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Adopting the Water Quality Index to assess the validity of groundwater in Al-Zubair city southern Iraq for drinking and human consumption

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ABSTRACT

Ground water is an alternative source of water in arid and semi-arid area. The present study aimed to assess the suitability of twenty well waters in Al-Zubair area, southern Iraq for drinking and human consumption. Water Quality index (WQI) was adopted to evaluate the water of the studied wells. Water Quality Index (WQI) was calculated depending on a fifteen physiochemical parameter including: pH, Total dissolved solids (TDS), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Chloride (Cl^-), Sulphate (SO_4^{-2}), Nitrate (NO_3^-), Sodium (Na^+), Potassium (K^+), Lead (Pb^{+2}), Cadmium (Cd^{+2}), Copper (Cu^{+2}), Zink (Zn^{+2}). Iron (Fe^{+2}) and manganese (Mn^{+2}). Results of WQI values indicated that the wet season has the lowest average of WQI(795.6), with range values from 604 to 1274, while the dry season recorded the highest average of WQI(1372.1), with range values (878 – 2997) respectively. The WQI results indicate that groundwater is classified as unfit for drinking and human consumption purpose. This study is useful in the planning and rational management of groundwater resources and their potential for use as drinking water.

Key words : *Ground water, Al- Zubair, Physiochemical parameters, WQI*

Introduction

Worldwide, freshwater resources are depleting as a result of population growth and industrial development. In the last two decades, global water scarcity has been evident in Iraq as a result of the degradation of its freshwater source (Tigris and Euphrates) (Alwan *et al.*, 2019). The construction of several dams on the headwaters of the Tigris and Euphrates rivers by Iraq's neighbors Iran and Turkey is one of the most important reasons for the deterioration of these rivers. ('Towards Sustainable Water Resources Management In Iraq', 2018). This coincided with significant population growth and lack of infrastructure and scientific planning for water resources management in the country. Iraq's location in the Middle East, one of the regions most affected by climate change (low rainfall, increased evaporation levels, rising the level of sea and drought) is an important factor in water scarcity. For these reasons the Iraq's freshwater resources becomes not meeting the overall needs. The consequences were numerous and had a adverse effect on facilities such as agriculture, industry, tourism and energy, leading to increased unemployment, poverty, food insecurity and malnutrition. Recently, the global trend towards groundwater has become a substitute for surface water as an important natural water resource, groundwater has many advantages making it better used "compared" to surface water 1. It's of higher quality. 2. It is less susceptible to contaminants. 3. Less affected by "seasonal and permanent changes". 4. Its spread is wide compared to surface water, 5. In addition, groundwater may occur in the area where rare in the surface water found (Zektser, 2004). Therefore source of surface water is stingy, groundwater is perfect, renewed, specific and quantitative provenance of water equipping. From another aspect the quality of groundwater act as determining factor for its various uses. The quality of groundwater usually effected by both natural processes and human effectiveness in the enclosure area (Ibrahim, 2019). Therefore, monitoring and evaluation of groundwater in the region is one of the basic and effective steps for the protection and management of groundwater. Determining water quality using some important and traditional criteria provides only a simple indication "of water quality, and gives a general idea and awareness of potential groundwater problems. The quality and suitability of drinking water can fixed via assessing their indexes of quality. An important tool in determining water quality in different regions is the Water Quality Index (WQI), which define as an indicator reflects the combined impact of several water quality indicators that are used to calculate the water quality index (Chaurasia *et al*., 2018). In this respect, WQI concider a prominent area in the water quality management. It provides a comprehensive "water quality representation for general use or specific use (Patel, 2018). The main thematic of WQI is to transform complex water quality data into understandable data that the public can use. Thus, an individual figure can tell the full history of water quality. Many studies have been made on the current studied area, and dealing with the study water quality of ground water in AL-Zubair distract (Mahmood *et al*., 2015); (Al-Tememi, 2015); (Abdulhussein, 2018); (Dawood *et al*., 2018). Al-sudani, (2019) studied the salinity pollution in the ground water in Al-Zubair distract. Therefore, the present study aimed to assessing the goodness of groundwater for the human consuming, using the water quality index as an effective tool in monitoring and managing water resources, so it can depended as a useful source in the planning and rational management of groundwater resources and their potential for use as drinking water.

