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Estimation of the water quality of selected wells from eastern wasit governorate for different human uses

Adnan jassam humadi // Iraqia university - college of education

Abstract

Groundwater is essential to secure the safety of water supply in the study area. In this study, 23 groundwater samples were collected, and were analyzed for 11 physico-chemical parameters constituents (pH, TDS,EC, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, and NO_3^-) to identify the hydrogeochemical characteristics, and to evaluate its suitability for drinking and irrigation purposes. The ground water in the study area is classified according to the total dissolved solids as slightly, slightly - brackish and brackish water. The electrical conductivity in water of the study area is 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 $NaSO_4^-$ (65.21%) 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 is poor (52.17%),very poor (30.43%) and unsuitable water(17.39%). Depending on, sodium absorption ratio (SAR) the water supply are good (13.04%) and excellent (85.95%) for irrigation ,electric conductivity (EC) the water are doubtful(21.73%) and unsuitable(78.26%) for irrigation, soluble sodium percentage(Na%) the water are good(21.73%), permissible(73.91%) and doubtful(4.34%) for irrigation, residual sodium carbonate(RSC) the water are safe to irrigation, WQI for irrigation the water are good(17.39%),poor(39.13%), very poor (26.08%) and unsuitable water(17.39%).

Keywords: estimation, quality index, irrigation, water type.

تقدير صلاحية مياه بعض الابار المختارة من شرق محافظة واسط لمختلف الاستخدامات البشرية

الخلاصة

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 فيزياويا وكيماويا (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. صنّفت المياه الجوفية لمنطقة الدراسة استناداً لقيم المواد الصلبة الذائبة الكلية على أنها مياه طفيفة الى قليلة الملوحة بينما كانت شديدة التمعدن استناداً لقيم التوصيلية الكهربائية، وأن هناك زيادة في تراكيز ايونات الصوديوم، الكالسيوم، المغنيسيوم، الكبريتات والكلورايد، كما بينت الدراسة أن النوعية السائدة للمياه هي كبريتات الصوديوم (65.21 ٪). وعند مقارنة نتائج مؤشر جودة المياه مع الموصفات العالمية وجدنا أن 52.17 ٪ من العينات تكون فقيرة، 30.43 ٪ فقيرة جداً، و17.39 ٪ تكون مياه غير مناسبة للشرب. وبالاعتماد على نسبة امتزاز الصوديوم فان المياه تراوحت بين ممتازة للري (85.95 ٪) وجيدة (13.04 ٪) واذا اعتمدنا على التوصيلية الكهربائية فان المياه تكون غير مناسبة (78.96 ٪) ومشكوك في استخدامها للري (21.37 ٪)، أما اذا اعتمدنا عل النسبة المئوية للصوديوم فان المياه تكون بين جيدة للري (21.73 ٪)، مقبولة (73.91 ٪) ومشكوك في صلاحيتها للري (4.43 ٪) . وتكون آمنة للري استناداً لقيم نسبة الصوديوم المتبقي، كما اشارت الدراسة أن المياه تراوحت بين جيدة للري (17.39 ٪)، فقيرة للري(39.31 ٪)، فقيرة جداً (26.08 ٪) وغير مناسبة للري (17.39 ٪) وذلك اعتماداً على قيم مؤشر جودة المياه للري.

الكلمات المفتاحية: تقدير، مؤشر الجودة، ري، نوعية المياه.

INTRODUCTION

Water shortage has been a critical issue in many parts of the world, especially in arid and semi-arid areas [1,2]. Due to the present conditions in Iraq, which are characterized by a shortage of surface water supply as a result of retaining water of the Tigris and Euphrates Rivers within the neighboring countries. In addition to the dry conditions during the present period which started some years ago. There is a need to search and find other sources of water supply from groundwater resource on regional scale. Groundwater is the important source of water used for human utilization and for both industrial and agricultural activities in regions where surface water is scarce[3]. Groundwater is the primary source for domestic water supply in the study area especially during dry periods. The study area lies between 32^{0}48’52” and 33^{0}15’46” latitudes and 45^{0}54’22” and 46^{0}33’59” longitudes in the northeastern wasit governorate, Iraq. It is bounded by hor al-shiwach from the west and south, wadi galas from the north, Iraqi-Iranian border from the east. Badra and Jassan are the main two cities within the question area. The study area is generally hot and dry. The major stream in the study area is Galal-Badra river. The mean monthly discharge of this river is 2.5 and 1000m^3/s in drought and flood period, respectively[4]. Most of farmers depend on the groundwater for their irrigation needs. The aim of this study is studying some of the hydrochemical properties of groundwater , the nature of this water and determination the validity of groundwater for drinking and irrigation uses by comparing them with the global determinants.

