EVALUATION OF GROUNDWATER QUALITY IN SELECTED AREAS OF NAJAF GOVERNORATE FOR DIFFERENT PURPOSES

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Abstract

This study is concerned with assessing suitability of groundwater in selected areas of Najaf governorate, Iraq, for multiple uses (human drinking , animal drinking , industrial , agricultural and irrigation). Water samples were taken from 29 wells over eleven months (January - December 2014); these samples were chemically and microbiologically analyzed using eleven parameters: Electrical Conductivity (EC), Total Dissolved Solid (TDS), pH values, Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+}), Chloride (Cl^{-}), Sulphate (SO_4^{-2}), Nitrate (NO_3^{-}), Total Hardness (T.H) and Total Coliform Bacteria (T.C). Sodium Adsorption Ratio (SAR) was also calculated to be compared with standards. It is found that the groundwater of the study area is not suitable for human drinking and industrial purpose (except groundwater of one well which was suitable for chemical industry and refinery) because of high concentration of chemical variables, but it was suitable for animal consumption and irrigation vegetables which resist moderate and high concentrations of EC in water, a salinity problem was expected based on Todd and American Salts Laboratory classifications, there were no harmful effects from sodium indicators on plants, most of water samples were within the classes poor and very poor for irrigation use according to Richard classification, and chloride toxicity problem was expected because 69 % of groundwater samples can cause severe problems.

Key words: Evaluation, Groundwater , Wells, Najaf, Irrigation.

تقييم صلاحية المياه الجوفية في مناطق مختارة من محافظة النجف للأغراض المختلفة

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المستخلص :

تهتم هذه الدراسة بتقييم صلاحية المياه الجوفية في مناطق مختارة من محافظة النجف / العراق للاستخدامات المتعددة (الشرب البشري , شرب الحيوانات, الصناعية, الزراعية والري). اخذت عينات المياه من (٢٩) بئرا خلال احد عشر شهرا (كانون الثاني- كانون الاول ٢٠١٤ م), تم تحليل هذه العينات كيميائيا وبايولوجيا لأحد عشر مؤشرا : الموصلية الكهربائية, الاملاح الذائبة الكلية, الرقم الهيدروجيني, الكالسيوم, المغنسيوم, الصوديوم, الكلورايد, الكبريتات, النترات, العسرة الكلية, بكتريا القولون الكلية. تم حساب نسبة امتزاز الصوديوم لمقارنتها مع المواصفات. بينت الدراسة ان المياه الجوفية غير مناسبة للشرب البشري والغرض الصناعي (ماعدا المياه الجوفية لبئر واحد كانت مناسبة للصناعات الكيميائية والمصافي) بسبب التركيز العالي للمتغيرات الكيميائية, لكنها كانت صالحة للاستهلاك الحيواني وري الخضروات التي تقاوم تراكيز عالية ومعتدلة من الملوحة في الماء. اعتمادا على تطبيقي Tood ومختبر الملوحة الامريكي توجد مشكلة الملوحة ولكن لا توجد تأثيرات ضارة من مؤشرات الصوديوم

على النباتات. معظم عينات المياه كانت ضمن الصنف Poor و Very Poor لاستعمال الري طبقا لتصنيفRichard . مشكلة سمية الكلوريد كانت موجودة لان(٦٩ %) من عينات المياه الجوفية كانت تسبب المشكلة.

Nomenclature

Ca^{+2}	Calcium ion
Cl^{-}	Chloride ion
EC	Electrical Conductivity
Mg^{+2}	Magnesium ion
Na^{+}	Sodium ion
NO_3^{-}	Nitrate
pH	Hydrogen Ion Concentration
ppm	Part per million
SAR	Sodium Adsorption Ratio
SO_4^{-2}	Sulphate
T.C	Total Coliform Bacteria
TDS	Total Dissolved Solids
T.H	Total Hardness
µmohs /cm	Micro mohs per centimeter

Introduction

Of all natural resources, water is necessary and precious as life began with water, and life is nurtured by water. There are organisms, such as anaerobes, which can stay alive without oxygen, but no organism can stay alive without water.

Water is a essential material for life. The total water existing for drinking is 0.3% from the total water found on the surface of the earth. Rivers, streams, lakes and reservoirs have long been significant sources of drinking water. In the past, these sources were often heavily polluted by sewage discharge and, unfortunately, were also significant in the transmission of communicable diseases such as typhoid and cholera (Al- Obaidi, 2009).