Materials and Methods

Desicription of the study area

The studied area is located in the Zubair district in the southern part of Basra Province, Iraq, between longitude 30.1672° N, 46.9805° E (Figure 1). In the year of 2008, Zubair district had a population of approximately 240,000 people (Dawood *et al*., 2018). This city is highly dependent on groundwater for many of its activities such as domestic, industry as well as irrigation.

Sample collection and analytical procedure

A gross of 40 Groundwater samples was gathered from different operating wells ranging in deepness between 7 and 30 m below surface level (Table 1 and Figure 2), through two various seasons, dry season (October) and wet season (April) during 2012-2013, respectively. The water samples were collected after pumping for 10 minutes. Samples were

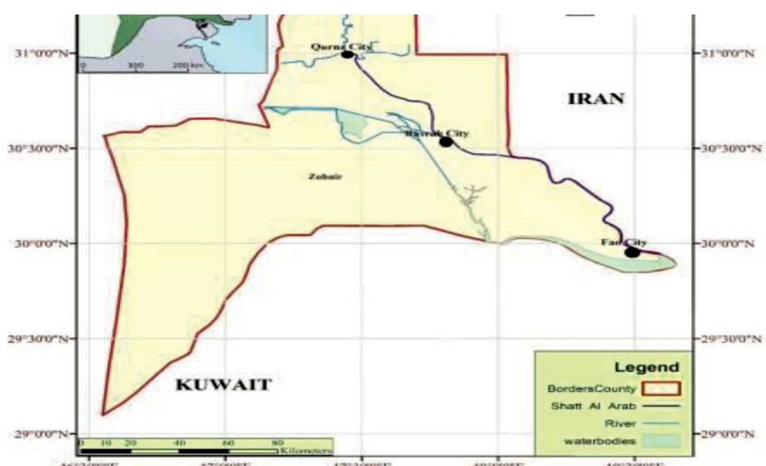

Fig. 1. Basra Province map with Zubair district

Table 1. The depth (m) and coordination of study wells

Well No.	Depth (m)	Coordinates
1	15	N : 30 22 52 .9, E : 047 32 20 .1
2	15	N : 30 20 04 .1, E : 047 35 16 .4
3	15	N : 30 20 40 .2, E : 047 37 51 .5
4	15	N : 30 19 58 .2, E : 047 38 23 .1
5	19.5	N : 30 20 44 .7, E : 047 39 07 .3
6	19	N : 30 21 15 .0, E : 047 38 48 .0
7	19.5	N : 30 21 32 .6, E : 047 38 37 .4
8	24	N : 30 21 35 .9, E : 047 39 33 .4
9	19	N : 30 22 40 .3, E : 047 40 27 .3
10	15	N : 30 20 52 .7, E : 047 42 58 .6
11	18	N : 30 20 58 .7, E : 047 41 59 .9
12	12	N : 30 21 07 .4, E : 047 42 10 .4
13	30	N : 30 19 34 .5, E : 047 41 36 .3
14	28	N : 30 19 35 .5, E : 047 42 05 .8
15	28	N : 30 19 43 .1, E : 047 42 42 .4
16	7	N : 30 24 52 .1, E : 047 41 34 .6
17	11	N : 30 24 52 .0, E : 047 40 50 .0
18	24	N : 30 24 14 .7, E : 047 39 43 .7
19	8.5	N : 30 19 46 .9, E : 047 44 14 .4
20	9	N : 30 18 58 .3 , E : 047 44 51 .7

