Evaluation The Quality of Wells Water in Greenbelt Area North of AL-Najaf Al Ashraf City

Dr. Sataa AL-Bayati
Building and Construction Engineering Department, University of Technology/Baghdad
Dr. Salih Albakeri
Building and Construction Engineering Department, University of Technology/Baghdad
Mohend M.Salih
Building and Construction Engineering Department, University of Technology/Baghdad
Email:mohendrazi@yahoo.co.uk

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ABSTRACT

The present study focuses on evaluating the quality of groundwater in Green – Belt project in Al- Najaf Governorate area for human drinking and irrigation. The samples have been collected from five wells, which, have been used to irrigate the plants in the project. Thirteen parameters has been selected for assessment quality of ground water: temperature, pH, electrical conductivity, total dissolved solids, sulfate ion, turbidity, oil & grease, cadmium, lead, chromium, iron, copper, zinc. In addition, the values parameters have been submitted as spatial distribution on map by using GIS. In addition, water quality index for irrigation and human drinking were calculated. Almost all samples have high salinity, which represented as EC., TDS and SO_4^{-2}. In addition, the results exceed the standard limits for irrigation and human drinking. O&G was very high concentration in wells GWF4 and five due to upstream AL-Najaf refinery and they are no recommend for drinking or irrigation. Heavy metals in samples were exceeding the limit of human drinking for lead and iron but other metals were within limits except few samples. For irrigation, almost all samples were within limits, but not recommended for fruits. Calculation of IWQI showed that wells GWF1, two, and three located in fair category, which, regarded as moderate restriction and possibility using for irrigation in Green-Belt project and no side effect on human except palms and olive. The values of IWQI in wells GWF4 and 5 are poor and regards as severe restriction which, can not be used due to contain of O&G in water from AL-Najaf refinery. WQI calculation showed GWF1, two and three were categorized poor and may be used as human drinking water with treatment units. Nevertheless, GWF4 and five were unfit for human drinking.
Keywords: Green Belt, ground water, heavy metals and WQI

INTRODUCTION

Water is one of the most vital resources for the sustenance of human, plants and other living beings. Surface and ground water is an important and major source of drinking water for urban and rural areas in Iraq. Due to a growing population and increasing concern in the delivery of food, weakening surface water resources in Iraq and newly conflict around the water and the emergence of the concept of a global water war. Therefore, the use of ground water became very important especially, in the west desert in Iraq. Ground water is rarely treated and presumed to be naturally protected, it is considered free from impurities, which are associated with surface water, because it comes from deeper parts of the earth[1]. This research aims to evaluate the quality of wells water in Green- Belt area north of Al-Najaf City. Quality of the ground water have been assessed by choosing the parameters; E.C., pH, turbidity, temperature ^oC, TDS, SO_4^{-2}, O&G and some heavy metals like Pb, Cu, Cd, Zn, Fe and Cr and compared with Iraqi central organization of standardization and quality control[2], World Health Organization standards [3] and Canadian Council of Ministers of the Environment for irrigation[4], as shown in Table (1) . In addition depending on water quality

(WQ) method to categorize the ground water. The Canadian Council of Ministers of the Environment; CCME modified CCME Water Quality Index for irrigation [4]. For drinking, Horton was the first researcher that developed and proposed the concept water quality index (WQI) , and have an active role in operations control of water quality strategy and its management so that they can from which water classification qualitatively for various activities within specific categories and scientific manner is simple and useful[5].
The water quality index was used by many researchers as [6,14]. In addition many researchers assessed the quality of ground water as, [6, 15,22]

Table (1) Irrigation and human drinking water standards [2,4]

Parameter	ICOSQC	WHO	CCME
Turbidity NTU	5	5	-
Temperature ^{o}C	ACC	ACC	-
pH	6.5-8.5	6.5-8.5	6.5-8.5
E.C. µmoh/cm	2000	2000	5000
T.D.S mg/l	1000	1000	3000
Sulphate mg/l	400	250	2000
Copper µg/l	1000	1000	2000
Chromium µg/l	50	50	100
Iron µg/l	300	300	5000
Zinc µg/l	3000	5000	5000
Lead µg/l	10	10	200
Cadmium µg/l	3	3	10

Oil&Grease; O&G are not included in these standards, this mean that O&G must be not exist in water and its value must be zero.

