*Kufa Journal of Engineering*
*Vol. 8, No. 1, January 2017, P.P.51-64*
*Received 27 April 2016, accepted 28 September 2016*

# THE USE OF WATER QUALITY INDEX TO EVALUATE GROUNDWATER QUALITY IN WEST OF BASRAH WELLS

**Dr. AHMED NASEH AHMED HAMDAN[1]**

**[1] Department of Civil Eng., College of Eng., Univ. of Basrah, Basrah-Iraq; ahmed_n_ahmed2005@yahoo.com**

## ABSTRACT

Groundwater is an important natural resource necessary for drinking use for many societies all over the world, particularly in the rural areas. Due to water shortage problem in southern part of Iraq, the need arises to use the ground water especially in west of Basrah governorate, where it is considered as an important agricultural area in Iraq that supplies other areas of the country by main vegetable crops.

Twenty-seven wells were chosen to be study cases for hydrochemical sampling and analyzing to determine the physical and chemical properties then compared with the requirements of World Health Organization (WHO 1993), and different water classifications, to estimate the groundwater suitability for different purposes.

The collected samples in the field were analyzed for total dissolved solids (TDS), electrical conductivity (EC), pH, major cations like magnesium, calcium, sodium, potassium and anions like chloride, nitrate, carbonate, bicarbonate, and sulphate, in the laboratory.

Water Quality Index (WQI) was used to assess the suitability of groundwater from the study area for human consumption. It has been calculated for each sample taken from wells and were compared to the standard guideline values as recommended by the (WHO) for drinking and public health in order to have an indication of the present quality of groundwater. According to the overall evaluation of the sites, almost all the parameters analyzed are above the desirable limits of WHO, therefore it was concluded that the quality of groundwater from the studied areas were not suitable for domestic purposes and far from drinking water standards.

**KEYWORDS:** Water quality index; Water quality; Ground water; Basrah wells

# استخدام مؤشر جودة المياه لتقييم نوعية المياه الجوفية في ابار غرب البصرة

د. احمد ناصح احمد حمدان

**الخلاصة**

تعتبر المياه الجوفية من أهم الموارد الطبيعية اللازمة للشرب لكثير من المجتمعات وفي جميع أنحاء العالم، ولاسيما في المناطق الريفية. ونظرا لمشكلة نقص المياه في الجزء الجنوبي من العراق، تبرز الحاجة إلى استخدام المياه الجوفية وخاصة في غرب محافظة البصرة. حيث تعتبر منطقة زراعية مهمة في العراق والتي تزود مناطق أخرى من البلاد بمحاصيل الخضروات.

قد تم اختيار سبعة وعشرين بئرا لتكون حالات للدراسه لأخذ العينات الكيميائيه وتحليلها لتحديد الخصائص الفيزيائية والكيميائية ومقارنتها مع منظمة الصحة العالمية (WHO 1993)، وتصنيفات المياه الاخرى، لتقدير مدى ملائمة المياه الجوفية لأغراض مختلفة.

وقد تم عمل تحليل مختبري لعينات المياه التي تم جمعها في المواقع كالمواد الصلبة الذائبة (TDS) ,التوصيل الكهربائي (EC)، ودرجة الحموضة (PH) ,الكاتيونات الرئيسية مثل المغنيسيوم والكالسيوم والصوديوم والبوتاسيوم والايونات مثل الكلوريد، النترات البيكربونات والكربونات، والكبريتات.

ثم تم حساب مؤشر جودة المياه (WQI) لتقييم مدى ملائمة المياه الجوفية في منطقة الدراسة للاستهلاك البشري ولكل نموذج ماخوذ من بئر للمياه الجوفية وتم مقارنتها بالقيم المرجعية القياسية على النحو الموصى به من قبل منظمة الصحة العالمية للشرب والصحة العامة من أجل أن يكون مؤشرا على النوعية الحالية للمياه الجوفية. وفقا لتقييم شامل من المواقع، وجد تقريبا جميع المعاملات التي تم تحليلها هي فوق الحدود المرغوب بها من منظمة الصحة العالمية، ولذلك كان الاستنتاج أن العينات غير مناسبة للأغراض المنزلية وبعيدة عن معايير مياه الشرب.

## 1. INTRODUCTION

Groundwater is an essential natural resource, depending on its usage and consumption, it is estimated that approximately one third of the world's population use groundwater for drinking, Arumugam et al. (2009), in recent years surface water in Iraq suffers from a decrease of flow rates due to the policy of the countries of the source, that causes a shortage water problems in Iraq for drinking and irrigation especially in Basrah governorate (south of Iraq). West of Basrah (regions of Al Zubair, Safwan, Khour Al Zubair, and Um Qaser) is far away from the rivers, and it depends mainly on ground water for irrigation in most places in that region and has been exploited to produce drinking water by using a desalination plants, therefore it is an important to study the quality of wells in west of Basrah for a particular use. Suitability of groundwater for domestic and irrigation purposes is determined by its groundwater geochemistry.

Direct rainfall recharge is considered as the main source of recharge in the study area; the Dibdibba aquifer has high values of permeabilities, direct recharge within rainstorms, accessibility and association with soils suitable for cultivation. The average of infiltration of soil is more than 2 m/day, Manhi, (2012).

Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of water to concerned citizens and policy makers. Therefore, it becomes an important parameter for the evaluation and management of groundwater. WQI is defined as a rating reflecting the composite influence of various water quality parameters; WQI is calculated from the standpoint of the suitability of groundwater for human consumption.

