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Evaluation of Ground Water Quality Status by Using Water Quality Indices at Basheqa Region, Iraq

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Abstract

Large areas of BASHEQA region haven't any source of surface water, at the same time, there are large quantities of olives trees and crops depend in its irrigating on Ground Water (GW) as a main source. So it is important to evaluate its (GW) for different uses. In this study the (GW) of 32 wells had been examined in the college of environmental science and technology laboratories to assess its Water Quality (WQ) for drinking, irrigation, and livestock purposes. Average twelve parameters (pH, Ca, Mg, Na, HCO3, SO4, Cl, NO3, EC, TDS, SAR, TH) data in the period 2008-2009 had been applied in three methods through computing Water Quality Indices (WQIS). The first method was the Weighted Average (WAV). The second one was that adopted by Ministry of Nature and Environment (MNE) of Mongolia, while the last one was the Canadian Council of Ministers of the Environment (CCME). The (WQIs) of the three methods results had been compared to assess the suitability of the best one. Although the statistical analysis indicated that there are no significant differences between both (CCME) and (WAV) methods, the (WAV) data had been used in this study as it gave more restrictive control. The analysis of (WQIs) using (WAM) method indicated that (25, 69, 88)% of (GW) are good for drinking, irrigation, and livestock purposes respectively.

Keywords: Water quality indices, Ground water, Basheqa region.

تقييم نوعية المياه الجوفية باستخدام مؤشرات نوعية المياه في منطقة بعشيقة ، العراق

الخلاصة

مساحات كبيرة من منطقة بعشيقة لا يتوفر فيها مصدر للمياه السطحية وفي نفس الوقت يتواجد هنالك كميات كبيرة من أشجار الزيتون والمحاصيل الزراعية تعتمد في ريها على المياه الجوفية . لذلك أصبح من الضروري تقييم المياه الجوفية لهذه المنطقة للاستخدامات المختلفة. في هذه الدراسة تم فحص مياه (32) بئر في مختبرات كلية البيئة وتقاناتها وذلك لتقييم نوعيتها لأغراض الشرب والري وسقي الحيوانات. تم اعتماد معدل بيانات إثنى عشر معلمة رئيسية (الدالة الحامضية، الكالسيوم، المغنيسيوم، الصوديوم، البيكاربونات، الكبريتات، الكلورايد، النترات، التوصيلية الكهربائية، المواد الصلبة الذائبة الكلية، نسبة امتزاز الصوديوم، العسرة الكلية) للفترة 2008-2009. تم إدخال بيانات هذه المعلمات على ثلاثة طرق لإيجاد مؤشرات نوعية المياه وهي كل من (طريقة المعدل الوزني، الطريقة المعتمدة في وزارة البيئة المنغولية، والطريقة المعتمدة في وزارة البيئة الكندية). نتائج هذه الطرق تمت مقارنتها إحصائيا لإيجاد الطريقة المثلى. بالرغم من نتائج التحليل الإحصائي بعدم وجود اختلاف معنوي بين الطريقة الكندية وطريقة المعدل الوزني، إلا أن بيانات طريقة المعدل الوزني المسجلة أعطت سيطرة أكثر تقييدا. أوضحت نتائج طريقة المعدل الوزني أن (25، 69، 88)% من مياه هذه الآبار جيدة لأغراض الشرب، الري وسقي الحيوانات على التوالي.

الكلمات الدالة: مؤشرات نوعية المياه، المياه الجوفية، منطقة بعشيقة.

Introduction

(WQI) gives the public a general idea of the water quality (WQ) in a particular region. (WQI) value makes information more easily and rapidly understood rather than a long list of numerical values for a large variety of parameters. Many different methods in computing (WQIs) had been developed

(Horton,1965)[1], suggested that the various (WQ) data could be aggregated into an overall index. Then (WQI) was developed by (Brown et al.,1970)[2], and then improved by (Scottish development department, 1975)[3].

(Soltan,1999)[4], used (GWQI) for ten wells located near the Dakhla Qasis in the Egyptian western.

(Mus،ab A.Al-Tamir,2005)[5] used (WQI) to evaluate (GW) in Al-Rasheedia and Guba region northwest of Mosul city by using geometric mean method .He revealed the this GW bad for drinking and irrigation uses while it was good for stockyard uses.

(Stigter et al., 2006)[6], used (GWQIs) for evaluating influence of agriculture activities on several key parameters of (GW) chemistry and portability.

