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Ground Water Quality Evaluation using WQI and GIS Technique in the Al-Samawa City -Iraq

Thair Sharif Khayyun[1,*], Ayad H. Mseer[2], Moayad M. Ismaeel[3]

[1] Building Construction and Eng. Dept., University of Technology, Baghdad-Iraq

[2] Building Construction and Eng. Dept., University of Technology, Baghdad-Iraq

[3] Building Construction and Eng. Dept., University of Technology, Baghdad-Iraq

[*]Corresponding author's email: thshkhma [at] yahoo.com

ABSTRACT- ***Ground water quality evaluation is the first step toward a good management of water resources to limit impacts on irrigation and drinking water. The objective of this study is to propose a technique to assess the groundwater quality and to generate a spatial variation map in terms of suitability for irrigation and drinking water in Al-Samawa city-Iraq. Groundwater samples were collected from 45 wells at different locations during (2013). The physical and chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^{1-} , $SO4^{2-}$, HCO^{3-} , NO^{3-} have been analyzed to determine geological and non-geological source of contamination. The results were evaluated in detail and compared with WHO guidelines for irrigation water (2004) and drinking water standard by Iraqi and WHO (2011).Overall chemical analytical study using Sodium Adsorption Ratio (SAR) and Sodium percentage (Na%) values reveals that 93% of the ground water samples fall into the unsuitable for drinking and irrigation purposes when SAR is used and 86.6 % of samples fall into the permissible when Sodium percentage (Na%) is used. The most effective way to describe the quality of water is Water Quality Index (WQI). Correlation matrix for the studied parameters and (WQI) are significantly correlated among each other and for the most 11 parameters (high correlation coefficients). There is no relation between (WQI) and the parameters (pH, K and NO_3) .The results demonstrate that seven water tests fall into the poor WQI. A large portion of the specimens (28) fall into the extremely poor water WQI class. Ten samples fall into the unsuitable WQI classification. TDS and SO_4 were highly interrelated with WQI. The coefficients of determination were 0.90 and 0.94 respectively. The parameters NO_3 and PH have a minimum negative correlation with WQI. Multiple linear regression equation correlating the highly interrelated parameters (TDS and SO_4) and WQI are simulated with (R^2 =0.952).MLR equation is very important in prediction the future WQI with knowing of some parameters like the TDS which is an important physicochemical parameter of drinking water quality. The present investigation exhibits high effectiveness for GIS to analyze complex spatial information and groundwater quality mapping. It shows higher concentration of groundwater salts in northeastern part of the study area. The overall ground water quality is not suitable for drinking water and irrigation water. It may be used for drinking after treatment process. It is currently so easier for a decision maker to evaluate the water quality for irrigation, drinking water, to find the most appropriate site for drilling wells and to provide a guideline for solving water quality problem in Al-Samawa city.***

Keywords--- Ground water Quality, Wells , WQI and GIS

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1. INTRODUCTION

Ground water contamination is a worldwide distributed problem which merits substantial consideration because of its ecological hazardous impacts as well as for the dangers to the human health and in addition the financial damages it produces.

In southern Iraq, two salinity layers can be recognized in the Dibdibba Formation, separated by consolidated silty clay beds. The upper horizon has Electrical Conductivity values between 2,400 and about 11,000 μS/cm. Lower salinity values of about1,000 mg/L TDS are found in morphologic depressions, where the daily recharge occurs. The salinity contained in the second layer typically exceeds 15,000 mg/L. The separation between the two layers with different salinity might be identified with low permeability layers or to a transitional salinity increase, with less saline water floating above water with higher salinity, UN-ESCWA (2013).

Despite the fact that Water Quality Index (WQI) is normally orientated to qualify urban water supply, it has been generally utilized by ecological planning decision makers. The quality of the irrigation water must be assessed to avoid or to limit impacts on agriculture (Mohammed, 2011).

WQI is a good management and general regulatory tool in communicating water quality data. NSF - WQI calculator is used to estimate the water Quality Index. Our findings highlighted the deterioration of water quality due to anthropological activities. According to NSF - WQI ranking Water quality is Bad to Medium and not appropriate for drinking purposes, **Dhok**, **R. P.** (2011).

As salinity passes 1,000 mg/L, water becomes less useful as it is not any more consumable for human utilization (WHO 1997). Above 3,000 mg/L, it is never again appropriate for most municipal or agricultural uses.The high salinity of irrigation water causes problems for most crops.

Water quality of a particular area or particular source can be assessed utilizing physical, chemical and biological parameters. The parameters values are harmful for human health if they occurred more than characterized limits (WHO, 2012). Consequently, the appropriateness of water sources for human utilization has been depicted in terms of Water quality index (WQI), which is one of the best approaches to know the quality of water.

Muzaffarnagar and Shamli regions of Uttar Pradesh are situated in Ganga-Yamuna doab of fertile alluvium of Indo-gangetic catchment area where the demands for surface water and groundwater are developing with fast increment in agricultural and industrial activities. Water quality index is worked out to evaluate the spatial variation of groundwater quality status for future planning and management of Muzaffarnagar and Shamli regions utilizing WQI. Data of 104 groundwater tests covering the entire regions have been utilized. The Water Quality Index has been estimated using five parameters viz., pH, Total Dissolved Solids, Total Hardness, Chloride and Sulphate. The WQI results show that the water quality class is ‘good’ and water is acceptable for domestic utilize, Gopal K. (2016).