Description of study area

The study area is named Green-belt project located in the west north of AL-Najaf Governorate, in the desert region and begins from Najaf-Karbala high way to strategy line of oil., This study area as shown in Figure (1), located in AL-Najaf Governorate between longitudes (44^{o} 10' 0"E & 44^{o} 20' 0"E) and latitudes (32^{o} 5' 0"N & 32^{o} 15’ 0"N) and covering an area of about 90 km^{2}.

The study area is a part of Najaf- Karbala plateau, which is limited between the East by alluvial plain and South by Najaf Fault. Najaf Governorate borders from north and Euphrates River in east and contains variety formations: Dammam, Euphrates, Fat'ha, Injana and Dibdiba Formation. Gypcrete covers the surface of the plateau [7].

Location of wells

Eight wells in the study area, three of these wells were out of service, therefore Five wells were used in this study. All wells had been implemented by Directorate of agriculture in cooperation with Directorate of wells of Al-Najaf Al- Ashraf. Table (2) explained the information and boundaries for each well.

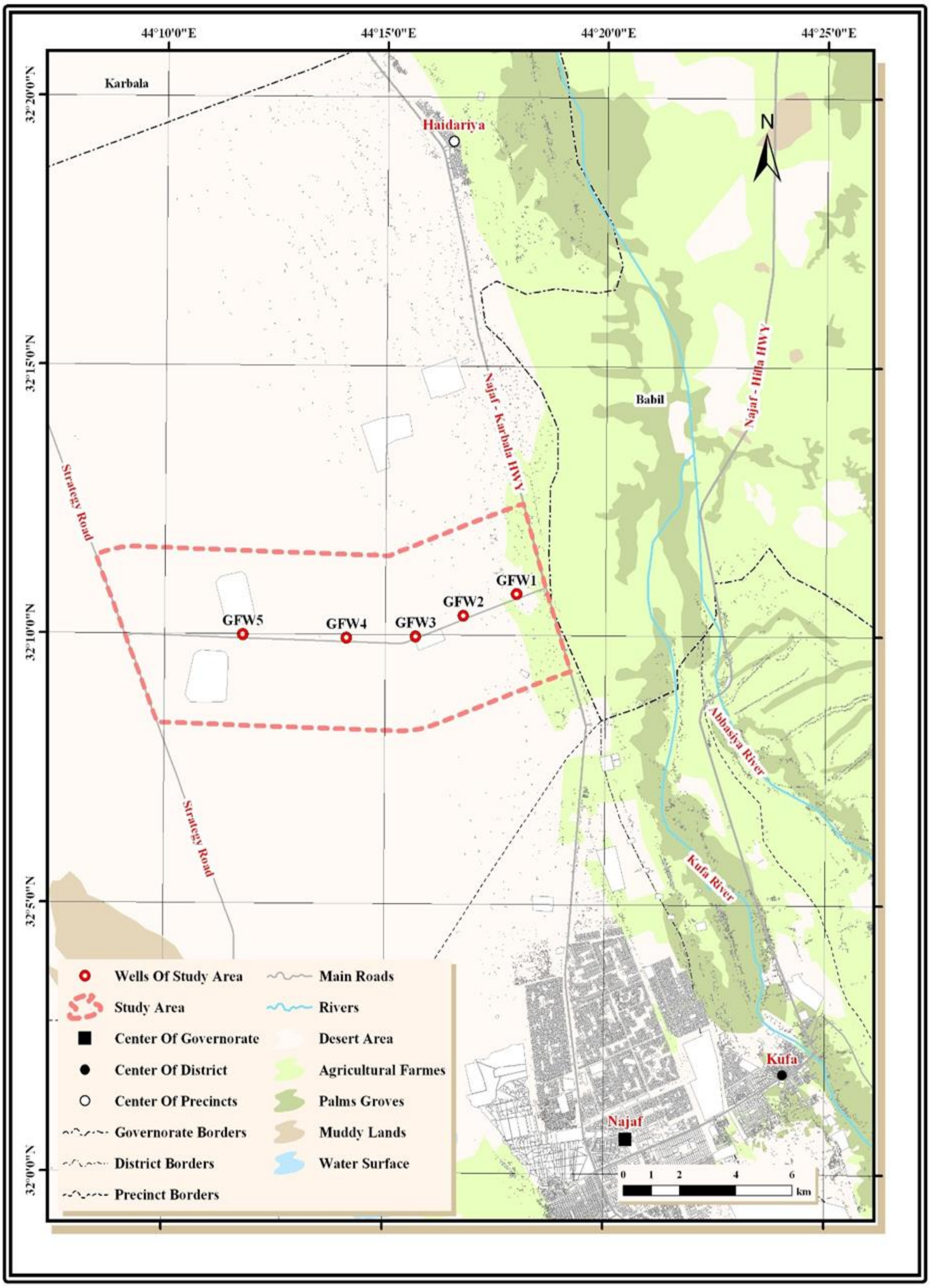

Figure (1) wells of Green-Belt project

Table (2) Information of wells in Green-Belt Project [23]

well	Y Longitude	X Latitude	Well depth m*	Static water level m	dynamic water level m	Discharge L/s
GFW1	44 17 58.68	32 10 46.26	50	18	25	9
GFW2	44 16 46.32	32 10 22.02	50	16	22	7
GFW3	44 15 41.28	32 9 58.2	50	24.9	32.1	6
GFW4	44 14 7.08	32 9 56.7	172	25	48	9
GFW5	44 11 46.02	32 9 59.64	183	48	45	7

Fieldwork

Before sampling, the wells were pumped for several minutes until the temperature, conductivity, and pH were stabilized. Polyethylene bottles were cleaned and rinsed thoroughly with the water of well so that the sample was representative of the ground water source. Sampling has been implemented for each well by four times every month during Dec. 2014 – Apr. 2015.