(Mayur C. Shah et al., 2008) [7], studied 15 parameters of (GW) of bore wells at 40 villages of Gandhinagar, India. They calculated (WQI) to evaluate the (GWQ) for drinking and irrigation purposes, and they established also a statistical relation for each pair of (WQ) parameters.

(Saeedi et al.,2010)[8], developed (WQI) with identified (GW) places with best quality of drinking within west central of Iran. This research aims to evaluate the (GWQ) at BASHEQA region for three purposes from the statistical results of the best method among three methods nationally depended and to point the suitability of the (GW) in a (GIS) map.

Methodology

In this study, average values of 12 parameters (pH, Ca, Mg , Na, HCO_3, SO_4, Cl, NO_3, EC, TDS , SAR, TH) of the (GW) for 32 deep wells had been selected to be involved in an indices calculations and tested in the collage of environmental science and technology laboratories at BASHIQA region for the period 2008-2009. All parameters tests had been done according to standard method for testing water and wastewater (APHA, 2005)[9].The locations of the wells had been determined by the Geographical position System (GPS) device and given a number. Locations of these wells had been pointed in the map shown in Figure (1) which was drawn by Geographical Information System (GIS 9.3) program. The selective parameter had been arranged according to its importance for three purposes drinking, irrigation and livestock. The selective parameters had been listed with their standard values in Table (1). Standards values of World Health Organization (WHO, 2004)[10] had been adopted in this study. After that, the results of the three computed methods had been arranged in three Tables (6,7and 8) and inserted in a statistical program (SPSS,vir.11.5) to give an opinion about the best one which gives the most significant values of (WQ). Indeed, determination of the best method had been done from statistical analysis and from the outer look of (WQ) data among the three methods which had been listed in Tables (2, 3, 4).The last step represented by inserting the best method data in (GIS 9.3) program in order to point the suitability of the (GW) in each well with different uses. The details of this map had been clearly shown in Figure (2). This map can gives us a general look of nature of the (GWQ) for the overall region.

Studied Area

Bqaashe region, located in north of Mosul city and it has an area reaches about 511.408 km^2. In the following, the details of the site of this region:

West longitude = 43° 10' 57.8566" E
East longitude = 43° 32' 18.6350" E
North latitude = 36° 34' 57.0138" N
South latitud = 36° 20' 49.9274" N

There aren't any sources of surface water near this reign except a small stream in the west of it called (Al-Khoser). The nearest wells to this stream have the numbers (2, 12, 16, 26).

The study area involved different agricultural activities which supply the needed water from (GW) resources.

