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Some hydro chemical characteristics of groundwater in Al-Kifl sub-district. Babel governorate \ Iraq.

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Abstract :

Securing water to satisfy the needs of humans and the ecosystem is one of the prime issues worldwide .Groundwater is essential to secure the safety of water supply in the study area. This study aims to characterize the hydro chemical properties and water quality of Al-Kifl district. In this study, 23 groundwater samples were collected, and were analyzed for 11 physicochemical parameters constituents (pH, TDS,EC, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, and NO_3^-) to identify the hydro geochemical characteristics, and to evaluate its suitability for drinking and irrigation purposes. All the samples were slightly alkaline in the nature and were not problematic for successful crop cultivation. Regarding to total dissolved solids (TDS) values, the ground water in the study area were distributed between slightly, slightly - brackish and brackish water. Based on electrical conductivity (EC) value, samples were classified as Excessively Mineralized Water. The study found that there is an increase in the concentrations of sodium, calcium, magnesium, sulfate, and chloride, due to the natural and anthropogenic. The prevailing water type is $NaSO_4^-$ in the wells of the study area. The study found that when comparing the results of the research with the global measurements according to water quality index (WQI) for drinking water, that the water type of wells are distributed between poor, very poor and unsuitable water. In respect of sodium absorption ratio (SAR) value, all the water samples were categorized as excellent for irrigation. According to the (EC) value the water types of wells were classified as permissible and unsuitable for irrigation. Considering soluble sodium percentage(Na%), the water of wells are distributed between good, permissible and doubtful for irrigation. Depending on residual sodium carbonate(RSC) value, the water were safe to irrigation.

Keywords: quality, index, irrigation, parameters, wells .

بعض الصفات الهايدروكيميائية للمياه الجوفية في ناحية الكفل. محافظة بابل / العراق

عدنان جسام حمادي ، كلية التربية / الجامعة العراقية

مستخلص

يعد تأمين المياه لتلبية احتياجات البشر والنظام البيئي احد القضايا الرئيسية في جميع انحاء العالم . تهدف هذه الدراسة الى وصف الخصائص الهيدروكيميائية ونوعية المياه في منطقة الكفل .تعتبر المياه الجوفية ضرورية في منطقة الدراسة لتأمين امدادات المياه. تم جمع ثلاثة وعشرون عينة من المياه الجوفية في هذه الدراسة وتحليلها لأحد عشر متغيراً فيزيائيا وكيمائيا (اس الهيدروجين ، المواد الصلبة الذائبة الكلية ، التوصيلية ألكهربائية وايونات الصوديوم ، البوتاسيوم ،الكالسيوم ، المغنيسيوم ، الكبريتات ، الكلورايد ، البيكاربونات ، والنترات) ومنها معرفة بعض الخصائص الكيماوية للمياه الجوفية وتقدير صلاحيتها لأغراض الشرب والري. تتراوح اصناف المياه الجوفية لمنطقة الدراسة استناداً لقيم المواد الصلبة الذائبة الكلية بين طفيفة الملوحة ، وطفيفة الى قليلة الملوحة وقليلة الملوحة بينما كانت شديدة التمعدن استناداً لقيم التوصيلية الكهربائية ، وأن هناك زيادة في تراكيز ايونات الصوديوم ، الكالسيوم ، المغنيسيوم ، الكبريتات والكلوريد ، كما بينت الدراسة أن النوعية السائدة للمياه هي كبريتات الصوديوم. وعند مقارنة نتائج مؤشر جودة المياه مع المواصفات العالمية وجدنا أن مياه الابار تراوحت بين انواع فقيرة ، وفقيرة جداً ، و غير مناسبة للشرب . وبالاعتماد على نسبة امتزاز الصوديوم فان المياه كانت ممتازة للري ، واذا اعتمدنا على التوصيلية الكهربائية فان نوعية المياه تراوحت بين مسموحة للري وغير مناسبة للري ، أما اذا اعتمدنا على النسبة المئوية للصوديوم فان المياه تكون بين اصناف جيدة للري ، ومسموحة للري ومشكوك في صلاحيتها للري .وتكون آمنة للري استناداً لقيم نسبة الصوديوم المتبقي .

الكلمات المفتاحية: نوعية ، مؤشر، ري ، مقاييس ، آبار.

1- INTRODUCTION

Babel is located approximately in the center of Iraq, about 100 km away from Baghdad’s capital(Fig. 1). Its Covered area of 5,119 km2, which constitutes 2% of the total area of Iraq. . The study area is located by the north latitudes $32^{0}15'$-$32^{0}25'$ and east longitudes $44^{o}21'$- $44^{0}32'$. The Euphrates River is the main source of irrigation for the study area, as the governorate depends mainly on agricultural activity, both plants, and animal.Recent sediments from the Quaternary age of both the Euphrates River and its branches are covered the study area. The sediments generally consist of thin layers of fine sand, silt and clay, as for the wind deposits in the eastern parts of the governorate [1].The age of the geological formations apparent in the region extends from the Lower Eocene (Dammam) to the Upper Miocene - Pliocene (Euphrates and AL Zahra) to the present time (modern sediments), and the quadripartite time deposits cover most of its areas, which are represented by river sediments and wind sediments. The groundwater in the study area is characterized by its high level and it is not different in nature from the rest of the sedimentary plain areas.

