

Groundwater quality assessment for drinking purposes using water quality index in Ali Al-Gharbi District, Iraq

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Abstract: The present study aimed to assess groundwater quality according to the water quality index (*WQI*) in Ali Al-Gharbi district of the Maysan Governorate in eastern Iraq. For this purpose, 10 physical parameters such as pH, total hardness (*TH*), magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), sodium (Na^+), sulphate (SO_4^{2-}), chloride (Cl^-), nitrate (NO_3^-), and total dissolved solids (*TDSs*) were examined since 2019 from 16 different locations (*viz.* wells). The analysis results indicated that 18.75% of the water samples were of good quality, 56.25% of them had low quality, and 25% of such samples were very poor. The *WQI* also varied from 69.67 and 297.6. Therefore, prior to water use, there is a dire need for some treatments, as protecting this district from pollution is significant.

Keywords: drinking water, groundwater, Iraq, water quality index

INTRODUCTION

The world's arid and semi-arid regions heavily depend on groundwater as one of the main water supplies, which is also among the most important sources for drinking purposes as well as agricultural and industrial activities [AFSHAR *et al.* 2021; MOLAJOU *et al.* 2021]. In this sense, the water quality index (*WQI*), classified as a rating scale, represents the spillover effect of the water quality parameters, and is calculated for the purposes of human consumption based on the health of groundwater [AFSHAR *et al.* 2020; JHA *et al.* 2020; OWAMAH 2020; RAMAKRISHNAIAH *et al.* 2009]. Besides, groundwater resources are the most notable ones used for agriculture and drinking in many countries across the world, especially in nations such as Iraq, characterized with an arid and semi-arid climate. On the other hand, the risk of less pollution in these resources compared with those resulting from other water treatment methods has led to their use to flourish even in regions where there is no shortage of surface water.

To determine the suitability of groundwater resources for human use, some parameters for groundwater samples should be analysed. In this line, the *WQI* digitally summarizes the single-value water quality parameters utilized to assess temporal changes [KRISHAN *et al.* 2016; SHIRAZI *et al.* 2015]. The *WQI* as a highly efficient gadget is the commonly used method for measuring

water quality worldwide to communicate it completely [AL-MOHAMMED, MUTASHER 2013; BENRABAH *et al.* 2016; HERNANDEZ CORDERO *et al.* 2020]. The *WQI* is also one of the most important references for people and decision-makers to communicate water quality knowledge [SUKUMARAN *et al.* 2015].

In several places, the scarcity of surface water contributes to an urgent need for groundwater, wherein it is considered as the primary source [PICHIAIAH *et al.* 2015]. Accordingly, awareness of physical, chemical, and biological characteristics of water is related to water quality knowledge [SANTHOSH, REVATHI 2014; ZAYED, ELHDAD 2017]. Several factors, including environment, rock form, soil characteristics, human activities, and terrain, can thus influence water quality [KELMENDI *et al.* 2018; PRASANNA *et al.* 2010].

In this regard, groundwater is a significant reservoir as a fresh water source, and even an important one to be exploited optimally by policy-makers. Natural soil and sediment filtration also make it free of impurities [KARANTH 1989]. Regional geological conditions, rock and soil geochemistry, along with land-use trends are thus the key factors influencing groundwater chemistry [KUMAR *et al.* 2006].

The present study was to apply the *WQI* and its relevance for human consumption to groundwater in Ali Al-Gharbi district of the Maysan Governorate, eastern Iraq. For this purpose, pH,

total hardness (*TH*), total dissolved solids (*TDS*s), cations (Ca, Mg, Na, K), and anions (K, Cl, bicarbonate [HCO_3], SO_4 , NO_3) were analysed in sixteen samples from the water wells located in the study area (i.e., one sample for each well). According to the *WQI*, water quality in these wells was clarified.

MATERIALS AND METHODS

STUDY AREA

The study area covers 659.74 km² northwest of the Maysan Governorate, eastern Iraq, between the latitude 31.8734° N and the longitude 47.1362° E, bordering Iran (Fig. 1).