Surface waters are facing an rising trouble through the disposal of pollutants due to the rapid growth of industrial and municipal actions because of the population expansion as well as the increase in land drainage due to agricultural activities. Thus, there has been an increasing concern about groundwater quality all over the world.

Groundwater is usually understood to mean water occupying all the voids inside a geologic layer. This saturated zone is to be distinguished from an unsaturated, or aeration, zone where voids are filled with water and air. Water contained in saturated zones is significant for engineering work, geologic researches, and water supply developments. Unsaturated zones are commonly found above saturated zones and extend up to the earth surface, because water here includes soil moisture inside the root zone; it is a main concern of agriculture, botany, and soil science. No rigid demarcation of waters between the two zones is possible, for they possess an interdependent edge, and water can move from zone to zone in either way (Tood, 2005).

There are two sources of groundwater: rain that penetrates the soil through pores and cracks in rock formations and finally up to the surface of groundwater. The second source is the water of rivers and lakes which is carried out through the soil to surface of groundwater.

Groundwater is considered the second main source of water all over the world and it hits the surface of the earth through the eyes and springs or drilling wells; the right benefits of this water are drinking, agricultural, livestock production and industrial uses where surface water is scarce or does not exit.

Groundwater represents one of the most important sources of water in rural areas. In many areas , it constitutes the largest storage of suitable drinking water and the only source of water for local, irrigation and industrial purposes. Generally, groundwater is preferred to surface water because it is less susceptible to contamination and it is slightly below the surface of the ground; in addition to that it is of constant temperature and available in many areas even those that are exposed to severe drought for many years.

In Najaf _ Iraq, Shatt Al- Kufa (Kufa River) is the major supply of water needed for drinking, irrigation, industry and other applications. This river shows decreasing quantity and quality of water because of the rapid growth of industrial, agricultural and municipal activities. Groundwater is another important source of water in this governorate especially for irrigation. In the last few years, farmers started to dig wells in many area to use them for agriculture; many vegetables are now produced in considerable amount by using groundwater.

The main objective of this study is to evaluate the quality of groundwater in selected areas of Najaf Governorate by identifying the chemical and microbiological properties and then assess the suitability of this water for various purposes.

Study Area

Najaf is situated in the south of Iraq (The Mid- Euphrates Region). It is situated between (42^o $50^/$ - 45^o $44^/$) longitude and (29^o $50^/$ - 32^o $21^/$) latitude (Al- Mthafer, 2011) . In this study four areas were selected from Najaf to evaluate their groundwater: Najaf city, Najaf – Karbala Road, Najaf Sea and Kufa city, each of which contains a number of studied wells, see **Fig (1)**.

Najaf city is the center of Najaf (largest urban center). It is surrounded by a group of urban centers: Al-Haidariya city to the North, Kufa city to the East, Al- Manathira city to the South- East and it is honorable on low of Najaf sea which is one of the more geomorphological phenomenas in the study area; where a length of (40 km) and width (19 km) while an area (366 km^2) and away (5 km) from Najaf city(Al- Janabi, 2012). Najaf – Karbala Road is the road which links Najaf with Karbala.

Ground elevations in the area rise about (55m) above sea level and the city area covers (183km^2) within the basic scheme for the year 2012 to 2035 (Al- Taghlubi, 2013).

The soil of the study area is silty sand on the whole and with high porosity and permeability, which help the groundwater movement to different trends depending on the topography of the land (Al-Murshidy, 1998).

The climate study is important in studies related to shallow groundwater. The different climate elements play an important role in increasing rainfall and humidity that affect the water content of the soil (Al- Adili, 1998).

The study area has a dry continental climate characterized by a cold winter with little rain and a long hot dry summer with a significant difference in temperature between day and night, **Table (1)** shows the monthly rates of climate elements for the period (1980 – 2014).

It was found that the study areas' climate is continental (desert dry climate); this type of climate contributes to increasing concentration of salts in water.

Selected Wells And Evaluation

The purpose of the experimental work in this study is to make an evaluation of groundwater of twenty nine selected wells. These wells and their locations and depths are shown in **Table (2)**.

The laboratory testing of the chemical and microbiological evaluation was done in Najaf Environmental Directorate / Environmental Analysis Department. The methods of testing the parameters are illustrated in **Table (3)**.

Results And Discussion

The Chemical Analysis

For the chemical analysis, samples were taken from twenty nine selected well over the period Jan. 2014 to Dec 2014; locations of selected wells are marked as shown in **Fig (1)**. These samples were chemically analyzed for different elements. These elements are (EC, TDS, pH, Ca^{+2}, Mg^{+2},

Na^+, Cl^-, SO_4^{-2}, NO_3^- and TH). Sodium Adsorption Ratio (SAR) was also calculated to be compared with its standard limitation.

