ASSEEESSMENT OF INDEX FOR AQUIFER WATER QUALITY FOR IRRIGSTION AND LIVESTOCK PURPOSES OF DAMMAM AQUIFER IN NAJAF AREA OF IRAQ

حساب مؤشر نوعية المياه الجوفية للإغراض الاروائية و سقي الحيوانات لتكوين الدمام لمنطقة النجف في العراق

Hussain Musa Hussain[1] Salwan S. Al-Hasnawi[2] Ayser M. Al-Shamma`a[3]
[1]Hussain Musa Hussain: Faculty of Science, University Kufa, Iraq.
[2]S. Al-Hasnawi: College of Remote Sensing, Al-Karkh University of Science, Iraq.
[3]Ayser M. Al-Shamma`a: College of Science, University of Baghdad, Iraq.

ABSTRACTION

The value of Water Quality Index (WQI) is a good indicator of water quality. The objective of this study is to assessment of Index of Aquifer Water Quality (IAWQ)for irrigation and livestock purposes for the Dammam confine aquifer in the western desert.The values of (IAWQ) are shown of chemical parameters which can delineate the areas of natural pollution especially in discharge areas. In spite of presence of pollution for such contaminated parameters correlate with presence of source rocks of theses parameters, it can be noted that most of groundwater samples over study area were permissible for irrigation. As a conclusion, the Index map shows that ground water lies within permissible-polluted for agriculture purposes. As a conclusion, the Index map shows that ground water lies within good for livestock purposes. The GIS technique was used to prepare IAWQ maps of study area to show the distribution of Index values for individual locations of samples over the study area.The IAWQ index together with GIS serve or benefit the decision makers for drill the wells in the area to get ground water with a less pollution and land use planning with a less danger from pollution. The groundwater in the study area is generally alkaline in nature with pH ranging from 7.02 to 8.50 for two seasons. The TDS values range between 880 to 2000 and 1030 to 2270 mg/l for wet and dry seasons. The analyses indicate much variation between the two seasons, where major ions and heavy metals have high concentration for wet than dry seasons. The SO_4^{2-} was the most pollution parameters the effects on ground water for different uses.

On the basin of the value of IAWQ was applied for agriculture purposes and for livestock purposes in study area, the ground water lie within permissible-polluted for agriculture purposes and lie within good for livestock purposes.

KEYWORDS Index of water quality (IAWQ), pollution of groundwater, geographic information system (GIS)

الخلاصة .

الهدف من هذه الدراسة هو تقييم مؤشر جودة المياه الجوفية(IAWQ) لأغراض الري والثروة الحيوانية لتكوين الدمام في منطقة الصحراء الغربية. وتظهر قيم (IAWQ) للمتغيرات الكيميائية لمنطقة الدراسة وجود ملوثات طبيعية وبالخصوص في مناطق التصريف. وعلى الرغم من وجود تلوث ملحوظ والذي يمكن إن ينسب إلى التلوث الناتج عن الصخور المصدرية ، لكن معظم عينات المياه الجوفية في منطقة الدراسة مسموح بها لاستخدامات الاروائية وكخلاصة لنتائج البحث ، تبين ان خريطة المياه الجوفية تقع ضمن الحدود المسموح بها للأغراض الزراعية وكذلك للأغراض الحيوانية. ولقد تم استخدام تقنية GIS لإعداد خرائط IAWQ لمنطقة الدراسة لإظهار التباين المكاني لتوزيع قيم المؤشر لمواقع العينات في منطقة الدراسة. حيث إن مؤشر IAWQ يخدم أو يفيد صناع القرار لتحديد أفضل المواقع لحفر الآبار في المنطقة من اجل الحصول على المياه الجوفية ذات تلوث اقل وكذلك تخطيط امثل لخارطة استخدامات الأراضي مع خطر أقل للتلوث . اشارة نتائج البحث الى ان المياه الجوفية عموما ذات طبيعة قلوية مع درجة حموضة تتراوح من 7.02 إلى 8.50 لموسمين. كما وتتراوح قيم المواد

الصلبة الذائبة بين 880 إلى 2000 و 1030 إلى 2270 ملغم / لتر للمواسم الرطبة والجافة. وتشير التحليلات إلى وجود اختلاف كبير بين الموسمين ، حيث توجد أيونات كبيرة ومعادن ثقيلة ذات تركيز عالٍ للموسم الرطب أكثر من المواسم الجافة و كان SO_4 - أكثر معايير التلوث تأثيرا في المياه الجوفية للاستخدامات مختلفة. استنادا الى قيم IAWQ للأغراض الزراعية ولأغراض الثروة الحيوانية في منطقة الدراسة ،فان المياه الجوفية كانت ضمن الحدود المسموح بها للأغراض الزراعية وكذلك صالحة لشرب الماشية.

INTRODUCTION

The water quality plays a significant role in irrigated agriculture. Many problems originated during inefficient management of water for agriculture use especially, when it carries high salt load. The effect of total dissolved salt in irrigation water (measure in terms of electrical conductance) on crop growth is extremely important. Soil water passes into the plant through the root zone due to osmotic pressure. As the dissolved solid content of the soil water in the root zone increases, it is difficult for the plant to overcome the osmotic pressure and the plants root membrane are able to assimilate water and nutrients. Thus, the dissolved solid contents of the residual water in the root zone also have to be maintained within limits by proper leaching. These effects are visible in plants by stunted growth, low yield, discoloration and even leaf burns at margin or top [1].

