Use of Water Quality Index Technique to Assess Groundwater Quality for Drinking Purposes in Saqlawiyah

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Abstract

Water Quality Index has been used in the present study to evaluate suitability of groundwater quality for drinking purposes in Saqlawiyah city and surrounded area, Al anbar, Iraq . This was carried out by subjecting twelve groundwater samples, collected from twelve selected site, to comprehensive physico-chemical analysis . WQI technique requires several parameters to satisfy the calculations . These parameters include physical and chemical characteristics of groundwater sampling such as: pH, total hardness, total dissolved solids, calcium, magnesium, bicarbonate, chloride, nitrate and sulphate. The computed WQI shows that two wells (11, 12) fall in class II (good water) while seven well (3,4,6,7,8,9,10,) fall in class III (poor water) and three wells (1,2,5) fall in class IV (very poor water) . The high value of WQI has been found to be mainly due to the higher values of TDS, Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, SO_4^{-2} and No_3^{-2} where it was found that there is a very high correlation coefficient between them. Such waters are not suitable for drinking purposes under normal condition and further action for salinity control is required .

Key words : Water quality Index, Drinking water, Saqlawiyah city, Al-anbar, Iraq .

Introduction

Iraq relies on the Tigris and Euphrates Rivers as a main source of water used for drinking purposes but in last years, these rivers exposed to industrial waste disposal, agricultural and civil affecting the quality of water. As well as the dams constructed on these rivers by Turkey lead to a significant lack of water therefore, has to be thinking about other sources of drinking water. Groundwater or well water is the most important source in many cities of the world, as it is believed to be safe and free from pathogenic bacteria and suspended matter. Most accessible groundwater resources have already been tapped in the area of study for irrigation purposes. Residents of these areas are using this water for drinking purposes, therefore the focus has shifted in the present study for evaluation of these waters for drinking purposes using water quality index (WQI) technique. WQI technique has been successfully used to asses the quality of groundwater in the recent time due to its serves the understanding of water quality issues by integrating complex data and generating a score that describes water quality status. [1] has firstly use the concept of WQI then developed by [2] and improved by [3] . The development of WQI for groundwater is described in the several studies [4], [5], [6], [7], [8], [9], [10] and [11] .

The objective of the present work is to determine the suitability of groundwater for human consumption based on computed water quality index values in Saqlawiyah city and surrounded areas of AL- Anbar provenance, in Iraq. The study area is located between latitudes 33° 22' 22" to 33° 26' 26" North and Longitude 43° 36' 36" to 43° 42' 42" East, covering an area of approximately 116 km^2 (Fig.1) .

Methodology

Groundwater samples were collected during July 2012, October 2012 and January 2013 from 12 wells located in Saqlawiyah city and surrounded area. Each of the groundwater samples was analyzed for 11 parameters which were pH, total dissolved solids (TDS), total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate, bicarbonate and sulphate using standard procedures recommended by [12]. The average measured values are summarized in table (1) and the locations of these sites are shown in Fig (1).

The standards for drinking purposes as recommended by Iraqi Standard, 1992 have been considered for the calculation of WQI which are including three steps. Firstly specific weights are assigned to the chemical parameters according to its relative importance in the overall quality of water for drinking purposes as shown in table 2. For example, nitrate parameter playing a prominent role in groundwater quality for drinking purposes [9] than the other parameters hence higher weightage is given to nitrate parameter. Whereas magnesium is assigned lesser weightage because it is not harmful to ground water quality for drinking purposes. In the second step, the relative weight *(Wi)* is computed from the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

Where, ***Wi*** is the relative weight, ***wi*** assigned weight of each parameter and ***n*** is the number of parameters. Calculated relative weight *(Wi)* values of each parameter are also given in table 2. In the third step, a quality rating scale *(qi)* for each parameter is assigned by dividing its concentration in each water sample by its respective standard .