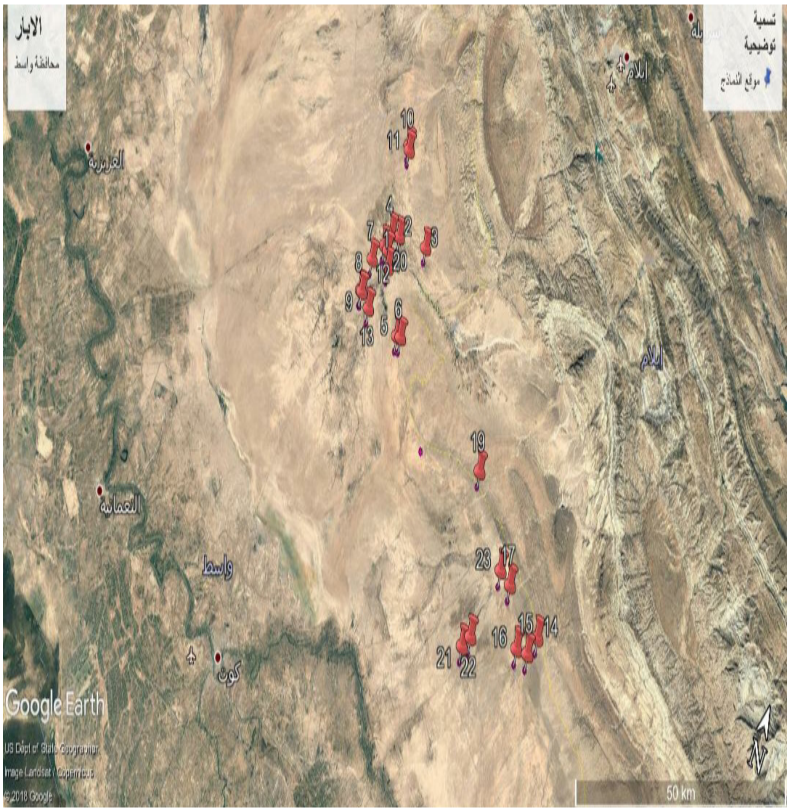


Figure 1: The location of sampling models in the study area

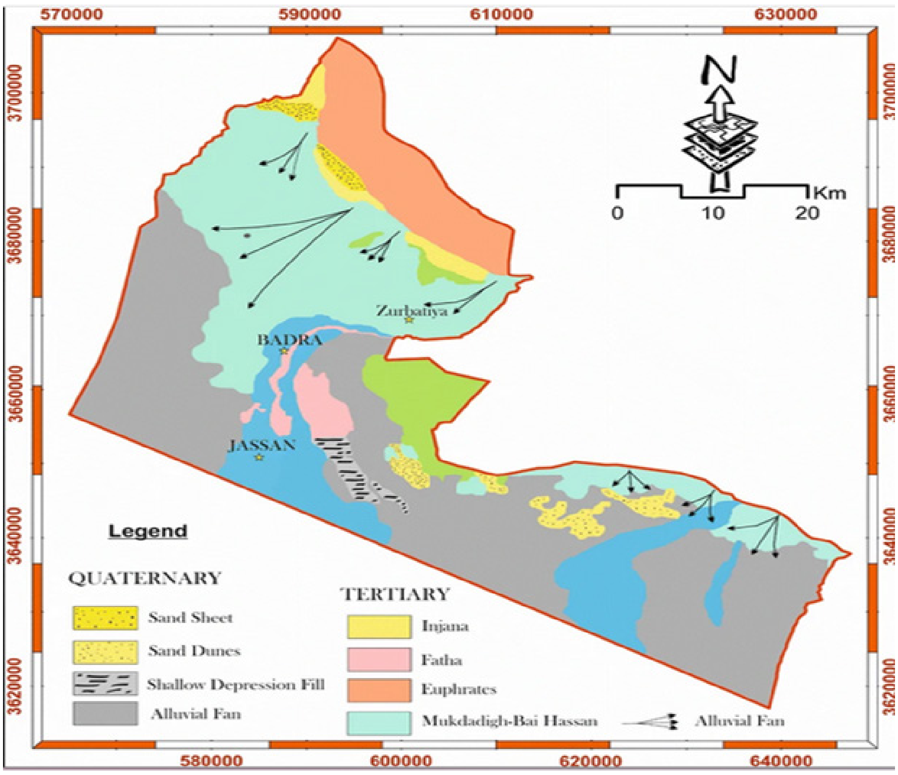
.GEOLOGY OF THE STUDY AREA

From a geological point of view, rocks in the investigated area range in age from Upper Miocene to Recent. In the western portion, the younger rocks are exposed and increasingly become old to the east. Most of the area is covered by rocks of alluvial and lacustrine origin, Pliocene or younger in age [5]. The stratigraphic succession is composed of Injana, Mukdadiya formations in addition to the quaternary deposits. The quaternary deposits mainly consist of a mixture of gravel, sand, silt and conglomerates of post Pliocene deposits. The distribution of these lithological units is shown in Fig.2. A brief description of these units is provided in Table1. Approximately 84% of the study area is covered with quaternary deposits. Tectonically, the platform of the Iraqi territory is divided into two basic units, the stable and unstable shelf [6].

Table 1: Brief description of the formations in the study area.