Ground water quality index demonstrating most of the specimens falls under excellent to poor classification of water. A positive correlation was observed with Cl^{1-}, $SO4^{2-}$, Ca^{2+}, Na, K, EC and TDS. The results of the correlation matrix and geochemical analysis recommended that the dominant ions of groundwater (Na, Ca^{2+}, K, Cl^{1-} and$SO4^{2-}$) were derived from seawater intrusion and gypsum dissolution process, Krishna Kumar , S. R. and Bharani, N. S. (2013).

The results of the irrigation water quality index(IWQI) map show that above 56% of the investigation region Karbala desert-Iraq falls within the “Severe restriction’’ category, which is the dominant in the central and southeast parts of the study area. The rest of the study area, which is the 44% and below falls within the ‘‘High restriction’’ category, and it is dominant in the western parts the investigation region. These categories of ground water should be utilized only with the soil having high permeability with some constraints imposed on types of plant for specified tolerance of salts (Rasul M. K. &Waqed, H. H. (2013)).The objective of this study is to propose a technique to evaluate the ground water quality and to map its spatial variation in terms of suitability for irrigation and drinking water in Al-Muthanna Governorate-Iraq.

2. THE STUDY AREA

Al-Samawa city (Al Muthanna Governorate) is located in the south part of Iraq, at the edges of the alluvial plain. The majority of its areas height varies between (70- 220 m) above the sea level. The River Euphrates and its branches pass through it. It is the second water resource for agricultural crops irrigation. The Governorate is 270 km from Baghdad to the south. It is the second biggest Governorate, after Anbar, regarding its area. It has a desert climate, and its center is Samawa Constituency. The area of the Governorate of Muthanna amounts to (51,740) km^2, 12% of the total area of Iraq. The desert occupies 47,000 km^2 (85% of the total area of the Governorate).The geographic coordinate of Muthanna governorate center is 30^o 12' N, 45^o 21' E, Fig.(1).

According to the water years (1980-2010), the total annual evaporation in this area as an average was about 3537.1 mm, the total rainfall annual average was 149.1mm and the maximum average of monthly temperature was 37.9 C^0.

The soil textures of the governorate land are clay, sandy loam and silt clay loam. The soils contain from 23-28 % of lime ($CaCo_3$). Lime is transported in the Euphrates river stream as small particles and deposited under the same conditions as the sand, caly soil particles. Although 26% of lime is found, no side effects were observed from the presence of lime in the soils as is the case with a high content of salts.

3. METHODOLOGY

Data Processing

The data of ground water quality for the selected (45) wells were collected from General Directorate of Groundwater (Minisrty of Water Resources),(2013).These wells were randomly located in the study area, Fig.(2).The locations of wells used for groundwater sampling were obtained by using a global positions system(GPS). Eleven physical and chemical parameters were selected (pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), K^+, Na^+, Mg^{2+},

Ca^{2+}, Cl^{1-} , $SO4^{2-}$,HCO_3 , NO_3).Table (1) shows the min., maximum and average values for all the parameters which were determined by several analyzed methods in laboratory.