Numerous studies on Groundwater quality assessment in the West of Basrah have been made, such as Al-Aboodi (2003), studied groundwater characteristics in Safwan-Zubair area and found that the groundwater in studied region is not suitable for human drinking. Also, Manhi,(2012) studied groundwater contamination in Safwan area and concluded that the groundwater was unsuitable to direct use as a human drinking, industrial, and building purposes. On the other hand, with regarding to suitability for irrigation, the researcher concluded that the groundwater was unsuitable for irrigation, but it has been used successfully in irrigation due to high infiltration soil conditions and continuous irrigation. Accordingly, the researcher concluded that the human activities especially agriculture are the main source of the groundwater contamination together with the different waste sources such as sewage, garbage, desalination plants, and polluted air. Mahmood, A. et al. (2013) studied groundwater quality in Bergussia and Al –Zubair, in Basrah city,. He found the values of WQI ranged from 2052 to 3511 in Burgussia and from 2219 to 3743 in Al- Zubair and rated unfit to human consumption according to the classification of Tiwari and Mishra (1985). Moreover, Al-Tememi, M.(2015) studied groundwater quality and origin within Dibdibba aquifer near Jabel Sanam area southern of Basrah Governorate, Iraq, and found that the groundwater quality was classified to chloride group-sodium family-type ($Na^{+}$ $>Ca^{2+}$ $>Mg^{2+}$). On the other hand, the groundwater origin investigated by Sullin diagram which showed that old meteoric origin for all studied wells.

The aim of the present work is to discuss the suitability of groundwater for human consumption based on computed water quality index values.

## 2. AREA OF STUDY

The area of study lies between latitudes 30$^o$ 1’ 54.3’’ N – 30$^o$ 29’ 3.7’’ N and longitudes 47$^o$ 30’ 52.9’’ E - 47 $^o$ 55’ 37.8’’ E , and it is a part of Dibdibba plain (the Dibdibba plain is considered as a part of southern desert extended from the south to central parts of Iraq), Manhi, (2012), the area of study is located in approximately 17 km west of Basrah center, The total area of study is about 2500 km$^2$.

The Dibdiba aquifer is set by two horizontal aquifer formations. The first formation is generally unconfined and has a saturated thickness of about 20 m. The second formation makes up the rest of the aquifer thickness. A consolidated, silty, clay bed with gypsum, locally referred “Chauchab”, usually separates the two formations. The first upper portion of the aquifer is the one thought to be naturally rechargeable, and that presently plays the most significant role as a resource for groundwater-based agriculture in the Safwan, Al Zubair, and Jebal Sanam regions west of Basrah, AL Dahaan, (2014).

In Safwan and Um Qaser area, the upper part of the groundwater is isolated by clay layer, while in Al-Zubair area in the west side of studied area, the clay layer either absent or within the aquifer.

In the study area, due to the ground slopes towards the lowlands of Basrah center, therefore the groundwater flows towards the Shatt al Arab River.

West of Basra has a hot desert climate, like the rest of the surrounding areas, although it has a little more precipitation than the interior locations due to its location near the coast. During Summer Months, Basrah is always one of the most important cities in the world, with temperatures exceeding 50°C regularly in the months of July and August. In winter, Basra experiences mild weather with average high temperatures around 20 °C. On some Winter Nights, minimum temperatures are below 0 °C. High humidity sometimes exceeding 90% is common due to the proximity to the Arabian Gulf.

West of Basrah area is considered as an important agricultural area in Iraq that supplies other areas of the country by main vegetable crops. Recently, and in addition to some other activities, groundwater in the study area has been exploited to produce drinking water by some of desalination plants, Manhi (2012). The average production from these wells is 4 l/sec, the depths of wells were arranged from 20 to 30 m and encased by steel pipes that are ranged between 8 5/8 " to 13 3/4 " in diameter, Water Resources Ministry, Water Resources directorate in Basrah, (Unpublished report).

Based on the climate data for the meteorological station of Basra for the period 1980-2015, the climate is classified as sub-arid to arid climate due to the decrease in the annual average of rain water and an increase in the average temperature, which causes drought conditions dominate, especially after 1997. In this study and during the rainy months, the maximum monthly averages is (28.4 mm) in December, 2013, and the minimum is (3.6 mm) in October, 2014, and the total rainfall annual average is (137.4 mm), Environmental statistics report in Iraq (2013).

## 3. FIELD WORK

Twenty seven wells were chosen to be the sites of hydrochemical sampling, and the data were carried out by the directorate of water resources in Basra, Water Resources Ministry, Water Resources directorate in Basrah, (Unpublished report). The samples were taken from December, 2013 until November, 2014. Figs. 1 and 2 show wells location. The locating of wells were specified by using GPS.

The water samples collected in the field were analyzed for total dissolved solids (TDS), electrical conductivity (EC), pH, major cations like magnesium, calcium, sodium, potassium and anions like chloride, nitrate, carbonate, bicarbonate, and sulphate, in the laboratory using the standard methods of American Public Health Association (APHA 1995). Samples were taken using polyethylene (PE) pre-cleaned containers. Results were evaluated according to the criteria provided by the World Health Organization drinking water quality (WHO 1993).