Formation	Age	Environmental	Description	Area(km^2)	Area(%)
Injana	Upper Miocene	Sub-Marine	Red or gray colored, silty marl or clay and puble silt stone	8	0.01
Muqdadyia	Pliocene	Continental	Gravely sandstone, sandstone, and red mudstone	103	0.15
Quaternary	Pleistocene - Holocene	Continental	Mixture of gravel, sand, silt and clay	596	0.84

Figure 2: Geological map of the study area



Laboratory work

The hydrochemical study of the candidate water within the study area included the analysis of groundwater for 23 wells (Table 2,3). The positive ions (K^+, Na^+, Mg^{2+}, Ca^{2+}) and negative ions ($SO4^{2-}$, HCO^{3-}, Cl^- ,NO^{3-}) as well as (pH), electrical conductivity (E.C.), and total dissolved salts (T.D.S, were conducted in the General Authority for Drilling of Wells and Groundwater of the Ministry of Water Resources.

Table 2: locations' of the study wells

District	Location	Depth meters	Latitude	Longitude	Well number
Badra	Sayed sufar/4	55	33⁰05'33"	45⁰57'33"	1
Badra	Faris village/2	60	33⁰08'29"	45⁰57'50"	2
Badra	Town council	60	33⁰09'26"	46⁰02'23"	3
Badra	Al-qerawy	60	33⁰08'14"	45⁰56'31"	4
Badra	Contemporary Iraq company/1	60	33⁰01'19"	46⁰01'53"	5
Badra	ALMC/1	60	33⁰01'28"	46⁰02'06"	6
Badra	Hamid mahmood	60	33⁰05'04"	45⁰54'41"	7
Badra	Salimah shamkhy	60	33⁰02'06"	45⁰54'22"	8
Badra	The desalination plant	60	33⁰02'06"	45⁰57'34"	9
Badra	Marai zurbatia/1	60	33⁰15'46"	45⁰55›06"	10
Badra	Marai zurbatia/2	60	33⁰15'27"	45⁰55'22"	11
Badra	Badra park	60	33⁰06'51"	45⁰55'56"	12
Badra	Kamil rashed	60	33⁰01'23"	45⁰56'21"	13
Khazena		60	32⁰50'30"	46⁰33'59"	14
Khazena	Alaa nafeih	60	32⁰48'52"	46⁰32'07"	15
Khazena	Salih salman	60	32⁰48'32"	46⁰31'25"	16
Al-shihabi	Saeed mutair	60	32⁰52'07"	46⁰28'15"	17
Al-shihabi	Ain Al-Abed police station	60	32⁰57'35"	46⁰1939"	18
Al-shihabi	Liberated secrecy	60	32⁰56'19"	46⁰10'01"	19
Badra	Hussian abed al wahid	60	33⁰06'41"	45⁰56'41"	20
Shaekh saad	Mohamed Farag	60	32⁰45'19"	46⁰23'42"	21
Al-shihabi	Marai shahbani	60	32⁰46›25"	46⁰24'32"	22
Al-shihabi	Majid Jabir	60	32⁰52'28"	46⁰26'24"	23

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Table 3: Explains the physical and chemical properties of the wells of the study area

Well no.	Ph	TDS (ppm)	EC (µs/cm)	K (ppm)	Na (ppm)	Ca (ppm)	Mg (ppm)	Cl (ppm)	SO4 (ppm)	HCO3 (ppm)	NO3 (ppm)
1	7.2	2650	3470	2.3	376	223	105	531	770	308	4
2	7.12	3624	4220	101	499	314	149	668	1215	491	6
3	7.41	4112	5820	109	603	369	185	719	1600	509	2
4	7.51	3070	4100	78	408	260	128	545	1002	450	6
5	7.18	3000	4210	85	480	300	138	650	1123	460	2
6	7.22	3087	4490	80	392	249	129	512	981	441	4
7	7.6	3700	4360	118	538	332	157	718	1289	500	2
8	7.5	2750	3160	15	254	290	159	781	670	182	3
9	7.19	2230	2850	13	270	185	120	610	540	165	2
10	7.19	15244	20600	75	1384	802	373	2202	2256	1342	9
11	7.7	15220	14980	74	1384	802	372	2201	2256	1342	9
12	7.18	2900	3390	80	408	260	127	541	989	540	5
13	7.24	2400	3130	15	369	241	106	486	925	240	4
14	7.6	2388	2930	3	200	150	88	319	500	387	4
15	7.11	1857	2700	12	239	172	111	542	487	164	2
16	7.14	2000	2660	16	423	71	37	360	515	166	3
17	7.55	3400	4430	80	529	283	139	651	1170	480	5
18	7.72	2334	3110	4.1	319	188	85	329	679	444	10
19	7.21	2400	3200	3.5	374	225	106	530	770	310	6
20	7.25	2406	3430	3.8	235	246	115	560	371	541	5
21	7.14	3674	5950	3	529	209	120	781	780	360	3
22	7.2	2850	3770	7	450	169	114	563	990	108	1.5
23	7.18	1560	2370	3	322	187	88	321	683	442	8
Rang	7.11-7.77	1560-15244	2370-20600	2.3-118	200-1384	71-802	37-373	319-2202	371-2256	103-1342-	1.5-10
mean	7.31	3285	4927.39	42.63	477.6	283.7	141.3	708.9	980.9	450.9	4.58

Results and Discussion

Physical Properties

Hydrogen 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 7.11 to 7.72, with a mean value of 7.32. The pH values were within the permissible limits (6.5-8.5) set by WHO and the Iraqi standards at all sites

Total Dissolved Solids (TDS): TDS, which is a comprehensive hydrochemical parameter, can be used to reflect the groundwater quality [7].

