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Evaluation of the Hydrochemical Characteristics of Groundwater and its Suitability for Desalination to Product Potable Water in Tolul Al-Baj, Salahaldin, Iraq

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Abstract

The study area, Tlul Al-Baj, suffers from a shortage of fresh water and most people depend on groundwater for different uses (drinking, domestic, irrigation, etc.).

The present research aims to select the most suitable wells for desalination and production of potable water in Tlul Al-Baj area.

Twenty-two samples of groundwater were collected to evaluate the hydrochemical properties of groundwater in the shallow aquifer in the area and to determine their suitability for desalination purposes. The study included measuring the physicochemical characteristics of groundwater, such as total hardness (TH), total dissolved solids(TDS), sodium adsorption ratio (SAR), sodium ratio (Na%), turbidity (Tur), pH…etc. Chemical analyses for the main components of water samples were also conducted, including cations such as sodium ($Na^{+)}$), potassium ($K^{+)}$), calcium ($Ca^{++)}$), and magnesium ($Mg^{++)}$), as well as anions such as chloride $(Cl)^-$, sulfate ($SO_4^{=}$), bicarbonates (HCO_3^-), and nitrate (NO_3^-). In addition, concentrations of trace elements such as iron (Fe), copper (Cu), zinc (Zn), lead (Pb), nickel (Ni),cobalt (CO), chromium(Cr) and cadmium (Cd) were determined.

The results of the physical and chemical analyses for the groundwater of the study area were compared with the international and local standards to determine their suitability for drinking uses and to select the most suitable wells for the production of drinking water by desalination. The results indicated that the most suitable wells for desalination were wells numbered 4, 8, 9, 17, and 19.

Keywords: Tlul Al-Baj; Desalination; Standard Specification; Potable Water; Physicochemical properties.

تقييم الخصائص الهيدروكيميائية للمياه الجوفية ومدى ملائمتها لأغراض التحلية وانتاج مياه الشرب في ناحية تلول الباج ، شمال صلاح الدين ، العراق

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الخلاصة

تعاني منطقة الدراسة من نقص في المياه العذبة وان اغلب الاهالي تعتمد على المياه الجوفية للاستخدامات المختلفة (شرب، استخدامات منزلية، ري، الخ). يهدف البحث الى اختيار الابار الانسب لغرض تحليتها وانتاج مياه صالحة للشرب في ناحية تلول الباج الواقعة اقصى شمال محافظة صلاح الدين/ العراق.

تم جمع (22) نموذج من خزانات المياه الجوفية لدراسة الخصائص الهيدروكيميائية لمياه الابار، وبيان مدى ملائمتها لأغراض التحلية، وتضمن قياس الصفات الفيزوكيميائية للمياه الجوفية، والمتمثلة بالتوصيلية الكهربائية (EC) ، والمواد الصلبة الكلية المذابة (TDS)، والرقم الهيدروجيني (pH)، العسرة الكلية (TH)، نسبة امتزاز الصوديوم (SAR)، النسبة المئوية للصوديوم (% Na)، العكورة (Tur)، والخ.

إجريت التحليلات الكيميائية للمكونات الرئيسة للنماذج المائية المنتخبة، والمتمثلة بالأيونات الموجبة (Cations)، وتشمل أيونات الصوديوم (Na^+)، البوتاسيوم (K^+)، الكالسيوم (Ca^{++})، والمغنيسيوم (Mg^{++})، وكذلك الأيونات السالبة (Anions)، وتشمل الكلورايد(Cl^-)، الكبريتات ($SO_4^=$)، والبيكاربونات (HCO_3^-)، والمكونات الثانوية مثل النترات(NO_3^-)، وبعض العناصر الثقيلة أو النادرة (Trace Elements)، مثل الحديد (Fe)، النحاس (Cu)، الخارصين (Zn)، الرصاص (Pb)، النيكل (Ni)، والكادميوم (Cd).

قورنت نتائج الفحوصات الفيزوكيميائية ونتائج التحاليل الكيميائية لمياه ابار منطقة الدراسة مع المواصفات القياسية العالمية والمحلية لتحديد مدى صلاحيتها للشرب واختيار الابار الانسب لإنتاج مياه الشرب وتبين ان اقرب الابار للمواصفات هي الابار رقم (4، 8، 9، 17، و19).

Introduction

Water is one of the most important materials for life. No internal biological process in the body of any organism takes place without water, as water represents the most widely distributed fluid in nature and plays a basic role in many of the vital processes in the body of the organisms; for example, water is found in human cells by in a proportion of **50-60%** [1].

Drinking water is the water free of chemical and biological contaminants and toxic material [2]. Many of the water sources used by humans contain some vectors of disease that may cause long-term problems. The World Health Organization (WHO) and other national and international organizations have set a number of standards for potable water. Most of these specifications agreed that a level of **500 ppm** is the acceptable limit for TDS in drinking water. Dissolved salts vary in their effects on human health; for example, calcium carbonate has no physiological effects, alkaline carbonate causes severe damages, while alkaline sulphates are less harmful. Alkaline chlorides, such as table salt exert moderate effects, magnesium sulfates give a bitter taste to water, whereas iron at 0.5ppm makes the taste of water unpalatable [3].

The main problem in most parts of the world is the supply of drinking water to the population as a result of the increase in human population. As the gap between drinking water supply and requirements can expand and reach dangerous levels in most parts of the world, it can be a threat to human existence [4], with the reports that the coming wars will be because of water [3].Therefore, the scarcity of fresh water can cause a growing problem around the world, especially in areas of dry climates with less than 100 mm of rain [5].