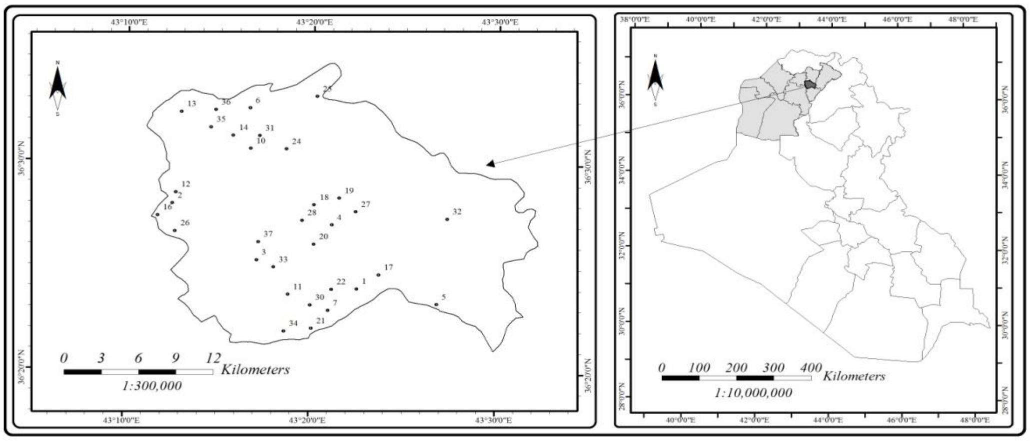

Fig. 1. The position of the selective wells under study

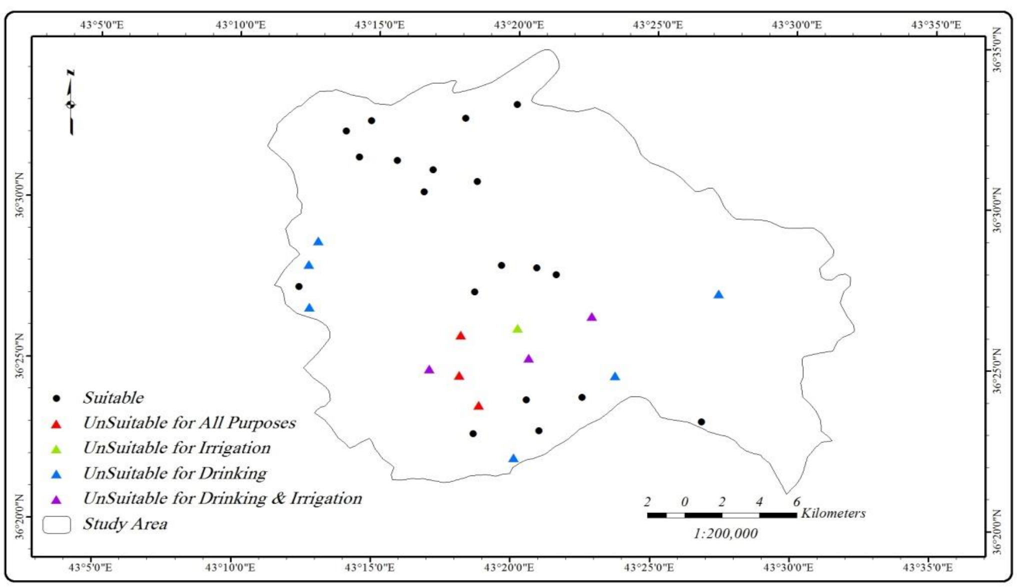

Fig. 2. The suitability of the (GW) for the three purposes

Table 1. WHO standard values for selective parameters and for three purposes

Drinking purpose			Irrigation purpose			Livestock purpose		
parameter	unit	limits	parameter	unit	limits	parameter	unit	limits
pH	---	6.5-8.5	EC	mmhos/cm	2700	TDS	mg/l	10000
TH as $CaCO_3$	mg/l	300	SAR	$(meq/l)^{0.5}$	15	SO_4	mg/l	1000
CL	mg/l	250	TDS	mg/l	1750	pH	-----	6.5-8.5
Na	mg/l	200	Na	mg/l	200	NO_3	mg/l	440
SO_4	mg/l	200	CL	mg/l	250	EC	mmhos/cm	12500
TDS	mg/l	1000	pH					
Ca	mg/l	200						
Mg	mg/l	50						
NO_3	mg/l	10						

Table 2. Results of WQIs by (WAV) method

No. of wells	WQI Drinking	WQ Drinking	WQI Irrigation	WQ Irrigation	WQI livestock	WQ livestock
1	46	Good	30	Good	23	Excellent
2	136	unsuitable	44	Good	38	Good
3	125	unsuitable	72	poor	38	Good
4	118	unsuitable	43	Good	36	Good
5	50	Good	33	Good	26	Good
6	328	unsuitable	124	unsuitable	84	Very poor
7	53	poor	39	Good	25	Excellent
8	53	poor	28	Good	27	Good
9	649	unsuitable	224	unsuitable	123	unsuitable
10	119	unsuitable	46	Good	37	Good
11	20	Excellent	19	Excellent	21	Excellent
12	39	Good	25	Excellent	25	Excellent
13	132	unsuitable	44	Good	39	Good
14	348	unsuitable	182	unsuitable	78	Very poor
15	76	Very poor	29	Good	31	Good
16	43	Good	32	Good	25	Excellent
17	72	poor	211	unsuitable	31	Good
18	472	unsuitable	64	Poor	91	Good
19	77	Very poor	65	poor	30	Good
20	38	Good	24	Excellent	25	Excellent
21	52	poor	36	Good	27	Good
22	140	unsuitable	46	Good	40	Good
23	71	poor	36	Good	30	Good
24	94	Very poor	40	Good	32	Good
25	61	poor	63	poor	28	Good
26	45	Good	26	Good	25	Excellent
27	45	Good	26	Good	25	Excellent
28	198	unsuitable	122	unsuitable	48	Good
29	58	poor	46	Good	27	Good
30	1100	unsuitable	303	unsuitable	190	unsuitable
31	94	Very poor	34	Good	31	Good
32	140	unsuitable	38	Good	40	Good