There are many dissolved for suspended substances in waters that may be toxic for livestock rearing view point. These may include inorganic elements and their salts, certain organic wastes for man's activities, pathogens and parasitic organisms, herbicides and pesticide residues, some biologically produced toxins and radio-nuclides. The concentrations of these toxic substances, which render the water unsuitable for livestock is subject to a number of variables. These include age, sex, species and physiological state of the animals, water intake, diet and its composition, the chemical form of any toxic element present and the temperature of the environment. Excessively dissolved salt can cause physiological upset or death of livestock (salt poisoning). In general it has been observed that water contained less than 5000 mg/l dissolved salt can be used continuously for all livestock. The animals can tolerate more salinity in water when feed on green feed in presence of low salt content feed, the water of higher salinity is also tolerable by the livestock. There are several trace elements and ions that occur naturally or as the result of man's activities at critical concentrations. The elements or ions become objectionable in water when their levels affect palatability of the water, become toxic to the animals due to accumulation in tissues or body fluids, rending the meat, milk, eggs or other edible products unsafe for human use [1].

The delineation of ground water quality for human rise in study area by using the Water Quality Index (WQI) methodology make of reduce the cost and time necessary to drill the wells for agriculture and livestock purposes in the area of high pollution in ground water, so that delineate the good areas of ground water to expand the human populations and establish others in the areas non inhabited, in addition to limited the polluted areas for healthy embedding. Consequently, the number of physical and chemical parameters which defines the ground water qualities that are to be monitored for proper assessment of ground water quality. The ground water samples are collected from different locations on the study area which is located in the south-western part of Iraq (southern of western desert).

The purpose of present study is assess the ground water quality in the study area and identifies the type of pollution and damage extended for irrigation and livestock uses. Also, it is to review the methods currently available for pollution index of ground water and develop an appropriate method suitable for the nature of study area. The farther purpose is to prepare a ground water quality index map for study area with GIS environment.

THE STUDY AREA

The study area (Dammam formation boundary) represents a part from Najaf area which lies between latitudes $29^{o}\ 48^{/}\ 20^{//}$ to $32^{o}\ 23^{/}\ 15^{//}$ N and longitudes $42^{o}\ 48^{/}\ 51^{//}$ to $44^{o}\ 45^{/}\ 10^{//}$E with total area of approximately 28824 km^2.TheGeographical location of study area location is shown in Figure (1) and (2), also Table (1) exhibit locations of ground water samples. The study area has very arid climate with the monthly average rainfall of about 8.78 mm. The study area considers as a part from Iraq generally and western desert especially which lack of surface water except in the north east part of study area. Therefore the area depends on ground water (which consider the main source of water) to use it in different activities. There are many springs which occur in the north-east of study area (Najaf depression). These springs extended with the line of Abu-Jir fault also there are many of artesian wells are distributed in study area, these wells have been drilled in period 1960-1994. Also, many of non-artesian wells distributing in study area, these wells drilled after year of 1994, in order to reducing the ground water loss from artesian. Most of study area is desert and occurs of some sand dunes in Al-Ramla area in Najaf depression. Also, some of Mesa feature occurs in study area.

GEOLOGICAL AND HYDROGEOLOGICAL BACKGROUND

Figures (3) show the geological map for the study area (Development from Sissakian, 2000) [2]. The Dammam Formation was first described by Bramkamp in 1941 from the Dammam dome in east Saudi Arabia (Bellen et al., 1959) where it comprises limestone (chalky, organodetrital or dolomitic), dolomites, marls, and shales [3]. The thickness of the formation, in the Iraqi supplementary type area, reaches 250 m. The maximum known thickness is 298 m in water well K7-17 south west of Anah.

The confine aquifer of Dammam consists of three beds; upper, middle (which represent the main source of Dammam water) and impermeable lower Jil bed which separate the formation from Umm Erdhama, [4]. The Digenesis process like Dolomitization and Silicification has great influence on Dammam permeability. The main consists of Dammam which is Limestone consider heterogeneous rock from hydrogeological side. The Dammam carbonate is one of the most important aquifers in south west of Iraq. Its karst porosity, associated with fissures, controls the aquifer storage properties, Karstification and high permeability near the water table is controlled by ground water level fluctuations. Permeability decreases with depth. Highest permeability occurs in depressions where strong water circulation occurs. The potential rate of evaporation in the desert is several times greater than the average rainfall. Infiltration through the karts system occurs quickly also facilitating ground water recharge.

Significant recharge occurs through sinkholes, depressions and highly permeable valley beds [5]. The direction of ground water flow generally is from south west to north east of study area.Despite of rainfall littleness in the desert area, especially in the study area, the Dammam confine aquifer recharge from rainfall through faults and fractures occurs at the western area toward Iraqi-Saudi border and occurs at the south-east of Saudi Arabia. Many studies conclude that most of Dammam water comes from source of old period which associated or followed of Dammam deposition [6].

FIELD WORK PROCEDURE

Through the present study, 36 ground water samples were collected distributed over the study area (Figures 1 and 2). The time of sampling was conducted during a certain seasons, end of winter and end of summer at the same year (March and August of 2009) in order to monitor the geochemistry changes in ground water during the Water surplus period (WS), or wet period and Water deficit period (WD), or dry period in the study area. The groundwater samples were analysed for, TDS, pH, Ec, SO_4, Ca, Mg, Na, k, and Cl. Also, later calculate SAR, Na% and T.H. [7].

These parameters recorded concentration values of wet period less than dry period. This is because of diluting occurring for ground water as a result of rainfall recharging in recharge area.

MODIFY THE INDEX OF AQUIFER WATER QUALITY (IAWQ) FOR AGRICULTURE AND LIVESTOCK PURPOSES

On the basis of the hydrogeological as well as the groundwater quality scenarios in the study area, the basic framework of the Index of Aquifer Water Quality (IAWQ) proposed by Hussain (2004)has been considered suitable for application in this study in order to fulfil study objective, which is to get an overall status of groundwater quality for agriculture and livestock purposes. Details of the IAWQ index have been presented as followed steps [8].