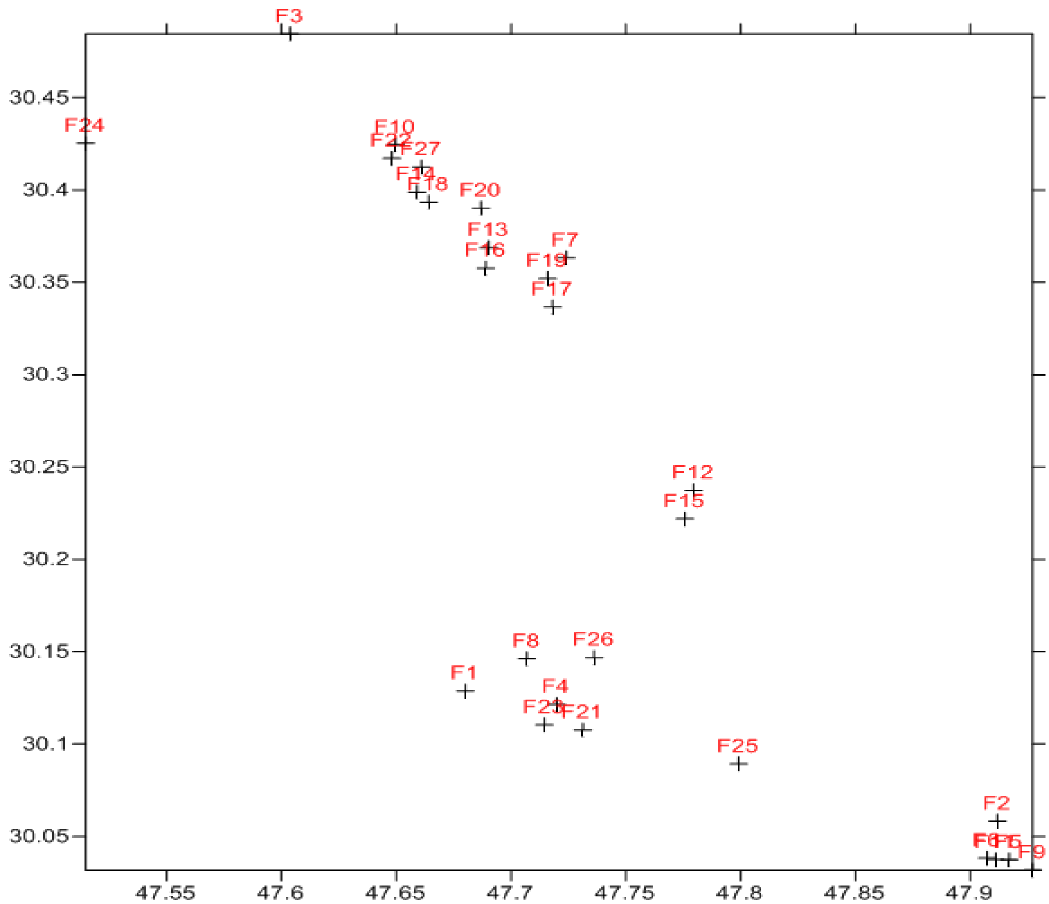


**Fig. 1. Location of wells.**

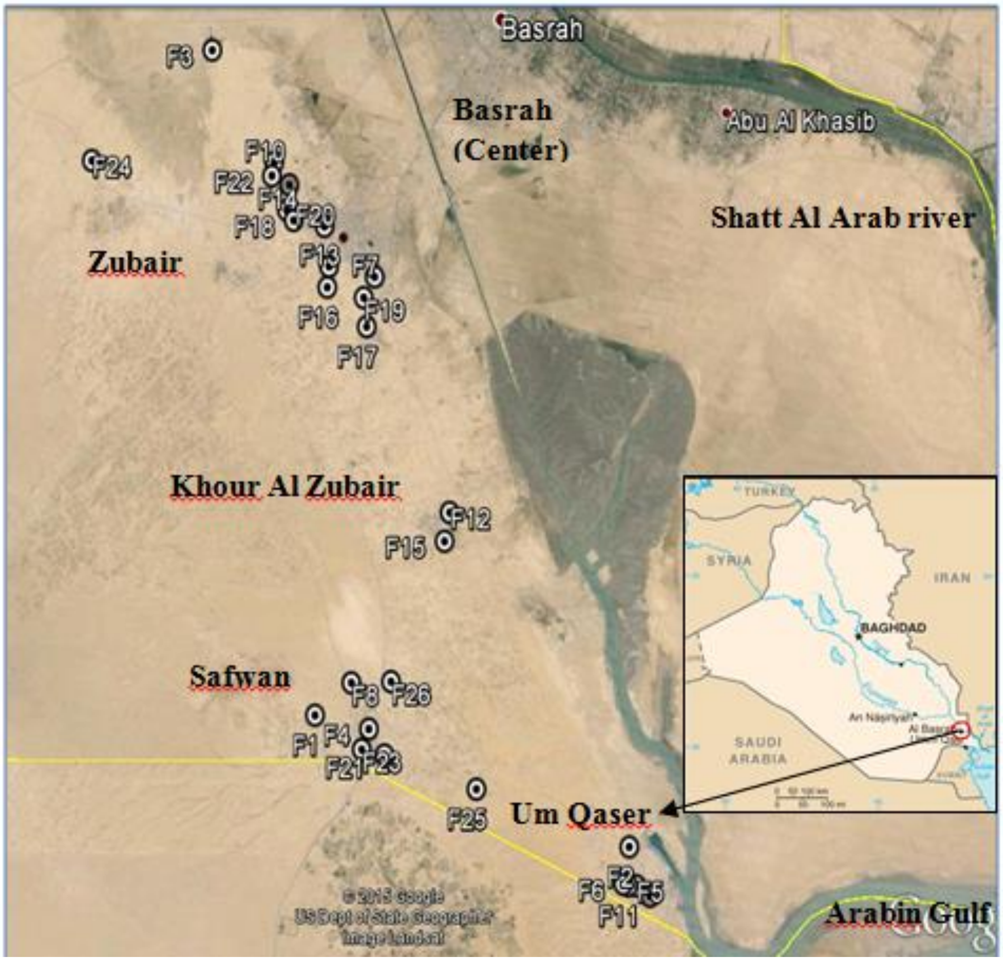


**Fig. 2. Location of the study area and ground water samples.**

## 3.1. DRINKING WATER QUALITY

The physical and chemical parameters of the analytical results of groundwater were compared with the standard guideline values recommended by the World Health Organisation (WHO 1993) for drinking and public health standards. Table 1 includes the limits of the most desirable and the maximum allowable limits of various parameters.

**Table 1. Number and percentage of groundwater samples of the study area that exceeding the allowable limits prescribed by WHO for domestic purposes, Arumugam et al. (2009).**

| Water quality parameters | WHO (1993) | | Number of samples exceeding allowable limits | Percentage of samples exceeding allowable limits |
|---|---|---|---|---|
| | Most desirable limits | Maximum allowable limits | | |
| pH | 8.5 | 9.2 | Nil | Nil |
| TDS (mg/l) | 500 | 1,500 | 26 | 96.30 |
| EC(µS/cm) | - | 1,500 | 27 | 100.00 |
| $Ca^{2+}$ mg/l | 75 | 200 | 27 | 100.00 |
| $Mg^{2+}$mg/l | 50 | 150 | 16 | 60.00 |
| $K^{+}$ mg/l | - | 12 | 25 | 92.60 |
| $Na^{+}$mg/l | - | 200 | 21 | 77.78 |
| $Cl^{-}$ mg/l | 200 | 600 | 22 | 81.48 |
| $NO_3^{-}$ mg/l | 45 | - | 3 | 11.11 |
| $So_4^{2-}$ mg/l | 200 | 400 | 26 | 96.30 |
| $HCO_3^{-}$ mg/l | - | 120 | 19 | 70.30 |

## 3.2. CALCULATION OF WATER QUALITY INDEX (WQI)

For calculating WQI, three steps were followed. In the first step, each of the 10 parameters (TDS, pH, Cl, $SO_4$, HCO, NO, Ca, Mg, Na, and K) has been assigned a weight (wi) based on their perceived effects on primary health (Table 2). The maximum weight of 5 has been assigned to parameters like TDS, chloride, sulfate, and nitrate due to their major importance in water quality assessment. Bicarbonate is given the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like calcium, magnesium, sodium, and potassium were assigned a weight between 1 and 5 depending on their importance in the overall quality of water for drinking purposes (Rokbani, 2011).

In the second step, the relative weight ($W_i$) of each parameter is computed using Eq. (1):

$$W_i = \frac{w\,i}{\sum_{i=1}^{n} wi} \qquad (1)$$