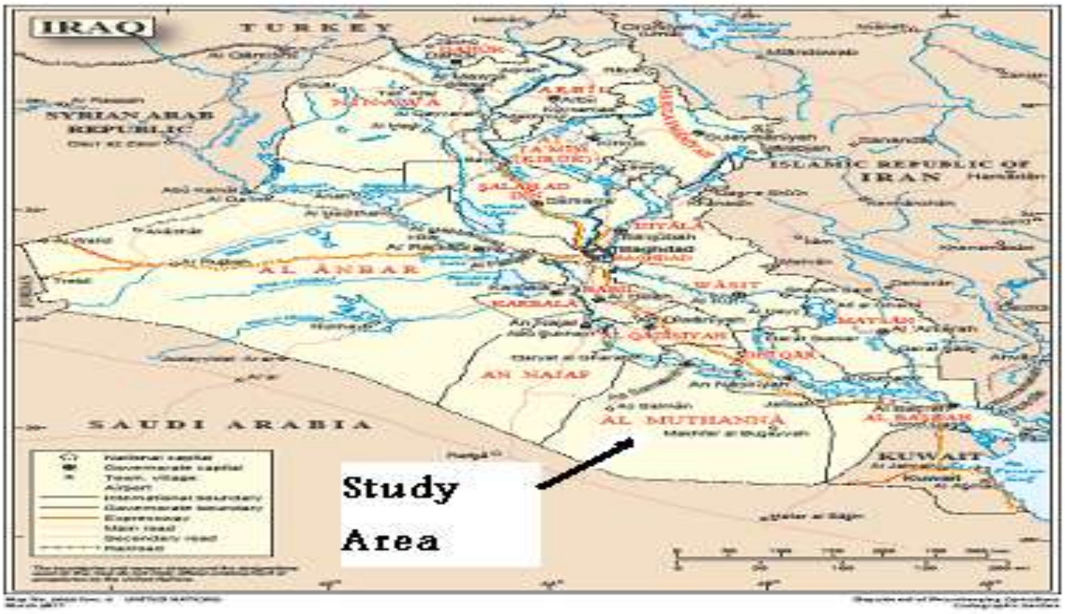


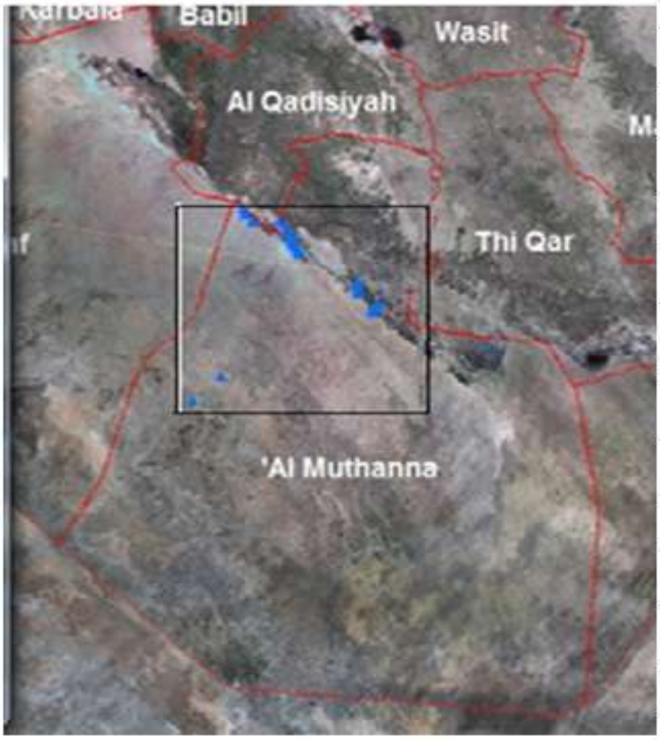
Fig.(1):Location of the study area (Al- Muthanna Governorate).

SAR hazard of irrigation:

The appropriateness of water for use in agricultural irrigation is determined by the Sodium adsorption ratio (SAR), as determined by the concentrations of solids dissolved in the water. It is likewise a measure of the sodicity of soil, as determined from analysis of water extracted from the soil. The equation for estimating sodium adsorption ratio is, (Ayers, R.S. and Westcot, D.W.(1985)):

$$SAR = \frac{Na^{+1}}{\sqrt{\frac{\left(Ca^{+2} + Mg^{+2}\right)}{2}}} \quad \text{...(1)}$$

Where SAR is in $(meq/l)^{1/2}$,sodium, calcium, and magnesium are in milliequivalents/liter.



Name	Geo-X	Geo-y
1	45 03 46.4	31 13 20.1
2	45 04 0.1	31 13 13.4
3	45 03 52.6	31 13 4.9
4	45 03 59.4	31 13 6.1
5	45 04 40.4	31 12 20.8
6	45 05 32.6	31 11 27.9
7	45 05 40.2	31 11 17.6
8	45 03 32.0	31 15 53.9
9	45 03 15.4	31 15 49.7
10	45 06 5.1	31 17 15.9
11	44 50 46.3	31 14 40.1
12	44 50 46.3	31 29 54.2
13	44 50 37.7	31 20 4.0
14	44 50 36.4	31 20 2.6
15	45 23 39.7	31 03 1.3
16	43 24 2.3	31 02 40.8
17	45 24 16.3	31 02 17.4
18	45 24 34.5	31 02 11.1
19	45 03 42.7	31 15 24.9
20	45 02 50.4	31 14 26.6
21	45 03 15.3	31 14 17.5
22	45 03 44	31 14 56.5
23	44 48 45.2	31 22 4.0
24	44 40 31.9	31 22 3.9
25	44 48 32.2	31 21 57.6
26	44 48 20.6	31 21 57.7

Fig.(2): Location of the selected wells in the study area.

Table.(1): Physical and chemical data of the ground water (Al-Muthanna Governorate- 2013).

Well No.	**Well Name**	**pH**	**Ec**	**TDS**	**K**	**Na**	**Mg**	**Ca**	**Cl**	**SO_4**	**HCO_3**	**NO_3**
			μs/cm	**ppm**								
1	AG1	7.1	6270	4500	86	610	145	350	250	670	920	12
2	AG2	7.7	4090	3800	12	216	141	280	841	790	204	7.1
3	AG3	7.5	7090	5044	12	622	177	362	735	1461	514	2
4	AG4	7.2	4150	2968	79	410	127	291	547	1002	451	5
5	AG5	7.2	7390	5279	10	800	240	450	1063	1739	583	9
6	AG6	7.2	7830	6437	120	550	164	350	791	1367	510	2.3
7	AG7	7.6	8010	8700	19	803	249	489	1060	1780	549	9
8	AM1	7.2	5930	4000	9	578	157	365	790	1300	425	8
9	AM2	7.2	5220	3863	6	569	142	260	529	1039	565	4
10	BS1	7.2	4450	3342	14	680	100	190	568	1200	410	4
11	WS1	7.7	6450	4590	100	570	160	335	680	1413	490	3
12	WS2	7.2	5530	4200	4.1	571	140	261	530	1042	564	3
13	WS3	7.8	3040	2204	3.2	329	100	219	445	779	242	5
14	WS4	7.3	6700	4422	9	568	160	329	682	1407	489	3
15	AS1	7.7	6290	4812	42	585	142	350	635	1490	412	6
16	AS2	7.2	5500	3870	6	340	121	213	530	861	453	2
17	AS3	7.8	6780	4732	102	567	162	332	684	1413	492	2