Table 3. Results of WQ by (MNE) method

No.	WQI Drinking	WQ Drinking	WQI Irrigation	WQ Irrigation	WQI Livestock	WQ Livestock
1	0.46	clean	0.32	clean	0.23	v.clean
2	1.3	S.P	0.43	clean	0.41	clean
3	1.25	S.P	0.78	clean	0.41	clean
4	1.125	S.P	0.42	clean	0.39	clean
5	0.51	clean	0.37	clean	0.27	v.clean
6	3.0	M.P	1.19	S.P	0.95	S.P
7	0.51	clean	0.42	clean	0.26	v.clean
8	0.51	clean	0.28	clean	0.28	v.clean
9	6.3	unsuitable	2.4	clean	1.39	S.P
10	1.1	S.P	0.44	clean	0.40	clean
11	0.2	v. clean	0.21	clean	0.21	v.clean
12	0.38	clean	0.26	S.P	0.25	v.clean
13	1.24	S.P	0.41	clean	0.43	clean
14	3.8	M.P	2.05	v. clean	0.88	clean
15	0.72	clean	0.39	S.P	0.32	clean
16	0.42	clean	0.31	clean	0.26	v.clean
17	0.70	clean	0.33	v. clean	0.32	clean
18	4.7	H.P	2.44	V .clean	1.01	S.P
19	0.79	clean	0.68	clean	0.31	clean
20	0.37	clean	0.25	S.P	0.25	V. clean
21	0.53	clean	0.38	clean	0.28	v. clean
22	1.32	S.P	0.44	v. clean	0.43	clean
23	0.67	clean	0.36	clean	0.32	clean
24	0.90	S.P	0.39	S.P	0.35	clean
25	0.60	clean	0.60	clean	0.29	v.clean
26	0.43	clean	0.27	v.clean	0.26	v.clean
27	0.46	clean	0.27	clean	0.25	v.clean
28	1.94	S.P	1.21	clean	0.53	clean
29	0.52	clean	0.45	clean	0.27	v.clean
30	10.2	unsuitable	2.83	clean	2.22	S.P
31	0.91	S.P	0.42	clean	0.33	clean
32	1.33	S.P	0.38	v.clean	0.44	clean

Table 4. Results of (WQ) by (CCME) method

No. of wells	WQI drinking	WQI drinking	WQI irrigation	WQI irrigation	WQI Livestock	WQI Livestock
1	90.79433	Good	100	Excellent	100	Excellent
2	41.23787	Poor	100	Excellent	100	Excellent
3	50.59609	Marginal	86.21133	Good	100	Excellent
4	59.80356	Marginal	100	Excellent	100	Excellent
5	100	Excellent	100	Excellent	100	Excellent
6	45.47017	Marginal	55.29365	Marginal	83.66959	Good
7	90.86463	Good	100	Excellent	100	Excellent
8	90.82809	Good	100	Excellent	100	Excellent
9	12.08662	Poor	35.48844	Poor	74.75967	Fair
10	58.24484	Marginal	100	Excellent	100	Excellent
11	100	Excellent	100	Excellent	100	Excellent
12	100	Excellent	100	Excellent	100	Excellent
13	57.1066	Marginal	100	Excellent	100	Excellent
14	22.96108	Poor	37.75788	Poor	79.84268	
15	71.54663	Fair	100	Excellent	100	Excellent
16	100	Excellent	100	Excellent	100	Excellent
17	89.71342	Good	100	Excellent	100	Excellent
18	13.91048	Poor	35.4979	Poor	80.01363	Good
19	72.03101	Fair	72.76778	Fair	100	Excellent
20	100	Excellent	100	Excellent	100	Excellent
21	90.81891	Good	100	Excellent	100	Excellent
22	49.22858	Marginal	100	Excellent	100	Excellent
23	80.63761	Good	100	Excellent	100	Excellent
24	69.59104	Fair	100	Excellent	100	Excellent
25	81.75036	Good	100	Excellent	100	Excellent
26	100	Excellent	100	Excellent	100	Excellent
27	89.24618	Good	100	Excellent	100	Excellent
28	44.63708	Poor	58.28561	Marginal	83.54899	Good
29	100	Excellent	100	Excellent	100	Excellent
30	40.73716	Poor	33.67614	Poor	42.04091	Poor
31	79.95833	Good	100	Excellent	100	Excellent
32	56.97811	Marginal	100	Excellent	100	Excellent