Step 1. Transformation of raw chemical data into rating values (Y) as regards to standards

In order to relate data to global norms, each value of a parameter, Pij (field data value of parameter i in cell j), is related to its desired standard value Pid (agriculture water standards which are depend on Don (1995) [9] and Todd (2007) [10] classification for Irrigation water (Table 2). Also, livestock water standards are considered in present study depending on Altoviskiclassification for livestock [11] (Table 3). Each relative value, Xij, can be estimated as:

$$Xij = Pij / Pid \qquad \ldots (1)$$

To express Xij as a corresponding index rating value, related to groundwater quality, Yi has been assigned to each Xij value as follows:

- For good water quality, with Xij equal to 0·1, the corresponding index rating value would be around 1;
- For acceptable water quality, with Xij equal to 1 (the raw value of the parameter Pi equal to its standard desired value), the corresponding index rating value would be 5; and
- For unacceptable groundwater quality, with Xij equal to or higher than 3·5 (the initial value of the parameter Pi equal to or higher than 3·5 times its standard desired value), the corresponding index value would be 10.

Operational hydrological experience indicates that Y1=1 for X1=0·1; Y2=5 for X2=1; and Y3=10 for X3=3·5 (usually values of Yi lie between 1 and 10). For any parameter i in any cell j, an adjusted parabolic function of rates Yij = f (Xij) can be determined for each cell from 2nd order polynomial as in Equation (2):

$$Yi = -0{\cdot}712\, Xi^2 + 5{\cdot}228\, Xi + 0{\cdot}484 \qquad \ldots (2)$$

From this equation the corresponding rating Yi can be estimated for any value of Xi. After this transformation of the field data, the index formula (IAWQ) involves only Y values, representing input data for the next step in the development of the indexation formula.

Step 2. The IAWQ formula

The IAWQ formula applied by summation of weights multiplied by respective ratings of various parameters i for each cell j as follows:

$$IAWQ = C/n\left[\sum_{i=1}^{n}\left(Wri.Yri\right)\right] \qquad \ldots (3)$$

Where:

C = a constant, used to ensure desired range of numbers (in this case, C=10)

i, n = number of chemical parameters involved (i= 1, . . . , n)

This value is incorporated in the denominator to average the data

Wri = the relative value of Wi/Wmax

Wi = a weight for any given parameter

Wmax = the maximum possible weight (5)
Yri = the value of Yi/Ymax
Yi = the rating as related to Xi [obtained from Equation (2)]
Ymax = the maximum possible rating for any parameter (Ymax=10)

The limitations come from that the Index map did not adequately address the implicit pollution of ground water for agriculture and livestock purpose by taking only two parameters and ignored the others. Therefore the Index can not reflect the detail actual quality of ground water in study area. Also, they were assigned the parameter weights based on personal opinion. Therefore the modifications were made in the original framework towards development of the Modified Index of Aquifer Water Quality for Melloul and Collin (1998) [12].

The modifications of Index (MIAQW) have been explained in the following sections:

Step 3.Choosing the Parameters Including in (IAQW) and Classify Cluster Groups

First, from the point of regional significance, andfrom major ions and heavy metals (TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, Ni, Mn, Pb, Cd, Fe, Cu and Zn) which were analyses, only those parameters were included which reflected a violation of the Don (1995) and Todd (2007) classification for Irrigation water, also, Altoviski (1962)for livestock standard in more than 10% of the sample population distributed laterally across the region , that mean the parameter exceeds the permissible quality level for a given use [8]. Accordingly, the chemical parameters finally selected for IAWQ were all parameters of Tables (2) and (3) for irrigation and livestock purposes respectively. The parameters are TDS, pH, Ec, SO_4, Ca, Mg, Na, k, and Cl. Also, later calculate SAR, Na% and T.H.

The clay minerals in soil adsorb divalent cations, like calcium and magnesium ions from irrigation water. Whenever the exchange sites in clay are filled by divalent cations, the soil texture is conductive for the plant growth. Sodium reacts with soil to reduce its permeability. In case, the irrigation water is sodium dominant, the clay lattice is filled with sodium ions due to ion-exchange.

Such soils become impermeable and sticky and as such the cultivation becomes difficult to support plant growth. However, the cation exchange process is reversible and can be controlled either by adjusting the composition of water or by soil amendment by application of gypsum, which releases cations (calcium) to occupy exchange position. The tendency of water to replace absorbed calcium and magnesium with sodium and be expressed by the Sodium Ratio (SAR), where all the ion concentrations are in mill-equivalents per litter (meq/l) as following equation [1] and [10] :

$$SAR = \frac{rNa}{\sqrt{r(Ca + Mg)/2}} \qquad \ldots\ldots (4)$$

Also, the sodium concentration is very important in classifying irrigation water because sodium reacts with soil to reduce its permeability. Sodium percent is usually expressed in terms of percent sodium (also known as sodium percentage (Na %) and soluble-sodium percentage (SSP)) and can be calculated as fallowing equation [10]:

$$Na\% = \frac{Na + K}{Ca + Mg + Na + K} \times 100 \qquad \ldots\ldots (5)$$

Where all the ion concentrations are in mill-equivalents per litter (meq/l).Also, the irrigation water with high Ec concentration leads to decrement in plant growth. While, the increment of chloride in irrigation water cause burn of tree leafs especially citrus trees and grape. Sulphate increment cause SAR increases which affects on plant growth [1]. In additions to problems above, the pH and TDS also affect on water suitable water.

Step 4. Weights (Wi) were assigned to these ten parameters as per their analytical hierarchy in the human health (effecting) significance and not in a subjective manner (as attempted in the original work of Melloul and Collin [12]. Details of the Analytical Hierarchy Process (AHP) which used by

Hussain [8] and its application have been described in the following section. Therefore, for irrigation purposes, the weights were given as 5 for SAR, 2.21 for TDS and Na%, and 1.21 for pH and Ec. Also, for livestock purposes, the weights were given as 5 for SO_4, 2.21 for Ca, Mg, Na and T.H, and 1.21 for TDS and Cl.