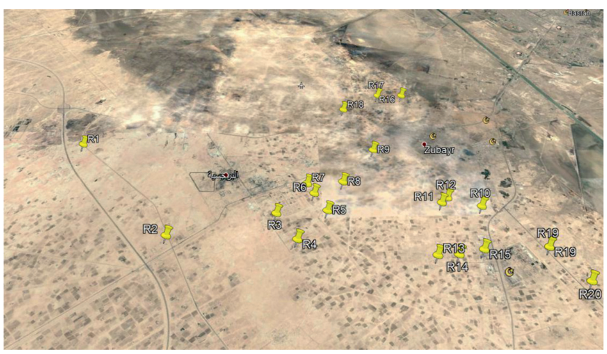

Fig. 1. Map of the studied region

taken in polyethene pre-cleaned bottles of one-liter capacity. Physical and chemical parameters including pH and TDS were measured *in situ* using a WTW 3110 pH meter and WTW Cond 3110 conductivity meter respectively. For the rest of the chemical parameters, water samples were preserved and analyzed according to the American Public Health Association (APHA, 2005). Fifteen parameters were used in the WQI calculation at the twenty wells for the assess suitability of groundwater quality for drinking and human consumption (Table 3).

Water Quality Index (WQI)

To assess sutibtibilty of studied ground water for drinking and human consumption, the present study was depended on the WQI. The WQI consider as one of the best efficient gadget to screen the pollution in both of surface and ground water as well as can act as a powerfully tools in the progress programs of water quality application. The application of the WQI requires an appropriate guideline. Therefore, the guidelines for drinking purposes as recommended by Iraqi Gugideline (number 417) (updated 2009) have been considered for the calculation of WQI(IQS, 2009). In order to compute the WQI three steps must be followed. Firstly, each of the fifteen studied parameters gives a weight (WI) according to its relative importance in the universal value of drinking water purposes (Table 2). Five (5) is the highest weight usually given to the given to the factor shaving the main effects on the quality of water, like TDS, Cl, SO_4, NO_3 and Pb. secondly, the relative weight (Wi) is calcualated using the following equation:-

Wi = *wi*/_*ni*=1*wi*:- Where: *Wi* is the relative weight. *wi* is the weight of each factors. *n* is the number of factors (Vasanthavigar *et al.*, 2010):

Finally, the scale of quality rating *(qi)* for all of factors is given by separating its concentration in every water sample by its particular guideline (Table, 2) the result, then multiplies by 100: *qi*= *(Ci/Si)* × 100:- Where: *qi* is the quality rating. *Ci* is the concentration of each factor in all water samples in milligrams per liter. *Si* is the Iraqi guideline for drinking water. For calculating the WQI, the SI is first calculated for all chemical factors, which is then used to define the WQI using the following equation: SIi = Wi × qi. WQI = _SIi:- Where, SIi is the sub index of *i th* parameter, qi is the rating based on concentration of *i* th parameter, n is the number of parameters.

The calculated WQI values are categorized into five types, excellent water to "water, unsuitable for drinking (Table 3).

Results and Discussion

The whole studied parameters were statistically analyzed to give universal chemical characteristics in groundwater. Table 4 showed the minimum, maximum, mean, and the standard deviation for eachparamete. For permition limite for drinking water, present study depend on World Health Organization and Iraqi guidline. Ground water recorded pH value reach to neutral to sub alkaline, where it was 7.09-8.18 in the wet and dry season respectively so it within the permition limite (Table

