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Impact of Climate Changes on Groundwater Quality in Al-Zubair District

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Abstract

The aim of this study is to evaluate the quality of groundwater in Al-Zuber district (Basra Governorate). Analysis of the physical and chemical properties of samples taken from seven wells distributed across the study area was conducted for the study year (2019). The results of the analysis were compared with data collected for samples taken from the same seven wells for three years prior to the year in which the study was conducted (2019), these years are (2014, 2017 and 2018) during the 3 previous years of the study. The results of hydrochemical analysis of the four years compared with the Iraqi Standards (IQS) and the World Health Organization (WHO) to determine their suitability for drinking and irrigation uses. The results of comparison showed that the values of pH (7.3-8.4), electrical conductivity (EC)(4140-7000 μs/cm), total dissolved solids (TDS) (2799-544ppm), free chlorine(CL) (220-380 mg/L), sulfate (SO4) (2637-3000 mg/L), and magnesium (Mg) (100-500 mg/L) are not suitable for drinking as they exceeded the limits of the standards. However for irrigation purposes, groundwater can be used after treatment.

Keywords: Climate Changes; quality of groundwater; (WHO); drinking and irrigation water uses, Experimental work.

تأثير التغيرات المناخية على جودة المياه الجوفية في منطقة الزبير

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الخلاصة

تهدف هذه الدراسة إلى تقييم نوعية المياه الجوفية في قضاء الزوبر (محافظة البصرة). تم إجراء تحليل الخواص الفيزيائية والكيميائية للعينات المأخوذة من سبعة آبار موزعة على منطقة الدراسة لسنة (2019). وتمت مقارنة نتائج التحليل مع البيانات التي تم جمعها للعينات المأخوذة من نفس الآبار السبعة لمدة ثلاث سنوات قبل السنة التي أجريت فيها الدراسة (2019)، وهذه السنوات هي (2014، 2017، 2018) خلال السنوات الثلاث السابقة للدراسة . تمت مقارنة نتائج التحليل الهيدروكيميائي للسنوات الأربع بالمعايير العراقية (IQS) ومنظمة الصحة العالمية (WHO) لتحديد مدى ملاءمتها لاستخدامات الشرب والري. أظهرت نتائج المقارنة أن قيم الرقم الهيدروجيني (8.4-7.3)، والتوصيل الكهربائي (EC) (4140-7000 ميكروثانية/سم)، والمواد الصلبة الذائبة الكلية (TDS) 2799-544)جزء في المليون)، والكلور الحر (CL) (220-380 مجم/لتر)، والكبريتات (SO4) (2637-3000 مجم/لتر)، والمغنيسيوم (Mg) (100-500 ملغم/لتر) غير صالح للشرب لأنه تجاوز حدود المعايير. مع ذلك لأغراض استخدامات الري فيمكن استخدام المياه الجوفية بعد المعالجة.

الكلمات المفتاحية: التغيرات المناخية؛ نوعية المياه الجوفية؛ (منظمة الصحة العالمية)؛ استخدامات مياه الشرب والري، العمل المختبري.

1. Introduction

Groundwater is an important resource in many areas of the world for drinking, irrigation, industry, and other uses. It is a vulnerable resource because it may deplete or degraded due to many reasons, including overexploitation, reduced groundwater recharge, and contamination. Water quality is an important factor in the governance of environmental changes closely linked to social and economic development. Al-Aboodi, A. H., & Atiaa, A. M. (2006). Understanding the potential impacts of climate change on surface water resources is widely understood in the literature, but few studies have indicated the impact of the climate on groundwater. Changes resulting from climate on surface water as well as precipitation may directly affect recharge to groundwater. The change in climate will affect the global hydrological cycle in frequency, time, and space (Al-Agidi, W. K., 1981; Al-Jawad, S. et al., 1989). The main contributor to waterways and rivers is groundwater, especially in areas of shallow water, during low and high flow periods. As a result, the groundwater system's status not only affects its benefits as a source of water supply, but it also affects the availability of surface-water supplies. The quantity and quality of groundwater are affected by changes caused by Earth’s climate change. The scientific consensus finds that the Earth's climate has changed, and this will continue in the future in response to the increasing concentrations of greenhouse gases in the universal atmosphere (Mohamed, M et al., 2023) and (Richards, L. A., 1954).