18	AS4	7.3	9480	7324	35	793	199	473	1026	1733	632	2.5
19	AM3	7.4	6430	4600	93	572	167	346	679	1512	478	3
20	AM4	7.4	5320	3900	17	615	167	339	673	1445	479	2
21	AM5	7.2	4270	3400	80	520	130	280	603	1178	470	3
22	AM6	7.3	6290	4390	95	570	172	332	685	1412	493	2.5
23	WS5	7.2	4270	1885	10	136	89	129	246	561	61	1
24	WS6	7.2	5420	3900	91	567	162	336	673	1410	487	5
25	WS7	7.4	4610	3300	119	526	150	340	719	1275	500	3
26	WS8	7.2	5990	4282	107	603	184	369	718	1601	808	3.1
27	WS9	7.8	3960	2770	20	420	38	73	360	510	268	5
28	WS10	7.3	4170	2892	17	390	131	267	550	991	244	3
29	AS6	7.2	7010	4949	48	609	176	358	693	1811	508	4
30	AS8	7.1	5580	8360	121	581	161	351	796	1365	511	2
31	ASE2	7.1	10060	7076	74	1084	239	541	1240	1925	789	6
32	ASE3	7.7	10210	7269	12.6	305	312	561	1526	2068	915	2.6
33	WS11	7.2	6063	8700	5.1	848	369	683	1489	2187	750	2.1
34	WS12	7.3	4990	3674	90	530	137	285	648	1177	473	2
35	AM7	7.1	7700	5005	120	580	164	350	795	1368	512	2
36	BS2	7.4	6640	4236	113	592	180	380	720	1580	518	4
37	ASE4	7.3	6150	4216	8	450	225	370	650	1078	390	3
38	ASE5	7.2	12070	8465	82	940	270	355	1220	2144	851	2
39	AP1	7.4	4530	3362	5.1	550	71	190	531	846	357	8.2
40	NAS1	7.3	4510	3500	83	470	136	298	645	1094	458	2
41	ASE6	7.9	5760	4130	30	482	176	270	641	1050	485	10
42	ASE7	7.4	7890	5509	16	660	200	415	780	1675	570	2
43	ASE8	7.3	6510	4385	95	577	169	343	679	1519	481	2
44	ASE9	7.2	5540	3950	91	541	141	300	661	1269	480	2
45	ASE1 0	7.1	5560	4039	91	566	166	340	685	1410	490	2.2
Min.		7.1	3040	1885	3.2	136	38	73	246	510	61	1
Max.		7.91	12070	8700	121	1084	369	683	1526	2187	920	12
Avg.		7.34	6171	4673	53	565	167	336	727	1332	505	4

In spite of the fact that SAR is just one factor in estimating the suitability of water for irrigation, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. If irrigation water with a high SAR is applied to a soil for a long time, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to shape stable aggregates and lost soil structure. This will likewise prompt a decline in infiltration and permeability of the soil to water making problems with crop production.

Sodium Hazard:

Irrigation water containing a lot of sodium is of special concern due to sodium's effects on the soil and poses a sodium hazard. Excess sodium produces the undesirable impacts of changing soil properties and decreasing soil permeability. Thus, the evaluation of sodium concentration is necessary while considering the suitability for irrigation Eq.(2),(Nishanthiny, S. C. (2010)):

$Na\ \% = ((Na+) / (Ca^{+2} + Mg^{+2} + Na^{+} + K^{+})) * 100\%$…………………(2)

the quantities of all cations are expressed in milliequivalents per liter (epm).

Water Quality Index:

Water quality index (WQI) is characterized as a method of rating that gives the composite impact of individual water quality parameter on the quality of water. It is computed from the point of view of human utilization. Water quality and its suitability for drinking purpose can be tested by determining the quality index. The standards for drinking purpose have been considered for computing of WQI. In this method the weight for different water quality parameters is assumed to be inversely proportional to the standards for the corresponding parameters .The Water Quality Index (WQI) is computed as follows,(Yogendra K. and Puttaiah E. T. (2008)):

$$WQI = \sum_{i=1}^{n}(Q_i \quad W_i) \Big/ \sum_{i=1}^{n} W_i \qquad \text{……………………………………(3)}$$

Where, Qi is the parameter sub index, Wi is the parameter unit weight, n is the number of parameters. Generally, the critical pollution index values is 100.Two methods have been utilized for computing the weight factors, one of these depends on the significance of the parameter and the other is depend on a quality value for every parameter and its range for wet and dry season.

Geographical Information System:

Geographical Information System (GIS) has been proven to be an effective tool to represent the distribution of major ions in the area of study. The major water quality parameters such as pH, EC,TDS, K^{+}, Na^{+}, Mg^{2+}, Ca^{2+}, Cl^{1-},$SO4^{2-}$,HCO_3,NO_3were investigated. The spatial variation maps of these ground water quality parameters were determined and coordinated through GIS.

4. RESULTS AND DISCUSSIONS

1- The results of assessment of the quality of ground water samples show that the average values of some of the physic-chemical parameters like pH and $NO3^{-}$ are not exceeding the permissible limits (WHO ,Guidelines for Irrigation Water (2004) and Drinking Water Standard by EPA(2011)), while the other parameters such as EC,TDS, Ca^{2+}, Mg^{+},K^{+}, SO4and HCO_3 are exceeding the permissible limits ,Table (2).The average values in Table(2) reveal that most of the ground water samples collected from the study area are not suitable for irrigation or drinking purposes because of low rainfall (less than 150 mm/year), high evaporation more than 3500 mm/year , soil conditions , highly dependent upon the supply of poor quality of water from upstream of the Euphrates River and the direction of ground water flow from the north and west aquifers to south aquifers of Iraq with low quality, Fig.(3).

Table (2): Allowable limit of water quality parameter according to Iraqi and WHO standards.