Step 5.Calculation of the Final IAWQ Map Using GIS

- The $X_j$values were calculated for each cell (*j*) based upon equation (1) and using the geographic distribution of the parameters by using the *spatial analyst extension* in software *ArcView GIS;* where SAR_d,TDS_d, $Na\%_d$, ph_d, and Ec_d, are desired Don (1995) [9] and Todd (2007) [10] classification for Irrigation water. Also, SO_{4d}, Ca_d, Na_d, $T.H_d$,TDS_d, and Mg_d, are desired Altoviski (1962) for livestock standard.
- The Y_i values were calculated for each cell based upon equation (2). Subsequently, the Y_{ri}cell values for each parameter were calculated by dividing the Yi values by the values 10 (Y_{max}).
- W_{ri} values in cells for each parameter were calculated based upon the weight values divided by 5 (W_{max}). Then for each parameter, the Y_{ri} values were multiplying by the values of W_{ri}.
- The final values of the IAWQ Irrigation purposes were calculated by employing equation 3, whereas the values arrived at after summation of the ten values (Y_{ri} x W_{ri}) were multiplied by the value 2.0 (C/N; where C=10 and N=5).C is constant and equal to 10 because the Y_i values range 1-10, and N= 5 because the No. of elements was 5 (Table 4).
- The final values of the IAWQ livestock purposes were calculated by employing equation 3, whereas the values arrived at after summation of the ten values (Y_{ri} x W_{ri}) were multiplied by the value 1.4 (C/N; where C=10 and N=7).C is constant and equal to 10 because the Y_i values range 1-10, and N= 7 because the No. of elements was 7 (Table 5).

INDEX AQUIFER WATER QUALITY (IAWQ) FOR AGRICULTURE PURPOSES

The modified Index of ground water was applied for agriculture purposes in study area. The standards of this Index are depend on Don [9] and Todd [10] [13] [14] classification for Irrigation water (Table 2). Table (4) exhibit IAWQ index values of ground water samples for agriculturepurposes for wet, dry and average of the two periods. This Table was imported for Arc View GIS software in order to prepare the final IAWQ maps of study area which are shown in the figure (4) for average of two periods. Table (6) exhibits the range of Index values which is used in Figure (4). It can be noted that most of groundwater samples over study area were permissible for irrigation. As a conclusion, the Index map shows that ground water lies within permissible - polluted for agriculture purposes.

GROUND WATER QUALITY INDEX (IAWQ) FOR LIVESTOCK PURPOSES

The modify Index of ground water was applied for livestock purposes in study area. The standards of this Index are depending on Altoviski classification for livestock [11] (Table 3). Table (5) exhibit IAWQ index values of ground water samples for agriculture purpose for wet, dry and average of the two periods. This Table was imported for Arc View GIS software in order to prepare the final IAWQ maps of study area which are shown in the Figure (5) for average of two periods. Table (6) exhibits the range of Index values which is used in Figure (5). It can be note that all ground water samples over study area we very suitable for livestock. As a conclusion, the Index map shows that ground water lie within good for livestock purposes.

CONCLUSIONS

It is found through the present study of the ground water depended on the Chemical examination of groundwater shows that the groundwater is generally alkaline in nature with pH ranging from 7.02 to 8.50 for two seasons. The TDS values range between 880 to 2000 and 1030 to 2270 mg/l for wet and dry seasons. The analyses indicate much variation between the two seasons, where major ions

and heavy metals have high concentration for wet than dry seasons. The SO_4^{2-} was the most pollution parameters the effects on ground water for different uses.
On the basin of the value of IAWQ was applied for agriculture purposes and for livestock purposes in study area, the ground water lie within permissible-polluted for agriculture purposes and lie within good for livestock purposes.

FUTURE WORK ENVISAGED

Groundwater quality index cannot be completely estimated without understanding of the hydrogeological condition as well as the groundwater balance, so it would be advisable to extend the above study by increasing the number of monitoring wells both for optimal observation of water level and for lithologs. This may help in a better understanding of the interaction of the groundwater regime.

REFERENCES

[1] Central Ground Water Board (CGWB) and Central Pollution control Board (CPCB), 2000. Status of Ground Water Quality and Pollution Aspects in NCT-Delhi.
[2] Sissakian, V.K., 2000. Geological map of Iraq ,central company of geological survey and mineralization ,GEOSURF
[3] Bellen, R. C. VAN, Dunnington, H. V., Watzel, and Morton, D. M., 1995.LexiqueStratigraique International, Asie.V.3, Fasc, 10a, Iraq, Paris 333p
[4] Al-Naief, A. A., 2000. Hydrogiological study for Al-Rahalia area, down of Al-Gadaf valley. Unpublished Ms.c Thesis, College of Science, University of Baghdad.
[5] Alsam, S., Jassim, S.Z. and F. Hanna, 1990. Water balance of Iraq: stage 2, geological and ydrogeologicalconditions, Report, Ministry of Irrigation, Iraq.
[6] Waierdy, N.W., 1994.The Hydraulic characteristic of the Dammam Formation in the western desert of Iraq. Unpublished Ms. Thesis, college of Science, University of Baghdad
[7] Al-Hasnawi, Salwan S., 2009. Study The Ground Water Quality Using Water Quality Index For Al-Dammam Formation in Western Desert: The Case Study in Najaf Governorate. Unpublished Ph.D. Thesis, college of Science, University of Baghdad.
[8] Hussain, H.M., 2004. Assessment of Ground Water Vulnerability in an Alluvial Interfluve using GIS.Unpublished Ph.D Thesis, Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee-247 667 (India).
[9] Don C.M., 1995. A grows guide to water quality. University college station, Texas.
[10] Todd, D.K., 2007. Groundwater Hydrology.3nd edition, John Wiley, New York, 550 pp.
[11] Altoviski, M. E., 1962. Handbook of hydrogeology, Gosgeolitzdat, Moscow, USSR, (in Russian) PP. 614.
[12] Melloul, A.J., and Collin M., 1998.A proposed index for aquifer water quality assessment: the case of Israel’s Sharon region. Journal of Environmental Management, 54, 131-142.
[13] Shah S.M. and Mistry N.J. , 2013, Evaluation of Groundwater Quality and its Suitability for an Agriculture use in, District Vadodara, Gujarat, India, Research Journal of Engineering Sciences, Vol 2 No 11.
[14] RASUL M. K. and WAQED H. H. , 2013 , EVALUATION OF IRRIGATION WATER QUALITY INDEX (IWQI) FOR AL-DAMMAM CONFINED AQUIFER IN THE WEST AND SOUTHWEST OF KARBALA CITY, IRAQ , International Journal of Civil Engineering (IJCE), Vol. 2, No. 3.