The reduction in groundwater storage of the usable aquifer and the drop in its hydraulic heads during the last three decades have led to the marked deterioration of groundwater quality. The upward seepage of the saline water from the deeper aquifers has become one of the sources of groundwater deterioration leading to the marked deterioration of groundwater quality (Al-Hayani, A. S., 2009). The main aim of this study is to assess the physicochemical properties of groundwater samples in order to control salt intrusion in the Al-Zubair district, south of Iraq. The area of southern Iraq is mainly dependent on groundwater, which was classified as suitable for agricultural purposes, but due to the expansion of agriculture and the increase in groundwater consumption, the water level lowered as well as the change in water quality, especially with the continuous pumping operations. Khor Al-Zubair is one of the most polluted areas due to the surrounding factories.

2. Study area and its climate

Al-Zubair district (figure 1) is located in the southern part of Iraq within its western desert, having latitudes of 30°05-30°25 and longitudes of 47°30-47°55. It covers an area of about 1235 km² from the total area of the Dibdibba plain and consists of a widespread sandy surface (Al-Naqib, K. M., 1970). Sand, gravel, silt interbedded with clay beds, and rare gypsum represent the main deposits of the area, which formed in tertiary to quaternary periods (Atiaa, A. M., & Al-Asadiy, S. A. 2007). The area is one of the largest and most important agricultural regions in Iraq, especially during the cold months of the year when the majority of other areas of the country have none because of the hard climate conditions. More than 75% of the water used in agriculture and irrigation is pumped from the same aquifer. Intensive utilization of the aquifer in the area began from about fifty years ago when diesel pumps were introduced. The study area has a flat plain morphology that generally slopes towards the northeast (Jaid, G. M., et al., 2019), as shown in figure 2. The important geomorphologic features within this area are shallow valleys, which may carry occasional runoff after rainstorms, and tidal flats, in addition to the sand dunes that are disposed throughout the area in the south and southwestparts (Black, C. A., et al., 1965 & Sadoon, A. M., 2007). The material types and hydraulic properties have more impact on the design and behavior of the hydraulic structure (Mohamed, M. J., et al., 2023).The area being investigated has a total average rainfall of about 140 mm. The annual average temperature is 33.30°C, while the total annual average evaporation is 3534 mm. In the last four decades of the past century, large-diameter pumping wells, which were hand-dug, were drilled randomly with non-uniform shapes (Al-Jubouri, S. F. M. 2011). The climate of the study area is generally characterized by high evaporation rates, high relative humidity, and low rainfall rates. The original groundwater reserves in the usable upper part of the aquifer are estimated to have been approximately 3136 × 106 m³ (Earman, E., & Dettinger, M. 2011). While each year, farmers take more than 92 × 106 m³ on average of the aquifer water. The effect of the intensive pumping due to the increase in random drilling wells and their pumping rates on reserved storage requires a comprehensive and detailed investigation (Davis, S. N., & DeWiest, R. J. 1966) and (GenereuxD.P.&,HooperR.,P,1998).