Laboratory work

Turbidity, E.C., TDS, pH and SO_4^{-2} have been tested in laboratory of Directorate for Water in AL-Najaf AL-Ashraf Governorate. Oil&Grease have been preserved in dark glass bottles and analyzed in laboratory of directorate of Environment in AL-Najaf AL-Ashraf Governorate. The best sample containers for heavy metals are made of polyethylene. Preserve samples immediately after sampling by acidifying with concentrated nitric acid HNO_3 to pH < 2. Usually 1.5 mL concentration HNO_3/L sample (or 3 mL 1 + 1 HNO3/L sample) is sufficient for short-term preservation. After acidifying sample, preferably store it in a refrigerator at approximately 4°C to prevent change in volume due to evaporation. tests have been done in University of Kufa- Collage of Pharmacy. Table (3) explained the methods of test for such above parameters[24].

Table (3) Methods of test for parameters[24]

parameter	Designation in ASTM	parameter	Designation in ASTM
E.C.	D1125-95	Cd	D3557-12
pH	D1293-12	Pb	D3559-08
Turbidity	D7726-11	Cr	D1687-12
TDS	D5907-13	Cu	D1688-12
SO_4^{-2}	D516-11	Fe	D1067-11
Temperature	E 1-88	Zn	D1691-12
O&G	D3921-96		

Application of Water Quality Index for Irrigation Purposes

After obtaining the results and classified according to the time and place in the matrix was used water quality index of the Canadian model (CCME-WQI) and described by Canadian Council of Ministers of the Environment[25]. This model is based on confusion between the three mathematical factors in calculating the final figure crossing on the status of water quality is the scope, frequency and amplitude, where these factors are calculated from the specific to each variable equations, where the final figure of acquired reflect on the state of water quality, as follows[26]:

1. The first factor F1 (Scope): Represents the ratio between the number of variables that do not match their values with the objectives set for the model (Objective) and the total number of variables and is calculated from the following equation:

$$\boldsymbol{F_1} = \left\{\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right\} - 1 \qquad \ldots\ldots(\mathbf{1})$$

2. The second factor F2 (Frequency): Represents the ratio between the number of tests that did not meet the objectives set for the model and the total number of tests values. This factor was Calculated from the following equation:

$$\boldsymbol{F_2} = \left\{\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right\} - 1 \qquad \ldots\ldots(\mathbf{2})$$

3. The third factor (F3) (Amplitude) : Represents the failed tests and which do not correspond with the objectives and values of the tests are calculated according to the following steps: -

i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as in the following equation, When the test value must not exceed the objective:

$$\boldsymbol{Excursion_i} = \left\{\frac{Failed\ test\ value_i}{Objective_i}\right\} - 1 \qquad \ldots\ldots(3a)$$

For the cases in which the test value must not fall below the objective, can be expressed as in the following equation:

$$\boldsymbol{Excursion_i} = \left\{\frac{Objective_i}{Failed\ test\ value_i}\right\} - 1 \qquad \ldots\ldots(3b)$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as in the following equation:

$$\boldsymbol{nse} = \frac{\sum_{i=1}^{n} Excursion}{number\ of\ tests\ (n)} \qquad \ldots\ldots(\mathbf{4})$$

iii) F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100, and can be Calculated from the equation(5) :

$$F_3 = \frac{\boldsymbol{nse}}{(0.01 * \boldsymbol{nse}) + 0.01} \qquad \ldots\ldots(\mathbf{5})$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors, then the WQI can be calculated by eq. (6) below:

$$WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \qquad \ldots\ldots(\mathbf{6})$$

The values of water quality index that products must be ranging from (0 – 100), and these values are express about water quality according to Table (4)

Table (4) : Classification of water quality index [25]

Rang	IWQI	Description
95-100	Excellent	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
80-94	Good	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
65-79	Fair	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45-64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0-44	Poor	Water quality is usually threatened or impaired; conditions usually depart from natural or desirable levels.

Application of Water Quality Index for Drinking Purposes

A weighted arithmetic index method have used to calculate WQI as shown[14]:

1. Calculating the constant of proportionality; k; by using equation (7):

$$k = \frac{1}{\sum_{j=1}^{n} \frac{1}{S_i}} \qquad \ldots..(\mathbf{7})$$

Where: S_i= permissible limit for the ith parameter. n = number of parameters.

2. Calculating of weightage of ith parameter; relative weight Wi by using equation (8)

$$W_i = \frac{K}{S_i} \qquad \ldots\ldots.(8)$$

3. Calculating sub index of ith parameter Qi by the expression:

$$Q_i = \frac{100Vi}{Si} \qquad \ldots\ldots.(9)$$

In which Vi is the monitored value of the i^{th} parameter. While, the quality rating for pH (Q_{pH}) was calculated based on:

$$Q_{pH} = 100\left[\frac{(Vi-S)}{(Si-S)}\right] \qquad \ldots\ldots.(10)$$

Where:

Vi = value of the water quality parameter obtained from the laboratory analysis.

S = the ideal value of pH considered as equal to 7.00.

S_i = value of the water quality parameter equal 8.5.

4. Calculating water quality index WQI as follows:

$$WQI = \frac{\sum_{j=1}^{n} QiWi}{\sum_{j=1}^{n} Wi} \qquad \ldots\ldots.(11)$$

Based on the WQI, the quality of the water have categorized into five statuses from excellent purpose to unfit for human drinking as shown in Table (5).