Iraq suffers from a shortage of fresh water resources as a result of its geographical location within the arid region. Moreover, the headwaters of the Tigris and Euphrates rivers are located outside Iraq's administrative boundaries. The continuous increase in population growth and the increasing demand rates made it necessary to find alternatives to fresh water resources. This led many researchers in this field to study groundwater as an alternative source of fresh water. One possible solution is treating groundwater for producing fresh water that can be used for human drinking purposes, as well as other domestic uses [6]. Groundwater desalination is an essential approach for the provision of drinking water in the dry areas and away from any freshwater source. Groundwater desalination is desirable for several factors that include high recovery rate, working with desirable energy sources such as solar energy, amount of local water produced, percentage of concentrated return water, and level of energy consumed [7].

One of the main reasons for this study is the lack of fresh water in the study area and the high number of people depending on groundwater for drinking, domestic and other uses. The population of the study area exceeds **10,000**, according to the census of the district council.

Desalination can be defined as any process that removes salts from water, whether it is groundwater or marine water. With improvements in technology, desalination processes are becoming cost-competitive with other methods of producing usable water for our growing needs [8]. Brackish Water is the water whose salinity is less than the salinity of sea water, in which the concentration of salts is between, 5000 and 20000 ppm, while that of sea water is higher than 20000 ppm [9].

A desalination process essentially separates saline water into two parts, one with a low concentration of salt, known as treated water or product water and the other with a much higher concentration than the original feed water, usually referred to as brine concentrate or simply as concentrate.

The major types of technologies that are used around the world for desalination can be broadly classified into either thermal or membrane. Both technologies need energy to operate and produce fresh water. Within those two broad types, there are sub-categories (processes) using different techniques. Membrane technologies can be subdivided into two broad categories; Electro-dialysis/ Electro-dialysis Reversal (ED/EDR), and Reverse Osmosis (RO) [10].

Thermal technologies, as the name implies, involve heating saline water and collecting the condensed vapor (distillate) to produce pure water. Thermal technologies have rarely been used for brackish water desalination, because of the high costs involved. They have however been used for seawater desalination and can be sub-divided into three groups; Multi-Stage Flash Distillation (MSF), Multi-Effect Distillation (MED), and Vapor Compression Distillation (VCD). The choice of desalination method depends on cost, water quality and quantity of water produced, [10].

Many countries in the world are trying to provide fresh water by developing their natural resources, rationalizing consumption, especially in agriculture, and treatment and reuse of industrial, agricultural and sanitary drainage water, as well as desalination of salt water.
Desalination is one of the alternatives to obtain fresh water in the world and is a strategic alternative to many countries, especially in the arid and semi-arid regions [11].

In recent years, RO is the best desalination technology for saline surface and groundwater to provide potable water. It is the most wide spread method that consumes less energy than other methods [8].RO is used in the production of80% of the desalinized water worldwide, while thermal methods represent only 20%.

The RO process is relatively new in comparison to other technologies. The cost of water desalination in membrane processes varies according to the type and composition of the feed water. Large-scale RO plants can use brackish water containing TDS of 2000 to 10 000 ppm, but, as TDS concentration increases, the unit cost of the desalinated water also increases [12].
The study area is located in the far north of Salahaldin governorate, northern Iraq, and represents the boundary between Salahaldin and Mosul governorates. The area covers about 240 Km^2 (Figure-1).