Parameters	Average values Of groundwater concentration	WHOs Guidelines for Irrigation Water(2004)	Drinking Water Standards(2011)	
			Iraqi	WHO
pH	7.34	6.5-9.2	6.5-8.5	6.5-9.5
Ec (µs/cm)	6171	1400	2000	750
TDS (ppm)	4673	1000	1500	1000
K (ppm)	53	12	10	12
Na (ppm)	565	200	200	200
Mg (ppm)	167	50	50	150
Ca (ppm)	336	200	200	100
Cl (ppm)	727	250	200	250
So_4 (ppm)	1332	250	250	400
Hco_3 (ppm)	505	240	200	----
No_3 (ppm)	4	45	10	50

2-The predominant cation trend for high concentrations in Al-Muthanna GW-aquifer is Na, Ca, Mg and K respectively. Sodium is the dominant cation. The average value is 565mg/l (Table (2)).The computed SAR values ranges from 13.02 to 57.10 (meq/l). All samples from wells are unsuitable for irrigation uses according to the classifications of ground water(Chandu (1995)), Table(3).93% of ground water samples fall in the field of unsuitable water .The Na concentration values varies between 40% to 80% for most wells in the study area, Table (4).The water classes are between permissible and doubtful. When the Na concentration of sodium ion is high in irrigation water, Na tends to be absorbed by clay particles, displacing calcium and magnesium ions as illustrated above.

3- WQI is the weighted average that is used to determine the quality of water. It is used to measure the levels of physical and chemical parameters in water. In this study, there are 11 parameters, each of them has been assigned a weight (W_i) from (1-7) according to its relative importance in the quality of ground water, Hemant, P. (2011) and Patil, V.T. (2013). The maximum weight of 5 has been assigned to NO_3 .The other parameters have been assigned a weight of 4,3,2 and 1 for (pH, SO_4), (TDS, Na, CL,HCO_3), (Mg, Ca) and (EC,K) respectively, Table (5).The WQI was calculated using Eq.(3).Its values for all of the selected wells shown in Fig.(4).The average value of WQI is 268.The results shown that WQI of ground water of wells in Al-Muthanna area according to Ramakrishnalah(2009) classification, ranged from poor ,very poor(62.2% of wells) and unsuitable for drinking water as well as for irrigation water, Table(6).

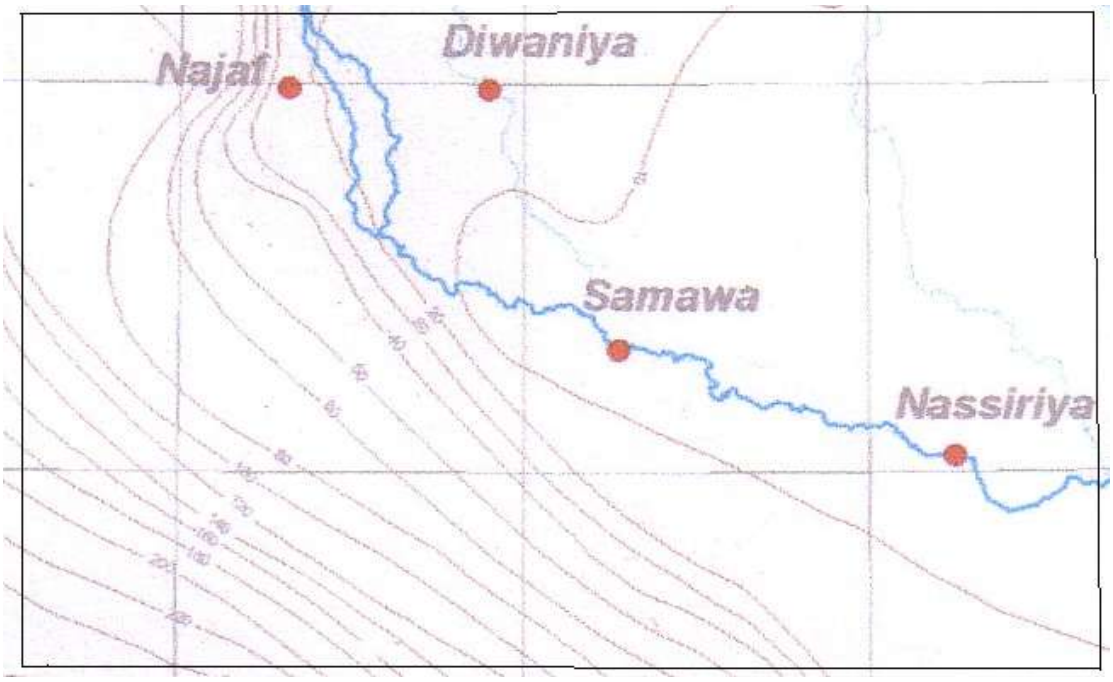


Fig.(3): Equipotential lines of ground water (contour map) in the study area.(Ministry of water Resources,2013).

Table (3): Classification of ground water for irrigation uses based on SAR.

SAR, epm	Water Class	No. of Wells	% of Wells
Less than 10	Excellent	---	---
10-18	Good	3	7
18-26	Permissible	---	---
More than 26	unsuitable	42	93

Table (4): Classification of ground water for irrigation uses based on Sodium Percentage.

Na %	Water Class	No. of Wells	% of Wells
<20	Excellent	----	----
20-40	Good	3	6.7
40-60	Permissible	39	86.6
60-80	Doubtful	3	6.7
>80	unsuitable	-----	-----

Table (5): Standard values and weight coefficients of chemical variables for drinking Use.