The results of chemical analysis of groundwater of the selected wells and values of calculated (SAR) are shown in **Table (4)**. Each analyzed chemical element was also plotted in **Figs (2-11)**.

The Microbiological Analysis

Samples were also microbiologically analyzed for Total Coliform Bacteria. **Table (5)** showed results of these analysis of groundwater of selected wells. Results were also plotted in **Fig (12)**.

Suitability Of Groundwater For Different Uses

Chemical, physical, and biological properties are determined qualities of water and its uses for different purposes such as human use, irrigation, and industry … etc. A chemical quality of water is as important as the availability of water itself, because the water can be suitable for a specific use and unsuitable for another.

Suitability Of Groundwater For Human Drinking

Standard specifications of the Iraqi specification (IQS – 2001) and World Health Organization (WHO) were adopted in evaluation the suitability of groundwater in the study area for human drinking. These specifications depend on the concentrations of major positive and negative ions, as well as values of TDS, TH and pH. Specifications refer to the existence limit to concentration of each ion and the increase about this standard limit means that water contaminated with this ion.

The comparison between values of the chemical analysis of groundwater in the study area given in **Table (4)** with the corresponding values shown in **Table (6)** shows that the groundwater was unsuitable for human drinking, because the concentrations of all ions as well as the concentrations of TDS and TH exceeded the permissible limits in the standard specifications. As known, water which contains TDS greater than (1000 ppm) will be unpalatable for drinking.

For the Total Coliform Bacteria of groundwater **Table (7)** sets water quality criteria for microbiological indicators for British Columbia, which are bacteria representing the danger of illness from pathogenic bacteria.

The comparison between values in the study area given in **Table (5)** with the values shown in **Table (7)** shows that some of groundwater of wells were needed disinfection only, other were needed partial and complete treatment when were used for drinking.

Suitability Of Groundwater For Industrial Purposes

The quality of water available for industrial purposes should take a broad range because each industry has a private specification. Some industries do not require critical limits but using any type of provided water; for example, the industry of raw materials concentration while other industries like pharmaceutical industry and paper with high quality industry are required water quality equals to distilled water in purity because water quality affects the quality and safety of product. Some industries such as the operation of modern steam boilers with high pressure are needed water purity outweigh the commercial distilled water (Mania, 2003).

The values of groundwater were also compared to the proposed limits in **Table (8)** . The result was that groundwater was not suitable for all industries (except groundwater of W_{23} was suitable for chemical industry and refinery) because high concentrations of hardness, calcium, magnesium, chloride and sulfates.

Kufa cement factory is existed in the study area and near the well (W_{23}). The comparison between results of chemical analysis of groundwater of (W_{23}) with the limits shown in **Table (8)** shows that the groundwater of the well is suitable to use in cement industry because the low concentrations of positive and negative ions, total hardness and total dissolved solid.

Suitability Of Groundwater For Animal Drinking

Most animals can drink poor quality water which human cannot drink. Proposal specification of Altoviski **Table (9)** for animal consumption were compared with the data given in **Table (4)** to assess the suitability of groundwater for livestock and poultry drinking.

The result of comparison was that the groundwater of the study area was fit for animal consumption because the concentrations of positive and negative ions, total hardness and total dissolved solid were within the permitted limits.

- Suitability Of Groundwater For Agricultural Purposes

Plants are different in resisting salinity of irrigation water. **Table (10)** shows the satisfactory limits of salinity in irrigation water for various crops based on EC standards which were classified by Tood classification.

The data given in **Table (4)** were compared with limits of salinity shown in **Table (10)**. The result of comparison was that: (1) water from W_{21} and W_{23} only was suitable to agriculture all crops because their salinity was low. (2) water from W_{17} suitable to agriculture all crops except fruit resisting low concentrations of EC in water. (3) water from all wells except (W_{14} ,W_{15} and W_{20}) was suitable to agriculture cucumber, feas, onion, carrot, potato, lettuce, cauliflower, tomato , sunflower, flax, corn, rice, wheat, spinach, kale, beet, cotton, sugar beet and barley because these crops are tolerated moderate and high salinity of groundwater. (4) water from (W_{14} ,W_{15} and W_{20}) was suitable to agriculture cotton, sugar beet, barley because of high salinity.

Suitability Of Groundwater For Irrigation Purposes

The selected criteria to evaluate the quality of irrigation water should show its ability to cause adverse changes in soil properties or detrimental effect on the crop, animal, or human who consumes this crop. Three characteristics are usually used to assess irrigation water: salinity, sodicity and toxicity.