Details of the Used Methods

Weighted Average (WAV) was the first method; it was adopted by many studies. (McDuffie and Haney, 1973) [11], used it firstly. In this method, each parameter for each purpose given a relative weight (wi) according to its importance, but the sum of these relative weights does not exceed one. These relative weights had been listed in Table (5). The quality rating scale (qi) was computed by using the following equation:

qi = (Ci/ Si)*100 , where Ci represents the concentration of ith parameter, (Si) represents the (WHO) standards. Then the sub index (Sli) of ith parameter could be computed by multiplying the relative weight by quality rating using the equation:

SIi = wi*qi.

Then (WQI) could be easily computed by summation of sub-index as in the equation: WQI = ∑SIi.

The results of (WQI) which they were listed in Table (6) classified (WQ) to five classes. The results of this method had been listed in Table (2).

The second method which was that adopted by the Ministry of Nature and Environment (MNE) of Mongolia [12]. In this method, the number of parameters has been taken into account and all the parameters have the same weight. Indeed, this method computes (WQI) by summing the average quality rating as follows:

WQI=∑(Ci/Si)/n, where (n) represents the number of parameters. This method which had been listed in Table (7) classifieds (WQ) in six classes. (WQIs) results of this method had been listed in Table (3).

Canadian Council of Ministers of the Environment (CCME) [11] is the third adopted method. Many stages in computing (WQIs) by this method should be done. Details of each stage as follows:

F_1 = (Number of failed variables / Total number of variables)*100.

F_2 = (Number of failed tests / total number of tests)*100.

Excursion=(failed of test value/objective j) -1

nse =∑excursion / number of tests

F_3 = [nse / (0.01nse + 0.01)] .

Finally the computing indices could be calculated by the following equation:

$$WQI = 100 - \sqrt{\frac{F1^2 + F2^2 + F3^2}{1.732}}$$

This method classified (WQIs) to five classes listed in Table (8).

Table 6. Classes of (WQI) by (AWM)

0-25	26-30	51-75	76-100	>100
Excellent	Good	poor	Very poor	unsuitable

Table 7. Classes of (WQI) by (MNE) method

≤ o.3	0.31-0.89	0.9-2.49	2.5-3.99	4-5.99	≥ 6.0
Very clean	clean	Slightly polluted	Moderately polluted	Heavily polluted	Dirty water

Table 8. Classes of (WQI) by (CCME)

95-100	80-94	65-79	45-64	0-44
Excellent	Good	Fair	Marginal	Poor

The Selective Parameters and its importance

Nine parameters had been selected for the calculation of drinking purpose. They are (pH, TH, Cl, Na, SO_4, TDS, Ca, Mg, NO_3), and six parameters had been selected for the calculation of (WQIs) for irrigation purpose. They are (EC, SAR, TDS, Na, Cl and pH) ,while five parameters for livestock purpose had been selected only. They are (TDS, SO_4, pH, NO_3, EC). The importance of each parameter as demonstrated below:

***pH**:* Higher values of pH hasten the scale formation in water heating apparatus and reduce germicidal potential of chloride. High pH induces the formation of trihalomethanes which are toxic. If pH dropped than 6.5, corrosion starts in pipes, thereby releasing toxic metals such as Zn, Pb, Cd and Cu…etc. For low pH ,there is may be a problem of increasing Aluminum (AL) and Manganese (Mn) cations which are toxic to the crops, also the suitability of some macro-nutrients such as Phosphate (PO_4) and Molipiedium (Mo) may be dropped. At the same, the increasing pH, cause an increasing in sodium (Na) cations which are toxic in both soil and plants. As we see that the selected of pH parameter was essential in computing (WQIs) for drinking, irrigation and livestock purpose.

EC: This parameter gives an idea about the concentration of the ionized substances in water, so it is important to insert this parameter in computing (WQI) for the three purposes.

TDS: It is the sum of cations and anions concentrations. The high content of dissolved solids elevated the density of water and harden the improving of (WQ), so it was taken an important parameter for the three purposes.

TH: Total hardness of water is due to presence of cations (Ca, Mg, Fe, Mn) and anions (HCO_3,SO_4,Cl,NO_3). Some evidence indicates that water hardness plays role in heart disease in human, so inserting this parameter in the drinking purpose was essential.