Where, wi is the weight of each parameter, n is the number of parameters and Wi is the relative weight.

The weight (wi), the calculated relative weight (Wi) values and the WHO standards for each parameter are given in Table 2.

In the third step, quality rating scale (qi) was calculated for each parameter using Eq. (2):

$$qi = \frac{c\,i}{s\,i} * 100 \qquad (2)$$

Where, qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/l and Si is the WHO standard for each chemical parameter in mg/l (Table 2).

For computing the WQI, the Sli is first determined for each chemical parameter using Eq. (3) which is then used to determine the WQI as per Eq. (4).

$$Sli = W_i * q_i \quad (3)$$

$$WQI = \sum_{i=1}^{n} Sli \quad (4)$$

Where, Sli is the sub-index of $i^{th}$ parameter $q_i$ is the rating based on concentration of $i^{th}$ parameter and n is the number of parameters. Computed WQI values are usually classified into five categories as shown in Table 3.

Excellent, good, poor, very poor and unfit for human consumption, Rokbani, (2011).

**Table 2. WHO standards and the calculation of relative weight (Wi)**

| Chemical parameters | WHO Standard | Weight (wi) | Relative weight (Wi) |
|---|---|---|---|
| pH | 8.50 | 3 | 0.103 |
| TDS (mg/l) | 500 | 5 | 0.172 |
| $Ca^{2+}$ mg/l | 75.0 | 2 | 0.068 |
| $Mg^{2+}$mg/l | 50.0 | 2 | 0.068 |
| $K^{+}$ mg/l | 12.0 | 1 | 0.034 |
| $Na^{+}$mg/l | 200 | 3 | 0.103 |
| $Cl^{-}$ mg/l | 250 | 3 | 0.103 |
| $NO_3^{-}$ mg/l | 45.0 | 5 | 0.172 |
| $So4^{2-}$ mg/l | 250 | 3 | 0.103 |
| $HCO_3^{-}$ mg/l | 120 | 2 | 0.068 |
| | | $\sum w\, i$=29 | $\sum W\, i$=1 |

**Table 3. Categories of WQI**

| Type of water | WQI Range |
|---|---|
| Excellent water | < 50 |
| Good water | 50-100.1 |
| Poor water | 100-200.1 |
| Very poor water | 200-300.1 |
| Unfit for drinking | > 300 |

## 4. RESULTS AND DISCUSSION

Evaluating water quality index for groundwater is important to determine their suitability for drinking use. Physical and chemical parameters including statistical measures, such as minimum, maximum, average, and standard deviation of EC, TH, pH, TDS, $Cl^{-}$, $Mg^{2+}$, $Ca^{2+}$,$CO_3$, $Na^{+}$, $K^{+}$, $NO_3^{-}$, $SO_4^{2-}$, and $HCO_3^{-}$ are listed in Table 4.