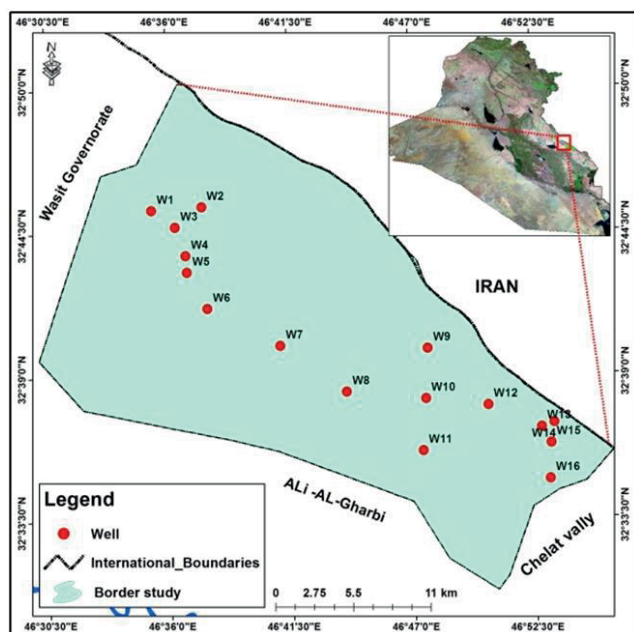


Fig. 1. Study area location; source: own elaboration

FIELD GEOLOGY

The geology of the study area involves numerous geological units dating back to the recent period. Sandstone, silt, conglomerate, gray and red marls, and modern glacial ice [PIRASTEH *et al.* 2010] also dominate the rocks in this area. Besides, the geological formation of the study area is the “Injana formation” characterized with siltstone, sandstone, and conglomerate as its constituent. As well, the “Mukdadiya formation” consists of siltstone, marl, and conglomerate rocks, and the “Bai Hassan formation” is comprised of conglomerate wherein recent sediments are finally deposited [BUDAY 1980].

CHEMICAL ANALYSIS AND SAMPLE SELECTION

The samples collected from the wells were placed in glass containers in the summer of 2019 (Tab. 1). They were then put in an icebox in accordance with normal protocols and transported to the laboratory.

The chemical analysis findings were then compared the World Health Organization [WHO 1993] and Iraqi requirements for drinking water [Drinking-Water Standard IQS 2001]. Total

Table 1. Geographic coordinates about wells in Ali Al-Gharbi district, the Maysan Governorate, Iraq

Well No.	Well name	Longitude	Latitude
1	Khzeena / 2	32°47'53"	46°34'58"
2	Khzeena / 1	32°48'53"	46°36'37"
3	Khzeena old	32°48'10"	46°35'10"
4	Arian Barghash	32°45'57"	46°36'03"
5	Abdul Wahid Karim	32°45'38"	46°36'40"
6	Hamid Massoud	32°43'15"	46°36'06"
7	Chifta / 1	32°39'45"	46°39'04"
8	Manar / 1	32°36'00"	46°50'00"
9	Janna / 1	32°38'08"	46°49'43"
10	Janna	32°36'29"	46°49'55"
11	Jirwa / 1	32°33'00"	46°50'00"
12	Janna / 2	32°37'00"	46°53'00"
13	Chilat / 1	32°35'50"	46°56'00"
14	Chilat / 3	32°35'02"	46°55'31"
15	Chilat / 2	32°35'00"	46°55'40"
16	Mohsen Faeel	32°31'07"	46°57'23"

Source: own elaboration.

pH and *TDS* measurements were further taken as defined by the Global Positioning System (GPS) for each well field and geographic position. Both concentrations of the chemicals were expressed in mg·dm⁻³. Total pH and *TDS* measurements were also taken as defined by the GPS for each well field and geographic position. Both concentrations of the chemicals were expressed in mg·dm⁻³. In Figure 1, sampling sites in Table 1 were identified.

WATER QUALITY INDEX (WQI) EVALUATION

The *WQI*, as a digital rating scale that begins from 0 to 100 [SALEEM *et al.* 2016], is an efficient water-contamination treatment method that can be used to improve groundwater quality with high efficiency. In this analysis, the *WQI* was designed using 11 parameters.

The meaning of the parameters (namely, weights) was associated with the expected water use, which was why the quality of water was formulated. The present study examined the quality requirements of water as acceptable for human use [ABDUL HAMEED *et al.* 2010]. The criteria (i.e., the values permitted for various parameters) in this analysis were those recommended in Iraqi drinking water standards.