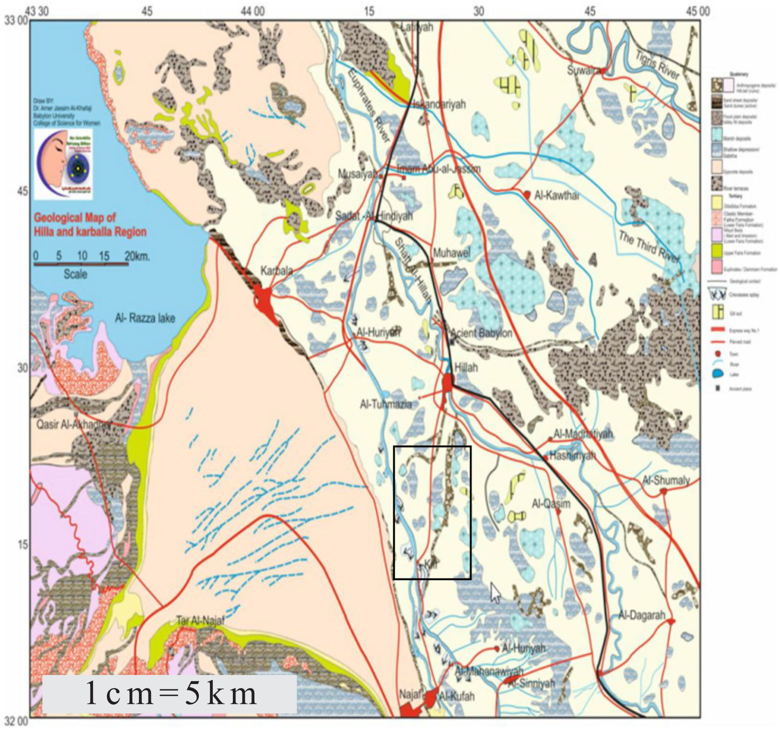

Figure 1: The location of the study area (alkifl)

1-1:Laboratory work

The hydro chemical study of the candidate water within the study area included the analysis of groundwater for 23 wells in the dry season (Table 2). The positive ions (K^+, Na^+, Mg^{2+}, Ca^{2+}) and negative ions (SO_4^{2-}, HCO_3^-, Cl^-, NO_3^-) as well as (pH), electrical conductivity (EC), and total dissolved salts (TDS), were conducted in the General Authority for Drilling of Wells and Groundwater of the Ministry of Water Resources. Water samples were analyzed to determine ions concentration in the laboratories of General Commission for Groundwater.

Table 1: locations' of the study wells

Well number	Elevation	Name of location	Well depth (m)	Geography (north)	Geography (east)
1	22	Lala edane	20	32 24 86 3	44 29 03 7
2	27	Hamza abd hani	20	32 24 96 6	44 29 67 3
3	25	Hamza jabra	20	32 25 15 1	44 29 91 1
4	20	Jassim obaid	20	32 24 87 3	44 29 32 5
5	16	Ahmed mohammed itwy	10	32 20 93 7	44 30 70 9
6	16	Mohammed hussain \1	10	32 21 14 4	44 30 76 3
7	15	Abd alammer\ 2	10	32 20 12 7	44 30 85 2
8	17	Emad thwany	10	32 19 69 6	44 30 94 6
9	18	Falah razzaq\ 2	10	32 21 01 9	44 30 36 7
10	19	Sayed jamal	10	32 16 68 6	44 31 68 7
11	14	Hussain alhakeem	10	32 17 11 4	44 31 85 8
12	11	Abo ali alkhafagy\2	10	32 19 15 0	44 31 11 0
13	17	Maysson rassol\1	10	32 18 66 0	44 31 12 8
14	17	Kazim jassim	12	32 16 05 2	44 31 46 8
15	20	Toqa abdallah	10	32 17 43 5	44 31 59 8
16	19	Hussain talib\1	10	32 15 89 1	44 32 03 6
17	17	Abo Khalil\1	10	32 15 77 9	44 32 20 1
18	17	Sattar salman	10	32 15 48 5	44 32 28 6
19	18	Abo mustafa	12	32 15 304	44 32 39 9
20	25	Ibrahim alkhlel school	12	32 22 44	44 21 48
21	16	Al-Rarangiya water complex	12	32 20 30	44 23 05
22	21	Al Rustamiya village	12	32 18 08.5	44 22 54
23	11	Al Rarangiya well	10	32 20 54	44 22 52