The maximum TDS values were recorded in well 10 (15244 mg/L) and, the minimum value was recorded in well 23 (1560 mg/L). By comparing the TDS values with references[8,9,10], it is concluded that the water in the type is often slightly- brackish water(table4).

Table 4 : Classification of water salinity according to the TDS (ppm)

Altoviski[8]	Drever[9]	Tood [9]	Water class	Samples of study
0-1000	<1000	10-1000	Fresh water	------
1000-3000	1000-2000	-----------	Slightly water	13,16,15,23(17.39%)
3000-10000	2000-20000	1000-10000	Slightly-Brackish water	Most of samples(73.91%)
10000-100000	-----------	10000-100000	Brackish water	10,11(8.69%)
------------	20000-35000	------------	Saline water	---------
>100000	>35000	>100000	Brine water	----------

Electrical conductivity (EC): In water of the study area, EC ranges from 2300 to 20600 µs/cm with 4927.3 µs/cm in average. The relationship between electrical conductivity and mineralization Located within Excessively Mineralized Water(table 5).

Table (5): The relation between EC and mineralization[11]

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.3,4)

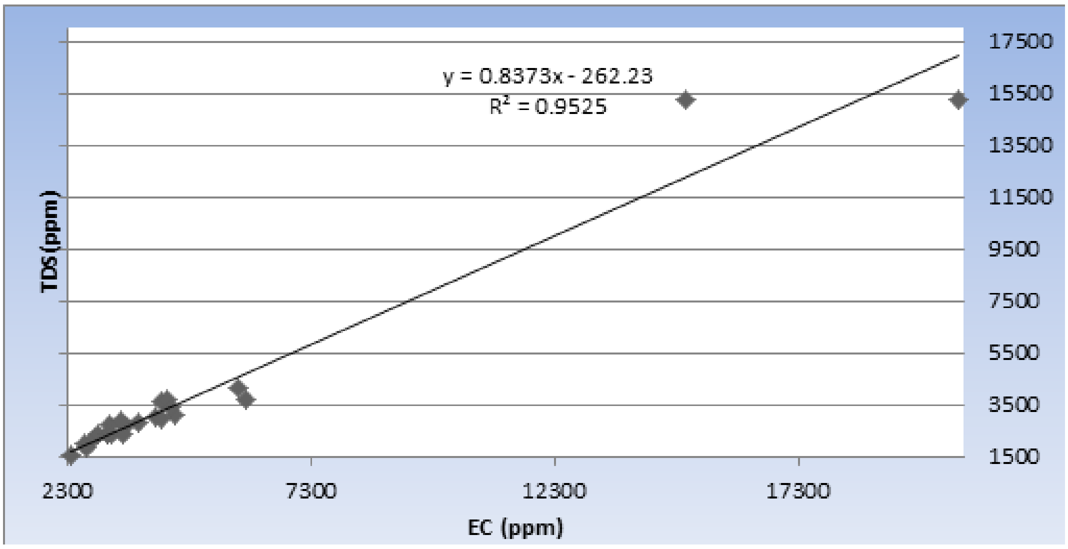


Figure (3): relation between TDS and EC in the study area.