Table (5) Status of water quality based on WQI [27]

WQI value	0-25	26-50	51-75	76-100	>100
Water quality statuses	Excellent	Good	Poor	Very poor	Unfit for human drinking purpose

Results and Discussion

The parameters have been studied, which are; pH, E.C., TD, turbidity, SO_4^{-2}, O&G, temperature as shown in Table (6)

Table (6) average values of parameters in all wells

Parameters	Wells				
	GWF1	GWF2	GWF3	GWF4	GWF5
pH	7.72	7.73	7.73	7.72	7.74
E.C. µmoh/cm	6307	6073	5597	7306	5929
TDS mg/L	4036	3886	3582	4671	3795
Turbidity NTU	1.3	0.6	0.4	27.1	45.3
SO_4^{-2} mg/L	2180	2123	2063	2182	1439
O&G mg/L	0	0	0	16	29
Temperature ^{0}C	25	24	26	29	29

1-Temperature:

The results of temperature were ranged between 24-29 ^{o}C as shown in Table (6). the lowest value in GWF2 and highest in GWF5. The deeper wells, as shown in Table (2), have the highest value may be due to that are near the core of the earth. In addition, the reactions of rocks and water may generate the heat.

2- Hydrogen Ion; pH

Table (6) showed that pH values in the wells of the present study are ranged between (7.72 - 7.74),. Comparison with standard limits for irrigation and drinking purpose, water samples analysis indicated that there are no abnormal pH values in the area of study and satisfied standards specifications.

3- Electrical conductivity; E.C.

Table (6) shows that the results were ranged between (5597-7306µmoh/cm). The minimum value was in GWF3 and maximum in GWF4. All values exceeded the standard for irrigation (≤5000 µmoh/cm). The results showed the impossibility of using ground water as human drinking because they more than the limits significantly (E.C.≤2000 µmoh/cm). Due to the types of layers of formations, which have different soil like; lime stone, gypsum, anhydrite and carbonate rocks; and rain and ground water dissolves the salts and carries ions while movement through soil, therefore increasing the concentration of variety ions as result increases E.C.

4- Total dissolved solids; TDS:

Table (6) shows that, the results ranged between (3582-4671mg/L). As comparing with standards of irrigation and human drinking (TDS≤3500, ≤1000 mg/L), respectively, almost samples exceed the standards limits. The rocks and soils of location effected directly on concentration of ions in ground water and increased ions values.

5- Turbidity

Table (6) show that the water of GFW1, 2 and 3 were within the limits depended on standard of WHO for drinking water, where all values were lower than five NTU. Turbidity in wells GFW 4 and 5 was abnormal and has a high values between (27.1-45.3 NTU). The Oil &Grease from AL-Najaf refinery give color and effect on measuring of turbidity and the data does not represent the turbidity.

4- Sulfate ion SO_4^{-2}:

Table (6) shows that the results were ranged between (1439-2182 mg/L). Lowest value has been recorded from GWF5, and the highest was from GWF4. The results indicated that about 100% of samples, except GWF4, exceeded the standard of irrigation and human drinking; ≤2000 and 400 mg/L, respectively. As the geology formation of study area, consists gypsum and anhydrite rocks, the rainwater may dissolve the salts and carry in to ground water. This is lead to increase the concentration of ions in water of wells.

5- Oil &Grease; O&G:

Table (6) shows that, the results of O&G have been ranged between (0.00 – 29 mg/L). The wells GFW1, 2, and 3 have no O&G, but GFW4 and 5 have high level of O&G. AL-Najaf Refinery represent the major source of pollution, there is no treatment to outflows of wastewater from refining operations. In addition, the wastewater has been disposal to land directly, and the waste was discharged through the layers of soil and received to ground water. The wastewater consisted of high level of waste petroleum like oil, grease, heavy metals and other compounds. The distance between study area and refinery is approximately 7km, therefore the refinery may be the source of O&G in the water of studies wells.

Results of Heavy Metals Tests

Table (7) listed the average values of heavy metals were studied in this research.