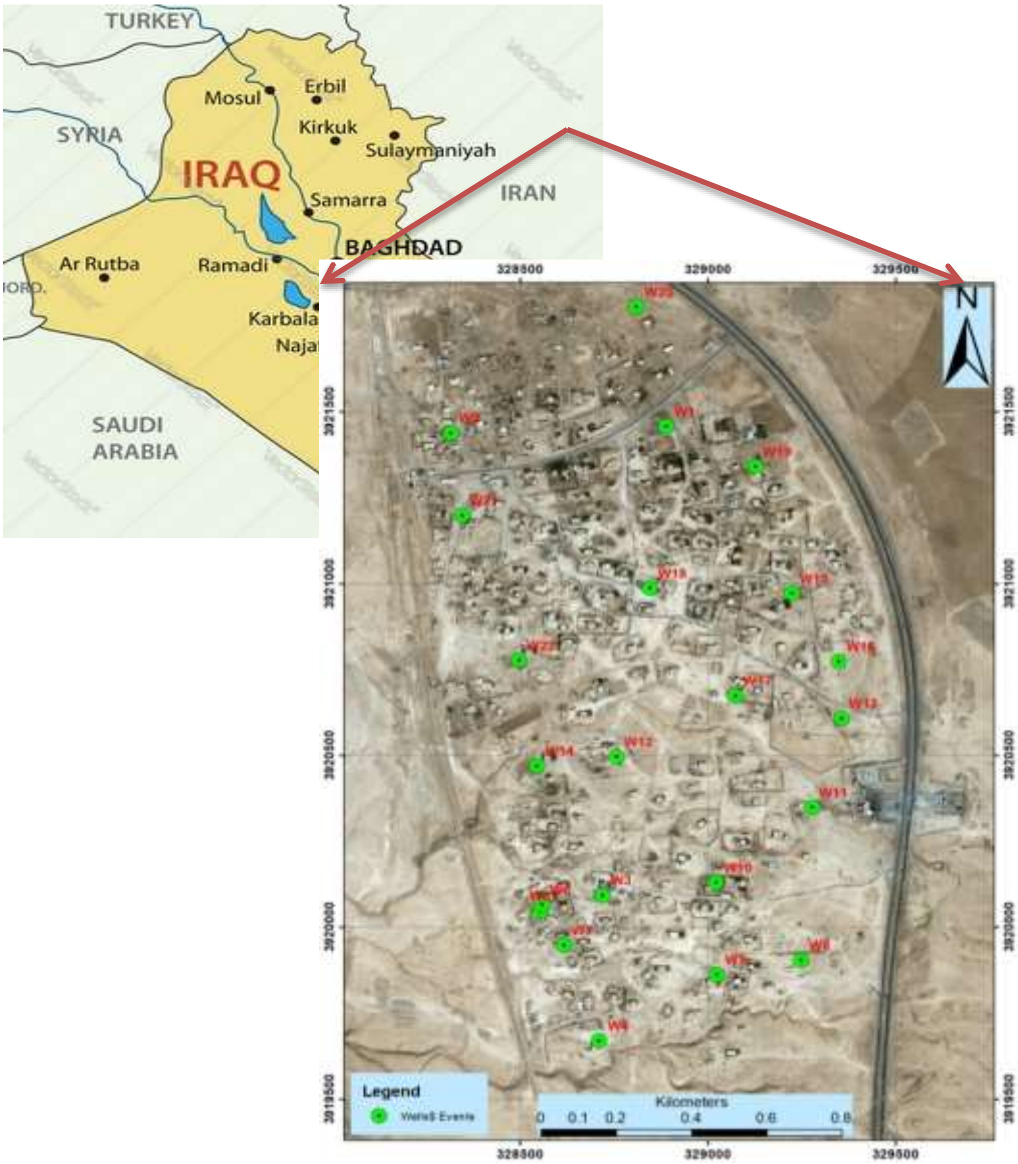

Figure 1-Location map of the study area.

Material and Methods

Geological, geomorphological and hydrological background of the study area was reviewed and extracted, then the topographic maps were prepared with the scales of 1: 100000 and 1: 2500000.

The accuracy of field measurements and sampling is usually reflected in the accuracy of laboratory results Therefore, samples with a possible error might indicate a lack of intensive care in the sampling, and these are secondary processes that occur on samples from the beginning of sampling to the end (analyses in the laboratory). Furthermore, in some samples the error may be above the permissible limits. This in turn is due to several reasons such as that sampling is inaccurate. Therefore, safe collection of water samples is as important as the test results. It is not possible to standardize a particular method of sampling, because of different source conditions and variety of tests. However, the following conditions were adopted in the sampling processes:

1. Water was pumped from the well for at least half an hour to ensure that the sample significantly represents the quality of the groundwater aquifer.
2. The amount of the sample was sufficient for all required analyses.
3. The temperature was recorded in the field because it has important significance.
4. The samples were labeled with information about the day and hour at which the sample was collected.
5. The sample was maintained so that there was no change in the hydrochemical properties of the water before testing.

Field work included:
1. A first field trip to the study area to identify the geomorphological effect and the rock outcrops of the geological formations, and to determine the different field measurements.
2. A second field trip that included a field survey of the study area to determine the locations and coordinates of the wells using GPS, and to collect **22** water samples taken from wells distributed in the study area, as homogeneously as possible.

Physiochemical measurements and chemical analyses of water samples were performed in the laboratories of the Water and Soil Science Center /Ministry of Science and Technology / Baghdad.

Accuracy, which is a measure of the appropriateness and proximity of the results to their true values, was calculated in epm using the ionic balance method. This was performed by measuring the relative difference, which is the difference among sum of major ions divided by the total ions[13].Ionic balance was used to verify the accuracy of the results and , (Table 1), as follows**:**

E%=(∑ r. Cat -∑ r. Ani\ r.Cat +∑ r. Ani) *100

Where concentrations of ions were expressed in epm.

A = 100 – E%

Where:

E%: Percentage of error.

∑ r. Cat: Total concentrations of Cations in units (epm).

∑ r. Ani: Total concentrations of Anions in units (epm).

A:Accuracy

The causes of the error in chemical analyses include the method of analyses, the method of preparation of the samples, the quality of chemicals materials, the efficiency of the devices, among others. Therefore, the error percentage (E%)must be calculated to ensure the accuracy of the results. When comparing the error percentage of chemical analyses of the water samples (Table 1), it was found to be within the permissible limits for the analyses accuracy, except for the results from two wells (W4, W21), which had an increase by a very small percentage that can be neglected.

Table 1-Accuracy classification of chemical analyses

Result	A% (ACCURACY)	E% (Error)
Certain	$A \geq 95\%$	$U \leq 5\%$
Probable certain	$90\% \leq A \leq 95\%$	$10\% \geq U \geq 5\%$
Uncertain	$A < 90\%$	$U > 10\%$

Arelevant software (Arc GIS, Surfer, 13) was used to draw and prepare the maps.

Results and discussion

Physiochemical characteristics

The results of the physiochemical characteristics are tabulated in table 3.

1. Temperature: The temperature of water directly affects many of its physical and chemical characteristics. Because groundwater is stored underground, it has a relatively constant temperature throughout the year [14]. The temperature values of water wells in the study area ranged between 23 and 25 Cº. The slight variation indicates the absence of thermal pollution, with the values being within the permissible limits (8.88-33.8 Cº).
2. pH: The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. pH value typically represents the result of the equation, pH=-Log [H+] [15]. The pH values were between 7-8, which were within the permissible limits.
3. Total Hardness: T.H. depends mainly on the presence of dissolved calcium and magnesium salts [16]. It can be calculated by the equation T.H. = 2.5 Ca + 4.1 Mg, with the ion concentrations (Ca^{+2}, Mg^{+2}) being expressed in ppm. T.H. values ranged 1206 -2704 ppm.
4. Turbidity: Tur. is an expression of certain light scattering and light absorbing properties of the water sample, caused by the presence of clay, silt, suspended matter, colloidal particles, plankton and other microorganisms [17], Their values ranged 0.9 – 21.5 NTU.
5. Alkalinity: Alk. is an index of the buffering capacity of water-produced anions of weak acids, such as hydroxides, bicarbonates and carbonates [17]**.** Their values showed a range of 61 – 244.