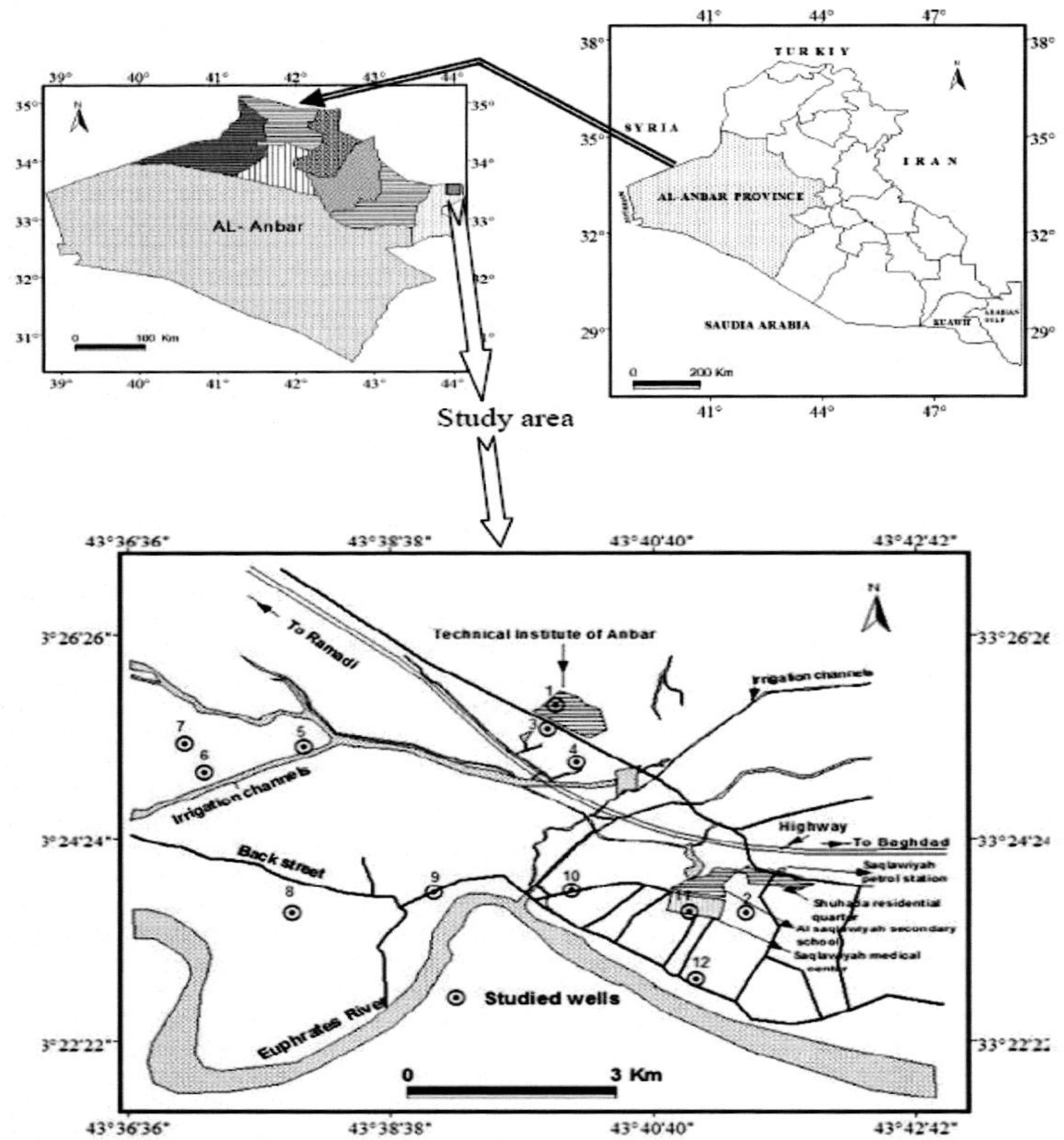

Fig.1: Location map of the study area showing studied wells

according to the guidelines laid down in the Iraqi standards which is illustrate in (table 2) and the result multiplied by 100.

$qi = (Ci / Si) \times 100$ (2)

Where ***qi*** is the quality rating, ***Ci*** is the concentration of each chemical parameter in each water sample, and ***Si*** is the Iraqi drinking water standards for each chemical parameter .