TDS amount ranges from 1200 mg/l to 10,790 mg/l with an average of 6,018 mg/l as shown in Table 4, according to WHO specification (Table 1); it can be shown that all the wells exceeds allowable limits.

The EC ranges between 1,720 and 18,030 µS/cm with an average of 8,601µS/cm as shown in Table 4. Knowing that the maximum limit of EC in drinking water is prescribed as 1,500µS/cm at 25°C, Rokbani, (2011). From Table 4, it can be shown that all the wells were higher permitted value for drinking water purposes.

pH is one of the most important operational water quality parameters with the optimum pH at the desired range of 6.5 -8.5. The maximum allowable limit of pH in drinking water as given by the WHO is 9.2 mg/l. The values of pH in the groundwater samples collected varied from 6.80 to 8.70 with an average value of 7.48 (Table 4). This shows that the groundwater of the study area was rather alkaline in most wells, and that all the samples displayed a pH value within the maximum permissible limit.

Water with hardness (TH) higher than 200 mg/l may cause scale formation in the distribution system. The high concentration of hardness in the range of 150-300mg/l and above may cause heart diseases and kidney problems. Groundwater exceeding the limit of 300mg/l is considered to be very hard. In this study, TH is in the range of 740-6950 mg/l with an average of 2,418 mg/l, so it can be shown that all TH values exceeds the permissible limits as shown in Table 1.

The magnesium ($Mg^{2+}$) ion concentration is in the range of 3.96 to 365 .49 mg/l with an average value of 165.38 mg/l. Table 4 shows that 60 % of the wells exceeds the maximum allowable limits of WHO specifications which is 150 mg/l; the high total concentrations of $Ca^{2+}$ and $Mg^{2+}$ are important factors which increase the hardness of waters.

Calcium ($Ca^{2+}$) concentration ranges between 257 to 1,002 mg/l with an average value of 648.49 mg/l. Table 4 shows that all the wells exceeds the maximum allowable limits of WHO specifications which is 200 mg/l.

Sodium ($Na^{+}$) concentration ranges between 12.2 to 763 mg/l with an average value of 382.11 mg/l. Table 4 shows that 78% of the wells exceeds the maximum allowable limits of WHO specifications which is 200 mg/l.

Potassium ($k^{+}$) concentration ranges between 4.60 to 267.2 mg/l with an average value of 73.38 mg/l. Table 4 shows that all the wells except F14 and F22 exceeds the maximum allowable limits of WHO specifications which is 12 mg/l.

The chloride ($Cl^{-}$) concentration ranges from 249.58 to 4,248.7 with an average value of 1,797.57 mg/l, The chloride ion concentration in groundwater of the study area exceeds the maximum permissible limit of 600mg/l in all wells excepts F9, F12, F14, F15, and F20 as shown in Table 4.

Nitrates ($NO_3^{-}$) are the end product of aerobic stabilization of organic nitrogen and a product of conversion of nitrogenous material. This phenomenon occurs in the polluted water. Nitrate concentration of groundwater samples varied from 6 to 86 mg/l with an average value of 31.14 mg/l (Table 4). In the studied wells, nitrate concentration was below allowable limit which is (45 mg/l) in all wells except F3, F11and F24, i.e. 89% of wells was within the acceptable limits of WHO specifications.

The bicarbonate ($HCO_3^-$) ion concentration was relatively low compared to chloride, and sulphate ion concentrations range from 61 to 296 mg/l with an average value of 156.15 mg/l. Table 4 shows that 70.3% of the wells exceeds the maximum allowable limits of WHO specifications which is 120 mg/l.

From Table 4, it can be shown that west of Basrah wells were characterized by a high sulphate ion content, which is the dominant anion. Its concentration ranges between 290 and 4,408 mg/l with an average value of 2,292 mg/l. Table 4 shows that all wells except F14 exceeds the maximum allowable limits of WHO specifications, which is 400 mg/l.

The calculation of WQI is represented in Table 5. It is obvious from this classification that on the basis of the WQI groundwater from the study area is not of acceptable quality for human consumption, where all WQI values were greater than 300, Which is classified as unfit for drinking, except the sample F 14 which classified as poor water and F 20 which is classified as very poor water, See Fig. 3.