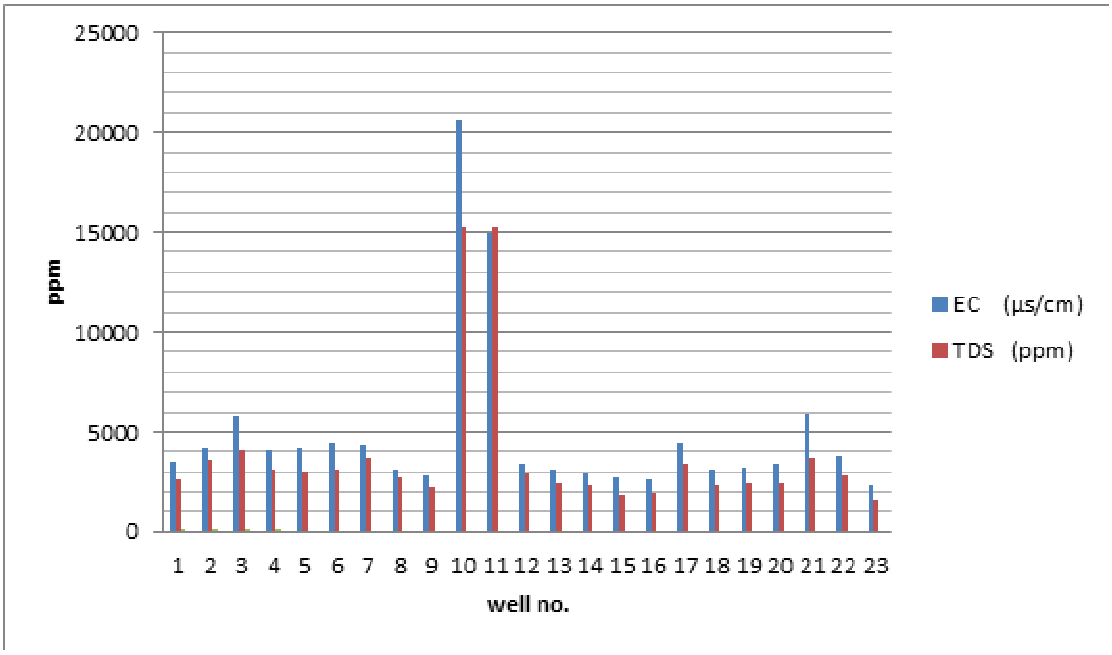
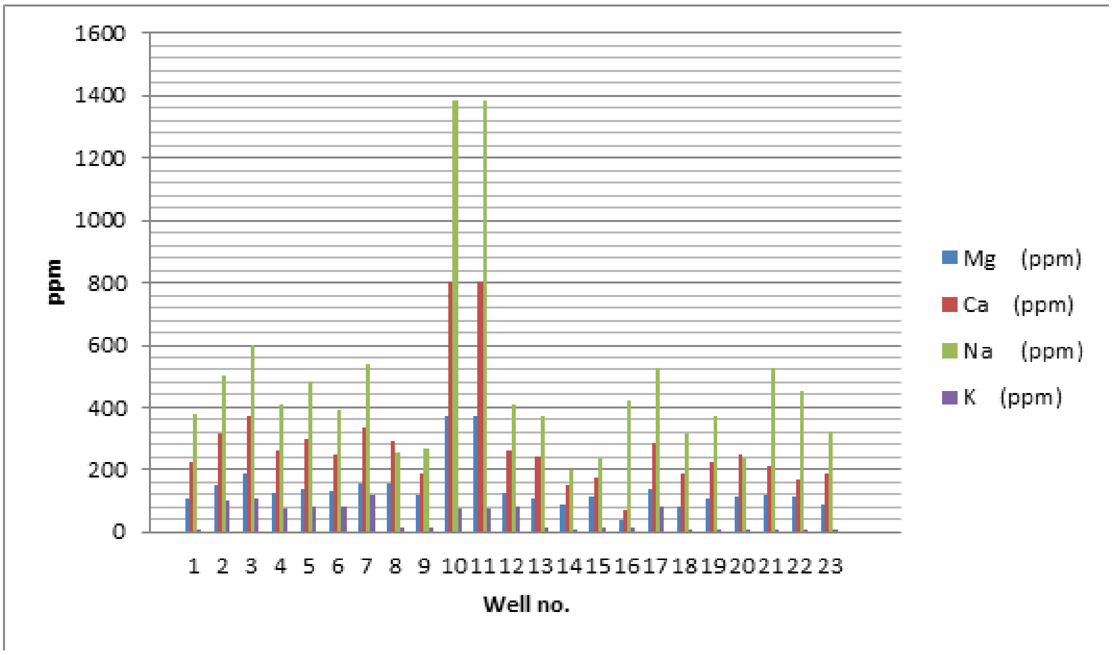


Figure (4): TDS and EC in the study area.

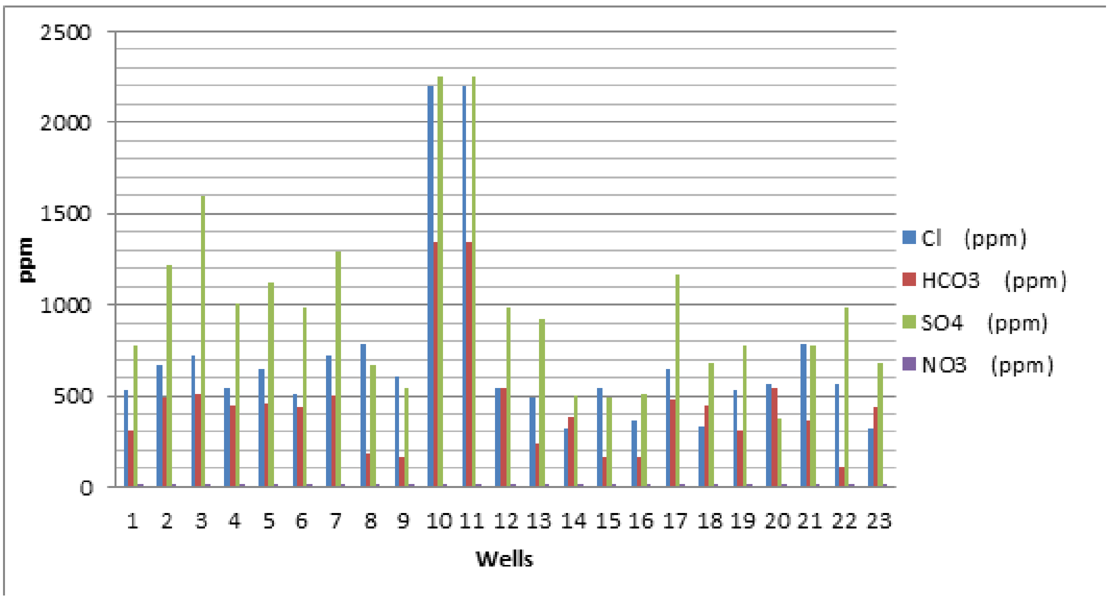
Chemical properties

Major Ions : Figure (5,6) 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 SO4 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 weathering, the leaching of sedimentary rock and soil, and domestic effluents [12]. abnormally high concentration of Na ,Ca, CL, and SO4 were measured in the wells