Na: Higher concentration of sodium ions can be related to cardiovascular diseases and in a women toxemia associated with pregnancy. Also higher concentration of this ion is toxic to the soil as well as to the plants, so it is important to insert this parameter in both of drinking and irrigation purpose.

Ca and Mg : The presence of these cations are essential for human health and for plants, but high concentration of them (more than 200 mg/l) for Ca and (more than 150 mg/l) for Mg causes an adverse effect such as hardness, so they are inserted as parameters in drinking purpose.

SAR (Sodium adsorption ratio): This parameter considered the most effective one for irrigation purpose. If the SAR value exceeded 15, water considered unsuitable for irrigation purpose. This parameter can be easily determined by following equation:

SAR= Na / $\sqrt{(Ca+Mg)/2}$

Units of Na, Ca, Mg must be changed to meq./l in using the above equation.

CL: Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply drinking water. Higher concentration of this ion considered toxic to the growth of the plants, so it is considered a parameter for irrigation purpose also.

SO_4: The high concentration of this an ion above 200 mg/l cause bitter taste and may cause gastro-intestine irritation and catharsis. Above 1000 mg/l cause the same effects on livestock, so it is important to insert this anion in the drinking and livestock purposes.

HCO_3: The presence of this anion in the (GW) means that presences of high concentration of soluble CO_2 in the water and less of dissolved oxygen. If the concentration of this ion exceeded 8.5 meq/l, irrigated water could be unsuitable for irrigation purpose.

Statistical Analysis

Because the irrigation importance of this region, data of irrigation purpose in the three methods had been selected and tested in (SPSS 11) program to give us an idea about the best depended method. Statistical analysis had been done in two stages, One-way analysis of variance (ANOVA) was adopted as a first step to give us an idea if there were any different of significant between the results of (WQIs) of the three methods. The results of this step had been listed in Table (9). In the second stage, (t) test analysis of each pair of methods had been done, this step was essential to determine the most effective method. The results of statistical analysis of this stage had been listed in Table (10).

Statistical Tables (9) and (10) showed that the results of (WAV) and (CCME) methods could be accepted since they have the same degree of significant while the results of (MNE) was unaccepted since it has less significant differences.

In comparing (WQ) results between (CCME) and (WAV) methods which had been listed in Tables (2) and (3), it is easy to say that (CCME) method gives one stage higher level of (WQ) than (WAV) method, in another word, (CCME) considered more elastic, however, we can depend upon the (WAV) method if there are need of restrictive control of uses of (GWQ).

Table 9. Significant between the three methods in (ANOVA) table

[for α=0.05 and degree of freedom = 2, 93]

Type of pair	Type of hypothesis	(f) calculated	(f) tabulated	differences	Result
WAV + MNE + CCME	$H_o : \mu_1 = \mu_2 = \mu_3$ $H_1 : \mu_1 \neq \mu_2 \neq \mu_3$	155.45	3.07	significant	There is need for (t) test to examine each pair

Table 10. Significant of each pair of methods

Type of pair	Type of hypothesis	(t) calculated	(t) tabulated	differences	Result
WA+MNE	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 \neq \mu_2$	5.6125	1.98	significant	(WAV) is the best
	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 > \mu_2$	5.6125	1.65	significant	(WAV) is the best
	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 < \mu_2$	5.6125	-1.98	No significant	--------
MNE+CCME	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 \neq \mu_2$	21.3	1.98	significant	(CCME)is the best
	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 > \mu_2$	-21.3	1.65	No significant	------
	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 < \mu_2$	-21.3	-1.65	significant	(CCME)is the best
WAV+CCME	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 \neq \mu_2$	1.52	1.98	No significant	------
	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 > \mu_2$	-1.52	1.65	No significant	------
	$H_o : \mu_1 = \mu_2$ $H_1 : \mu_1 < \mu_2$	-1.52	-1.65	No significant	------

Results and Discussion

(WQIs) results which were adopted by (WAV) method are clearly shown by the Figures (3), (4) and (5).

Figure (3) shows, that most of (GW) in this region considered suitable for livestock purpose which represent about (88)% except the (WQ) of the wells (9 and 30) considered unsuitable, these wells had been given red color in (GIS) map as shown in Figure (2).

Figure (4) shows, that (69)% of wells were good for irrigation purpose, while only six were unsuitable. These wells are (6, 9, 13, 17, 28 and 30).They were given blue color.