RESULTS AND DISCUSSION

In this analysis, the *WQI* was employed to determine the suitability of groundwater for drinking purposes in Ali Al-Gharbi district of the Maysan Governorate, eastern Iraq. To reach accurate estimations, the *WQI* included many parameters. The physical and chemical properties of groundwater sampling could also provide certain parameters. Ten parameters were thus

evaluated for each sample, including *TDSs*, pH, *TH*, Ca^{2+} , Na^+ , Mg^{2+} , K^+ , SO_4^{2-} , Cl^- , and NO_3^{-1} (Fig. 2). Mathematically, the effects of such parameters were used to calculate the *WQI*. Table 2 illustrates the chemical and physical parameters of water quality in the study area.

Three measures were also included in estimating the *WQI*. As the first step, the weight of the chemical parameters was determined according to the relative value of the overall water quality for human use, ranging from one to five. It becomes obvious that the groundwater quality for human use, for example, the NO_3 parameter is of utmost importance (Tab. 3) for other

parameters and then gives it higher strength than other cases. In contrast, *Mg* has less strength because it does not affect water in terms of human use [RAMAKRISHNAIAH *et al.* 2009].

The relative weight (W_r) was established in the second point, based on the following equation [AL-ALI *et al.* 2017]:

$$W_r = \frac{W_i}{\sum W_i} \tag{1}$$

where: W_r represents the relative weight, W_i shows the weight of each parameter, i is the parameter number.