(10, 11). 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 [13]



Figure(5): shows positive ions concentrations in the study area



Figure(6): Shows the concentrations of negative ions in the study area

Calcium ion (Ca^{2+}): The highest concentration of calcium ion in the water of the study area was 802 mg/l in well (10,11), while the lowest concentration of calcium was (71) mg/L in well (16) Figure (5). The mean concentration of calcium was 283.7 mg/l. Most groundwater models(69.6%) in the study area exceeded the permissible drinking water limit of 75-200 mg/l(Table 6) according to international standards [14]. 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 and comparing with study area.

Parameters`	Desirable-permissible limits(WHO 2011)	Study area
pH	6.5-8.5	All samples
TDS	1000	No sample
EC	500-1500	No sample
TH	100-500	No sample
Na	200-600	1,2,4,5,6,7,8,9,12,13,14,15,16,17,18,19,20,21,22,23(86.9%)
K	10-12	1,14,15,18,19,20,21,22,23(39.1%)
Ca	75-200	9,14,15,16,18,22,23(30.43%)
Mg	50-100	14,16,18,23(17.39%)
CL	250-500	13,14,16,18,23(21.73%)
SO_4	200-250	No sample
NO_3	50	All samples
HCO_3	200-500	1,2,4,5,6,7,8,9,13,14,15,16,17,18,19,21,22,23(78.26%)

.**Magnesium ion (Mg^{2+}):** The highest concentration of magnesium ion in the water of the study area was (373) mg/L in well (10) while the lowest concentration of magnesium (37) mg/L in well (16). 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.

Sodium (Na^+): The highest concentration of sodium in the water of the study area was (1384) mg/L in well (10,11), while the lowest concentration was (200) mg/L in well (14).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.

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 (118) mg/L in well (7) while the lowest concentration of potassium (2.3) mg/l in well (1).

Anions

Sulfates (SO_4): The water of the study area is characterized by the abundance of sulphates where the highest concentration of sulphate (2256) mg/l in well (10,11) . The lowest concentration of sulphate was (371) mg/l in well (20). All candidate water models in the study area exceeded the drinking water limit of 200-250 mg/l according to international standards [14]. The high concentration of sulphate 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.

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 (1342) mg/L in well (10,11), while the lowest concentration of bicarbonate (108) mg/l in well (22). 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.

Chloride (Cl): The highest concentration of chloride in the water of the study area was (2202) mg/L in well (10), while the lowest concentration of chloride was 319 mg/l in well (14). Higher concentration of chloride may be indicating to dominance of industrial activities and salt pan leaching to the groundwater. The chloride concentration in the water area of the study area was 598.5 mg/l. Most groundwater models(69.6%) in the study area exceeded the permissible drinking water limit of 250-500 mg/l(Table 6) according to international standards [14].

Nitrate (NO_3): The lowest concentration was (1.5) mg/L in well (22), and the highest concentration was 10 mg\L in well 18. 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 [14].

Hydrochemical Formula and Water Type

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

Table 7: epm% values for parameters

Wel. no.	SAR epm	RSC epm	Na% epm%	K^+ epm%	Na^+ epm%	Mg^{+2} epm%	Ca^{+2} epm%	CL^- epm%	SO_4^{-2} epm%	HCO_3^- epm%	NO_3^- epm%
1	4.4	-14.8	41.6	0.17	41.5	25.6	32.6	41.4	44.4	13.9	0.17
2	5.6	-10	46.3	4.9	41.4	23.1	29.5	36	48.4	15.4	0.17
3	6.3	-25	46.1	4.4	41.7	24.5	54.4	32.6	53.8	13.4	0.04
4	5.1	-16	45.4	4.6	40.8	24.5	29.9	35.1	47.7	16.8	0.2
5	5.7	-18	46.4	4.3	42.1	23.2	30.2	37.1	47.4	15.3	0.06
6	5	-15.9	45.1	4.8	40.2	25.4	29.4	48	38.3	13.5	0.11
7	6	-21.4	47	5.3	41.7	23.3	29.5	36.5	48.5	14.8	0.05
8	2.8	-24.7	28.4	0.9	27.4	34.1	37·3	56.4	35.7	7.6	0.1
9	3.7	-16.5	38.5	1.05	37.4	31.9	29.5	^{5}5.1	36.1	8.6	0.09
10	10	-49.1	46.5	1.4	45.1	23.3	30	47.2	35.8	16.7	0.1
11	10	-49.1	46.6	1.4	45.1	23.2	3^0.1	47.2	35.8	16.7	0.1
12	5.1	-14.7	45.8	4.7	41	24.5	30.1	34	46	19.7	0.17
13	4.9	-16.9	44	1.1	43	23.6	32.3	37	52.1	10.6	0.16
14	3.1	-8.4	37.1	0.32	36.8	31	31.7	34.8	40.3	24.5	0.2
15	3.4	-15.1	38.1	1	36.4	32.4	30.1	54.2	36	9.5	0.1
16	10.1	-3.9	73.9	1.6	72.3	12.1	13.9	42.9	45.3	11.5	0.16
17	6.7	-15.6	51.6	4.2	47.3	23.8	24.5	36.1	48.1	15.5	0.15
18	4.7	-9.7	45.1	0.32	44.7	22.8	30.3	30	45.8	23.5	0.51
19	5.13	-15	44.8	0.21	44.6	24.2	30.8	41.2	44.3	14	0.24
20	3.08	-13	32	0.27	31.7	29.7	38.2	48	23.5	26.9	0.24
21	7.19	-14.5	53	0.19	52.8	22.9	24	49.7	36.7	13.3	0.09
22	6.55	-16.1	52.3	0.47	51.9	25.2	22.4	41.4	53.8	4.62	0.05
23	4.8	-9.4	45.7	0.22	45.5	23.8	30.4	29.5	46.4	23.6	0.39