3). The values of pH recorded in the present study are similar to these recorded in the previous works (Bieranye *et al*., 2016); (Rupal *et al*., 2012) and (Bieranye *et al*., 2016). Present study recorded means of the TDS (8024.4±1833.1 and 7933.6±1821.7 mg/l) during dry and wet seasons respectively, which exceeds the permissible limit of 1000 mg/L as per Iraqi standards and WHO Standards (Table 3). The TDS values indicate that groundwater is brackish to saline types where (TDS > 1000 mg/L) (Al-sudani, 2019). Total dissolved solids (TDS) in ground water generally combined with natural source, Demostic sewage, wastewater of industry, urban run-off and compound used in water management procedure (Agency, 2015). In groundwater, when the TDS has great value, it may be not harmful to humman, but it has harmful effect on the persons who are sorrow from heart and kidney diseases (Dawood *et al*., 2018). The mean of Calcium ion concentration for the whole water samples was 1068.8±392 and 881.4±455.6 mg/L for the dry and wet seasons respectively (Table 4). In the ground water the Calcium ion (Ca^{2+}) occur naturally by the degeneration of carbonate minerals and the disintegration of sulphate, phosphate given and silicate minerals (Cobbina and Nyame, 2012). The higher concentrations of Ca^{2+} recorded in this study may be related to the presence of sulphate and phosphate containing rocks in the study area rather than contaminats. This results indicated that the concentration of Ca^{2+} above the Iraqi standards and WHO (Table 3). Present result for Calcium concentration is in agreement with previous works, (Mahmood *et al*., 2015) in their study recorded (Ca^{2+}) concentration 649.30 in Al- Zubair city, (Dawood *et al*., 2018) recorded mean concentration of the Ca^{2+} (617.23 mg/L) in Al-Zubair district. Present study also indicated that the concentration of magnesium ion is not within the permission limit of Iraqi guideline (Table 4 and 3) and this in agreement with previous works, (Mahmood *et al*., 2015); (Dawood *et al*., 2018) and (Al-Sudani, 2019). Sodium is considered one of the most important components of groundwater due to its presence in high concentrations. The concentration of sodium up to 200 mg/L makes the water unsuitable for home use due to the health problems it causes like hypertension, congenial diseases, kidney disorders and nervous disorders inhuman body (Adimalla *et al*., 2018). The means concentration of sodium recorded in the present study wear 515.65±232.5 mg/L and 515.65±232.5 mg/L for dry and wet seasons respectively (Table 4), and it therefore exceed the permition guidline (Table 3). The high concentration of sodium in ground water may be due to disband of halite during the locomotion of ground water through sediments. Previous studies also recoded high concentration in ground water in Basra city (Mahmood *et al*., 2015); (Al-Tememi, 2015) and (Dawood *et al*., 2018). Present study recorded potassium concentration range from 21-130 mg/L with average 60.1±30.1 in dry season and from 25-69mg/L with average 43.7±12.2 mg/L in

Table 2. Standards of water quality (Iraqi guideline (IQS, 2009) and WHO guideline (WHO, 2007) and the calculation of relative weight (Wi)

Parameters	Iraq guideline 2009	WHO 2007	Weight *wi*	Relative weight *Wi*
pH	6.5-8.5	6.5-8.5	4	0.069
TDS (mg/L)	1000	1000	5	0.086
Ca (mg/L)	150	75	3	0.052
Mg (mg/L)	100	125	3	0.052
Na (mg/L)	200	200	4	0.069
K(mg/L)	12	12	2	0.034
Cl (mg/L)	350	250	5	0.086
SO_4 (mg/L)	400	250	5	0.086
NO_3 (mg/L)	50	50	5	0.086
Pb (mg/L)	0.01	0.01	5	0.086
Cd (mg/L)	0.003	0.003	4	0.069
Cu (mg/L)	1	1	4	0.069
Zn (mg/L)	3	3	3	0.052
Fe (mg/L)	0.3	0.3	3	0.052
Mn (mg/L)	0.1	0.1	3	0.052
			Σwi = 58	Σ*Wi* = 1

wet season (Table 4). Potassium value recorded exceeds both of Iraqi and WHO guideline (Table 3). Concentration of Chloride recorded in the present study exceed the Iraqi and WHO guideline (Table 4 and 3). The high concentration in ground water responsible for salty test of water (Bacha, 2016). The high value of Chloride may be resulting from halite minerals dissolution, Deposition of sea water in addition to the disposal of waste water, previous study also recorded high concentration of chloride in ground water in the same studied area (Mahmood *et al.*, 2015); (Al-Tememi, 2015); (Dawood *et al.*, 2018). In related to the concentration of sulphate recorded in the present work (Table 4) it was above the permission limit (Table 3), present finding is in agreement with, (Al-Tememi, 2015); (Abbas and Dawood, 2016; Dawood *et al.*, 2018), where they recoded high mean value of sulfate (2276 mg/L), (1317.2 mg/L) and (1423.077) mg/L respectively.