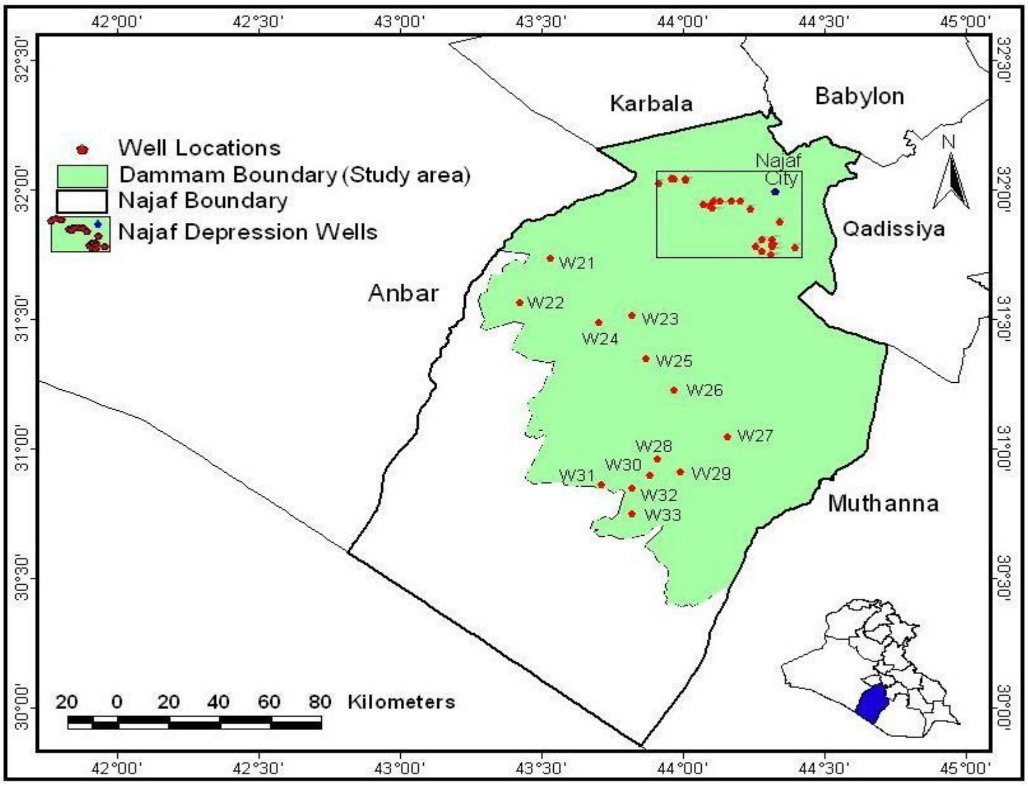

Figure 1: Location of the study area including wells (ground water) samples.

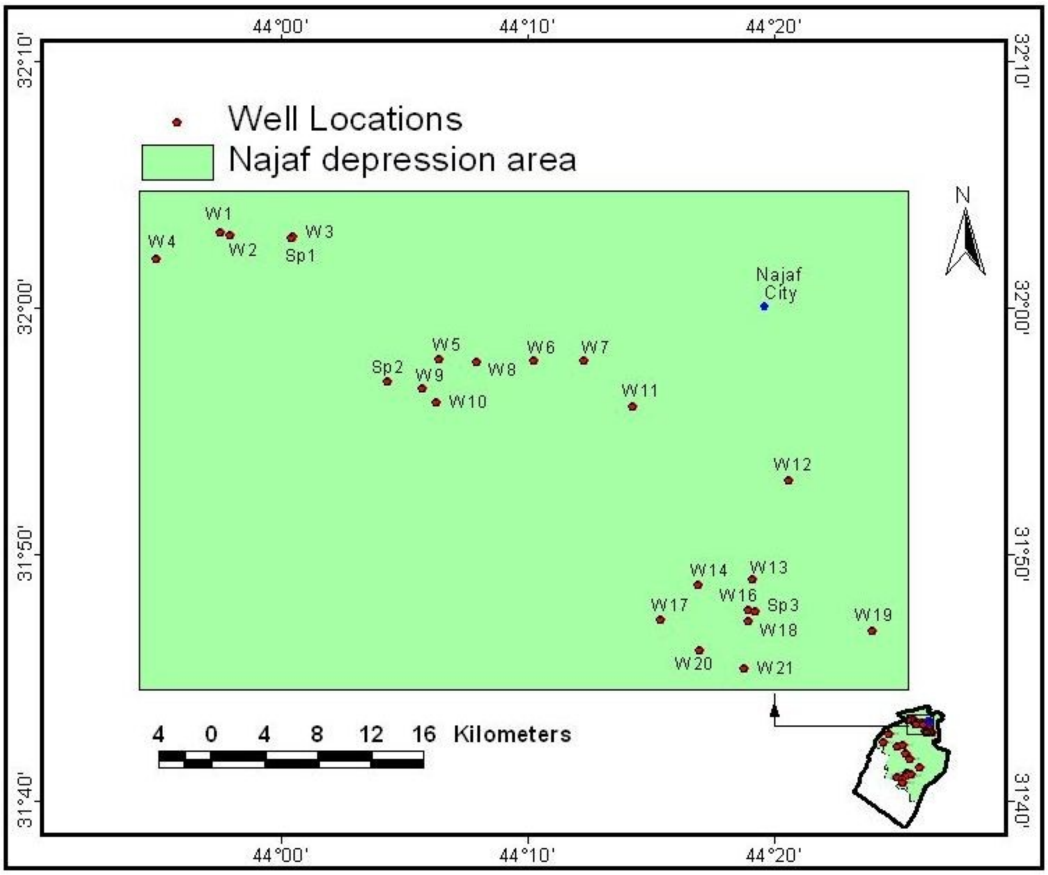

Figure 2: Location of Najaf depression wells samples.