For computing ***WQI***, the ***SIi*** is first determined for each chemical parameter, which is then used to determine the ***WQI*** as the following equation:

$SIi = Wi \cdot qi$ (3)

$WQI = \sum SI_i$ (4)

Table 1: Average chemical analysis of collected groundwater samples during July 2012, October 2012 and Januray 2013

Parameter (mg\l)	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10	Well 11	Well 12
pH	7.5	7.3	7	7.2	7.1	7.4	7.3	7.1	7	7.2	7.1	7.2
TH	2134	2328	1940	1970	2076	2000	1203	1157	1190	1188	1200	776
Ca^{+2}	404	421	429	305	328	290	179	265	207	213	163	141
Mg^{+2}	297	311	211	281	306	299	184	264	210	99	95	99
Na^{+}	764	855	360	487	570	542	315	470	284	270	160	177
K^{+}	25	27	25	8	7	7	7	20	6	9	7	6
HCO_3^-	442	427	343	421	534	436	560	525	452	387	305	354
Cl^-	433	540	317	403	495	357	368	207	306	234	208	241
TDS	3218	3778	2652	3124	3296	3045	2126	2462	2083	1851	1935	1524
SO_4^{-2}	1452	1541	1506	1262	1508	1158	979	610	510	439	532	523
NO_3^{-2}	46	49	48	40	48	37	31	19	16	14	17	17

Table 2: Relative weight and the Iraqi drinking water standard for each parameter [9]

Chemical parameters	Si	Weight (wi)	Relative weight (Wi)
pH	6.5-8.5	4	0.1212
Total hardness (TH)	500	2	0.0606
Ca^{+2}	200	2	0.0606
Mg^{+2}	150	2	0.0606
Na^{+}	200	2	0.0606
K^{+}	12	2	0.0606
HCO_3^-	200	3	0.0909
Cl^-	600	3	0.0909
TDS	1500	4	0.1212
SO_4^{-2}	400	4	0.1212
NO_3^{-2}	40	5	0.1515
Total		$\sum$ wi= 33	$\sum$ Wi= 1

SIi is the sub index of the parameter; ***qi*** is the rating based on concentration of the parameter and ***n*** is the number of parameters .

The computed WQI values are classified into five types; according to [9] "excellent water" to "unsuitable for drinking" as shown in table (3) .

Table.3: Water quality classification based on WQI value [9]

WQI value	Class	Water quality	Percentage of studied water sample
<50	I	Excellent	0
50-100	II	good water	17%
100-200	III	poor water	58%
200-300	IV	very poor water	25%
>300	V	Unsuitable water	0

Result and discussion

Statistical analysis was carried out using statistical package for social sciences (SPSSVersion14) .
The statistical tests applied were basic statistics (mean, standard deviation) and Spearman's correlation matrix (assuming $p < 0.01$) . The mean and standard deviations is calculated to know the chemical parameters which are deviating from Iraqi standard for drinking water standard (table 4) .

Table 4: Descriptive statistics for all wells

	pH	TH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^-	Cl^-	TDS	SO_4^{2-}	NO_3^{2-}
Minimum	7.0	776.0	141.0	95.0	160.0	6.0	305.0	207.0	1524.0	439.0	14.0
Maximum	7.5	2328.0	429.0	311.0	855.0	27.0	560.0	540.0	3778.0	1541.0	49.0
Mean	7.2	1596.8	278.8	221.3	437.8	12.8	432.2	342.4	2591.2	1001.7	31.8
Std. Deviation	0.2	520.9	101.7	85.2	219.6	8.6	78.8	111.0	700.7	453.1	14.4
Iraqi standard	6.5-8.5	500	200	150	200	12	200	600	1500	400	40

It has been observed that the mean for all parameters are more than the limits of Iraqi standard except Cl^- and nitrite within the limits while the standard deviation for all parameters are within the limits of Iraqi standard for drinking water except SO_4^{2-}, TH and Na^+.

The degree of a linear association between any pair of the water quality parameters, and water quality parameters with WQI as measured by the simple correlation coefficient (r) is presented in table 5. Correlation analysis measures the closeness of the relationship between chosen variables. If the correlation coefficient is nearer to +1 or –1, it shows the perfect linear relationship between the two variables. This way analysis attempts to establish the behavior of the relationship between the water quality parameters and WQI. It is observed that the TDS variations are mainly controlled by Na^+ (r = 0.93), Mg^{+2} (r = 0.92), SO_4^{2-} (r = 0.88), NO_3^{2-} (0.87), Cl^- (r = 0.86) and Ca^{+2} (r = 0.85) concentration. In some site the relationship between Mg and Cl is highly significant indicates that the hardness of the water is permanent in nature. Computed WQI also show that the highly significant interrelated with the values of TDS (r = 0.96), NO_3^{-2} (0.95), SO_4^{-2} (r = 0.95), Na^+ (r=0.92), Ca^{+2} (r = 0.91), Cl^- (r = 0.88) , Mg^{+2} (r=0.88) and K^+ (r = 0.63) .