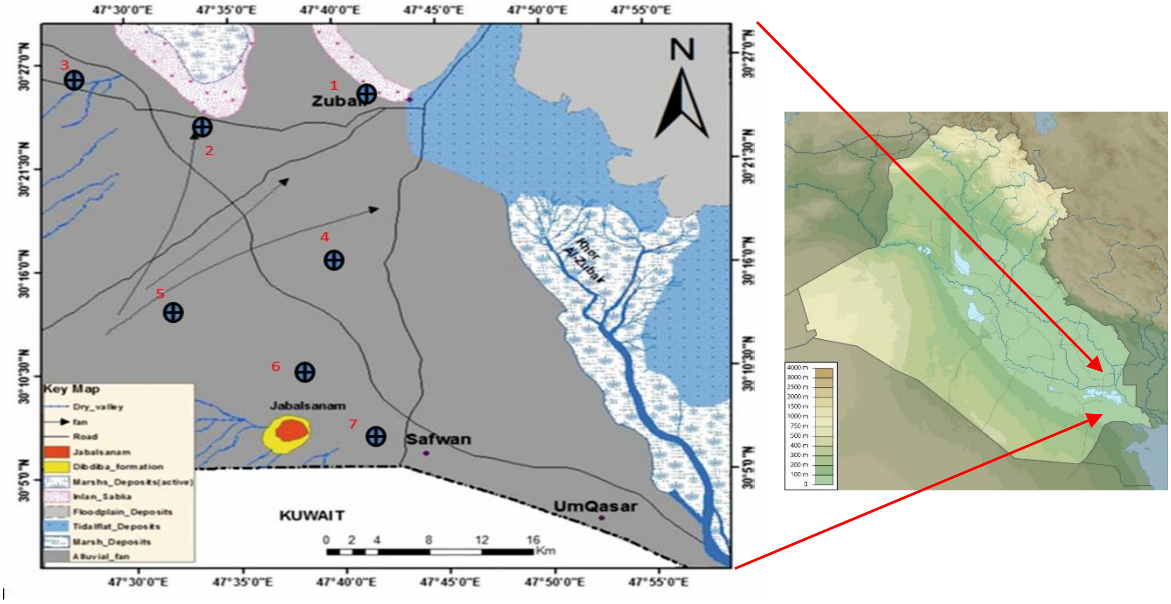

Figure 1: Study area.

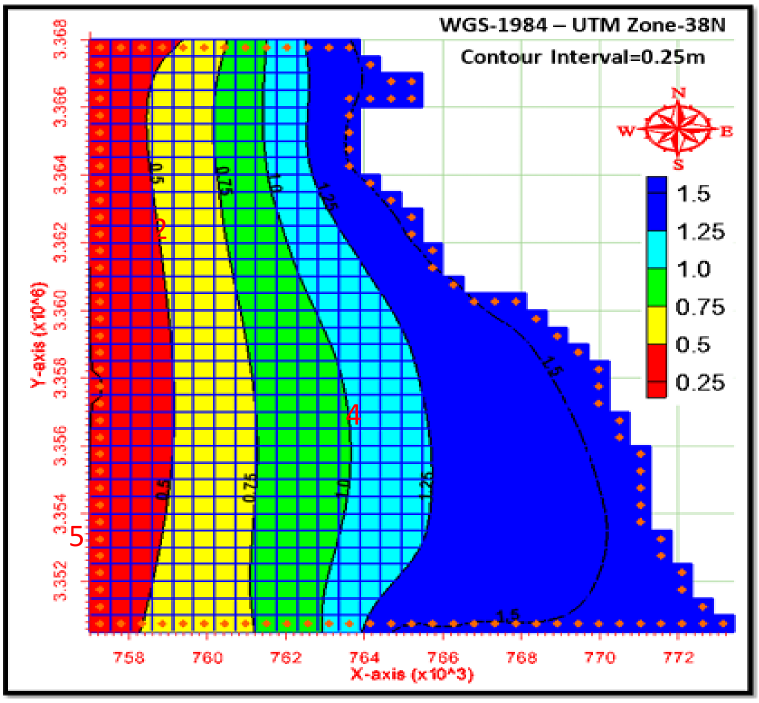

Figure 2: Groundwater heads in the study area

3. Materials and Methods

The water samples were taken from seven wells in the Zubair area within the governorate of Basrah (Fig. 1). Which were kept in polyethylene containers. The samples were transferred to the laboratory of the desalination research unit/university of technology. Iraq. TDS and EC of samples were examined for the 2019 year through the devices shown in figure 3. Chloride, positive, and negative ions were also calculated for the 2019 year, and the laboratory data were compared with data obtained from the National Center for Water Resources for the years 2014, 2017, and 2018.

Figure 3: Devices used in the laboratory.