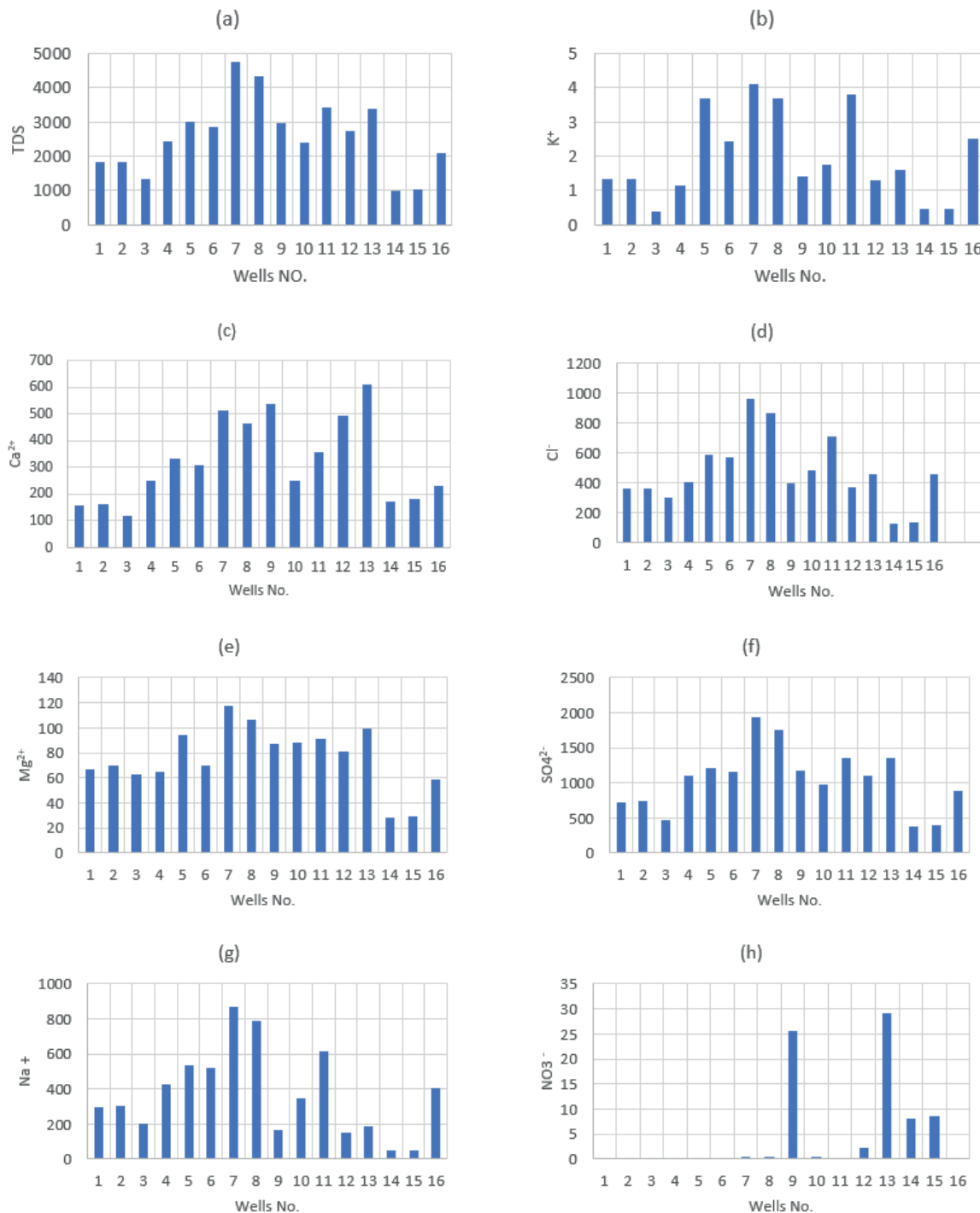


Fig. 2. Concentration of selected components: a) total dissolved solids (*TDSs*), b) K^+ , c) Ca^{2+} , d) Cl^- , e) Mg^{2+} , f) SO_4^{2-} , g) Na^+ , h) NO_3^- ; source: own study

Table 2. Physical-chemical parameters of water in study area

Well No.	Parameter										
	pH	TH	TDSs	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻
			mg·dm ⁻³								
1	7.2	664.5	1813	156.7	66.4	295.5	1.32	50.6	361.9	730.4	0.33
2	7.3	700.0	1826	165.0	70.0	300.0	1.33	51.0	364.0	734.8	0.33
3	7.2	552.0	1330	117.1	63.1	200.0	0.37	70.7	302.5	476.0	0.19
4	7.2	886.0	2450	248.4	64.6	423.2	1.15	57.5	408.7	1 094.8	0.05
5	7.1	1219.3	2990	333.4	94.0	535.0	3.70	73.0	588.3	1 218.3	0.28
6	7.1	1053.8	2850	306.7	70.0	517.6	2.44	92.1	571.8	1 149.5	0.27
7	7.0	1762.6	4736	512.1	117.6	870.9	4.10	155.0	962.2	1 934.3	0.45
8	7.0	1190.5	4321	466.4	106.3	787.0	3.70	140.1	870.0	1 747.7	0.41
9	7.1	1365.5	2953	535.0	87.2	164.3	1.40	406.1	401.0	1 182.8	25.5
10	7.1	993.0	2414	252.8	88.4	349.2	1.77	67.4	481.7	972.4	0.44
11	7.1	1265.3	3420	356.6	91.1	618.2	3.80	82.7	710.6	1 366.3	0.13
12	7.1	1568.5	2757	495.8	80.8	152.3	1.30	376.5	371.8	1 096.4	2.34
13	7.1	1933.1	3402	610.2	99.5	187.5	1.60	463.3	457.6	1 349.4	29.1
14	7.4	544.5	980	171.9	28.0	50.4	0.45	130.5	128.7	379.5	8.10
15	7.3	574.6	1042	181.5	29.5	53.2	0.47	137.5	135.8	400.6	8.55
16	7.3	822.5	2100	231.8	59.2	402.0	2.52	53.7	462.0	888.3	0.08

Explanations: TDSs = total dissolved solids, TH = total hardness.

Source: own study.

Table 3. Relative weight (W_r) for each parameter [RAMAKRISHNAIAH *et al.* 2009]

Parameter	Iraqi standard; Drinking-Water Standard IQS [2001]	Standard value of WHO [1993]	Weight (W_i)	Relative weight (W_r)
pH	6.5–8.5	7–8	4	0.1333
TH	500	100–500	2	0.0666
TDSs (mg·dm ⁻³)	1000	1000	4	0.1333
Ca ²⁺ (mg·dm ⁻³)	150	75–200	2	0.0666
Mg ²⁺ (mg·dm ⁻³)	50	30–150	2	0.0666
Na ⁺ (mg·dm ⁻³)	200	200	2	0.0666
K ⁺ (mg·dm ⁻³)	–	12	2	0.0666
Cl ⁻ (mg·dm ⁻³)	250	250	3	0.1
SO ₄ ²⁻ (mg·dm ⁻³)	250	250	4	0.1333
NO ₃ ⁻ (mg·dm ⁻³)	50	50	5	0.1666
Total			$\sum W_i = 30$	

Explanations: TH, TDSs as in Tab. 1.