Table 5: Correlation coefficient matrix of water quality parameters and WQI

Parameters	*pH*	*TH*	*Ca^{+2}*	*Mg^{+2}*	*Na^+*	*K^+*	*HCO_3^-*	*Cl^-*	*TDS*	*SO_4^{2-}*	*NO_3^{-2}*	*WQI*
pH	1											
TH	0.37	1										
Ca^{+2}	0.21	0.89	1									
Mg^{+2}	0.33	0.81	0.74	1								
Na^+	0.55	0.85	0.81	0.88	1							
K^+	0.19	0.52	0.80	0.43	0.64	1						
HCO_3^-	0.17	0.11	0.06	0.54	0.36	-0.05	1					
Cl^-	0.41	0.84	0.67	0.76	0.82	0.32	0.38	1				
TDS	0.38	0.95	0.85	0.92	0.93	0.53	0.30	0.86	1			
SO_4^{-2}	0.33	0.93	0.87	0.76	0.77	0.54	0.20	0.85	0.88	1		
NO_3^{-2}	0.33	0.92	0.87	0.76	0.77	0.53	0.19	0.85	0.87	1.00	1	
WQI	0.39	0.95	0.91	0.88	0.92	0.63	0.32	0.88	0.96	0.95	0.95	1

Total dissolved solids (TDS) , Total hardness and pH

The ***total dissolved solids*** (TDS) are the concentrations of all dissolved minerals in water indicate the general nature of salinity of water. The total dissolved solids in all the study area varies from 1524 to 3778 mg/l (Fig. 2) . The higher value of total dissolved solids is attributed to application of agricultural fertilizer contributing the higher concentration of ions into the groundwater [13] All studied samples were exceeding maximum permissible limit of Iraqi standard for drinking water. High values of TDS in groundwater are generally not harmful to human beings but high concentration of these may affect persons, who are suffering from kidney and heart diseases [14]. Water containing high solids may cause also laxative or constipation effects [15] .

Total hardness (TH)

Total Hardness is considered as a major character of drinking water. Hardness is defined as the concentrations of calcium and magnesium ions. Calcium (Ca) and magnesium (Mg) are dissolved from most soils and rocks. A total hardness value varies from 776 to 2328 mg/L (table1 & fig.2) which may be due to presence of Calcium (Ca) and magnesium (Mg). The study concluded that 100% samples were exceeding maximum permissible limit and is general classify as extremely hard water .

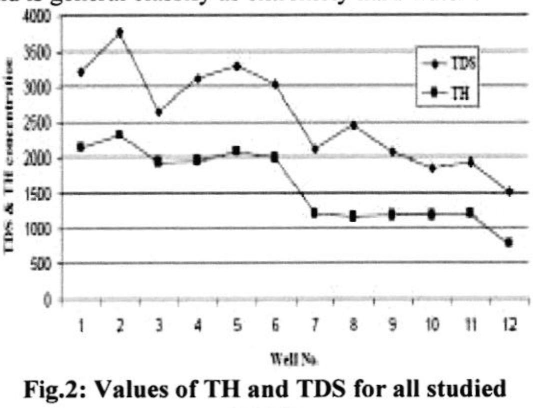

Fig.2: Values of TH and TDS for all studied sample

The **Hydrogen-ion concentration (pH)** in the study area varies from 7-7.5 (table 1 & Fig. 3). The mean value of pH was lower than the desired limit (8.5) of Iraqi standard indicating acidic nature of ground water .

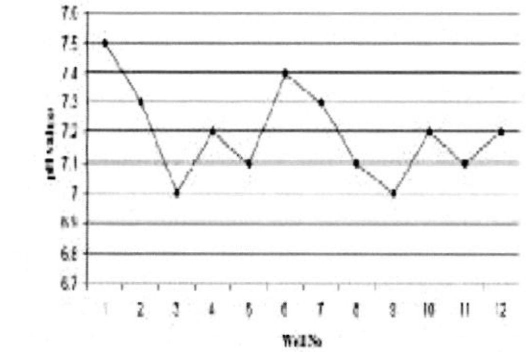

Fig.3: Values of pH for all studied sample

Cations Concentrations

Calcium can be found in water as Ca^{+2} ions therefore it is a determinant of water hardness. The ranges of Ca^{+2}, is 141 to 429 mg/L as shown in figure (4). All samples were exceeding maximum permissible limit of Iraqi drinking water standard except well no 7, 11 and 12. High concentration of calcium ion is observed in Well 1,2,3,4,5,6,8,9,and 10 due to its frequent use of water wells as well as the distance from the river and irrigation channels .