Table 2: Explains the physical and chemical properties in the wells of the study area

w.no.	pH	EC(µs\cm)	TDS(ppm)	K(ppm)	Na(ppm)	Mg(ppm)	Ca(ppm)	Cl(ppm)	SO4(ppm)	HCO3(ppm)	NO3(ppm)
1	7.91	4990	3410	12	681	119	189	624	1198	410	9
2	7.5	8130	5774	13	705	210	456	980	1642	562	2
3	7.15	7650	5326	17	661	200	416	781	1680	565	1.5
4	7.6	4960	3660	3	528	119	208	780	779	359	4
5	7.21	7910	5506	13	721	189	411	939	1549	540	3
6	7.31	5320	3748	17	615	167	339	673	1445	479	2.5
7	7.35	7660	5420	32	526	160	351	753	1398	335	1.5
8	7.62	8180	5700	19	803	249	459	1060	1750	549	9
9	7.5	6030	4344	45	540	132	260	520	1488	320	1.2
10	7.12	8190	5774	13	708	210	460	980	1642	862	2
11	7.32	4920	3950	118	840	160	335	722	1328	510	2
12	7.81	6710	4770	47	604	175	354	690	1552	508	4
13	7.16	7420	5279	10	800	240	450	1063	1739	553	9
14	7.09	11990	9580	5	841	375	685	1491	2200	745	4
15	7.2	5040	3910	120	560	165	340	746	1363	512	1.1
16	7.3	6900	4816	65	780	185	366	740	1870	520	3
17	7.61	6340	4520	43	590	143	352	646	1495	414	6
18	7.82	6720	2732	102	867	162	332	684	1413	492	2
19	7.1	9850	6601	18	731	175	410	916	1819	811	4
20	7.71	16090	13200	7	889	421	781	1680	2302	1033	16
21	7.2	1631	1300	10	259	42	102	358	420	78	0.1
22	7.2	1375	1260	9	164	80	117	311	459	84	9
23	7.5	1922	1800	13	344	82	131	459	670	90	2
range	7.09-7.82	1375-16090	1260-13200	3-120	164-889	42-421	102-781	311-1680	420-2302	78-1033	0.1-16
mean	7.4	6779.4	4886	32.6	641.6	180.86	341.0	808.5	1443.5	492.6	4.169

2- Results and Discussion

2-1:Physical Properties

2-1-1Hydrogen ion concentration (pH): The pH of water is controlled by the equilibrium achieved by dissolved compounds in the system. Groundwater in this area was slightly alkaline, as the recorded pH values ranged from 7.01 to 7.92, with a mean value of 7.4. The pH values were within the permissible limits (6.5–8.5) set by WHO and the Iraqi standards at all sites.

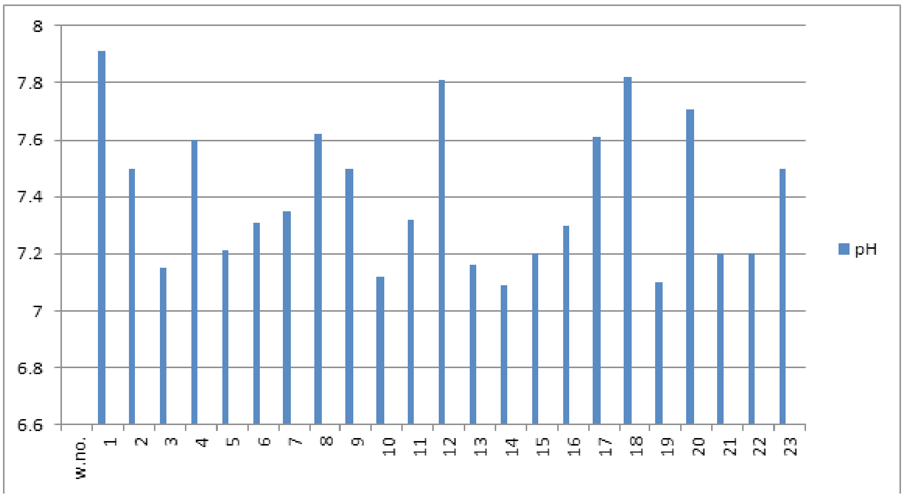

Figure 2 : The pH values of all samples.

2-1-2:Total Dissolved Solids (TDS): TDS, which is a comprehensive hydrochemical parameter, can be used to reflect the groundwater quality [2].The maximum TDS values were recorded in well number 20 (13200 mg/L) and, the minimum value was recorded in well 22 (1260 mg/L) with mean value of 4886. By comparing the TDS values with references[3,4,5], it is concluded that the water in the type is often slightly- brackish water (table3).

