, in the studied area for irrigation purposes, the following parameters: sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) have been calculated and shown in Table (2). The SAR and EC values of the groundwater samples were plotted in the graphical diagram for irrigation water (U.S. Salinity Laboratory, 1954) (Fig.7). The samples of Mam Hatam, Sar Qala, Tapa Spi, Umar Bil Bichuk, Aziz Qadr, Kani Maran and Smaq are within C3S1 (high salinity with low sodium), and the remaining samples are within C2S1 (medium salinity with low sodium).

In addition to SAR, the U.S. Salinity Laboratory (1954) denoted that RSC value less than 1.25 meq/l is acceptable for irrigation; a value between (1.25 – 2.5) meq/l is of marginal quality and a value of more than 2.5 meq/l is unsuitable for irrigation. In the present study, all collected groundwater samples were found to be suitable for irrigation (Table 2).

Table 2: Calculated SAR and RSC to evaluate groundwater samples for irrigation purposes

Sample Name	SAR	RSC (meq/l)
Mam Hatam	1.95	0.30
Umar Bil Gawra	1.08	– 0.16
Bakra Shal	1.60	– 0.02
Chwar Shakh	0.61	– 0.41
Fatah Umar	1.41	0.01
Tula Bi	0.91	0.00
Sar Qala	1.72	0.14
Tuken	0.77	– 0.21
Tapacharmu	2.04	– 0.17
Hazar Kani	1.62	– 0.09
Umar Bil Bchuk	1.86	– 1.05
Aziz Qadr	1.49	– 0.55
Tapasawz	1.45	– 0.06
Kani Maran	1.91	– 0.27
Smaq	2.39	– 0.12
Drozna	1.21	0.10

While based on Todd (1980) classification for irrigation water, according to the soluble sodium percentage (Table 3), the groundwater samples of Mam Hatam, Bakra Shal, Fatah Umar, Sar Qala, Tapacharmu, Hazar Kani, Tapasawz, Kani Maran and Smaq are permissible for irrigation and the remaining samples are of good water class (Table 3).

The groundwater of the studied area also has been evaluated for live stock consumption, depending on the classification proposed by MaKee and Wolf (1963) (Table 4). It was found that all of the collected groundwater samples are suitable for livestock consumption.