The values of ***magnesium*** (mg^{+2}) range from 95 to 311mg/l (Fig.4). 25% samples were crosses the maximum permissible limit. Magnesium has many different purposes and consequently may end up in water in many different ways [16]. A large number of minerals contain magnesium; it is washed from rocks and subsequently ends up in water. Magnesium also adds as a fire protection measure or as filler to plastics and other materials from Chemical industries. It also ends up in the environment from fertilizer application and from cattle feed. In the study area the rock type is indurate to compacted clastic sediments hence the source of magnesium in the groundwater is clay sediments .

All groundwater contains some ***sodium*** (Na^{+}) because most rocks and soils contain sodium compounds from which sodium is easily dissolved. The increasing pollution of groundwater has resulted in a substantial increase in the sodium content of drinking water. According to the Iraqi drinking water standard, U.S.A. standards and [17] the water used for drinking purposes should not contain sodium in amount exceeding 200 mg\l accordingly 83% of the studied samples are unsuitable for drinking (Fig.4) .

In most wells ***Potassium ions*** (K^{+1}) were observed less than the allowable concentration as shown in fig. 4 because of the ability of potassium to combine with several soil minerals structure or digest by plants [12]. As per Iraqi drinking water standard, 33% of samples exceeding maximum permissible limit while 67% of samples of the study area within permissible limits .

Anions concentration

The concentration of ***Bicarbonate*** (HCO_3^-) in the studied samples ranges between 305 and 560 mg\l as shown in fig 5. Accordingly, all of these samples are unsuitable for drinking uses .

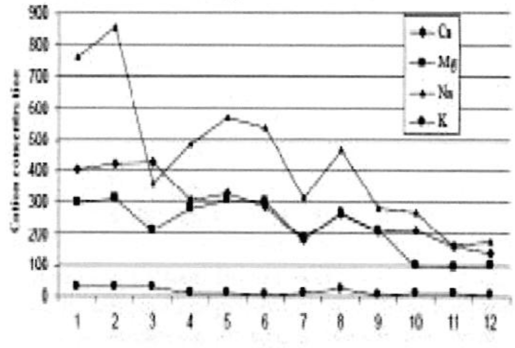

Fig.4: Values of Cations for all studied samples

The ***chloride*** Cl^- content was found to be well within the permissible limits (Fig. 5 and table 1). It is a widely distributed element in all types of rocks in one or the other form. Therefore, it is high in ground waters, where the temperature is high and rainfall is less [9]. Soil porosity and permeability also has a key role in building up the chlorides concentration [18] .

The ***nitrate*** NO_3^- value varies from 14 to 40 mg/l in the study area, as shown in fig.5 and table 1. The nitrate value for the study area is found to be more than 40 mg/l as per Iraqi drinking water standard in five locations due to over-application of fertilizer from agricultural land .

The concentration of ***sulphate*** SO_4^{-2} in the studied samples ranges between 439 and 1541 mg\l (Fig.5) . Accordingly, all of these samples are unsuitable for drinking uses .

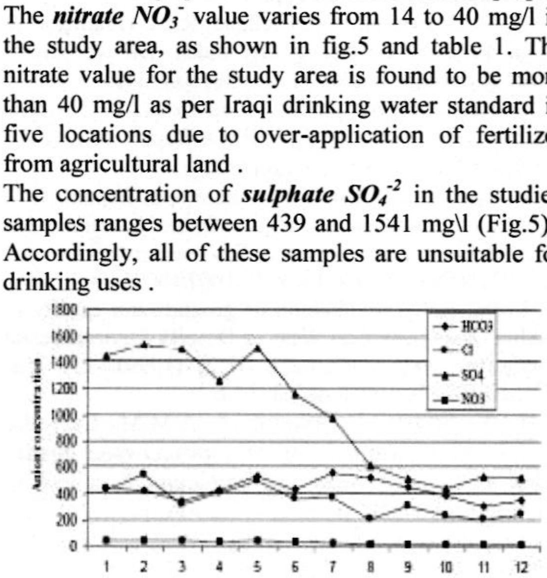

Fig.5: Values of Anions for all studied samples

Water Quality Index (WQI)