Table 3 : Classification of water salinity according to the TDS (ppm)

Altoviski[3]	Drever[4]	Tood [5]	Water class	Samples of study
0-1000	<1000	10-1000	Fresh water	------
1000-3000	1000-2000	-----------	Slightly water	18,21,23,22(17.3%)
3000-10000	2000-20000	1000-10000	Slightly-Brackish water	Most of samples(78.4%)
10000-100000	-----------	10000-100000	Brackish water	20(4.3%)
------------	20000-35000	------------	Saline water	---------
>100000	>35000	>100000	Brine water	----------

2-1-3 **Electrical conductivity (EC):** In water of the study area, EC ranges from 1375 to 16090µs/cm with 6779.4 µs/cm in average. The relationship between electrical conductivity and mineralization Located within Excessively Mineralized Water(table 5).

Table 4: The relation between EC and mineralization[6]

EC(µS\cm)	Mineralization	The Study area
<100	Very weakly mineralized water(granite terrains)	
100-200	Weakly mineralized water	
200-400	Slightly mineralized water (limestone terrains)	
400-600	Moderately mineralized water	
600-1000	Highly mineralized water	
>1000	Excessively mineralized water	All samples

The results are drawing that EC trend is concordant to the TDS trend in the studied area. (Fig.3)

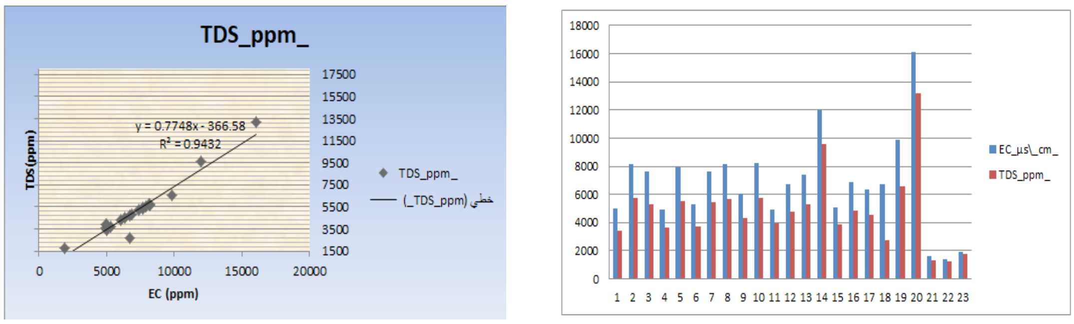

Figure 3: Relation between TDS and EC in the study area.

2-2: Chemical properties

Major I0ns: Figure (4) are showing Ions values. The abundance of the major ions is as follow Na>Ca>Mg>K and SO_4>CL>HCO_3>NO_3. Most of samples had higher values of Na, Ca, Mg, CL, and SO_4 which were beyond the acceptable limits of WHO (>200, 75, 50, 250, and 250 mg/L), respectively. This implies that hard water (caused by compounds of Ca and Mg). chloride is an extremely stable element in water, which may be derived from the weathering, the leaching of sedimentary rock and soil, and domestic effluents [7]. The observation may imply the adverse impact of sewage or effluent on groundwater quality were consistent with the result of hydrochemical characteristics of groundwater carried out in the alluvial plain [8].

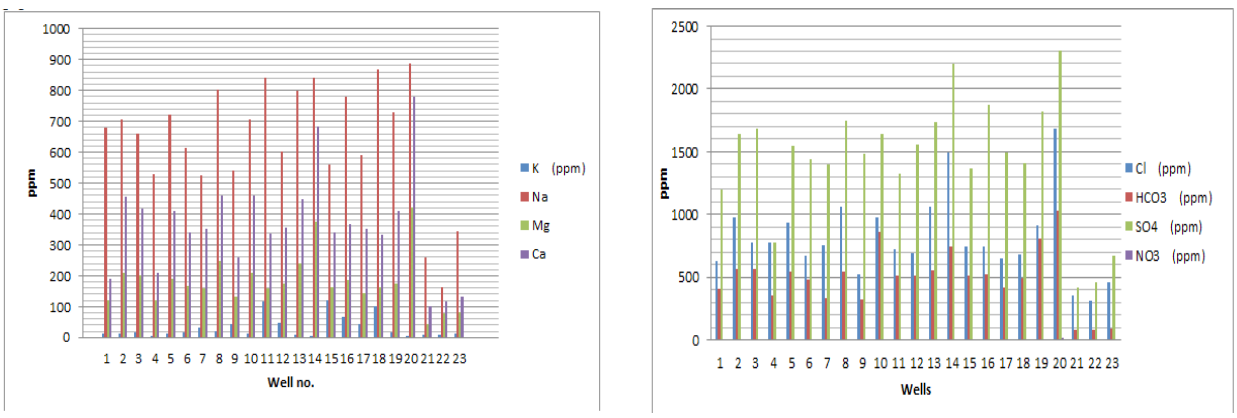

Figure 4 : Shows the concentrations of ions in the study area

2-2-1:Calcium ion (Ca^{2+}): The highest concentration of calcium ion in the water of the study area was 781 mg/l in well (20), while the lowest concentration of calcium was (102) mg/L in well (21) Figure (5). The mean concentration of calcium was 361mg/l. Most groundwater models(86.6%) in the study area exceeded the permissible drinking water limit of 75-200 mg/l(Table 6) according to international standards [9]. The increase in the concentration of calcium in the water of the study area is due to the effect the process of ion exchange between sodium and calcium.