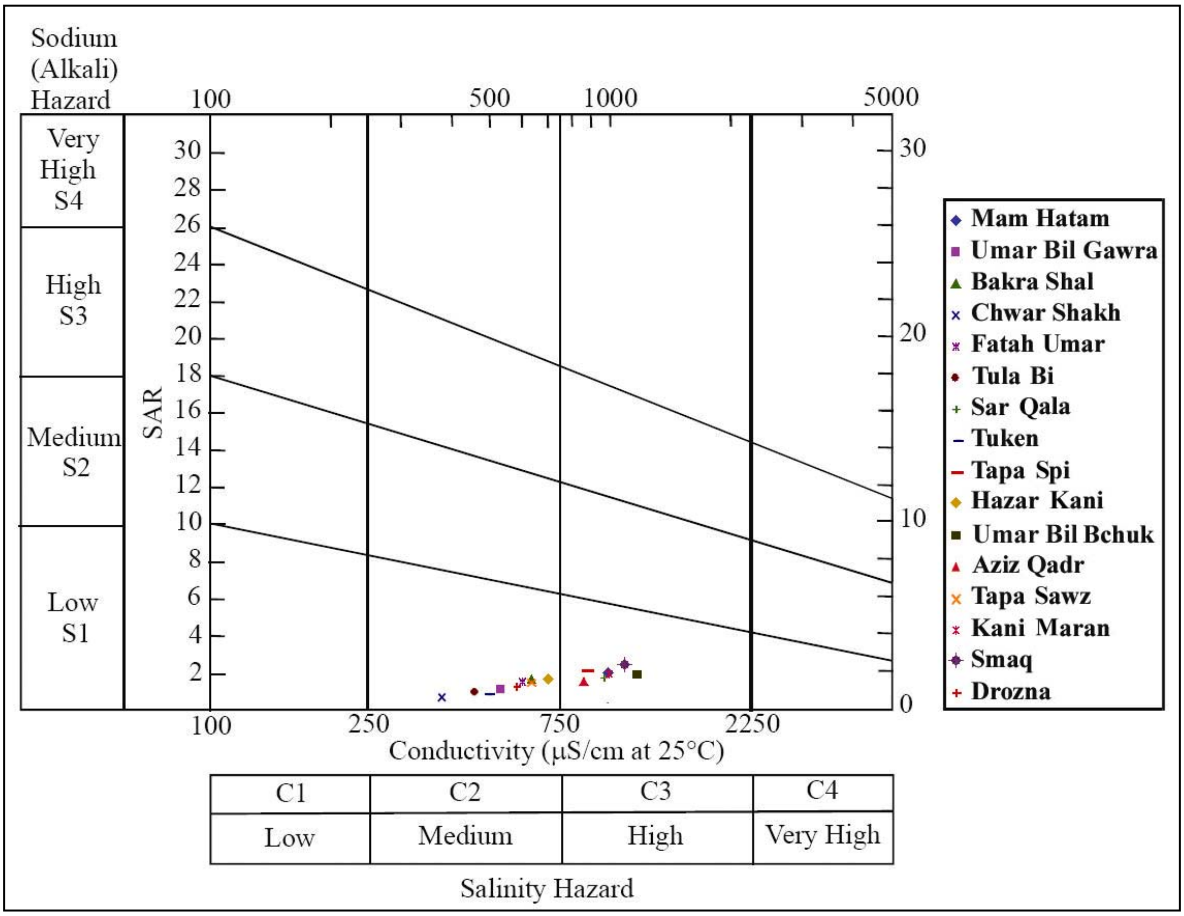

Fig.7: The quality of groundwater in relation to salinity and sodium hazard (after U.S. Salinity Laboratory, 1954)

Table 3: Classification of irrigation water based on SSP (Todd 1980)

Water Class	SSP	EC (µs/cm)
Excellent	< 20	< 250
Good	20 – 40	250 – 750
Permissible	40 – 60	750 – 2000
Doubtful	60 – 80	2000 – 3000
Unsuitable	> 80	> 3000

Table 4: Recommended TDS concentration limits for livestock consumption (after MaKee and Wolf, 1963)

Livestock	(TDS) Concentration (mg/l)
Poultry	2860
Horses	6435
Cattle (diary)	7150
Cattle (beef)	10100
Sheep (adult)	12900

CONCLUSIONS

The main conclusions of the present study are:

- The hydrogeology of the studied area is characterized by the presence of two aquifer systems. Bai Hassan Formation and Quaternary sediments form the main aquifer system in the studied area, while the Injana Formation is the second aquifer system of less transmissivity than that of former.
- The hydrochemical properties of the groundwater show the dominance of Ca – HCO_3 type in the aquifer systems of the studied area.
- The chemical weathering of the rocks is the major mechanism that influences groundwater quality in the studied area.
- The EC values increase towards the central part of the studied area, along the groundwater flow direction, because the low salinity waters enter the studied area from the northern parts, where groundwater receives most of its meteoric recharge, and flows towards the central parts carrying dissolved ions.
- The low transmissive beds and clogging nature of the sediments permit intermittent flushing and hence the dissolved ions sustain longer, which increases the residence time, and reactions take place within the aquifers.
- The nitrate concentration of Tapa Sawz, Kani Maran and Smaq groundwater samples exceed the recommended level and reach the polluted level, due to extreme affects of human and animals wastes and fertilizers.
- All of the collected groundwater samples are suitable for drinking, except Tapa Sawz, Kani Maran, and Smaq samples, because the nitrate concentration exceeds the acceptable level.
- The groundwater of the studied area is suitable for irrigation purposes.
- The groundwater of the studied area is suitable for livestock uses.

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