Water Quality Parameter	Standard Guideline Value			Weight (w_i)	Relative Weight $W_i=w_i / \sum w_i$
	Excellent Limit	Desirable Limit	Max. Permissible Limit		
PH				4	0.129
Ec (µs/cm)	500	1000	1500	1	0.032
TDS (ppm)	300	500	1000	3	0.097
K (ppm)	2	5	12	1	0.032
Na (ppm)	20	175	250	3	0.097
Mg (ppm)	30	50	150	2	0.065
Ca (ppm)	50	75	200	2	0.065
Cl (ppm)	50	150	250	3	0.097
So_4 (ppm)	50	150	250	4	0.129
Hco_3 (ppm)				3	0.097
No_3 (ppm)	2	5	20	5	0.161
$\sum w_i$				31	1.00

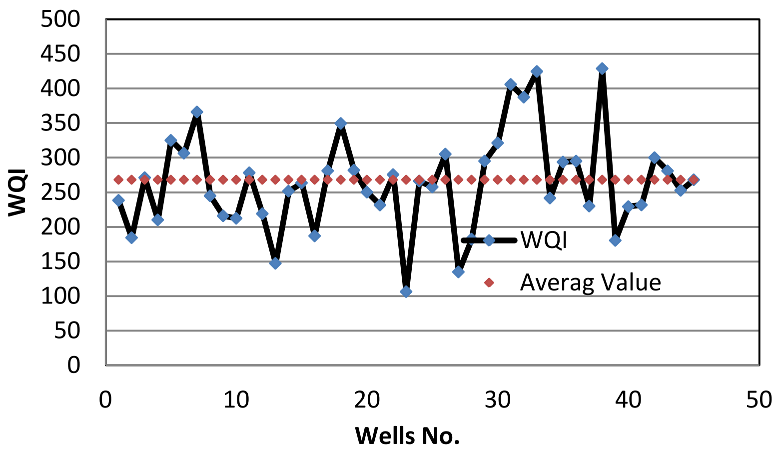


Fig.(4): WQI for ground water of wells.

Table (6): Water quality classification based on WQI value

WQI value	Water quality	Class	No. of Wells	% of Wells
<50	Excellent	I	-----	-----
50-100	good water	II	-----	-------
100-200	poor water	III	7	15.6
200-300	very poor water	IV	28	62.2
>300	Unsuitable water	V	10	22.2

The correlation coefficient matrix for the physical, chemical parameters and WQI were calculated by using multiple regressions, Table (7). TDS and SO_4 were highly interrelated with WQI. The coefficients of determination were 0.90 and 0.94 respectively. The parameters NO_3 and PH have a minimum negative correlation with WQI .The multiple regression equation correlating the highly interrelated parameters (TDS and SO_4) as independent variables and WQI as dependent variable are given below (R^2 =0.952):

WQI= 0.289 $TDS^{0.392}SO_4^{0.489}$……………………………………..(4)

Eq.(4) is very important in prediction the future WQI with knowing of some parameters like the TDS which is an important physicochemical parameter of drinking water quality. For the regression model of WQI in Eq.(4),to be useful as a predictor ,many equations for another study areas must be considered. The relationship between the simulated and calculated WQI is shown in Fig.(5), with a good correlation. Regression analysis (Eq.(4)), can be misleading without probing data, which could reveal relationships that a casual analysis could overlook. When the standard guideline value (excellent, desirable and permissible limits of Table (5)) were used in Eq.(4), WQI values were 18.31, 38.28 and 64.50 (less than 100) .These values represent an excellent and good water quality due to water classification based on WQI values, Table(6).

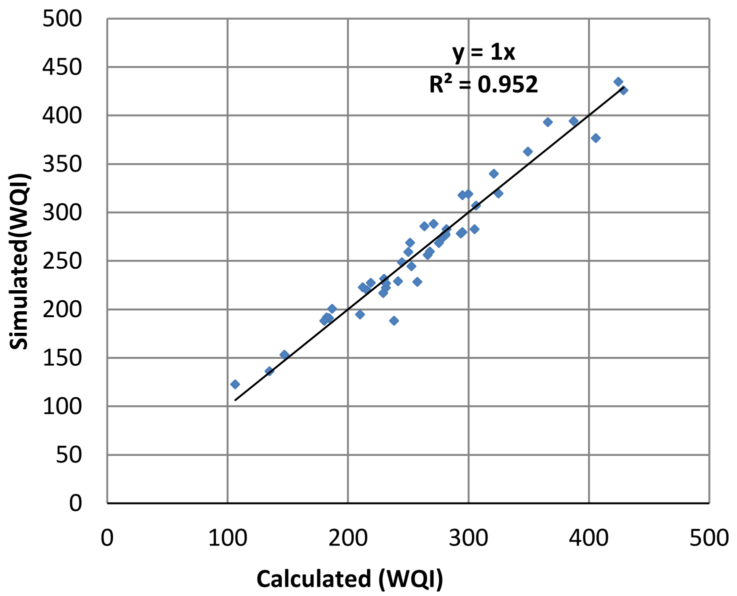
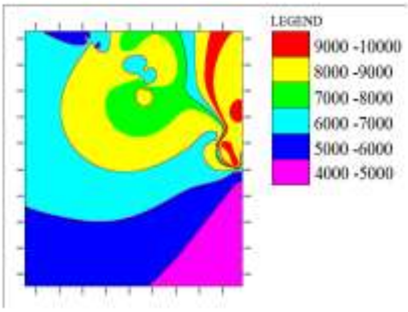


Fig.(5):Simulated verses calculated WQI for the ground water .

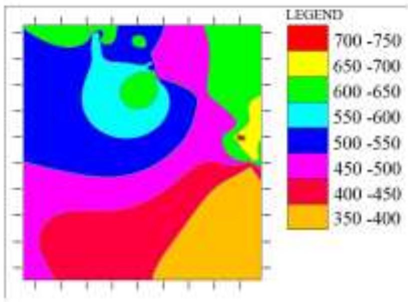
Table (7): Correlation coefficients between WQI and the physical and chemical parameters of ground water wells-Al-Muthanna Governorate.