Table 6: Desirable-permissible values limits for parameters[9] and comparing with study area.

Parameters’	Desirable-permissible limits(WHO 2011)	Samples of the Study area
pH	6.5-8.5	All samples
TDS	1000	No sample
EC	500-1500	22
TH	100-500	21
Na	200-600	4,7,9,15,17,21,22,23(34.7%)
K	10-12	1,4,13,14,20,21,22(30.4%)
Ca	75-200	21,22,23 (13.4%)
Mg	50-100	21,22,23 (13.4%)
CL	250-500	21,22,23 (13.4%)
SO_4	200-250	No sample
NO_3	50	All samples
HCO_3	200-500	1,4, 6,7, 9, 17,18,21,22,23(23.4%)

2-2-2: Magnesium ion (Mg^{2+}): The highest concentration of magnesium ion in the water of the study area was 421 mg/L in well (20) while the lowest concentration of magnesium was 42 mg/L in well (21) with mean value of 180.8. The high concentration of magnesium ion in the water of these regions is due to the effect of the ion exchange process and the effect of evaporation processes.

2-2-3: Sodium (Na^{+}): The highest concentration of sodium in the water of the study area was 889 mg/L in well (20), while the lowest concentration was 164 mg/L in well (22) with mean value of 641.6 .The high concentration of sodium in water is due to the dissolving of sodium salts concentrated in the soil as a result of watering of plants. Household cleaning agents also increase sodium as a result of containing sodium hypochlorite, which is transferred from the sewage system to the groundwater system by means of dispersion.

2-2-4: Potassium (K^{+}): Potassium can be added to groundwater through fertilizer use and the breakdown of animal or human waste products .The highest concentration of potassium ions in the water of the study area was 120 mg/L in well (15) while the lowest concentration of potassium 3 mg/l in well (4).

2-2-5: Sulfates (SO_4): The water of the study area is characterized by the abundance of sulfates. The highest concentration of sulfate was 2302 mg/l in well (20) , while the lowest concentration of sulfate was 420 mg/l in well (21) with mean value of 1443.5. All candidate water models in the study area exceeded the drinking water limit of 200-250 mg/l according to international standards [9]. The high concentration of sulfate in the water of the study area is due to the presence of sulfur salts in the soil, as well as the presence of secondary gypsum.

2-2-6: Bicarbonates (HCO_3): Alkalinity is a measure of the ability of a substance to neutralize acids. The key elements contributing to alkalinity are bicarbonate and carbonate. The main sources of these are from natural reactions between water and carbon dioxide, or as byproducts of naturally occurring reduction processes. The highest concentration of bicarbonate ion in the water of the study area was 1033 mg/L in well (20), while the lowest concentration of bicarbonate was 78 mg/l in well (21) with mean value of 492.6. The increased concentration of bicarbonates in these waters resulted in the melting of sodium bicarbonate in the soil due to irrigation processes, as well as the effect of wastewater through the drainage system in these areas. Most of the study models fall within the permissible limits of bicarbonate concentration.

2-2-7: Chloride (Cl) : The highest concentration of chloride in the water of the study area was 1680 mg/L in well (20), while the lowest concentration of chloride was 311 mg/l in well (22) with mean value of 808.5 . Higher concentration of chloride may be indicating to dominance of industrial activities and salt pan leaching to the groundwater. Most groundwater models(86.6%) in the study area exceeded the permissible drinking water limit of 250-500 mg/l(Table 6) according to international standards [9].

2-2-8: Nitrate (NO3): The lowest concentration was 0.1 mg/L in well (21), and the highest concentration was 16 mg\L in well (20) with mean value of 4.25. It should be noted that all candidate water models in the study area fall within the permissible drinking water limit of 50 mg/L according to international standards [9].

2-3: Hydrochemical Formula and Water Type

The hydrochemical formula of water can be determined by taking the concentrations of main cations and anions in mill equivalent percent (meq%) (Table 7) in water with total dissolved solids concentration (TDS) as (mg/l) or (g/l).