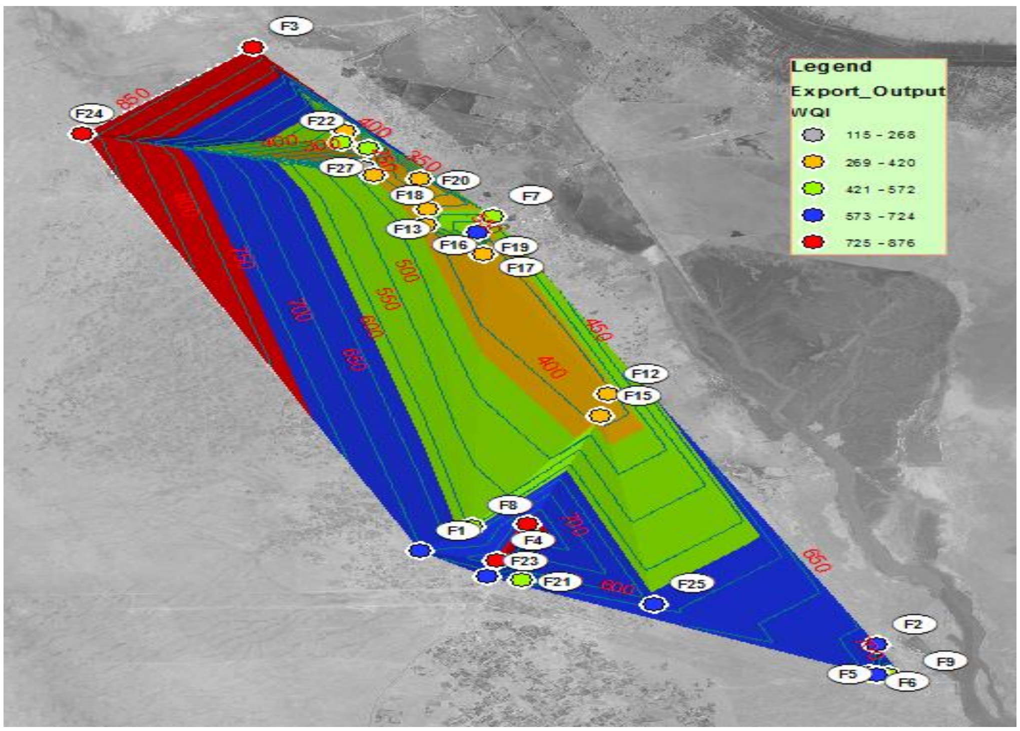


**Fig. 3 : Distribution of WQI**

**Table 4. Normal statistics of water quality parameters of groundwater samples**

| Well No | Longitude | Latitude | EC μ/cm | TH mg/l | pH | TDS mg/l | $Cl^-$ mg/l | $Mg^{2+}$ mg/l | $Ca^{2+}$ mg/l | $CO_3$ mg/l | $Na^+$ mg/l | $K^+$ mg/l | $NO_3^-$ mg/l | $So_4^{2-}$ mg/l | $HCO_3^-$ mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | 47.68011111 | 30.12880556 | 11670 | 2450 | 8.7 | 7650 | 2949 | 157.7 | 721.4 | 24 | 465.1 | 21 | 38.25 | 2929 | 122 |
| F2 | 47.91183333 | 30.05825 | 11570 | 2750 | 7.5 | 7850 | 2849 | 279.8 | 641.2 | 24 | 683 | 202.9 | 39.25 | 2832 | 122 |
| F3 | 47.60372222 | 30.48436111 | 18030 | 2850 | 7.7 | 10580 | 2598.8 | 365.49 | 541 | 60 | 763 | 65.2 | 52.9 | 4408 | 122 |
| F4 | 47.71983333 | 30.12147222 | 11280 | 3150 | 7.7 | 7720 | 2149 | 291.8 | 781 | 36 | 596.9 | 242 | 38.6 | 3360 | 219.6 |
| F5 | 47.91694444 | 30.0374444 | 9650 | 2750 | 7.6 | 5780 | 1849 | 316.4 | 581 | 84 | 503.9 | 34.5 | 28.9 | 2016 | 207.4 |
| F6 | 47.90738889 | 30.03830556 | 12000 | 2950 | 7.8 | 7310 | 3049 | 109 | 1002 | 24 | 616 | 207 | 36.55 | 2448 | 97.6 |
| F7 | 47.72405 | 30.36317222 | 2550 | 1750 | 7.4 | 5310 | 1499 | 84.6 | 526 | 24 | 179.5 | 25.7 | 26.55 | 2784 | 124 |
| F8 | 47.70688888 | 30.14613889 | 8810 | 2500 | 7.6 | 5820 | 1749 | 182.1 | 701.4 | 24 | 527.1 | 121.4 | 29.1 | 2256 | 134.2 |
| F9 | 47.92716667 | 30.03175 | 8550 | 2350 | 7.6 | 6140 | 249.58 | 243.34 | 541 | 160 | 458 | 57.3 | 7.9 | 2784 | 296 |
| F10 | 47.64966667 | 30.4243333 | 4570 | 1900 | 7.2 | 3660 | 700 | 3.96 | 753.5 | 60 | 225.9 | 12.4 | 18.3 | 1766 | 122 |
| F11 | 47.91108333 | 30.03747222 | 9870 | 2700 | 7.6 | 6990 | 1800 | 200.8 | 721 | 96 | 570.8 | 42.7 | 86 | 3408 | 73.2 |
| F12 | 47.77944444 | 30.23722222 | 5800 | 6950 | 7.2 | 4350 | 250 | 210 | 632 | 84 | 330.7 | 17.9 | 21.75 | 1956 | 123 |
| F13 | 47.69027778 | 30.36869444 | 4690 | 2820 | 7.3 | 3720 | 700 | 103.8 | 958 | 72 | 21.5 | 230.7 | 18.6 | 1344 | 292.8 |
| F14 | 47.65905556 | 30.39877778 | 1720 | 740 | 7.4 | 1200 | 300 | 24 | 257 | 48 | 71.4 | 4.6 | 6 | 290 | 122 |
| F15 | 47.77566667 | 30.22183333 | 5280 | 2200 | 7.3 | 3510 | 600 | 60 | 781.5 | 48 | 12.2 | 267.2 | 17.55 | 1448 | 244 |
| F16 | 47.689 | 30.35758333 | 6790 | 1900 | 7.5 | 4730 | 1449 | 60.2 | 661 | 120 | 366 | 14.4 | 23.65 | 1776 | 61 |
| F17 | 47.71811111 | 30.33652778 | 5950 | 1325 | 7.6 | 4165 | 850 | 164 | 260.52 | 39.9 | 127 | 59.6 | 20.825 | 1800 | 210 |
| F18 | 47.6641111 | 30.39327778 | 6450 | 2400 | 7.5 | 5120 | 1400 | 280 | 501 | 187.2 | 292.3 | 32.7 | 25.6 | 1200 | 120 |
| F19 | 47.71594444 | 30.352 | 12170 | 1700 | 8.1 | 8620 | 2149.3 | 170.3 | 400.8 | 110 | 251 | 103.8 | 43.1 | 1650 | 100 |
| F20 | 47.68688889 | 30.39011111 | 4670 | 1250 | 7.4 | 3390 | 600 | 109.4 | 320.64 | 83.4 | 116.5 | 43.1 | 16.95 | 1100 | 120 |
| F21 | 47.73130556 | 30.10755556 | 9260 | 2300 | 7.3 | 6710 | 2149 | 72.2 | 801.6 | 24 | 436.1 | 30.7 | 33.55 | 2496 | 170.8 |
| F22 | 47.648 | 30.41711111 | 4280 | 2100 | 7 | 3960 | 2300 | 210 | 777.5 | 103.6 | 280 | 10.9 | 19.8 | 1887 | 134 |
| F23 | 47.71458333 | 30.11047222 | 10000 | 1900 | 6.8 | 7150 | 2600 | 160 | 801.6 | 141 | 463 | 41.1 | 35.75 | 2100 | 256.2 |
| F24 | 47.51469444 | 30.42519444 | 15490 | 2800 | 7.4 | 10790 | 4248.7 | 206.4 | 781.5 | 96 | 687.2 | 25.9 | 53.95 | 3456 | 292.8 |
| F25 | 47.79908333 | 30.08927778 | 9970 | 2300 | 7.3 | 6750 | 2299 | 206.6 | 581.1 | 12 | 421.7 | 22.1 | 33.75 | 2928 | 122 |
| F26 | 47.73613889 | 30.14677778 | 13890 | 2750 | 7.1 | 8990 | 3798 | 96.5 | 941.8 | 24 | 525 | 17.4 | 44.95 | 3120 | 97.6 |
| F27 | 47.66091667 | 30.41233333 | 7290 | 1750 | 7.3 | 4530 | 1400 | 97 | 541.1 | 12 | 326.3 | 27 | 22.65 | 2352 | 109.8 |
| Max | - | - | 18,030.00 | 6,950.00 | 8.70 | 10,790.00 | 4,248.70 | 365.49 | 1,002.00 | 187.20 | 763.00 | 267.20 | 86.00 | 4,408.00 | 296.00 |
| Min | - | - | 1,720.00 | 740.00 | 6.80 | 1,200.00 | 249.58 | 3.96 | 257.00 | 12.00 | 12.20 | 4.60 | 6.00 | 290.00 | 61.00 |
| Av. | - | - | 8,601.85 | 2,417.96 | 7.48 | 6,018.33 | 1,797.57 | 165.38 | 648.49 | 67.45 | 382.11 | 73.38 | 31.14 | 2,292.37 | 156.15 |
| SD | - | - | 3,952.71 | 1,074.87 | 0.36 | 2,287.15 | 1,072.54 | 92.63 | 196.24 | 47.49 | 210.43 | 81.12 | 16.37 | 885.36 | 69.39 |