6.Dissolved oxygen: The level of dissolved oxygen in water is used as an indication of pollution and its potability [18]. DO%, values for samples showed a range of 28.2 – 46.6%.

7.Total dissolved solids: TDS are the total dissolved salts in a solution, whether ionized or non-ionized, and do not include suspended solids and dissolved gases in that solution. TDS consists mainly of the sum of cations and anions [19]. When comparing TDS values of groundwater samples in the study area using previously adopted classifications of Todd [20] and Klimentove [21],the results indicated that the groundwater of the studied area was Slightly Water and Brackish Water, with the values ranging between 1934 and 7910 ppm (Figure-2).

Table 2-Classification of water by T.D.S content in ppm

Water class	Todd, 2005	Klimentove, 1983
Super	-	**200**
Fresh water	<1000	**200 – 1000**
Slightly water	1000 – 3000	**1000 – 3000**
Brackish Water	3000 – 10000	**3000 – 10000**
Saline Water	10000-35000	**10000 – 35000**
Brine	> 35000	**> 35000**

8. Electrical conductivity: EC is the ability of $1cm^3$ of water to conduct electricity [22]**,** dependent on dissolved ions in water. Values of EC for water samples ranged between 2720 to 11340 ms (Figure-2).

Table 3-The range of the hydrochemical variables of well water in the study area

No.	Easting	Northing	Z m	pH	EC mc\cm	TDS Ppm	T.H. ppm	SAR	T C°	Do %	Tur NTU	Alk
W.1	328889	3921457	218	7.92	6570	3184	1890	3.52	24.1	31.5	21.5	128
W.2	328315	3921438	220	7.44	6450	3010	2095	3.33	24.5	32.4	1.6	134
W. 3	328719	3920092	224	7	7300	4299	2609	3.98	24	33.3	6	244
W. 4	328711	3919668	220	7.1	3760	2274	1294	3.90	23	34	10.3	122
W. 5	328554	3920045	216	7.1	10130	7770	2704	4.46	23.6	33.7	2	158
W. 6	328559	3920064	216	7.1	8451	5978	1642	3.06	23.7	33.9	5	137
W. 7	328617	3919946	214	7.3	11340	7910	2196	3.38	24.7	32.8	3.9	152
W. 8	329248	3919902	235	8	2820	1934	1521	2.48	24	37.2	8.8	61
W. 9	329024	3919861	227	7.54	3770	2197	1378	2.75	24.1	28.2	8.8	85
W. 10	329021	3920129	228	7.5	4250	2828	1762	3.12	24	33	1.3	122
W. 11	329277	3920348	223	7.37	4400	2884	1666	3.52	24.3	37.1	2.3	122
W. 12	328757	3920495	221	7.41	5240	3002	1622	2.77	23.7	34.7	3	134
W. 13	329356	3920607	227	7.9	4610	2946	1442	2.68	23.7	46.6	3.5	79
W. 14	328546	3920469	214	7.8	9100	7251	2156	2.34	23.8	34.4	0.9	164
W. 15	329223	3920971	219	7.27	7270	4896	1553	3.13	24	42.7	4	97
W.16	329348	3920773	223	7.4	5350	2981	1643	3.20	24.2	37.7	9	97
W. 17	329074	3920673	222	7.5	3370	2119	1206	2.96	23.9	34.1	3	122
W. 18	328846	3220986	216	7.46	4820	2500	1340	3.51	24	34.8	3.3	134
W. 19	329126	3921340	216	7.61	3387	2177	1357	3.28	23	30.7	1	213
W. 20	328810	3921805	206	7.5	6878	4021	1805	2.93	23.5	41.8	7	151
W. 21	328345	3921198	216	7.18	7220	4858	1609	4.69	24.6	37.5	3	122
W. 22	328497	3920776	222	7.54	7540	4877	1457	3.41	24.7	33.3	4	123