Table 7: epm% values for parameters

Wel. no.	WQI	SAR epm	RSC epm	Na% epm%	K^+ epm%	Mg^{+2} epm%	Ca^{+2} epm%	CL^- epm%	SO_4^{-2} epm%	HCO_3^- epm%	NO_3^- epm%
1	253	9.5	-12.6	60.0	0.62	20.1	19.1	35.5	50.5	13.6	0.29
2	347	6.8	-31.08	42.9	0.46	24.5	31.9	38.8	48.1	12.9	0.04
3	347	8.6	-12.9	55.9	0.84	2.7	40.4	33.1	52.8	13.9	0.03
4	222	7.2	-14.4	52.9	0.17	22.8	23.9	49.7	36.7	13.3	0.14
5	328	7.3	-27.4	46.1	0.48	23.1	30.2	39.1	47.7	13.0	0.07
6	289	6.8	-23.02	46.0	0.74	23.9	29.2	33.2	52.8	13.7	0.07
7	308	5.8	-30.8	41.9	1.5	24.4	32.1	37.9	52.1	9.8	0.04
8	392	7.4	-34.7	44.1	0.61	26.2	29.0	39.5	48.3	11.9	0.19
9	280	6.7	-18.7	48.2	2.37	22.6	26.7	29.0	60.5	10.3	0.03
10	389	6.8	-26.3	42.9	0.46	24.4	32.1	36.3	45.0	18.5	0.04
11	348	9.4	-21.7	52.4	4.34	19.1	24.0	36.0	49.0	14.8	0.05
12	333	6.5	-23.9	43.9	2.01	24.4	29.6	32.3	53.7	13.8	0.10
13	377	7.5	-33.4	44.8	0.33	25.7	29.0	39.0	48.4	12.13	0.19
14	528	6.3	-53.2	35.8	0.12	30.6	33.5	41.9	45.7	12.1	0.06
15	340	6.2	-22.3	41.8	5.2	23.6	29.2	36.3	49.1	14.5	0.03
16	360	8.2	-25.1	48.9	2.4	22.2	26.4	30.4	56.9	12.4	0.07
17	315	6.6	-22.7	45.5	1.95	21.1	31.2	32.3	55.3	12.0	0.17
18	323	9.7	-22.03	53.5	3.71	19.1	23.2	33.9	51.8	14.2	0.05
19	441	7.5	-21.7	47.2	0.68	21.6	30.5	33.4	49.1	17.2	0.08
20	565	6.3	-57.1	34.2	0.15	31.0	34.5	42.0	42.6	15.0	0.22
21	101	5.4	-7.3	55.9	1.27	17.3	25.3	50.1	43.5	6.3	0.007
22	114	2.8	-11.1	56.5	1.17	34.1	29.9	44.1	48.1	6.9	0.73
23	138	5.7	-11.9	52.1	1.16	23.8	22.8	45.5	49.1	5.1	0.11

The hydrogeological formula of the study area was as follows:

$$TDS\,(mg\,¿)\,\frac{Anions\ epm\ \% \in decreasing\ order}{Cations\ epm\ \% \in decreasing\ order}\,pH$$

So that the quality of the prevailing water is $NaSO_4^-$ in the wells of the study area. Table (8) shows the hydrochemical formula and the water type in the study area. Four types of water are shown: Sodium sulfate(86.9%), sodium chloride (8.6%), calcium sulfate (4.3%) , which indicating that sulfates are predominant in the sense of negative ions, while sodium ions is predominant for positive ions in most water models studied.

Table 8: shows the hydrochemical formula and water type in the study area.

Well No.	Hydro chemical Formula	Water Type
1	$7.9\ \frac{SO4-2(50.52)CL-(35.5)}{Na+(60.07)Mg+2(20.1)Ca+2(19.17)}\ 3410$	Na–Sulfate
2	$7.5\ \frac{SO4-2(48.1)CL-(38.8)}{Na+(42.9)Ca+2(31.9)Mg+2(24.5)}\ 5774$	Na–Sulfate
3	$7.15\ \frac{SO4-2(52.8)CL-(33.1)}{Na+(55.9)Ca+2(40.4)}\ 5326$	Na –Sulfate
4	$7.6\ \frac{CL-SO4-2}{Na-Ca+2Mg+2}\ 3660$	Na Chloride
5	$2\ .7\ SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 5506$	Na- Sulfate
6	$7.31\ SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 3748$	Na--Sulfate
7	$7.35\ SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 5420$	Na –Sulfate
8	$5700\ SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.6$	Na –Sulfate
9	$4344\,SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.5$	Na –Sulfate
10	$7.12\ SO4-2CL-HCO3-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 5774$	Na –Sulfate
11	$3950\,SO4-2CL-\frac{-\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.3$	Na – Sulfate
12	$4770\,SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.81$	Na –Sulfate
13	$5279\,SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.16$	Na –Sulfate
14	$7.09\ SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 9580$	Na – Sulfate
15	$3910\,SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.2$	Na-Sulfate
16	$7.3\ SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 4816$	Na-Sulfate
17	$4520\,SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.61$	Na-Sulfate
18	$2732\,SO4-2CL-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.82$	Na-Sulfate
19	$6601\,SO4-2CL-HCO3-\frac{\text{¿}}{Na+Ca+2Mg+2}\text{¿}\ 7.1$	Na-Sulfate
20	$13200\,SO4-2CL-HCO3-\frac{\text{¿}}{Ca+2Na+Mg+2}\text{¿}\ 7.71$	Ca –Sulfate
21	$1300\ \frac{CL-SO4-2}{Na+2Ca+2Mg+2}\ 7.2$	Na-Chloride
22	$1260\ SO4-2CL-\frac{\text{¿}}{Na+Mg+2Ca+2}\text{¿}\ 7.2$	Na-Sulfate
23	$1800\,SO4-2CL-\frac{\text{¿}}{Na+2Mg+2Ca+2}7.5\text{¿}$	Na-Sulfate