Nitrite concentration in the present studied ground water has range 2.1-20.7mg/L with an average 11.5±6.9 mg/L in dry season and 2.1 -31.5 mg/L with average 12.4±8.4 mg/L in wet season, so its within the Iraqi guideline and WHO standers (Table 3).

Table 3. Water quality classification based on the computed value of WQI (Rupal *et al.,* 2012)

Range	Type of water
<50	Excellent water
50–100.1	Good water
100–200.1	Poor water
200–300.1	Very poor water
>300	Water unsuitable for drinking purposes

Heavy metals

The presence of heavy metals in the drinking water is one of the most serious issues that it may cause savior health impact. In this work we made an effort to study the concentration of six heavy metals (Pb, Cd, Cu, Zn, Fe and Mn) in groundwater indifferent locations of Al-Zubair city. The means of these heavy metals were represented in Table 4. Result indicated that the studied heavy metals (Pb, Cd, Zn Fe and Mn) have mean concentrations higher permissible limits of drinking water suggested by the Iraqi guideline and WHO (Table 3). Present study is in aggrement with these reported in Baghdad (Joda *et al.*, 2019), where they recorded high concentration of As, Cd and Pb. The recorded values in the collected work for Cd in drinking water were (0.018-0.056 mg/L) from ground water (Joda *et al.*, 2019). Hajar Ameen Ameen, (2019), also recorded high concentration of Cd(2.45 to 3.78 μg/L)in Duhok city in Iraq. The higher values of Cd recorded in present work may be due to many activates occurring near or round the studied well including agriculture, waste of human, sewage.

The permition limit for the Pb in drinking wateris 0.01mg/L (Table 3). In the study area, the mean concentration of Pb were 4.13±2.4 mg/L during dry season and 12.4±8.4 mg/L during the wet season. It is a matter of anxiety that the Pb concentration of all the water samples in the studied wells is above the

Table 4. Seasonal statistical variation for the groundwater parameters

Parameters	Dry season			Wet season			Annual		
	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD
pH	7.38	8.16	7.7±0.19	7.09	7.53	7.35±0.14	7.09	8.16	7.52± 0.24
TDS (mg/L)	4648	11640	8024.4±1833.1	4544	11504	7933.6±1821.7	4544	11640	7979±1804.4
Ca (mg/L)	641	1969	1068.8±392	401	2684	881.4±455.6	401	2684	975.1± 430.1
Mg (mg/L)	399	995	692.15±167.6	490	980	627.3±125.9	399	995	659.72±150
Na (mg/L)	172	948	515.65±232.5	824	2408	1699.05±392.7	172	2408	1107.35±678.6
K (mg/L)	21	130	60.1±30.1	25	69	43.7±12.2	21	130	51.92±24.19
Cl (mg/L)	1710	6597	3043.2±1156.6	1249	5523	3636.2±929.4	1249	6597	3339.7±1078.3
SO_4 (mg/L)	688	4232	2197.95±1001.7	1936	5292	3132.9±964.6	688	5292	2665.45±1080
NO_3 (mg/L)	2.1	2.17	11.5±6.9	2.1	31.5	12.4±8.4	2.1	31.5	11.96±7.64
pb (mg/L)	1.498	12.99	4.13±2.4	0.01	2.747	0.7±0.6	0.01	12.99	12.45±2.45
Cd (mg/L)	0.027	0.365	0.13±0.08	0.0193	0.085	0.04±0.01	0.0193	0.365	0.092±0.07
Cu (mg/L)	0.091	0.559	0.23±0.1	0.034	0.205	0.08±0.04	0.034	0.559	0.16±0.12
Zn (mg/L)	0.2	1.387	0.77±0.3	0.077	0.366	0.16±0.07	0.077	1.387	0.27±0.26
Fe (mg/L)	0.444	16.66	4.38±3.3	1.166	15.272	3.45±3.4	0.44	16.66	3.92±3.38
Mn (mg/L)	0.022	0.403	0.16±0.07	0.037	0.149	0.08±0.02	0.022	0.403	0.12±0.07