The hydrogeological formula of the study area was as follows:

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

So that the quality of the prevailing water is NaSO4- 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 sulphate(65.2%) (1, 2, 4, 5, 7, 12, 13, 14,15, 16, 17, 18,19, 22, 23), sodium chloride (21.7%) (6, 9,10, 11, 21) , calcium chloride(8.69%) (8, 20) and calcium sulfate (3) , which indicating that sulphates are predominant in the sense of negative ions, while sodium ions is predominant for positive ions in most water models studied.

Table ٨: shows the hydrocochemical formula and water type in the study area.

Well No.	Hydro chemical Formula	Water Type
1.	$2650 \frac{SO4-2\ (44.41)\ CL-(41.41)}{Na+(\ 41.5)\ Ca+2\ \ (32.67)\ \ \ Mg+2(25.6)}\ 7.2$	Na–Sulfate
2.	$3624 \frac{SO4-2\ \ (48)CL-(36)}{Na+(41)\ \ Ca+2\ (29)\ Mg+2\ \ (23)}\ 7.12$	Na–Sulfate
3.	$4112 \frac{SO4-2(53.38)CL-(32.4)}{Ca+2(54.4)Na+(41.7)Mg+2(27.7)}\ 7.41$	Ca –Sulfate
4.	$3070 \frac{SO4-2\ \ CL-\ HCO3-}{Na-\ Ca+2\ \ Mg+2}\ 7.5$	Na – Sulfate
5.	$3000 \frac{SO4-2\ \ CL-\ \ \ HCO3-}{Na+\ \ \ Ca+2\ \ \ \ Mg+2}\ 7.\ 1$	Na- Sulfate
6.	$3087 \frac{CL-\ SO4-2}{Na+\ \ Ca+2\ \ Mg+2}\ 7.2$	Na--Chloride
7.	$3700 \frac{SO4-2\ \ CL-}{Na+\ \ \ Ca+2\ \ \ Mg+2}\ 7.6$	Na –Sulfate
8.	$2750 \frac{CL-\ \ \ SO4-2}{Ca+2\ \ \ Mg+2\ \ \ Na+}\ 7.5$	Ca –Chloride
9.	$2230 \frac{CL-\ \ \ SO4-2}{Na+\ \ Mg+2\ \ \ Ca+2}\ 7.1$	Na – Chloride
10.	$15244 \frac{CL-\ SO4-2\ \ HCO3-}{Na+\ Ca+2\ Mg+2}\ 7.1$	Na-- Chloride
11.	$15220 \frac{CL-\ \ SO4-2\ \ HCO3-}{Na+\ \ Ca+2\ \ \ Mg+2}\ 7.7$	Na – Chloride
12.	$2900 \frac{SO4-2\ \ CL-\ \ HCO3-}{Na+\ \ Ca+2\ \ Mg+2}\ 7.1$	Na –Sulfate
13.	$2400 \frac{SO4-2\ CL-}{Na+\ Ca+2\ \ Mg+2}\ 7.2$	Na –Sulfate
14.	$2388 \frac{SO4-2\ \ CL-\ \ \ HCO3-}{Na+\ \ \ \ Ca+2\ \ \ Mg+2}\ 7.6$	Na – Sulfate
15.	$1857 \frac{CL-\ \ \ SO4-2}{Na+\ \ \ MG+2\ \ \ CA+2}\ 7.1$	Na-Sulfate
16.	$2000 \frac{SO4-2\ \ CL-}{Na+\ \ Ca+2\ \ Mg+2}\ 7.1$	Na-Sulfate
17.	$3400 \frac{SO4-2\ \ CL-\ \ HCO3-}{Na+\ \ \ Ca+2\ \ Mg+2}\ 7.5$	Na-Sulfate
18.	$2334 \frac{SO4-2\ CL-\ \ HCO3-}{Na+\ \ Ca+2\ \ Mg+2}\ 7.7$	Na-Sulfate
19.	$2400 \frac{SO4-2\ \ \ CL-}{Na+\ \ Ca+2\ \ Mg+2}\ 7.2$	Na-Sulfate
20.	$2466 \frac{CL-\ HCO3-\ SO4-2}{Ca+2\ \ \ Na+\ \ \ \ Mg+2}\ 7.2$	Ca –Chloride
21.	$3674 \frac{CL-\ \ SO4-2}{Na+2\ \ Ca+2\ \ Mg+2}\ 7.1$	Na-Chloride
22.	$2850 \frac{SO4-2\ \ CL-}{Na+\ \ Mg+2\ \ \ Ca+2}\ 7.2$	Na-Sulfate
23.	$1560 \frac{SO4-2\ \ CL-\ \ \ HCO3-}{Na+2\ \ \ Ca+2\ \ \ Mg+2}\ 7.1$	Na-Sulfate