Source: own study.

The W_r values were further determined for each parameter, as shown in Table 3.

In the third step, the q_i for each parameter was ascertained by dividing its concentration by its criterion for each water sample (Tab. 4) in accordance with the guidelines set out in the Iraqi standards (Tab. 4) and multiplying the outcome by 100 [GEBREHIWOT *et al.* 2011].

$$q_i = \frac{C_i - C_o}{S_i - C_o} 100 \quad (2)$$

where: q_i refers to the quality scale, C_i denotes the value of the water quality parameter obtained from the laboratory study (mg·dm⁻³), C_o indicates the perfect value for each chemical

parameter of this parameter in pure water ($C_o = 0$ excepting pH = 7), S_i is the parameter of the index.

$$Sl_i = W_r q_i \quad (3)$$

Sl_i was also first defined for each parameter used to calculate the WQI, and was then employed to estimate the WQI value, as expressed in the following equations:

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

where: Sl_i represents the parameter of the index, as shown in Table 4.

Table 4. Values of quality scale (q_i), parameter of the index (Sl_i), and water quality index (WQI) for each parameter in water samples

Well No.	Specifi- cation	pH	TH	TDSs	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	WQI
1	q_i	40.0	132.9	181.3	104.4	132.8	147.7	11.00	144.7	292.1	0.66	
	Sl_i	5.33	8.85	24.1	6.95	8.84	9.83	0.73	14.5	38.9	0.11	118.1
2	q_i	60.0	140.0	182.6	110.0	140.0	150.0	11.10	145.6	293.9	0.66	
	Sl_i	7.99	9.32	24.3	7.32	9.32	10.0	0.73	14.5	39.1	0.10	122.7
3	q_i	40.0	110.4	133.0	78.0	126.2	100.	3.10	121.0	190.4	0.38	
	Sl_i	5.33	7.35	17.7	5.2	8.4	6.66	0.20	12.1	25.4	0.06	88.4
4	q_i	40.0	177.2	245.0	165.6	129.2	211.6	9.50	163.5	438.0	0.10	
	Sl_i	5.33	11.8	32.6	11.02	8.6	14.1	0.60	16.3	58.3	0.01	158.6
5	q_i	20.0	243.8	299.0	222.2	188.0	267.5	30.80	235.3	487.3	0.56	
	Sl_i	2.66	16.2	39.8	14.8	12.5	17.8	2.00	23.5	64.9	0.09	194.2
6	q_i	20.0	210.7	285.0	204.4	140.0	258.8	20.30	228.7	459.8	0.54	
	Sl_i	2.66	14.0	37.9	13.6	9.3	17.2	1.30	22.8	61.2	0.08	180.0
7	q_i	0.0	238.0	432.1	310.9	212.6	393.5	30.80	348.	699.0	0.80	
	Sl_i	0.0	23.4	63.1	22.7	15.6	29.0	2.20	38.4	103.1	0.10	297.6
8	q_i	0.0	238.1	432.1	310.9	212.6	393.5	30.80	348.0	699.0	0.80	
	Sl_i	0.0	15.8	57.0	20.7	14.1	26.0	2.00	34.8	93.1	0.13	263.5
9	q_i	20.0	273.1	295.3	356.6	174.4	82.0	11.60	160.4	473.1	51.00	
	Sl_i	2.6	18.1	39.3	23.7	11.6	5.40	0.70	16.0	63.0	8.50	187.9
10	q_i	20.0	198.6	241.4	168.5	176.8	174.6	14.70	192.6	388.9	0.88	
	Sl_i	2.6	13.2	32.1	11.2	11.7	11.6	0.90	19.2	51.8	0.14	154.4
11	q_i	20.0	253.0	342.0	237.7	182.2	309.1	31.60	284.2	546.5	0.26	
	Sl_i	2.6	16.8	45.5	15.8	12.1	20.5	2.10	28.4	72.8	0.04	216.6
12	q_i	20.0	313.7	275.7	330.5	161.6	76.1	10.80	148.7	438.5	4.60	
	Sl_i	2.6	20.8	36.7	22.0	10.7	5.0	0.70	14.8	58.4	0.77	172.4
13	q_i	20.0	386.6	340.2	406.8	199.0	93.7	13.30	183.0	539.7	58.2	
	Sl_i	2.6	25.7	45.3	27.0	13.2	6.2	0.80	18.3	71.9	9.70	220.7
14	q_i	80.0	108.9	98.0	114.6	56.0	25.2	3.75	51.5	151.8	16.20	
	Sl_i	10.66	7.25	13.06	7.63	3.7	1.67	0.24	5.1	20.2	2.70	72.2
15	q_i	35.0	114.9	104.2	121.0	59.0	26.6	3.90	54.3	160.2	17.10	
	Sl_i	4.66	7.65	13.88	8.05	3.9	1.77	0.26	5.4	21.3	2.80	69.6
16	q_i	60.0	164.5	210.0	154.5	118.4	210.0	21.00	184.8	355.3	0.16	
	Sl_i	7.90	10.9	27.9	10.3	7.8	13.3	1.40	18.4	47.3	0.02	145.2