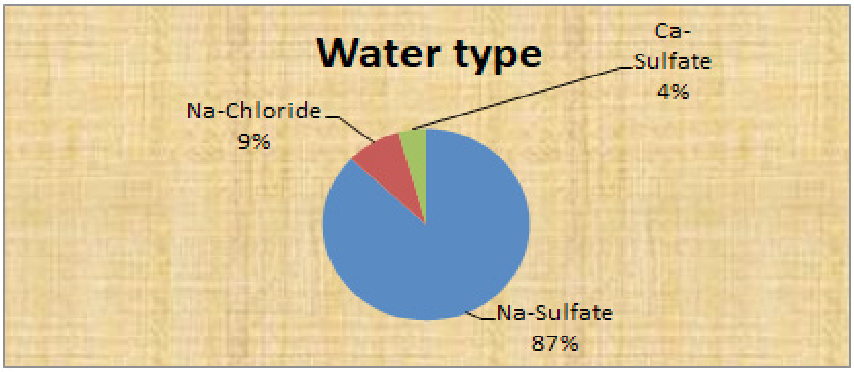

Figure 5: Shows the prevailing water type in the study area

3- Uses of Groundwater

3-1: Groundwater Suitability for Human Drinking : Usage water for drinking depends on the ionic concentration of water, TDS, pH and other components. When the ionic concentrations exceed the allowable limits for drinking water (Table 6) ,water is not recommended for drinking.

Water quality index for drinking water (DWQI): The quality of groundwater and its suitability for drinking was assessed using WQI method. The water quality index (WQI) is an efficient technique to express water quality by aggregating various water quality parameters[10]. Ten parameters (pH,TDS,Ca,Mg,Na,Ka,CL,SO_4,NO_3 and HCO_3) were taken into account for calculation of WQI and WHO drinking water standards were considered. The weights were assigned to compute the WQI values for each groundwater parameters between 1and 5 (Table 9) depending on their prominence in water quality [11,12].

Table 9: specific weight, relative weight and standard values for drinking water[9]

Parameters	WHO standards values	Weight of parameter (Wi)	Relative weight (Wr)
pH	6.5-8.5	4	0.125
TDS ppm	1000	5	0.1562
Ca ppm	75	3	0.09375
Mg ppm	50	1	0.03125
Na ppm	200	2	0.0625
K ppm	12	2	0.0625
CL ppm	250	3	0.09375
SO_4 ppm	250	4	0.125
NO_3 ppm	10	5	0.1562
HCO_3 ppm	120	3	0.09375
		$\sum 32$	

The relative weights (Wr) were calculated for each parameter using Eq.1. WQI values were computed using following Eq. 2,3 and 4.

$$Wr = wi / \sum_{n=1}^{n} wi$$ --------(1) where, Wr: Relative weight, wi: Assigned weight for each parameter in each water sample , n:number of parameters.

$$qi = \left(\frac{Ci - Co}{Si - Co}\right) * 100$$ ---------(2) where qi is the quality rating for each parameter in each sample, Ci is the concentration of each parameter, Co is the ideal value of this parameter in pure water (Co=0 except for pH= 7) and Si is the WHO standard (2011) for drinking purposes of each parameter (table 9).

$$Sli = Wr * qi$$ -----------(3) where Sli is the sub index for each parameter.

$$WQI = \sum Sli$$ ------------(4)

The water may be classified into five types based on computed WQI as given below in Table 10.

Table 10 :Water quality classification for drinking based on WQI value [13]

WQI	Water quality	.Sample no	of % samples
50>	Excellent water	------	0%
50-100	Good water	--------	0%
100.1-200	Poor water	21,22,23	13.4%
200.1-300	Very poor water	1,4,6,9	17.4%
300<	Unsuitable	2,3,5,7,8,10,11,12,13,14,15,16,17,18,19,20	69.05%

Table 10 shows that the water in the study area is poorly water(13.4%), very poor (17.4%) and unsuitable (69.05%) for drinking water due to high salinity, accompanied by a rise in concentrations of sulfur ions Calcium , other ions and other values.