Table (1): Locations of ground water samples

Well	Longitude	Latitude	Depth (m)	Well	Longitude	Latitude	Depth (m)	Well	Longitude	Latitude	Depth (m)
W01	43 57 32	32 03 03	150	W11	44 14 16	31 55 58	150	W22	43 25 12	31 34 12	150
W02	43 57 57	32 02 56	110	W12	44 20 34	31 52 58	140	W23	43 49 12	31 31 12	160
W03	44 00 28	32 02 52	200	W13	44 19 08	31 48 57	85	W24	43 42 00	31 29 24	160
SP1	44 00 25	32 02 49	-	W14	44 16 55	31 48 46	150	W25	43 52 12	31 21 00	150
W04	43 54 57	32 01 58	150	W15	44 18 57	31 47 45	120	W26	43 58 12	31 13 48	150
W05	44 06 25	31 57 54	150	SP3	44 19 15	31 47 42	-	W27	44 09 36	31 03 00	150
W06	44 10 15	31 57 50	161	W16	44 15 25	31 47 20	150	W28	43 54 36	30 57 36	150
W07	44 12 18	31 57 50	138	W17	44 18 57	31 47 16	120	W29	43 59 24	30 54 36	160
W08	44 07 58	31 57 46	75	W18	44 24 00	31 46 51	120	W30	43 52 48	30 54 00	160
SP2	44 04 19	31 57 00	-	W19	44 16 58	31 46 04	120	W31	43 42 36	30 51 36	150
W09	44 05 45	31 56 42	85	W20	44 18 46	31 45 21	140	W32	43 49 12	30 51 00	150
W10	44 06 18	31 56 09	150	W21	43 31 48	31 44 24	120	W33	43 49 12	30 45 00	160

* W: Well

* SP: Spring

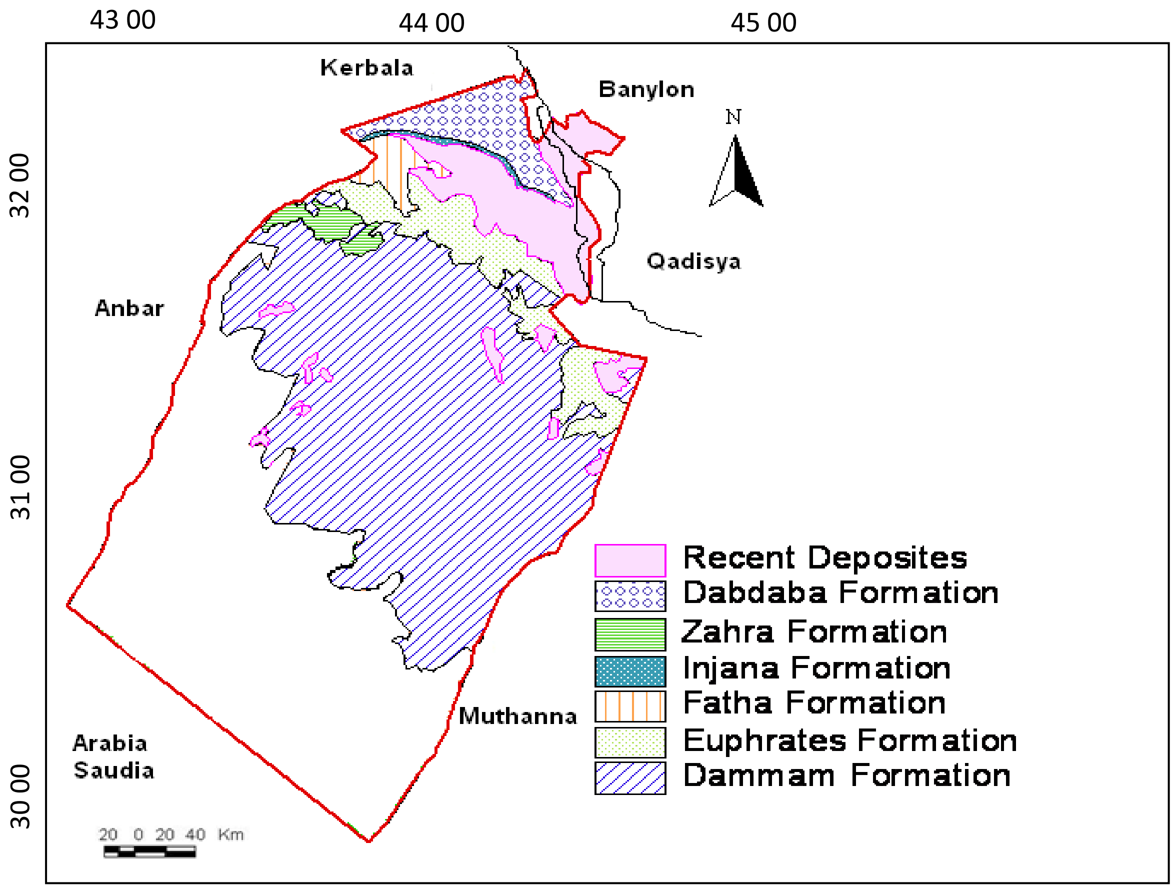

Figure 3: The geological map of study area.
(Development from Sissakian, 2000)

Table 2: Don (1995) and Todd (2007) classification for Irrigation water

pH	EC (µs)	TDS (ppm)	SAR	Na%	Water Quality
6.5	250	175	3	20	Excellent
6.5-6.8	250-750	175-525	3-5	20-40	Good
6.8-7.0	750-2000	525-1400	5-10	40-60	Permissible
7-8	2000-3000	1400-2100	10-15	60-80	Doubtful
>8	>3000	>2100	>15	>80	Unsuitable

Table 3: Standard of selected parameters for livestock purposes (Altoviski, 1962) [11].