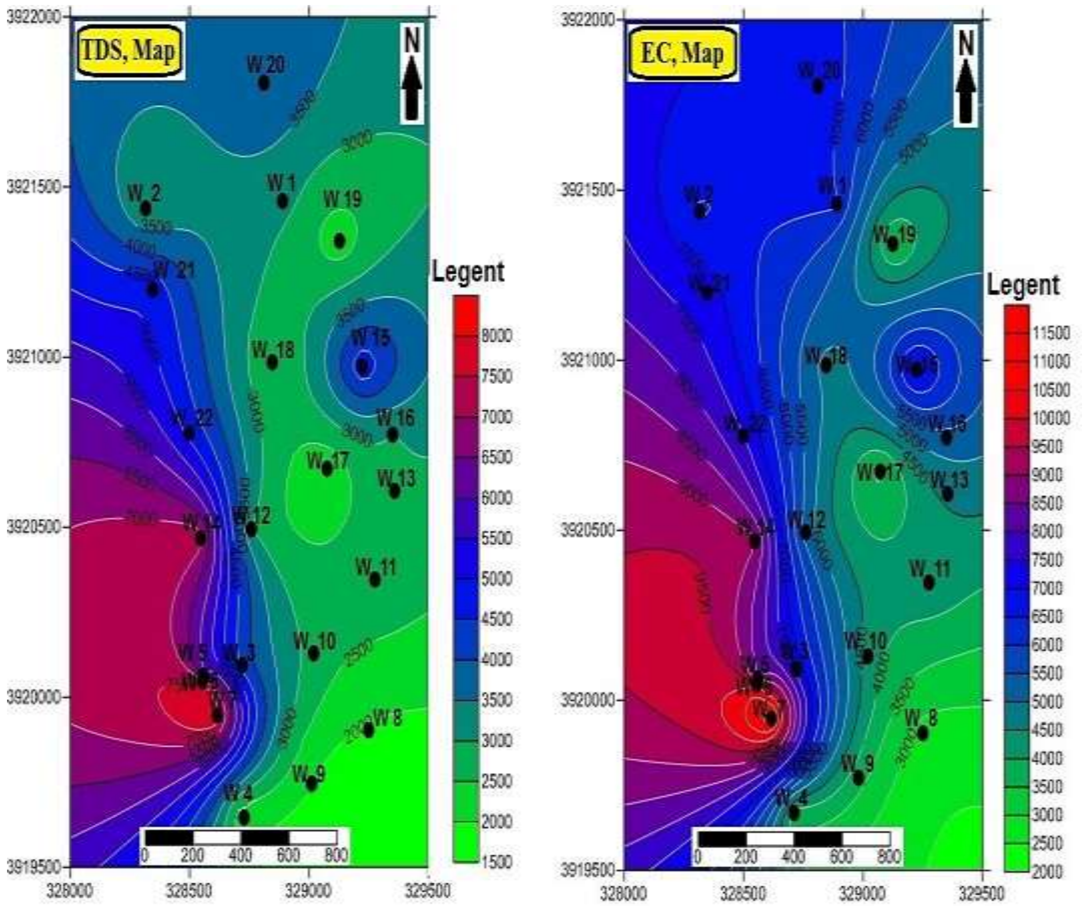

Figure 2-TDS and EC distribution maps in sites of water samples.

The above figure shows a high compatibility between TDS and EC results, which is an important indicator that reflects the accuracy of the analyses results, since the relationship between them is direct [20]. Salt content and electrical conductivity were minimum in the eastern and southeastern parts of the study area.

Chemical analyses

The results of the chemical analyses are tabulated in table 4.

Cations

1**.**Calcium (**Ca^{+2}**): The main source of calcium ion in aquifers is the dissolution of some sedimentary minerals, such as calcite, dolomite, anhydrite, and gypsum [22]. Calcium ion values in water samples of the study area ranged 300- 654 ppm.

2. Magnesium (**Mg^{+2}**): Gypsum and clay minerals are the most important sources of magnesium ions in water[23]. Its concentrations in the present study ranged between 60 and 334 ppm.

3. Sodium **(Na^{+1})**: Weathering the evaporative rocks is the most important source of sodium ion[24]. Its concentrations ranged between 222 – 533 ppm.

4. Potassium **(K^{+1})**: The concentration of potassium in natural water is much lower than that of sodium [23]. Its concentrations in the water wells of the study area were within the permissible limits, and ranged 8- 16 ppm.

Maps of Ca^{+2}, Mg^{+2} and Na^{+1} distribution (ppm) in groundwater samples are shown in Figure-3.