4. Water classification by Piper Chart

A piper chart (figure 4) represents an effective graphical procedure for separating relevant analytical data to understand the sources of water-soluble components. This procedure was generated according to a statement that most natural water contains cations and anions in a chemical equilibrium state. It is assumed that the most abundant cations are two "alkaline earth" elements, calcium and magnesium, and one "alkali" element, sodium (Na). The most common anions are "weak acid" bicarbonate (HCO_3), sulfate "strong acids" (SO_4), and chloride (Cl). The less common anions and cations are summarized with the three main anions and cations as shown in table 1, where this table represents the WHO and IQS standards that will be compared with in this study. in view of the limited water imports resulting from the establishment of dams on river sections under conditions of climate change, which affected the difficulty of achieving requirements for human, agricultural, and industrial use. Global warming and rising water demands increase the strain on finite freshwater resources, resulting in a state of "water bankruptcy" and its associated socioeconomic effects (Mahmood J Al Shammary and Ibtisam R Kareem 2025 & Mahmood J Al Shammary, 2025).

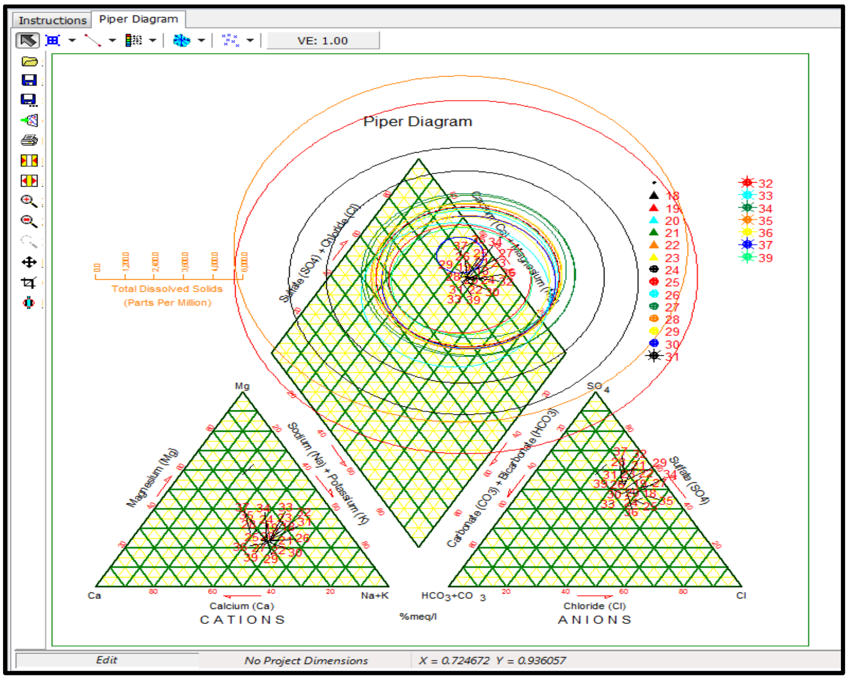

Figure 4: Piper diagram for study area.

Table 1: The physio-chemical parameters compared WHO and IQS standards. (City et al. 2018).

Parameter	IQS417, (2001)	WHO (2007)
pH	6.5-8.5	6.5-8.5
Dissolved Oxygen (DO) mg/l	5	6.5
Turbidity (NTU)	5	5
Chloride (Cl) mg/l	250	250
Total hardness as CaCO3 mg/l	100-500	500
Electrical conductivity (EC) µS/cm	1000	1500
Total dissolved solid (TDS) mg/l	500-1000	1000
Free chlorine mg/l	0.3-2	0.3

5. Results and discussion

In order to achieve the aim of this study, physical and chemical investigations were carried out for the samples taken from the seven wells distributed in the study area. The laboratory parameters, such as pH, EC (µS/cm), TDS, Na^{+}, Mg^{+2}, Ca^{+2}, and SO_4^{-2} (ppm), are shown in table 2 and discussed in the following items:

Table 2: Measured parameters

Well No	Well Dep m	pH (µS/cm)	EC (µS/cm)	TDS ppm	SO_4^{-2} (ppm)	Ca^{+2} (ppm)	Na^{+} (ppm)	Mg^{+2} (ppm)
1	48	7.3	7000	5400	2826	632	590	600
2	30	8.3	7100	5219	2740	650	537	459
3	20	7.4	6997	4650	2972	800	700	451
4	22	7.71	6833	4873	2637	512	555	500
5	21	8.22	6820	5105	2920	525	605	435
6	25	7.5	6000	4254	3000	360	499	511
7	40	8.1	4041	2799	2935	650	299	654