Parameters (mg/l)	Very Good	Good	Permissible	Possible	Max. Limit
Na	800	1500	2000	2500	4000
Ca	350	700	800	900	1000
Mg	150	350	500	600	700
Cl	900	2000	3000	4000	6000
SO_4	1000	2500	3000	4000	6000
T.D.S	3000	5000	7000	10,000	15,000
T.H	1500	3200	4000	4700	54,000

Table 6:The groundwater classes' base on the range of Index values.

Y_i	Index Value (IAWQ)	Groundwater Class
1	0.417 (0-0.417)	Very Good
2.5	1.043 (0.417-1.043)	Good
5	2.086 (1.043-2.086)	Permissible
7.5	3.069 (2.086-3.069)	Polluted
10	4.172 (3.069-4.172)	Very Polluted

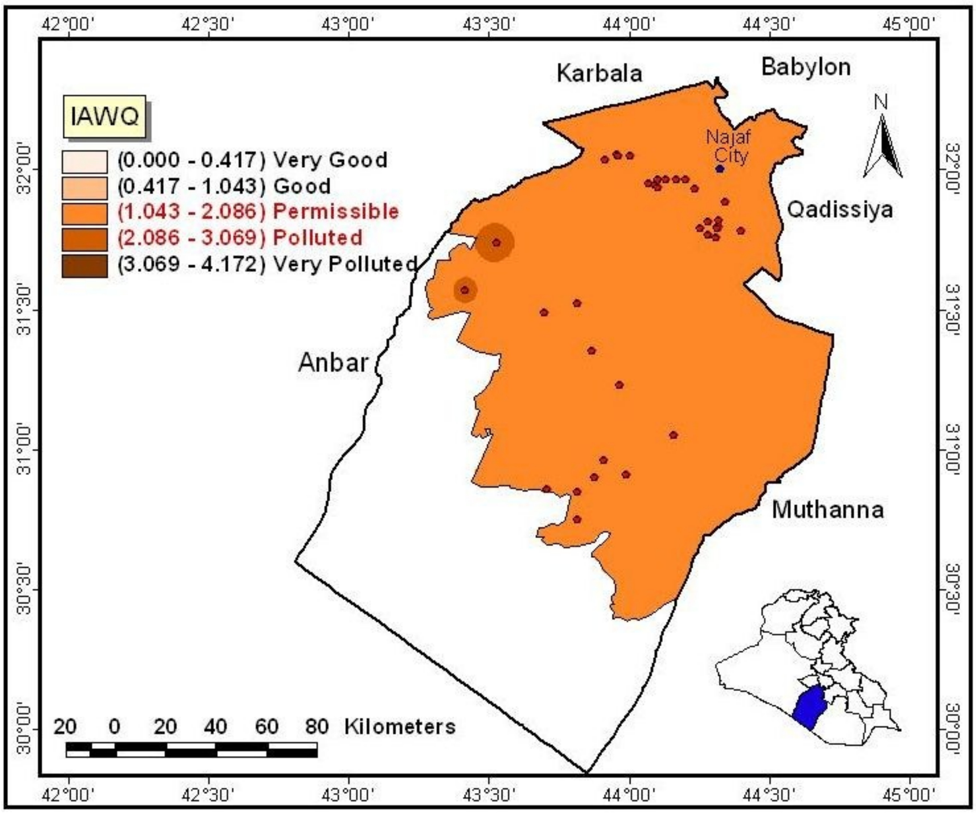

Figure 4: Relative index map of Aquifer water quality (IAWQ) for average of two periods for agriculture purposes in study area

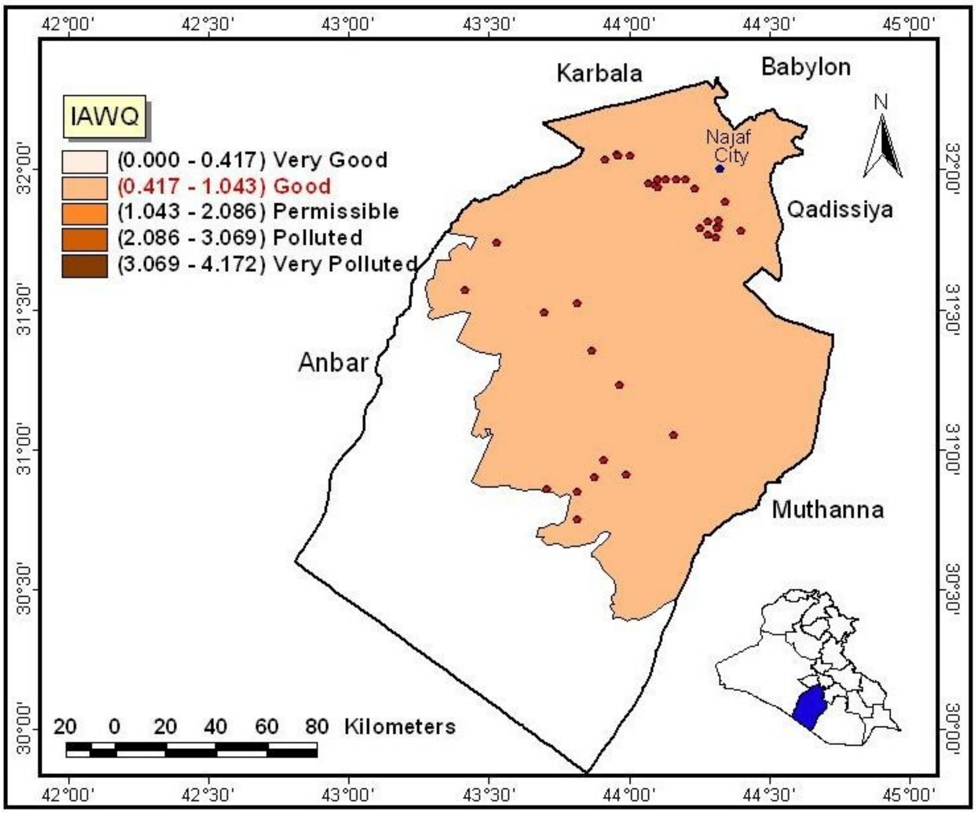

Figure 5: Relative index map of Aquifer water quality (IAWQ) for average of two periods for livestock purposes in study area

Table 4: IAWQ index values of ground water for Agriculture purpose.