Parametrs	PH	EC	TDS	K	Na	Mg	Ca	Cl	SO_4	HCO_3	NO_3	WQI
PH	1.00											
EC	-.09	1.00										
TDS	-.09	.78	1.00									
K	-.21	.13	.10	1.00								
Na	-.31	.62	.66	.16	1.00							
Mg	-.07	.70	.79	-.02	.54	1.00						
Ca	-.11	.65	.78	.08	.60	.92	1.00					
CL	-.00	.71	.81	-.02	.40	.89	.85	1.00				
SO_4	-.12	.77	.77	.17	.70	.84	.84	.85	1.00			
HCO_3	-.25	.70	.66	.25	.63	.68	.69	.59	.66	1.00		
NO_3	.21	-.06	-.03	-.24	.12	-.06	.01	-.08	-.20	.08	1.00	
WQI	-.16	.83	.90	.28	.76	.87	.88	.87	.94	.79	-.09	1.00

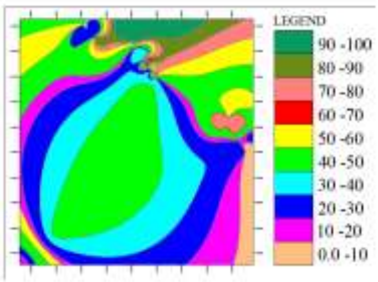
4- Using GIS technique with Arcview, spatial distribution contouring maps of the physical and chemical parameters, have been created. The spatial analysis of ground water quality from the (45) wells, shows higher concentration of groundwater salts in north-eastern part of the study area. The lowest concentration of salts was observed in southwestern, and some other parts of the study area. .It is easily illustrated when the spatial distribution of the ground water quality was created by using GIS technique in the contour maps, Figs. (6) .The water quality maps show that 100% of the study area can be considered unsuitable for irrigation and drinking water when the quality parameters (Ec, TDS, Na, Ca, Cl, HCO_3 and SO_4) are used in the assessment. The percent of unsuitable area for the other parameters (K and Mg) were 95% and 40% respectively.NO_3 was within the permissible limits for irrigation and drinking purposes.



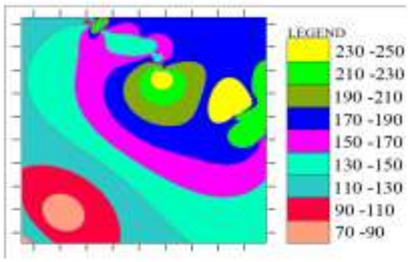
1- EC (μs/cm)



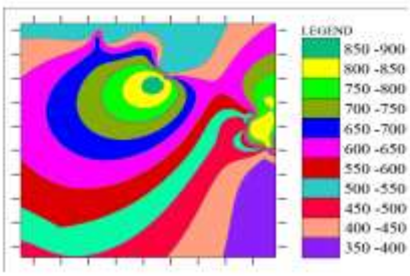
2-HCO_3(ppm)



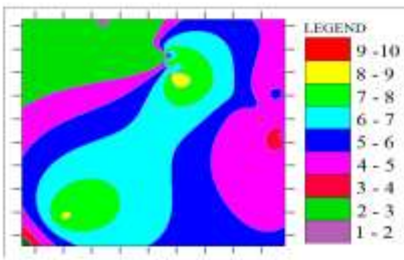
3-K (ppm)



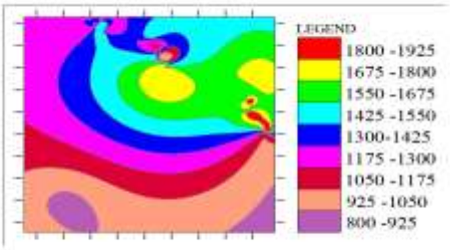
4- Mg (ppm)



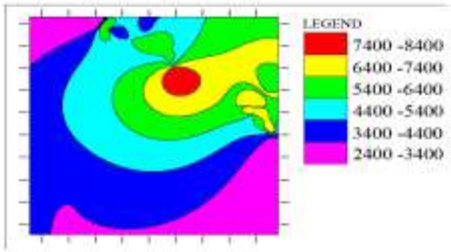
5- Na (ppm)



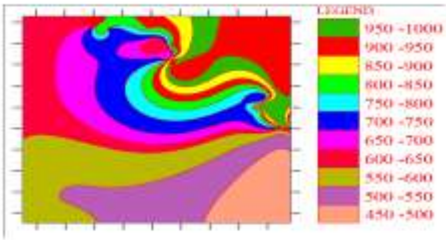
6- No_3 (ppm)



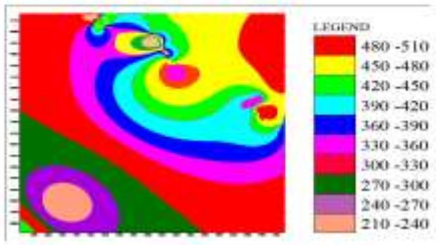
7- So_4(ppm)



8- TDS (ppm)



9- Cl(ppm)



10- Ca (ppm)

Fig. (6): Spatial distribution maps of many groundwater qualityparameters of wells

Soils information of Al-Muthanna Governorate land ,were obtained from National Center for Water Resources Management / Ministry of Water Resources-Iraq (2013),Fig.(7). These soils can be used to estimate erosion, infiltration, agricultural soil properties and to know the geological source of contaminants in the ground water. Alluvium soil was the dominant in the right and left of Euphrates River which represents the northeastern part of the study area, and these soils are typically poorly to poorly drain. The positions of the groundwater wells were near the boundary between the poorly drained, sand dune and mixed gypsiferous soils as illustrated in Fig.(7).So the spatial distribution of physical and chemical parameters concentration was along a line from northeastern to southwestern which is perpendicular to the line of distribution of wells in the study area. Management practices is essential for reducing the movement of pollutants from the land to ground water because of existence of sand and clay soils which one cannot hold a large quantity of salts and the other absorbed material.