Uses of Groundwater

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[15]. 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 [16,17]

Table 9: specific weight, relative weight and standard values for drinking water[14]

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
		∑32	

The relative weights (Wr) were calculated for each parameter using Eq.1. WQI values were computed using following Eqs. 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 [18]

WQI	Water quality	Sample no.	% of samples
<50	Excellent water	------	0%
50-100	Good water	--------	0%
100.1-200	Poor water	1,8,9,13,14,15,16,18,19,20,22,23	52.17%
200.1-300	Very poor water	3,4,5,6,12,17,21	30.43%
>300	Unsuitable	2,7,10,11	17.39%

Table 10 shows that the water in the study area is poorly water(52.17%), very poor (30.43%) and unsuitable (17.39%) for drinking water due to high salinity, accompanied by a rise in concentrations of sulfur ions Calcium , other ions and other values.

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.

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 [19]. Karanth, defines sodium adsorption ratio SAR of water as:

$$SAR = \frac{Na^{+}}{\left\{\sqrt{\left(Ca^{+2}+Mg^{+2}\right)}/2\right\}} \quad \text{---------(5)} \quad [20]$$

Where all ionic concentrations are expressed in epm.

Four classes of water for agriculture depending on SAR value according to Subramain classification[19] and most samples in study area have been SAR beneath than 10 epm which indicate an excellent water (class S1) for agriculture while sample 10,11 and 16 indicate to good class (S2) (Table 11).

Table(11): Alkalinity hazard classes of water [21]

SAR (epm)	Alkalinity hazard	Water class	Representing samples
<10	S1	Excellent	Most samples (86.95%)
10-18	S2	Good	Sample(10,11,16) (13.04%)
18-26	S3	Doubtful	--------
>26	S4	Unsuitable	----------

Na % and EC

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

$$Na\% = (rNa + rK / rCa + rMg + rNa + rK) \times 100$$ ---------(6) [22]

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 [23]. 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(78.26%) are from unsuitable for irrigation.

Table (12): Classification of water for irrigation based on Na % and EC [22].

Water class	Na%	Study area	EC µS/Cm	Study area
Excellent	<20	-------	<250	-----
Good	20-40	8,9,14,15,20 (21.73%)	250-750	------
Permissible	40-60	Most samples (73.91%)	750-2000	-------
Doubtful	60-80	16 (4.34%)	2000-3000	9,14,15,16,23 (21.73%)
Unsuitable	>80	--------	>3000	Remaining samples (78.26%)

*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 [24].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)[25]

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) (Table 13) all samples of groundwater in study area are safe for irrigation.

Table(13): Classification of irrigation water based on RSC values [25]

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

WQI for irrigation purposes: Many parameters has been used to calculation of WQI for irrigation purposes and by using standard analytical methods recommended by APHA 1999[26]. The guidelines irrigation water quality recommended by Ayers and West cot, 1999[27] (table 14) have been applied for calculation of WQI.

Table (14): specific weight, relative weight and standard values for each parameter

parameters	Standard (Si) [26]	Weight (wi)	Relative weight (Wr)
pH	6.0-8.5	3	0.0909
EC(μS/cm)	3000	5	0.1515
TDS(ppm)	2000	4	0.1212
SAR	15	4	0.1212
Ca^{+2}(epm)	2	2	0.0606
Mg^{+2}(epm)	5	2	0.0606
Na^{+}(epm)	40	2	0.0606
K^{+}(epm)	0.05	1	0.0303
HCO_3^{-}(epm)	10	3	0.0909
CL^{-}(epm)	30	3	0.0909
SO_4^{-2} (epm)	20	2	0.0606
NO_3^{-2}(epm)	0.16	2	0.0606
		∑wi=33	

To calculate this index, we follow the same previous steps for calculating WQI for drinking water. Table (15) shows that variation of groundwater types in the study area, good, poor, very poor and unsuitable for irrigation purposes.

Table (15): Groundwater quality classification for irrigation based on WQI value [18]

WQI	Water quality	Sample no.	% of samples
<50	Excellent water	---------	0%
50-100	Good water	14,15,16,23	17.39%
100.1-200	Poor water	1,8,9,13,18,19,20,21,22	39.13%
200.1-300	Very poor water	2,4,5,6,12,17,	26.08.43%
>300	Unsuitable	3,7,10,11	17.39%

Conclusion

The type of groundwater in study area is 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 NaSO4 (65.21%), NaCL(21.73%) CaCL (8.69%) and CaSO4 (4.34%). According to the WQI for drinking purposes, the water quality in the study area was 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 was 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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