Figure (5) shows that (WQ) of (25)% of the wells were suitable for drinking purpose, while (13) wells considered unsuitable. They are (2, 3, 4, 6, 9, 10, 13, 14, 18, 22, 28, 30 and 32).

Figures (3, 4 and 5) show that (WQ) in the wells (6 and 9) were unsuitable for any purpose.

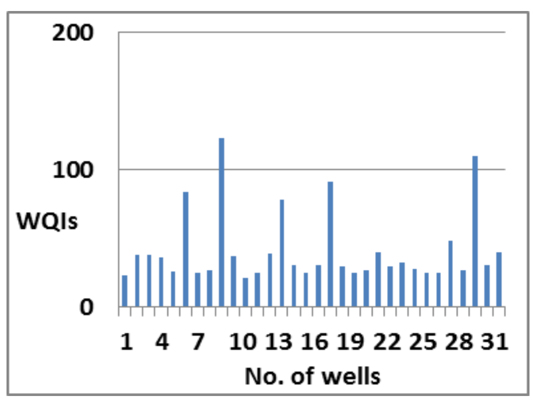

Fig. 3. WQIs for livestock purpose

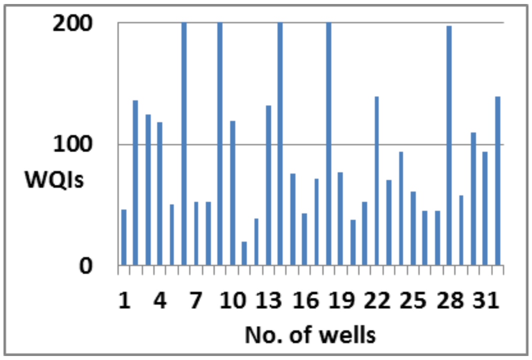

Fig. 4. (WQIs) for drinking purpose

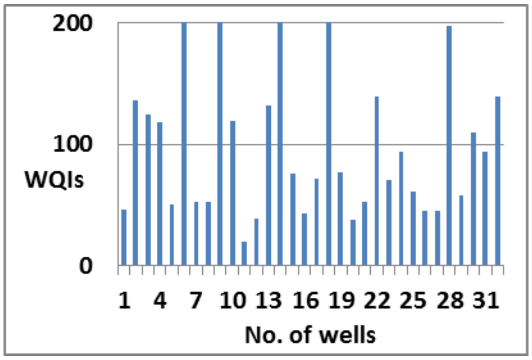

Fig. 5. (WQIs) for drinking purpose

Conclusion

Figures (6 and 7) show that, the most effective parameters in reducing (GWQ) in this region comes from the presence of high concentrations of Total Dissolved Solids (TDS) and Sulfate (SO_4) in most (GW),

Figure (2) showed that most unsuitable wells located at the center and south of this region because the levels at these areas consider the lowest from the surrounding areas.

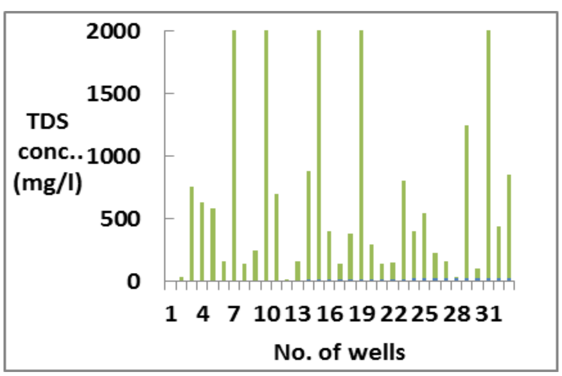

Fig. 6. TDS concentrations

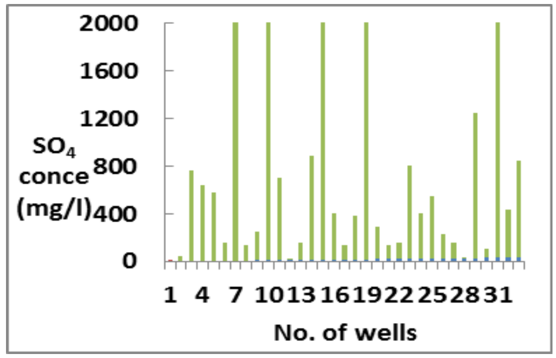

Fig. 7. SO_4 concentrations

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