Table (7) Average values of heavy metals in all wells

Heavy metals	Concentration mg/L				
	GWF1	GWF2	GWF3	GWF4	GWF5
Cd	2.276	1.941	1.7	1.647	1.918
Pb	11.92	14.01	10.9	7.8	7.988
Cr	18.76	18.19	27.75	10.84	11.19
Fe	34.96	18.72	23.74	462.5	817.5
Cu	13.31	8.135	11.42	8.229	7.976
Zn	102.1	38.62	15.72	62.86	63.71

1- Cadmium; Cd

Table (7) shows that, the concentrations of Cd were ranged between (1.647-2.276µg/L). Generally Cd has been observed within the standard limits of human drinking; ≤3µg/L and irrigation ≤10µg/L. The results described that no risk from cadmium contaminants when using the wells water for irrigation or drinking.

2- Lead; Pb

Table (7) shows that, the results ranged between (7.8 -14.01µg/L). The concentrations of Pb in GWF 1,2 and 3 exceeded the standard of drinking ≤10 µg/L. But the concentration in GWF 4 and 5 were within the limits. The results showed apprehensive when using the ground water as human purposes. The wastewater from refinery presents the important source due to consist of variety compounds like organolead and without any treatment for waste. Nevertheless, the results showed possibility use ground water for irrigation purpose due to all concentration of lead were less than the standard limit ≤200 µg/L.

3-Chromium; Cr

Table (7) shows that, the results ranged between (10.84-27.75µg/L). The average of results for every well was acceptable when compering with the limit of irrigation ≤100 µg/L and human drinking ≤50 µg/L.

4- Iron; Fe:

Table (7) shows that, the results ranged between (18.72 -817.5µg/L). The highest values were found in wells GWF4 and 5 which exceeded the limits of human drinking ≤300µg/L . But the concentrations of iron in other wells were within the limits. Compering with standard of irrigation ≤5000µg/L, all samples less than the standards.

5- Copper; Cu

Table (7) shows that, the results ranged between (7.976-13.31 µg/L) and lower than standard limits for irrigation and drinking (≤2000 and 1000 µg/L), respectively.

6- Zinc; Zn

Table (7) shows that, the values of samples ranged between (15.72 -102.1 µg/L) and lower than standard limits for irrigation and drinking (≤5000 and 3000 µg/L).

Water Quality Index Values for Irrigation:

There are three stage to calculation IWQI , first stage includes the classification of variables. Second stage includes calculation the values of the three factors: Scope (F1) and Frequency (F2) and Amplitude (F3) , then complete the last stage which is including calculation water quality index values for irrigation purposes as shown in Table (8). Figure (2) characterized the spatial distribution of the IWQI in the area of study.

Table (8) Irrigation water quality index for wells

GWF	1	2	3	4	5
F_1	33.4	33.4	41.7	41.8	41.7
F_2	25	24.51	24.51	31.8	31.8
Excursion	10.5	7.2	4.045	2779	4917
nse	0.0513	0.0352	0.02	13.62	24.1
F_3	4.88	3.4	1.96	93	96
IWQI	75.75	76	72	38.3	39.3
Categorizes	Fair	Fair	Fair	Poor	Poor