Table 5. The values of WQI with corresponding classification

Well No.	WQI score value			
	Dry Season	Classification	Wet Season	Classification
1	941	unsuitable for drinking	636	unsuitable for drinking
2	1614	unsuitable for drinking	800	unsuitable for drinking
3	1993	unsuitable for drinking	1113	unsuitable for drinking
4	1705	unsuitable for drinking	797	unsuitable for drinking
5	1118	unsuitable for drinking	951	unsuitable for drinking
6	1097	unsuitable for drinking	791	unsuitable for drinking
7	1018	unsuitable for drinking	959	unsuitable for drinking
8	2997	unsuitable for drinking	539	unsuitable for drinking
9	1157	unsuitable for drinking	788	unsuitable for drinking
10	1521	unsuitable for drinking	1274	unsuitable for drinking
11	1431	unsuitable for drinking	855	unsuitable for drinking
12	1278	unsuitable for drinking	897	unsuitable for drinking
13	1392	unsuitable for drinking	824	unsuitable for drinking
14	1030	unsuitable for drinking	650	unsuitable for drinking
15	1122	unsuitable for drinking	604	unsuitable for drinking
16	1024	unsuitable for drinking	751	unsuitable for drinking
17	878	unsuitable for drinking	624	unsuitable for drinking
18	1115	unsuitable for drinking	621	unsuitable for drinking
19	1879	unsuitable for drinking	610	unsuitable for drinking
20	1132	unsuitable for drinking	828	unsuitable for drinking

permissible limit. Lead is toxic and non-essential metal, and the high concentration of Pb recorded in this study reflects the increased urban activity around the studied wells. The high concentration of lead during wet season compare to the dry season may be due to the low evaporation rate as a result of decrease the temperature rate and subsequent inflow of groundwater leading to the accumulation of this metal (Bhardwaj *et al.*, 2017). Present result is in agreement with previous work (Hajar Ameen Ameen, 2019); (Shaymaa *et al.*, 2019) and (Joda *et al.*, 2019).where they recorded high concentration of Pb in ground water in deferent city in Iraq.

Cu means concentration were within the perdition standard limit of Iraqi guideline (Table 3) in both of seasons (0.23±0.1 and 0.08±0.04 mg/L), dry and wet seasons respectively. The means concentration of Zn in the studied wells (Table 4) were within the perdition limit (Table 3), dependently can be conclude that there no contamination with this metals in the studied area, and this finding is in agree with the previous works (Al-paruany *et al.*, 2018) and (Mahmood and Hussein, 2015). Means concentration of Iron in all the studied wells as appeared in Table 4, the means concentration of Iron in both studied season was over the permitted limited (Table 3). Iron may be released to water from natural deposits, manufacturing wastes, and corrosion of Iron covering metals. Present result is in agreement within previous work (Mahmood and Hussein, 2015); (Al-paruany *et al.*, 2018). The last studied metals (Mn) recorded mean concentration higher of promotion limit recorded by both of Iraqi guideline and WHO guidelines (table 3).

Water quality index (WQI)

WQI is formed by, depending of some important physicochemical variables measurement for the studied wells. The values of some physicochemical parameters for the calculation of WQI are presented in Tables 4. The results of the WQI are listed in Table 5. WQI values at the wet season appear to have the lowest average of 795.6, with range values from 604 to 1274 and the highest average 1372.1 with range values 878 to 2997 at the dry season, respectively. The WQI values indicate that groundwater is classified as unfit for drinking and human consumption (Table 5). These results belong to high water salinity (TDS) and most other chemical parameters were exceeded the permissible limits of drinking guideline of all studied wells (Table 4).

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