5.1. For drinking water

a) PH

The pH of the solution represents a logarithmic numerical value of an inverse concentration. The hydrogen ion in the solution is intended to measure its acidity or base [9], where:

$$PH = -Log\,[H+]$$

The values of pH at the seven sampling sites are shown in figure 5 ranged between (7.3 to 8.4). The results revealed that the values of pH in 2014 were slightly higher, in some sites than others, though represent good values within the limits of WHO and IQS-417-(2001) standards. While the minimum values of pH were in 2014 in all sites.

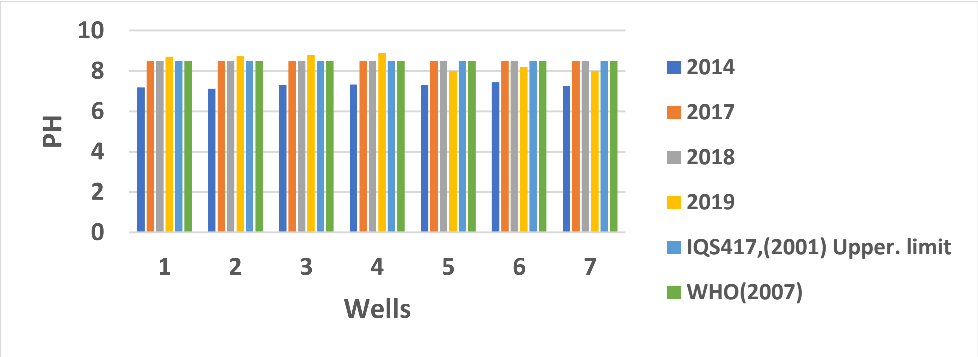

Figure 5: PH values.

b) EC: The importance of measuring electrical conductivity is through its use in hydrological, hydrochemical, and agricultural applications. As many standard specifications depend on electrical conductivity, the salinity measurement is a quick method for estimating salinity through the mathematical relations that connect them together Toure, A., Diekkruger, B., & Mariko, A. (2016). The EC values in the wells varied between 4140 µs/cm and 7000 µs/cm. The results showed that there is an increase in the electrical conductivity in 2014 and 2017 and a decrease in 2019 due to the reduction of pollutants such as agricultural pollutants (fertilizer residues) or sewage and the low temperatures in 2019, as shown in figure 6.

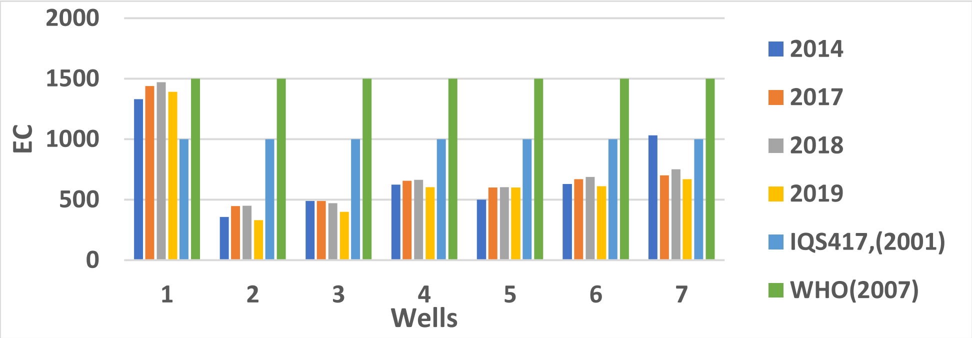

Figure 6: EC values.

c) **TDS:** The TDS values in the wells ranged between 2799 ppm and 5400 ppm. A difference in the concentration of TDS was observed due to variation in the geology of the region, as well as the slope and terrain of the earth, which was reflected in the salinity of groundwater to give this large scale. Figure 7 shows that the water salinity was low in 2014, increased in 2017 and 2018, and had a significant decrease in 2019. This variation is due to the large rainfall in that year.