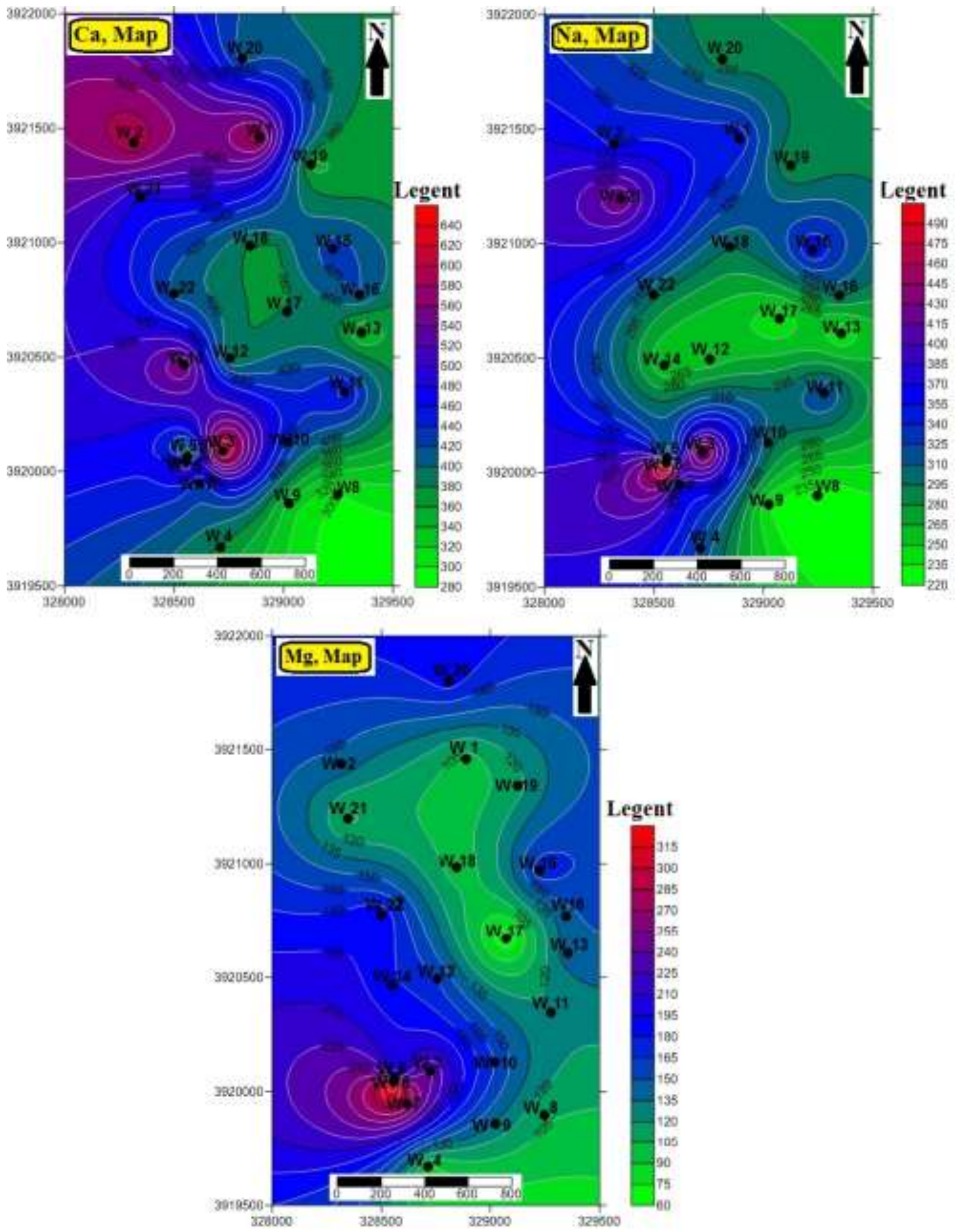

Figure 3-Maps of calcium, magnesium and sodium distribution (ppm) in groundwater samples

Table 4-The results of chemical analyses of groundwater of the study area

No. of Well		Cations				Anions				Accuracy %
	Con.	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	SO_4^{-2}	HCO_3^{-}	Cl^{-}	NO_3^{-}	
1	ppm	597	97	352	11	1189	128	809	20	96.87 %
	epm	29	7.98	15.31	0.28	24.75	2.1	22.82	0.32	
2	ppm	600	145	350	12	1234	134	868	36	95.84 %
	epm	29.94	11.93	15.23	0.30	25.69	2.2	24.49	0.58	
3	ppm	645	243	467	9	1456	244	1234	17	98 %
	epm	32.19	19.99	20.31	0.23	30.31	4	34.81	0.27	
4	ppm	378	85	322	9	812	122	545	18	93 %
	epm	18.86	6.99	14.01	0.23	16.91	2	15.37	0.29	
5	ppm	534	334	533	10	1650	128	1567	24	97.83 %
	epm	26.65	27.47	23.19	0.25	34.35	2.1	44.21	0.39	

6	**ppm**	345	190	285	16	1102	104	701	14	**98.96 %**
	epm	17.22	15.63	12.40	0.40	22.94	1.7	19.78	0.23	
7	**ppm**	424	277	364	8.9	1890	125	800	20	**96.40 %**
	epm	21.16	22.79	15.83	0.22	39.35	2.05	22.57	0.32	
8	**epm**	300	108	222	9.5	810	61	543	19	**97 %**
	epm	14.97	8.88	9.66	0.24	16.86	1	15.32	0.31	
9	**ppm**	333	133	235	9.6	836	85	565	18	**96.07 %**
	epm	16.62	10.94	10.22	0.24	17.41	1.39	15.94	0.29	
10	**ppm**	434	165	301	8.9	1002	122	845	31	**98.39 %**
	epm	21.66	13.57	13.09	0.22	20.86	2	23.84	0.50	
11	**ppm**	468	121	330	10	932	122	780	18	**95.5 %**
	epm	23.35	9.95	14.36	0.25	19.40	2	22	0.29	
12	**ppm**	378	165	256	11	890	134	675	22	**95.5 %**
	epm	18.86	13.57	11.14	0.28	18.53	2.2	19.04	0.35	
13	**ppm**	339	145	234	11	899	79	600	27	**97.74 %**
	epm	16.92	11.93	1018	0.28	18.72	1.29	16.93	0.44	
14	**ppm**	564	182	250	13	1123	164	875	25	**97.20 %**
	epm	28.14	14.97	10.88	0.33	23.38	2.69	24.68	0.40	
15	**ppm**	433	175	356	12	965	97	798	23	**97.79 %**
	epm	21.6	14.40	15.49	0.30	20.09	1.59	22.51	0.37	
16	**ppm**	421	144	298	12	934	97	789	16	**97.54 %**
	epm	21.01	11.85	12.96	0.30	19.45	1.59	22.26	0.26	
17	**ppm**	384	60	236	10.9	765	122	543	18	**98.72 %**
	epm	19.16	4.94	10.27	0.27	15.93	2	15.32	0.29	
18	**ppm**	377	97	295	11.2	823	134	678	27	**98.81 %**
	epm	18.81	7.98	12.83	0.28	17.13	2.2	19.13	0.44	
19	**ppm**	354	115	278	8	945	213	512	14	**98.24 %**
	epm	17.66	9.46	12.09	0.20	19.67	3.49	14.44	0.23	
20	**ppm**	412	189	286	11	1187	147	629	30	**96.34 %**
	epm	20.56	15.55	12.44	0.28	24.71	2.41	17.74	0.48	
21	**ppm**	478	101	432	9.2	1236	122	1100	17	**93 %**
	epm	23.85	8.31	18.79	0.23	25.73	2	31.03	0.27	
22	**ppm**	414	103	299	9.6	823	123	687	29	**95.62 %**
	epm	20.66	8.47	13.01	0.24	17.13	2.02	19.38	0.47	

Anions

1.Chloride **(Cl^{-1})**:The most important sources of chloride are the evaporation deposits such as Halite and Sylvite or from rainwater,[24].The values of chloride in the samples ranged between 512 and 1567 ppm **(**Figure-4).