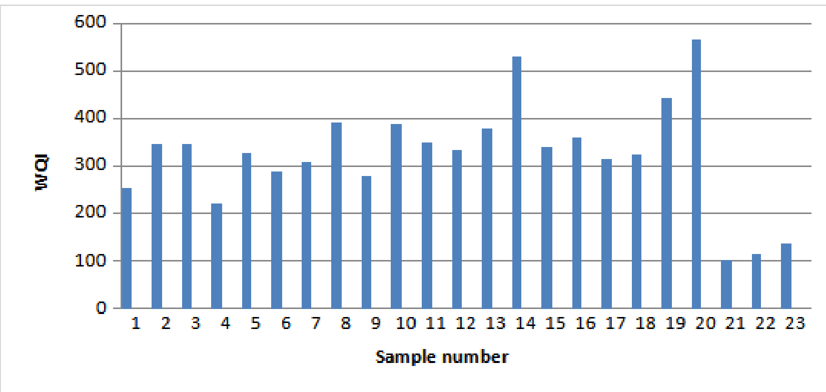

Figure8: The WQI values of all samples

3-2: Groundwater Uses for Irrigation Purposes**:** TDS, EC, SAR, Na%, RSC ,pH, cations , and anions values has been used in the present study to evaluate suitability of groundwater for irrigation purposes.

3-2-1:Sodium adsorption ratio (SAR indicator)

The SAR parameter evaluates the sodium hazard in relation to calcium and magnesium concentrations. If SAR value is <10, the water is safe to irrigate with no structural deterioration. High salt concentration in water leads to formation of saline soil and high sodium concentration leads to development of an alkaline soil [14]. Karanth, defines sodium adsorption ratio SAR of water as:

$$SAR=\frac{Na^{+¿}}{¿¿}¿ \quad \text{---------(5)} \quad [15]$$

Where all ionic concentrations are expressed in epm.

Four classes of water for agriculture depending on SAR value according to Subramain classification[16] and all samples in study area have been SAR beneath than 10 epm which indicate an excellent water (class S1) for agriculture (Table 11).

Table11: Alkalinity hazard classes of water [16]

SAR (epm)	Alkalinity hazard	Water class	Representing samples
<10	S1	Excellent	All Samples
10-18	S2	Good	--------
18-26	S3	Doubtful	--------
>26	S4	Unsuitable	----------

3-2-2:Na % and EC

Sodium percentage is an important parameter for studying sodium hazard. Na % is calculated using the following formula:

$$Na\%=(rNa+rK/rCa+rMg+rNa+rK)\times 100 \quad \text{-------------(6)} \quad [17]$$

Where all ionic concentrations (rNa, rK, rCa, rMg) are expressed in epm.

High-percentage sodium water for irrigation purpose reduces soil permeability and may prevent the plant growth [18]. One important classifications of water for irrigation is depending on Na% and EC values as following in table (12). Due to this classification, most of samples are from unsuitable for irrigation.

Table 12: Classification of water for irrigation based on Na % and EC [17].

Water class	Na%	Study area	EC µS/Cm	Study area
Excellent	<20	-------	<250	-----
Good	20-40	14,20 (8.6%)	250-750	------
Permissible	40-60	Most samples (91.3%)	750-2000	21,22,23(13.0)
Doubtful	60-80	----------	2000-3000	--------
Unsuitable	>80	--------	>3000	Most samples (87.0%)

3-2-3:Residual sodium carbonate (RSC): A high concentration of bicarbonate in irrigation water may lead to precipitation of calcium and magnesium in the soil and thus to a relative increase of sodium concentration, therefore the sodium hazard will increase [19].The bicarbonate hazard expressed by residual sodium carbonate (RSC) which introduced by Eaton as follow:

$RSC = (CO_3^{-2} + HCO_3^{-}) - (Ca^{+2} + Mg^{+2})$. -----------(7)[20]

Where all ions measured by equivalent weight (epm)(Table 7).RSC values in study area ranges between (-49.6 to -3.9 epm). According to classification of Eaton, all samples of groundwater in study area were safe for irrigation(Table 13).

Table13: Classification of irrigation water based on RSC values [20]

RSC (epm)	Water type	Area study
<1.25	Safe	All samples(negative values)
1.25-2.5	Marginal	
>2.5	Unsuitable	

4- Conclusion

The type of groundwater in study area were often slightly to brackish water according to values of TDS and excessively mineralized according to EC. Four types of water in the study area and it is order $NaSO_4$, NaCL, CaCL and $CaSO_4$ .According to the WQI for drinking purposes, the water quality in the study area were as follows poor (52.17%), very poor (30.43%) and unsuitable (17.39%). According to the WQI for irrigation purposes, the water quality in the study area were as follows good (17.39%), poor (39.13%), very poor (26.08%) and unsuitable (17.39%). Most samples (86.95%) was excellent for irrigation water according to SAR values, permissible (73.91%) according to Na% values and unsuitable for irrigation (78.26%) according to the EC values. All samples are from safe water type for irrigation according to the RSC value.

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