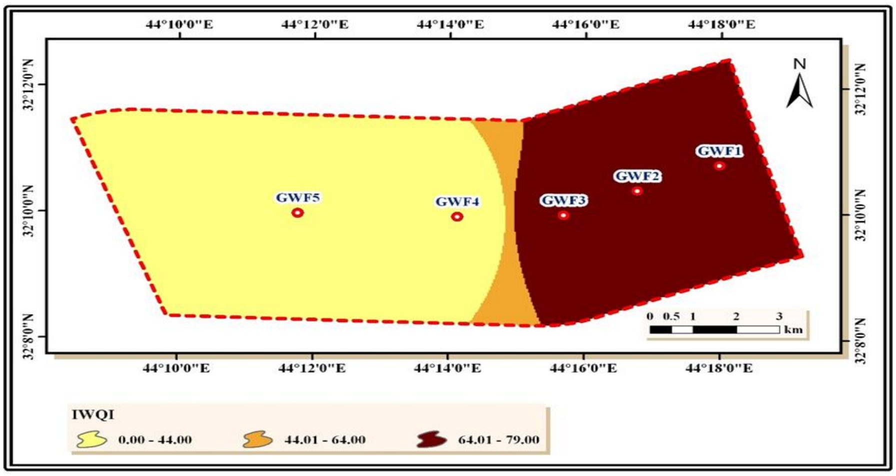

Figure (2) spatial distribution of IWQI in area of study

According to the recommendation in Tables (4) , GWF 1,2 and 3 characterized is fair quality and moderate restriction and can use for irrigation with the soil of high permeability. Fortunately, all the study area are located in AL-Najaf desert, which, have very high permeability sandy soil. So, the groundwater could be used with moderately tolerant to salt and type of plant. Wells GWF 4 and 5 categorized as poor and severe restriction. There are many troubles and constraints when use the water of these wells. The recommended not allowed using them wells for irrigation. Now, the refinery is the major reason to decrease values of IWQI in GWF 4 and 5. Almost plants except olive and palm in the project Green-belt are perennial and fruitless trees which , resistance the weather and consumed little amount of water in addition, its roots can received to deeper layers and obtain the water[23]. Therefore, ground water may be use except GWF4 and five due to risk effects on soil and plants.

It could be considered as a general suitability map for providing irrigation water from the aquifer. According to Figure (2) eastern part, brown color, represent fair and moderate restriction while the area of yellow color classified as poor and sever restriction and green zone as marginal and high restriction.

Water Quality Index for Drinking; WQI

The WQI and relative weights; Wi for all wells were calculated as shown in Table (9) and (10).

Table (9) Relative weight; Wi for the WQI parameters

parameters	Relative weight W_i	parameters	Relative weight Wi
E.C. µmoh/cm	0.000735676	Pb µg/L	0.147135191
TDS mg/L	0.001471352	Cr µg/L	0.029427038
SO4-2 $^{-2}$ mg/L	0.00367838	Fe µg/L	0.004904506
O&G µg/L	0.147135191	Cu µg/L	0.001471352
PH	0.173100225	Zn µg/L	0.000490451
Cd µg/L	0.490450638		

Table (10) values of WQI for all wells

	Q_iW_i in GWF 1	Q_iW_i in GWF 2	Q_iW_i in GWF 3	Q_iW_i in GWF 4	Q_iW_i in GWF 5
E.C.	0.232	0.223	0.209	0.269	0.218
TDS	0.594	0.572	0.536	0.687	0.558
SO_4^{-2}	2.004	1.973	1.949	2.006	1.324
O&G	0.000	0.000	0.000	24039	42657
pH	8.309	8.424	8.424	8.309	8.540
Cd	35.966	31.062	27.792	26.157	29.427
Pb	17.509	20.608	16.038	11.477	11.771
Cr	1.106	1.071	1.636	0.636	0.659
Fe	0.057	0.031	0.039	0.756	1.337
Cu	0.002	0.001	0.002	0.001	0.001
Zn	0.002	0.001	0.000	0.001	0.001
QWI	66	64	57	24090	42712
Class	Poor	Poor	Poor	Unfit for drinking purpose	Unfit for drinking purpose

The values of WQI for GWF1, 2 and 3 were in class poor, according to Table (4). The increase in the salinity and some heavy metals in ground water affected directly the value of WQI. The salinity depended on the nature of formation of the study area. There were not any concentrations of O&G in wells. The results explained that could not use the well as drinking purpose and need units of treatment for civil consumption. The values of WQI for GWF 4 and 5 were very high results. Due to increase in concentration of O&G therefore, the parameter was the major factor to calculate the results and reduced the significance for rest parameters. That means impossibility using these wells as drinking even if using units of treatment. The treatment need especially units to remove the O&G and the traditional treatment cannot use for this water. Figure (3) shows that brown zone represent unfit for drinking. However, other area may be used as drinking with treatment to conform standard of drinking.