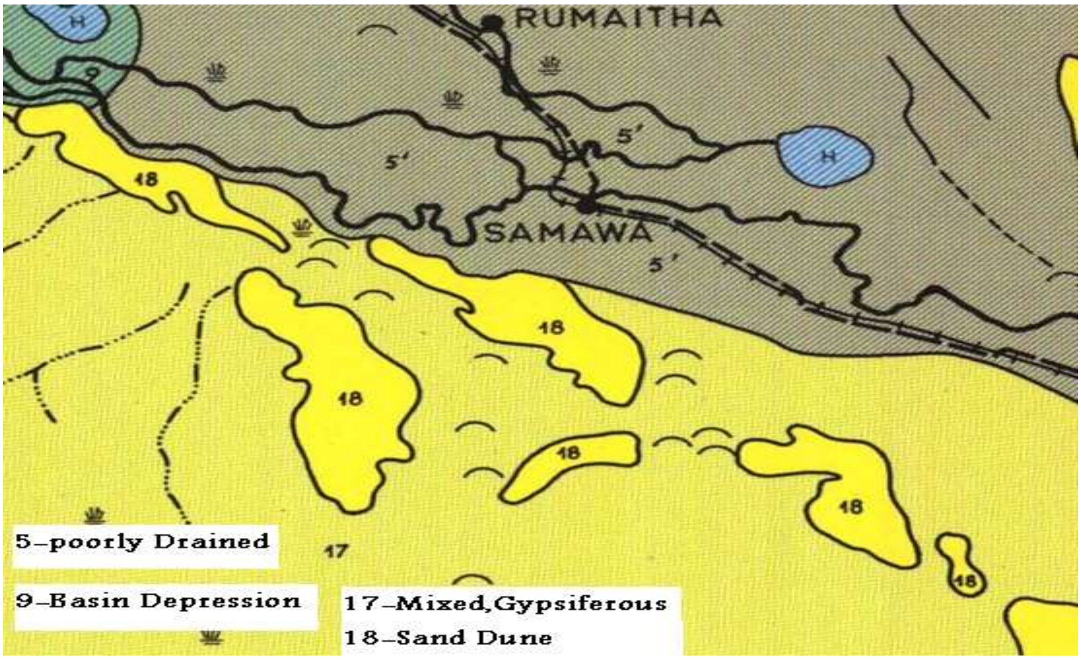


Fig.(7): Soil map of Al-Muthanna Governorate land.

5. CONCLUSIONS

The application of SAR, NA %, WQI and GIS in this study have been found useful in assessing the quality of groundwater in Al-Muthanna Governorate. The results were evaluated in detail and compared with WHO guidelines for irrigation water (2004) and drinking water standard by Iraqi and WHO (2011). The predominant cation trend for high concentrations is Na, Ca , Mg and K respectively. Sodium is the dominant cation. All samples from wells are unsuitable for irrigation uses according to the classifications of groundwater .High percent of ground water samples (93%) fall in the field of unsuitable water. The average value of WQI is 268. WQI of ground water of wells in the study area according to the classifications, ranged from poor, very poor (62.2% of wells) and unsuitable for drinking water as well as for irrigation water. The application of MLR shown that TDS and SO_4 were highly interrelated with WQI with (R^2=0.952).The parameters NO_3 and PH have a minimum negative correlation with WQI . The MLR equation is very important in prediction the future WQI with knowing of some parameters like the TDS which is an important physicochemical parameter of drinking water quality.The spatial analysis of ground water quality from the (45) wells, shown higher concentration of ground water salts in northeastern part of the study area. The lowest concentration of salts was observed in southwestern, and some other parts of the study area. Alluvium soil was the dominant in the right and left of Euphrates River which represents the northeastern part of the study area and these soils are typically poorly to poorly drain so the groundwater is unsuitable for drinking and agricultural purposes. The positions of the groundwater wells were near the boundary between the poorly drained, sand dune and mixed gypsiferous soils. Management practices is essential for reducing the movement of pollutants from the land to ground water because of existence of sand and clay soils which one cannot hold a large quantity of salts and the other absorbed material. Also the study area is highly dependent upon the supply of poor quality of water from upstream of the Euphrates River and the direction of ground water flow from the north and west aquifers to south aquifers of Iraq with low quality. The following solutions apply for SAR problems in the study area: i) change irrigation sources ;ii) increase aerification; iii) water lower in sodium levels mix with irrigation water and iv) application of sulfur, gypsum, or injection of sulfuric acid. Different technical methods may be utilized for improving the quality of groundwater for drinking purposes are desalination with reverse osmosis, and membrane technology. For agricultural purposes are i)selection of suitable salt-tolerant crops ;ii) water management improvements(the adoption of advanced irrigation technology); iii) maintenance of soil-physical properties to assure a suitable soil permeability to meet crop water and leaching requirements and iv) utilize permeable reactive barrier technology.

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