Explanations: TH, TDSs as in Tab. 1.

Source: own study.

It was thus possible to classify the computed WQI values as [RAMAKRISHNAIAH *et al.* 2009]: $WQI < 50 \rightarrow$ excellent; $WQI = 50-100 \rightarrow$ good; $WQI = 100-200 \rightarrow$ poor; $WQI = 200-300 \rightarrow$ very poor; $WQI > 300 \rightarrow$ unsuitable.

The application of the results to the wells of the Ali Al-Gharbi district, the Maysan Governorate, Iran, from the WQI , showed that they varied from good to very poor water. Wells No. 3, 14, and 15 were good; wells No. 1, 2, 4, 5, 6, 9, 10, 12, and 16 were poor ones, and wells No. 7, 8, and 11 were very poor cases (Tab. 5). Figure 3 shows the distribution of the WQI in the study area.

Table 5. Classification of water quality based on water quality index (WQI) importance acc. to PARMAR and PARMAR [2010]

WQI value	Water quality	Well sample No.
<50	excellent	-
50-100	good	W 3, W 14, W 15
100-200	poor	W 1, W 2, W 4, W 5, W 6, W 9, W 10, W 12, W 16
200-300	very poor	W 7, W 8, W 11, W 13
>300	unsuitable	-

Source: own study.

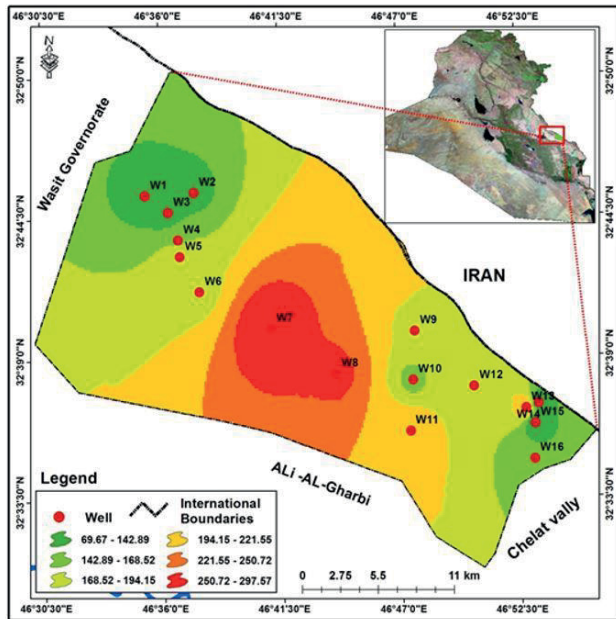


Fig. 3. Distribution of water quality index in study area; source: own study

CONCLUSIONS

The present study was an attempt to assess groundwater quality for drinking purposes in Ali Al-Gharbi district of the Maysan Governorate, eastern Iraq. The results indicated that the high-quality groundwater samples were about 18.75% and the low-quality ones were by 56.25%. As well, 25% of the samples had very poor water quality. The water quality index (WQI) also varied from 69.67 and 297.6. Therefore, prior to use, some treatments are needed to protect the environment from pollution. To recharge groundwater and to optimize its supplies, rainwater must be well handled. To sustain the consistency and the quantity of aquifers in this area, the high concentration of chemical components and soluble salts should be reduced. In order to encourage knowledge and understanding of the supply of drinking water to humans around their places of residence, public awareness campaigns should be implemented.

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