**Table 5. Calculation of WQI with corresponding classification**

| Sample | WQI | Classification |
|---|---|---|
| F1 | 654.17 | Unfit for drinking |
| F2 | 723.95 | Unfit for drinking |
| F3 | 845.62 | Unfit for drinking |
| F4 | 738.87 | Unfit for drinking |
| F5 | 521.51 | Unfit for drinking |
| F6 | 702.94 | Unfit for drinking |
| F7 | 460.99 | Unfit for drinking |
| F8 | 543.05 | Unfit for drinking |
| F9 | 487.17 | Unfit for drinking |
| F10 | 334.14 | Unfit for drinking |
| F11 | 635.43 | Unfit for drinking |
| F12 | 372.50 | Unfit for drinking |
| F13 | 412.18 | Unfit for drinking |
| F14 | 115.31 | Poor Water |
| F15 | 389.85 | Unfit for drinking |
| F16 | 408.21 | Unfit for drinking |
| F17 | 350.88 | Unfit for drinking |
| F18 | 416.74 | Unfit for drinking |
| F19 | 586.85 | Unfit for drinking |
| F20 | 271.06 | Very Poor Water |
| F21 | 567.20 | Unfit for drinking |
| F22 | 448.93 | Unfit for drinking |
| F23 | 605.95 | Unfit for drinking |
| F24 | 876.45 | Unfit for drinking |
| F25 | 584.97 | Unfit for drinking |
| F26 | 756.07 | Unfit for drinking |
| F27 | 420.85 | Unfit for drinking |

## 4.1. TOTAL DISSOLVED SOLIDS

To establish the suitability of groundwater for any purposes, it is necessary to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Freeze and Cherry 1979; Davis and DeWiest 1966) which are represented in Tables 6 and 7, respectively. The groundwater of the study area is not a fresh water it was a brackish water for all samples except F3 and F24 which was located in the north part of study area (Akl Zubair district), which is considered as a saline water based on Freeze and Cherry (1979) classification.