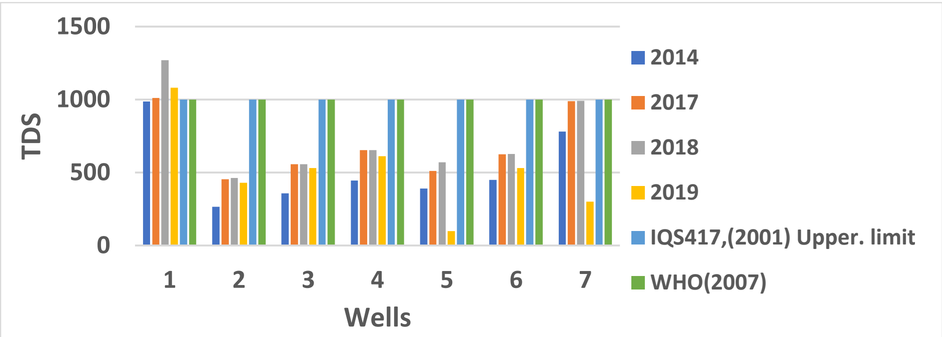

Figure 7: TDS values.

d) **Mg^{-1}:** The results showed that there is an increase in this ion in the wells for the years 2014 and 2019, as shown in Figure 8. This is due to the dissolution of dolomite in sulfate-rich water under near-neutral pH conditions (pH=7). The presence of limestone and dolomite leads to the partial dissolving of carbonates, resulting in the precipitation of $CaCO_3$ and the release of Mg^{+2} and SO_4^{-2} ions into the water.

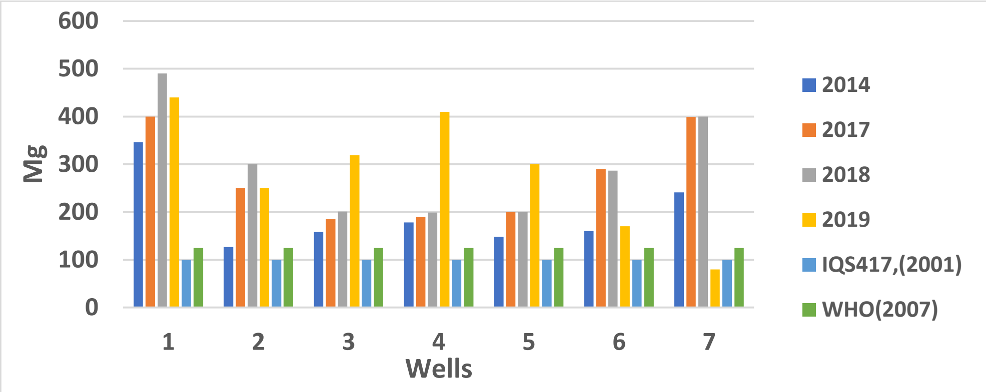

Figure 8: Magnesium values.

e) **Cl^{-1}:** Concentrations ranged between 1.7 ppm and 4 ppm, as shown in Figure 9.The high concentration of this ion in swells may be attributed to agricultural activities, such as the use of chloride-based fertilizers.

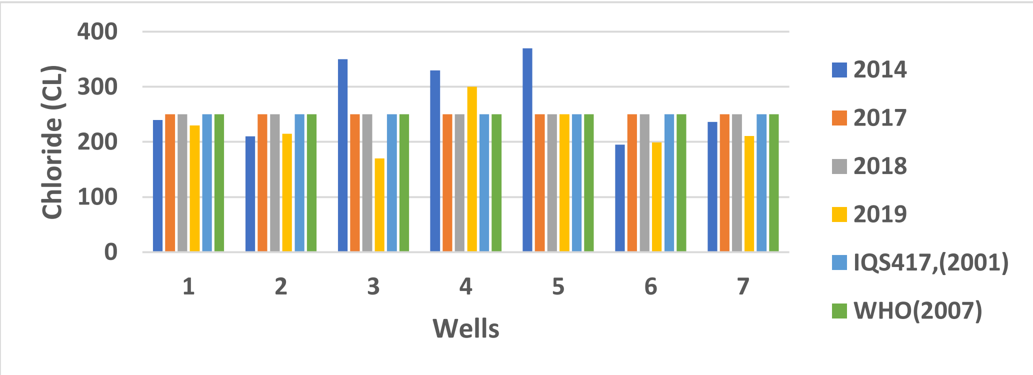

Figure 9: Chloride ion values

f) **SO_4^{-2}** concentrations ranged from SO4 (2637 ppm – 3000 ppm) as shown in figure 10. It has been observed that there is an increase in this ion in 2019 in the groundwater. The high concentration of this ion in groundwater is due to the melting of abundant gypsum and anhydrite rocks that covering the majority of the study area.