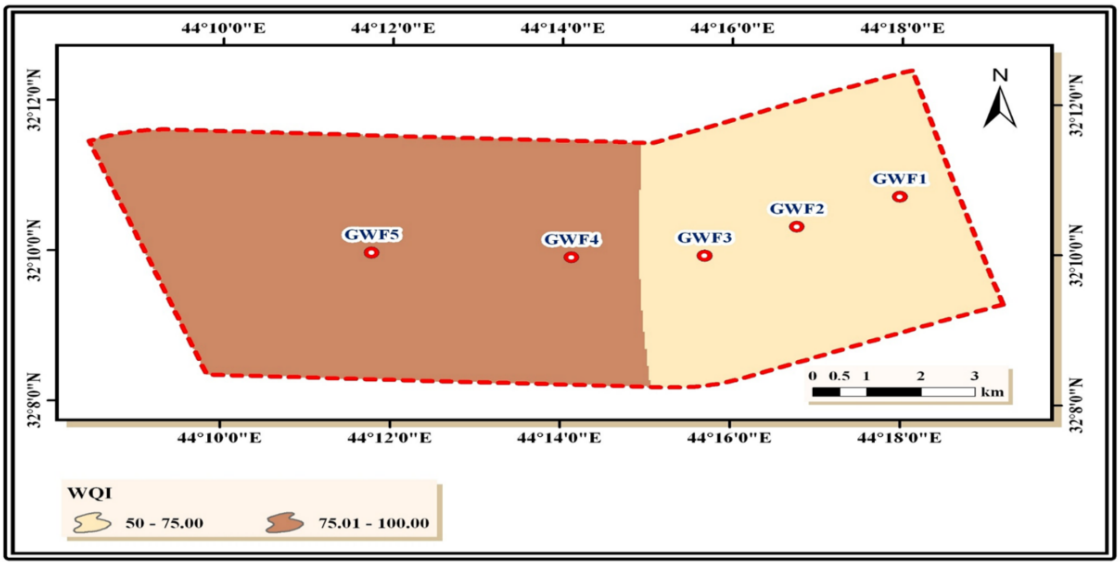

Figure (3) spatial distribution for WQI in area of study

CONCLUSION

1. The wells GWF 1, 2, 3, 4 and 5 have high salinity and exceed the standards limits for human drinking and irrigation. There are many restrictions on ground water if it is used as irrigation water, especially with fruitful tree, but no problems with fruitless plants.
2. Almost concentrations of the studied heavy metals in the samples of ground water were within standards of irrigation. However, in the comparison with standards of human drinking, the results showed that the percentages of heavy metals in samples were 21, 43.5, 17.6 and 9.4 for metals Cd, Pb, Fe and Cr, respectively within drinking limits. For Cr and Zn, all samples were within limits.
3. The study indicates the possibility of using the ground water that has been categorized as fair for irrigation in Green-Belts Project, because all seedlings are perennial and fruitless except palms and olive. Other wells that, categorized as poor cannot be used for irrigation purpose, due to the high concentration of O&G.
4. The values of WQI for wells ranged between “57-42712” that categorized as poor to unfit for drinking purpose. The wells GWF1, 2 and 3 were categorized as poor and may be used as drinking water after treatment. However, the wells GWF 4 and 5 were categorized as unfit for human drinking and cannot ever use for drinking purpose.
5. Turbidity in wells GWF 1, 2 and 3 were within the limit of drinking. However, in wells GWF 4 and 5 the high concentration of Oil & Grease changes the color, effected on the readings of turbidity values, and gave the fault results.
6. AL-Najaf Refinery may be representing the major sources of pollution for wells GWF4 and five.

Recommendations

1. The following authorities; AL-Najaf refinery, agriculture and environment directorate, should make a joint committee, to study how to control the pollutants from refinery and prevent their effects on ground water.
2. Test other parameters in ground water like arsenic and use other methods to calculate WQI.
3. Drilling deep wells exceed the depth of wells in the present study area. This may modify the quality of water.

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