Well	Long.	Lat.	IAWQ - Wet	IAWQ - Dry	IAWQ - Average
W01	43 57 32	32 03 03	1.722	1.789	1.756
W02	43 57 57	32 02 56	1.559	1.710	1.634
W03	44 00 28	32 02 52	1.689	1.762	1.725
SP1	44 00 25	32 02 49	1.692	1.866	1.779
W04	43 54 57	32 01 58	1.629	1.773	1.701
W05	44 06 25	31 57 54	1.604	1.801	1.703
W06	44 10 15	31 57 50	1.672	1.805	1.738
W07	44 12 18	31 57 50	1.807	2.044	1.925
W08	44 07 58	31 57 46	1.719	1.726	1.723
SP2	44 04 19	31 57 00	1.818	2.099	1.959
W09	44 05 45	31 56 42	1.664	1.758	1.711
W10	44 06 18	31 56 09	1.824	1.906	1.865
W11	44 14 16	31 55 58	1.660	1.814	1.737
W12	44 20 34	31 52 58	2.015	2.174	2.095
W13	44 19 08	31 48 57	1.939	2.076	2.007
W14	44 16 55	31 48 46	1.625	1.750	1.688
W15	44 18 57	31 47 45	1.875	2.074	1.974
SP3	44 19 15	31 47 42	1.915	1.931	1.923
W16	44 15 25	31 47 20	1.842	1.902	1.872
W17	44 18 57	31 47 16	1.988	2.095	2.042
W18	44 24 00	31 46 51	1.707	1.924	1.815
W19	44 16 58	31 46 04	1.654	1.731	1.693
W20	44 18 46	31 45 21	1.836	1.994	1.915
W21	43 31 48	31 44 24	2.119	2.186	2.153
W22	43 25 12	31 34 12	2.050	2.166	2.108
W23	43 49 12	31 31 12	1.710	1.903	1.807
W24	43 42 00	31 29 24	1.684	1.944	1.814
W25	43 52 12	31 21 00	1.897	2.011	1.954
W26	43 58 12	31 13 48	1.788	1.902	1.845
W27	44 09 36	31 03 00	1.829	2.004	1.916
W28	43 54 36	30 57 36	1.781	1.909	1.845
W29	43 59 24	30 54 36	1.682	1.722	1.702
W30	43 52 48	30 54 00	1.743	1.935	1.839
W31	43 42 36	30 51 36	1.915	2.088	2.002
W32	43 49 12	30 51 00	1.753	2.054	1.903
W33	43 49 12	43 49 12	1.752	2.193	1.973

Table 5: IAWQ index values of ground water for Livestock purpose.

Well	Long.	Lat.	IAWQ - Wet	IAWQ - Dry	IAWQ - Average
W01	43 57 32	32 03 03	0.537	0.592	0.565
W02	43 57 57	32 02 56	0.615	0.662	0.638
W03	44 00 28	32 02 52	0.536	0.592	0.564
SP1	44 00 25	32 02 49	0.546	0.592	0.569
W04	43 54 57	32 01 58	0.601	0.644	0.622
W05	44 06 25	31 57 54	0.580	0.639	0.609
W06	44 10 15	31 57 50	0.664	0.717	0.690
W07	44 12 18	31 57 50	0.596	0.672	0.634
W08	44 07 58	31 57 46	0.679	0.695	0.687
SP2	44 04 19	31 57 00	0.553	0.578	0.566
W09	44 05 45	31 56 42	0.582	0.634	0.608
W10	44 06 18	31 56 09	0.553	0.596	0.574
W11	44 14 16	31 55 58	0.654	0.743	0.698
W12	44 20 34	31 52 58	0.692	0.744	0.718
W13	44 19 08	31 48 57	0.672	0.708	0.690
W14	44 16 55	31 48 46	0.603	0.679	0.641
W15	44 18 57	31 47 45	0.553	0.584	0.569
SP3	44 19 15	31 47 42	0.746	0.801	0.774
W16	44 15 25	31 47 20	0.763	0.784	0.773
W17	44 18 57	31 47 16	0.643	0.724	0.683
W18	44 24 00	31 46 51	0.597	0.639	0.618
W19	44 16 58	31 46 04	0.561	0.617	0.589
W20	44 18 46	31 45 21	0.701	0.752	0.727
W21	43 31 48	31 44 24	0.557	0.614	0.585
W22	43 25 12	31 34 12	0.546	0.579	0.562
W23	43 49 12	31 31 12	0.550	0.587	0.569
W24	43 42 00	31 29 24	0.544	0.580	0.562
W25	43 52 12	31 21 00	0.534	0.572	0.553
W26	43 58 12	31 13 48	0.526	0.566	0.546
W27	44 09 36	31 03 00	0.522	0.564	0.543
W28	43 54 36	30 57 36	0.502	0.539	0.520
W29	43 59 24	30 54 36	0.501	0.531	0.516
W30	43 52 48	30 54 00	0.506	0.543	0.524
W31	43 42 36	30 51 36	0.507	0.537	0.522
W32	43 49 12	30 51 00	0.502	0.560	0.531
W33	43 49 12	43 49 12	0.489	0.532	0.510