The study shows that there is no sample is below 1000 mg/l that mean there is no well is permissible for drinking, so there was one well which is F14 (located in the center of Al Zubair district) have a TDS value between 1000 and 3000 mg/l which is classified as useful for irrigation and the rest of the samples classified as unfit for drinking and irrigation, because there values exceeds 3000 mg/l based on Davis and DeWiest (1966) classification.

**Table 6. Groundwater classification of all ground waters, (Freeze and Cherry, 1979)**

| Total dissolved solids (mg/l) | Classification | Sample numbers | Number of samples | Percentage of samples |
|---|---|---|---|---|
| <1000 | Fresh water type | Nil | 0 | 0.00 |
| 1000–10,000 | Brackish water type | All /F3 and F24 | 25 | 92.6 |
| 10,000–100,000 | Saline water type | F3 and F24 | 2 | 7.40 |
| >100,000 | Brine water type | Nil | 0 | 0.00 |
| Total | | | 27 | 100 |

**Table 7. Groundwater classification of all ground waters, (Davis and DeWiest, 1966)**

| TDS (mg/l) | Classification | Sample numbers | Number of samples | Percentage of samples |
|---|---|---|---|---|
| <500 | Desirables for drinking | Nil | 0 | 0.00 |
| 500–1,000 | Permissible for drinking | Nil | 0 | 0.00 |
| 1,000–3,000 | Useful for irrigation | F14 | 1 | 3.70 |
| >3,000 | Unfit for drinking and irrigation | All/ F14 | 26 | 96.3 |
| Total | | | 27 | 100.0 |

## 5. CONCLUSIONS

1. The WQI results verify that the groundwater in the study area is unsuitable for direct consumption as human drinking water.
2. The high value of WQI at these stations has been found to be mainly from the higher values of TDS in the groundwater.
3. The effect of sea water intrusion to the wells was well observed.
4. F14 well was classified as poor water, and F20 was very poor water.
5. Depending on TDS values and by using Davis and DeWiest calcification, 96.3% of wells were considered as unfit for drinking and irrigation. And based on Freeze and Cherry classification, 92.6% were considered as brackish water type and 7.4 % as saline water type.
6. Analysis revealed that the groundwater in the region needs to be some degree of treatment before consumption, and also must be protected from the risk of contamination.

## 6. SUGGESTIONS

Where most wells were unsuitable for drinking purpose, therefore the most suitable treatment technique for salinity removal is Reverse Osmosis units.

## 7. REFERENCES

Arumugam, K. and Elangovan, K.(2009), "Hydrochemical characteristics and groundwater quality assessment in Tirupur Region, Coimbatore District, Tamil Nadu, India", Environmental Geology Journal , 58: 1509–1520.

Manhi, H.(2012),"Groundwater contamination study of the upper part of the dibdibba aquifer in safwan area (southern iraq)", M.S. Thesis, University of Baghdad, College of Science, Department of Geology.

Al-Aboodi, A. H. (2003), "A study on groundwater characteristics in Safwan Zubair area", M.Sc. Thesis, College of Engineering, University of Basrah, 105 P.

Mahmood, A., Eassa, A., Mohammed, M. and Shubbar, I. (2013), "Assessment of ground water quality at Basrah, Iraq by water quality index (WQI).", Journal of Babylon University, 7(21): 2531-2543

Al-Tememi, M.K.(2015), " Groundwater quality and origin within Dibdibba aquifer near Jabel Sanam area southern of Basrah Governorate, Iraq", Mesopot Journal, Marin Science Center, University of Basrah, Basra, Iraq, 30(1): 47 – 56.

**S**.A.J.M., AL Dahaan, S. (2014), " Evaluation of Groundwater for I irrigation at Safwan area, South Iraq", Conference of geotunis8,

Water Resources directorate in Basrah, the Ministry of Water Resources, Discharge, parameters, and aquifer description records from 2012 until 2014, (unpublished).

Directorate of Environmental Statistics, Ministry of Planning, Central Bureau of Statistics, Environmental statistics report in Iraq, (2013).

Rokbani, M. (2011)," Use of Geographical Information System and Water Quality Index to Assess Groundwater Quality in El Khairat Deep Aquifer (Enfidha, Tunisian Sahel)", Iranica Journal of Energy & Environment, 2 (2): 133-144.

Aladejana J.A. and Talabi A. O. (2013), "Assessment of Groundwater Quality in Abeokuta Southwestern, Nigeria", International Journal of Engineering and Science, 2(6): 21-31.

Ganeshkumar B. and Jaideep C.( 2011), "Groundwater quality assessment using Water Quality Index (WQI) approach – Case study in a coastal region of Tamil Nadu, India", International Journal of Environmental Sciences and Research, 1( 2) : 50-55.

Dabral1, S., Bhatt, B., Joshi, P. and Sharma, N. (2014), "Assessment and spatial distribution of quality of groundwater in mahi-narmada inter stream region gujarat india using water quality index (wqi)", International Journal of Geology, Earth and Environmental Sciences, 4(1): 184-195.

Ramakrishnaiah, C., Sadashivaiah, C. and Ranganna, G. (2009)" Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India", E-Journal of Chemistry, 6(2): 523-530.

Ibrahim M. A. (2012)"Assessment of Water Quality Status for the Euphrates River in Iraq ", Engineering & Technology Journal, 30(14): 2536-2549.