2. Sulfate **(SO_4^{-2})**: The source of sulfate ion in groundwater is the dissolution of evaporates such as gypsum and anhydrite. It may also result from the decomposition of organic materials which are used in agriculture fertilizers [25]. Its concentrations in the water wells of the study area had a range of 765 - 1890 ppm (Figure-4).

3. Bicarbonate **(HCO_3^{-1})**: Its sources in water are the dissolution of carbonic acid, which consists of the dissolution of gas (CO_2), which comes from the atmosphere. This ion is found in groundwater due to the dissolution of limestone rocks and salt deposits of geological formations [25]. Its concentrations ranged between 61 and 244 ppm, which is within the permissible limits.

4. Nitrate **(NO_3^{-1})**: Nitrate sources in groundwater are several, including rainwater, waste water, soil biological processes, agricultural activity [26].Nitrate value ranged 14 - 36 ppm, which is within the permissible limits.

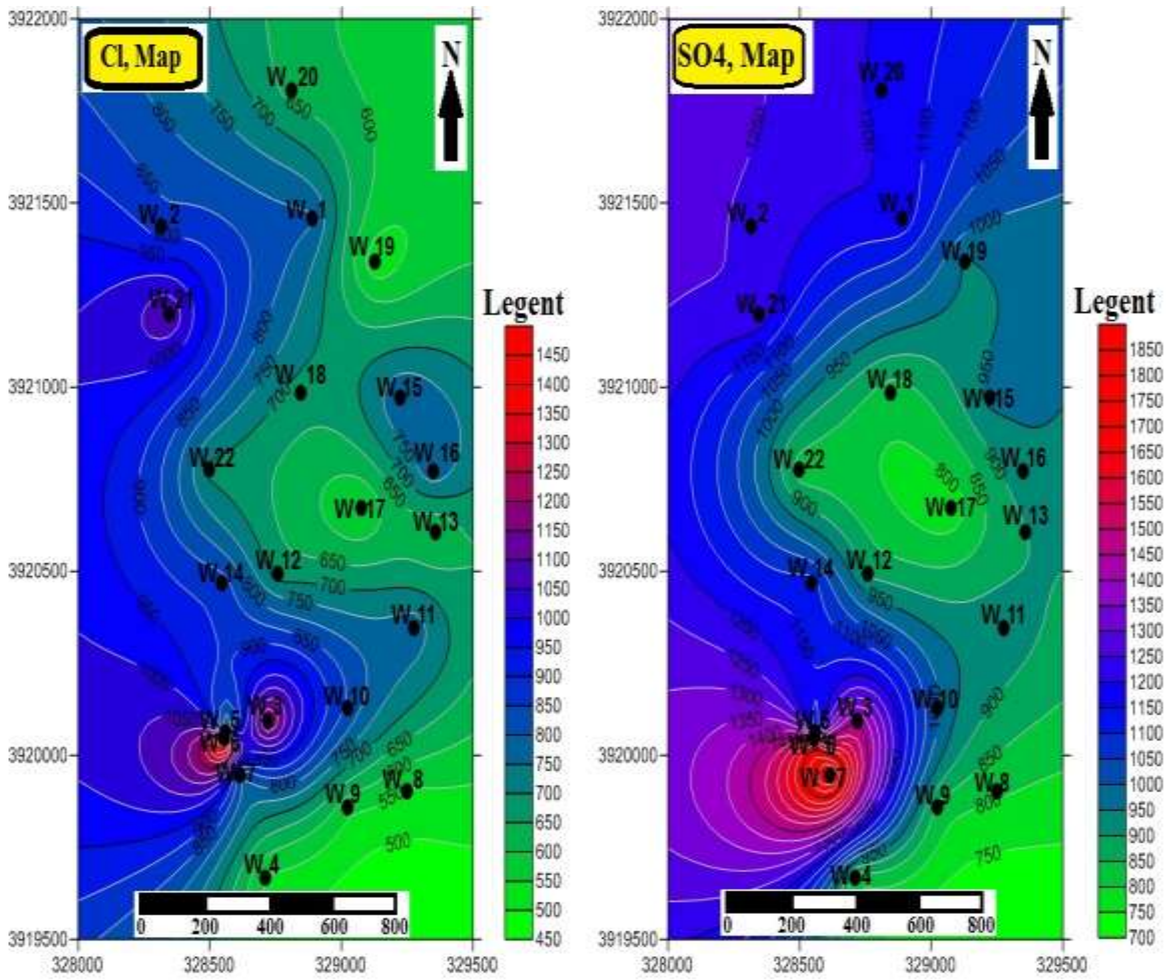

Figure 4-Maps of Sulfate and Chloride distribution (ppm) in groundwater samples

Trace elements

The concentrations of the trace elements in the groundwater samples are tabulated in Table-5.

1. Copper, **Cu**$^{+2}$: Copper values in water samples of the study area were between 0.01 and0.15 ppm.
2. Lead, **Pb**$^{+2}$: Lead values ranged between 0 and 0.0011 ppm.
3. Iron, **Fe**$^{+2}$: Its values ranged 0.01 - 0.3 ppm.
4. Zinc, **Zn**$^{+2}$: Zinc values were between 0.01 and 0.38 ppm.
5. Cadmium, **Cd**$^{+2}$ and Chromium, **Cr**$^{+2}$: Their value was Zero.
6. Nickel, **Ni**$^{+2}$: its values ranged 0 - 0.0032 ppm.
7. Cobalt**CO**$^{+2}$: The values of cobalt ranged 0.01 - 0.07 ppm.