In this study, the computed WQI values for 12 wells in Saqlawiyah city and surrounded area range from 91 to 227 as shown in fig.6. It can be classified into three types "good water" to "very poor water ". The percentage of water samples that falls under different quality as shown in table 4. Accordingly 17% of wells water falls in class (II) (good water), 58% falls in class (III) (poor water) and 25% falls in class (IV) (very poor water) .

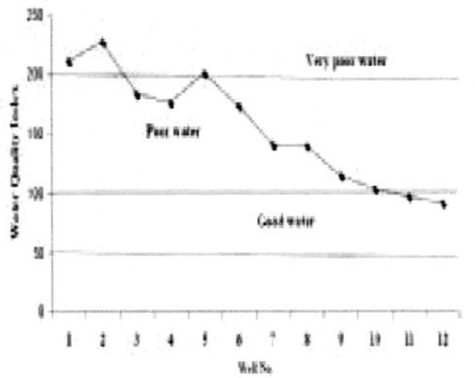

Fig.6: Values of WQI for all studied samples

The high value of WQI in this region because of it is considered as a discharge area for a groundwater. These values has been found to be mainly due to the higher values of TDS, Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, SO_4^{-2} and NO_3^{-2} where it was found that there is a very high correlation coefficient between them .The groundwater quality may improve in this region due to inflow of freshwater of good quality during rainy season .

Conclusion

Suitability of groundwater quality for drinking purposes in Saqlawiyah city and surrounded areas have been evaluating in the present study using water quality index technique. For calculating the WQI nine parameters have been considered such as: pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, and total dissolved solids. The result shows that 17% of water sample falls in good water category, 58% falls in the poor water category and 25% falls in very poor category. The high value of WQI has been found to be mainly from the higher values of total dissolved solids, calcium, magnesium, sodium, chloride, sulphate and nitrate in the groundwater. The current study shows that the study area contains mostly unsuitable groundwater for drinking purposes and need to be treated in the case of use .

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استخدام تقنية مؤشر جودة المياه لتقييم نوعية المياه الجوفية لأغراض الشرب

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(تاريخ الاستلام: 11 / 3 / 2013 ---- تاريخ القبول: 9 / 6 / 2013)

الملخص

تم تطبيق مؤشر المياه في هذه الدراسة لتحديد مدى ملائمة المياه الجوفية لأغراض الشرب في مدينة الصقلاويه والمناطق المحيطه بها في محافظة الانبار في العراق عن طريق اجراء التحليل الكيميائي لاثنتي عشر عينة مياه جمعت من اثني عشر موقعا لكافة المحددات الفيزوكيميائية . ان حساب مؤشر نوعية المياه يتطلب العديد من المحددات مثل درجة الحموضة ، وكمية الاملاح الذائبة ، والكالسيوم والمغنيسيوم والصوديوم والكلور والكبريتات والنترات . تبين من خلال حساب مؤشر المياه الجوفية ان اثنين من الابار المدروسة (11 ، 12) تقع ضمن صنف II (مياه جيده) وسبعة ابار (3,4,6,7,8,9,10) تقع ضمن صنف III (مياه رديئة) وثلاثة ابار (1,2,5) من مجموع عينات المياه المدروسة تقع في صنف المياه الرديئة جدا (IV) وتبين من خلال النتائج ان القيمة العليا لمؤشر المياه الجوفية سببها وجود تراكيز عالية من Ca^{2+}, Na^{+}, Mg^{+2}, Cl^{-}, SO_4^{2-}, NO_3^{2-}, TDS حيث تبين ان هناك معامل ارتباط عالي جدا بينهما. وهذه المياه غير صالحة للشرب تحت الظروف الاعتيادية وتحتاج الى عمل كثير للسيطرة على الملوحة العالية .

الكلمات الدالة : مؤشر نوعية المياه جوفيه ، الشرب ، مدينة الصقلاويه ، الانبار ،العراق .