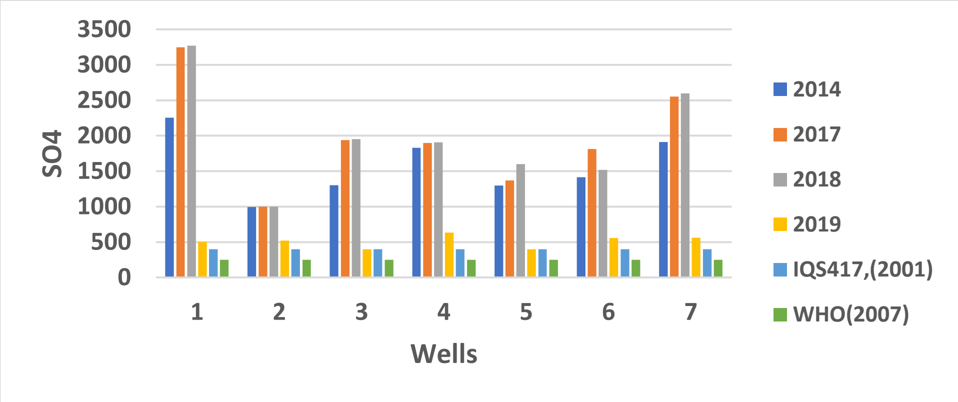

Figure 10: SO_4 values.

5.2 For Irrigation purposes

The validity of the seven wells water for irrigation was tested based on the classification of the United States Environmental Protection Agency (US EPA, 2008), which adopts TDS with the help of EC. Comparing the results of the years 2014, 2017, 2018, and 2019 as listed in Tables 3 and 4 shows that all wells are not suitable for irrigation uses.

Table 3: Result comparison of TDS with EPA, 2008 standard for irrigation purposes.

EPA (2008)	TDS(mg/L)	(2014)	(2017)	(2018)	(2019)
Low salinity	0-250	2	--	--	5,7
Moderate salinity	250-750	2,3,4,5,6	2,3,4,5,6,7	2,3,4,5,6	2,3,4,5,6,7
Salty	750-2250	1,7	1	1,7	1
Very salty	2250-5000	--	--	--	--

Table 4: Result comparison of EC with EPA, 2008 standard for irrigation purposes.

EPA, 2008	EC(mg/L)	(2014)	(2017)	(2018)	(2019)
Low salinity	less than 160	--	--	--	
Moderate salinity	160-480	2,3,4,5,6	2	2	2,5,7
Salty	480-1440	1,7	1,3,4,5,6,7	1,3,4,5,6,7	1,3,4,6
Very salty	1440-3200	1	--	--	--

6. Conclusion

The samples of groundwater were taken at different depths from the wells to cover the types of saltwater intrusion in the study area. The samples were tested for (EC, TDS, pH, Na^+, Mg^{+2}, Ca^{+2}, $SO4^{-2}$, and CL) to know the problem of salt intrusion that occurring in the region.The following conclusions were noted:

- A high for both values of EC and TDS concentrated in each year in well 1 when comparing with the other wells. The salinity of the water in the study was varied during the period of the study. This water is classified as salinity.
- A minimum for the concentrated values of EC, TDS, chloride ion, and SO_4 in each well except in well 1 appears in 2019.
- Also, small variation in the value of chloride ion concentration appears in each well and in all years except in 2014.
- Finally, low variation in the value of pH displyed in all the wells and overcomes the reference level (7) in each of the years except in 2014. Hence, the behavior of water trends to low alkalinity.it recomnded to treatment the water source befor uses.

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