Table 5-The concentrations of trace elements in the groundwater samples from the study area

Station	Cr^{+2}	Ni^{+2}	Cu^{+2}	Pb^{+2}	Fe^{+2}	Zn^{+2}	Cd^{+2}	CO^{+2}
W1	BDL	BDL	0.04	BDL	0.04	0.06	BDL	**0.01**
W2	BDL	BDL	0.06	BDL	0.01	0.08	BDL	**0.01**
W3	BDL	BDL	0.07	BDL	0.02	0.01	BDL	**0.02**
W4	BDL	0.003	0.01	BDL	0.014	0.15	BDL	**0.01**
W5	BDL	BDL	0.15	BDL	0.019	0.2	BDL	**0.06**
W6	BDL	0.006	0.04	BDL	0.013	0.05	BDL	**0.02**
W7	BDL	BDL	0.02	BDL	0.01	0.22	BDL	**0.06**
W8	BDL	0.0032	0.06	BDL	0.01	0.22	BDL	**0.01**
W9	BDL	BDL	0.08	0.0011	0.012	0.27	BDL	**0.02**

W10	BDL	BDL	0.07	BDL	0.02	0.3	BDL	**0.01**
W11	BDL	BDL	0.11	BDL	0.01	0.35	BDL	**0.01**
W12	BDL	BDL	0.08	BDL	0.02	0.38	BDL	**0.01**
W13	BDL	0.003	0.09	0.001	0.023	0.22	BDL	**0.02**
W14	BDL	BDL	0.05	BDL	0.019	0.23	BDL	**0.01**
W15	BDL	BDL	0.09	BDL	0.02	0.24	BDL	**0.01**
W16	BDL	BDL	0.04	BDL	0.21	0.25	BDL	**0.01**
W17	BDL	BDL	0.07	BDL	0.3	0.18	BDL	**0.02**
W18	BDL	BDL	0.06	BDL	0.02	0.18	BDL	**0.01**
W19	BDL	BDL	0.02	BDL	0.013	0.05	BDL	**0.01**
W20	BDL	0.001	0.01	BDL	0.01	0.2	BDL	**0.07**
W21	BDL	BDL	0.02	BDL	0.02	0.08	BDL	**0.01**
W22	BDL	BDL	0.02	BDL	0.021	0.05	BDL	**0.01**

BDL: Below Detection Limit

Table 6-A set of standards (international and local) for drinking water

Types	Parameters (ppm)	WHO 2017	Canada 2017	India 2012	IQS 2009	Range of Wells (ppm)
Physio-chemical	**TDS**	600	500	500	1000	**1934-7910**
	pH	8.5	6.5-8.5	6.5-8.5	6.5- 8.5	**7-8**
	T.H.	500	500	200	500	**1206-2704**
	Alk	200	--	--	--	**61-244**
Cations	Ca^{++}	100	--	75	150	**300-645**
	Mg^{++}	125	--	30	100	**60-334**
	Na^{+}	200	200	--	200	**222-533**
	K^{+}	12*	--	--	--	**8-16**
Anions	$SO_4^{=}$	250	≤ 500	200	400	**765- 1890**
	HCO_3	350*	--	--	--	**61-244**
	Cl^{-}	250	250	250	350	**512-1567**
	NO_3^{-}	50	45	45	50	**14-36**
Trace Elements	Cu^{2+}	2	1	0.5	1	**0.01-0.15**
	Pb^{2+}	0.01	0.01	0.01	0.01	**0-0.0011**
	Fe^{2+}	0.3*	≤ 0.3	0.3	0.3	**0.01-0.3**
	Zn^{2+}	3	≤ 5	5	3	**0.01-0.38**
	Cd^{2+}	0.003	0.005	0.003	0.003	**0**
	CO^{2+}	0.002	--	--	--	**0.01-0.07**

* **WHO 2006**

The results of physiochemical tests and chemical analyses of groundwater samples were compared with the international and local specifications of drinking water **(WHO 2017, Canada 2017, India 2012, IQS 2009)**, table 6, it was showed that this water is not suitable for drinking purposes, because most of the parameters' concentrations were higher than the permissible limits for drinking purposes, except those of carbonate and nitrate, which were within the permissible limits.

The general principle of desalination is that productivity and efficiency are inversely proportional to the salt content of raw water. Therefore, it is necessary to find water sources with minimal dissolved salt content, so that the desalination process can be more economic, with high quality, efficiency, and productivity, and with reduction of rejected water.

Depending on the values of TDS and EC, which are used as a key measurements of water salt content, and the results of chemical analyses, the results show that wells with closest values to the applied specifications are those with numbers 4, 8, 9, 17, and 19. Depending on the TDS value, **RO** is the most suitable method for desalination. It is also the most widely used method of desalination of groundwater in the recent time recently.

Conclusions

1. From comparing the results of physical and chemical tests with the international and local standards and specifications, the groundwater of the study area is not suitable for drinking purposes.
2. A variation in the concentration of **TDS was observed**, that may be caused by variability in lithology of the aquifer or the characteristics of the outcrops rocks of the charged zone. The quality of water ranged from slightly water to brackish water.
3. Salt content values of groundwater in wells numbered 4, 8, 9, 17, and 19wereclosest to the specifications. Therefore, these wells are considered the most suitable for treatment and desalination.
4. Concentrations of the trace elements were within the permissible limits, except that for cobalt.
5. Depending on these results, east and southeast wells of the study area are considered as having water with much better quality than that from western and south-western zones.

Recommendations

1. Residents of the study area should be informed not to use this water for drinking and domestic purposes.
2.Conducting analyzes of heavy metals that were not studied in this research, such as barium, boron, strontium and silver, to ensure that the water is not contaminated with these elements.

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