Salinity Problem

Salinity represents the potential danger of damage to plant. The electrical conductivity (EC) is usually used to express the contain of salinity. There are two kinds of salt troubles: one related to the total salinity and another related to sodium. These two troubles may be affect on soils. **Table (11)** shows Tood categorization of irrigation water according to (EC) values.

According to Tood classification, the test results showed that the EC values fall within the water class of unsuitable except values of (W_{21} and W_{23}) fall within doubtful and permissible classes respectively.

TDS values were categorized into four – classes based on American Salts Laboratory as illustrated in **Table (12)**.

Based on the classification of (TDS) values which stated by the American Salts Laboratory, the test results showed that the groundwater of the study area is outside the limitation of the classification except (W_{23}) fall within C3 and (W_4 , W_5, W_7 ,W_9, W_{13}, W_{17} and W_{21}) fall within C4.

Sodium Problem

Sodium Adsorption Ratio (SAR) is recommended by the salinity laboratory of the U.S. Department of Agriculture because of its straight relation to the adsorption by soil. It is defined by the following equation:

$$SAR = \frac{Na}{\sqrt{Ca+Mg)/2}} \qquad (1)$$

Where the unit epm (milli equivalent per liter) is used to express the concentration of the elements. (Tood, 2005).

The effect on soil permeability and water infiltration is the major trouble with high sodium concentration. Sodium also may be toxic to sensitive crops because it contributes directly to the total salinity of the water. The sodium causes dispersion of soil particles because it replaces calcium and magnesium adsorbed on clay minerals. The breakdown of soil aggregates results from this dispersion and causes a cementation of the soil under drying conditions as well as preventing infiltration of rain water.

The groundwater of the study area is classified according Richard Classification with respect to the values of (SAR and EC) in water as shown in **Tables (13 and 14)**. Also **Fig (13)** shows a diagram for the classification of irrigation water.

The test results showed that the SAR values in irrigation water varied from (0.305 - 17.18). Based on the classification of (Richard , 1954) for (SAR) values, there was no harmful effects of sodium on plants because all the values of SAR (except value of W_7) were less than ten. **Table (14)** and **Fig (13)** showed that most of the water samples were within the classes (poor and very poor) which index (C4S1, C4S2 and C4C4) for agriculture use except (W_{23}) was within the class (Appropriate) which index (C3S1).

Toxicity Problem

Chloride (Cl^-) is found in most normal waters. It is harmful to some plants in high amounts. All common chlorides are soluble and contribute to the total salt content (salinity) of soil. In evaluation of irrigation waters the chloride content should be calculated, if(TDS) is greater than (1000 ppm), Chloride should be below (300 ppm) to avoid harm to citrus (Boman, 2002).

Chlorine does not adversely affect on soil properties; so, soil quality is neglected in classification of the quality of irrigation water for concentration of chlorine (Asmaeel, 1988).

Chloride is necessary to plants in very low concentrations, it can cause toxicity to sensitive crops at high amounts (Mass, 1990). **Table (15)** shows chloride classification of irrigation water.

The chloride test results showed that all groundwater samples were above (141 mg / l) except water from (W_{23}) it was within (70 – 140). So, sensitive plants show injury from this water, (28%) of groundwater samples were within (141- 350) so moderately tolerant plants show injury and (69 %) of samples were above (350 mg / l) so can cause severe problems.

Coliform Bacteria

Awareness is growing that fresh or minimally processed fruit and vegetables can be sources of illness – causing bacteria, viruses, protozoa, and helminthes. Fruit and vegetables can become polluted with food borne pathogens when poor – quality water is used for irrigation. The risk of disease transmission from pathogenic.

The level of pollution; the persistence of pathogens in water, in soil, and on crops; and the route of exposure influence on microorganisms present in irrigation water . Bacteria and protozoa tend to show the poorest survival outside a human host, whereas viruses and helminthes can remain infective for months to years (Al- Bahrani, 2012).

Table (16) sets water quality criteria for microbiological indicators for British Columbia, which are bacteria representing the danger of illness from pathogenic bacteria.

The comparison between values of the Total Coliform Bacteria of groundwater in the study area given in **Table (5)** with the values shown in **Table (16)** shows that all groundwater samples except groundwater of (W_{29}) were used in general irrigation.

Conclusions

1. Groundwater of the study area was unsuitable for human drinking because the concentrations of all ions as well as concentrations of TDS and T.H exceeded the permissible limits in the standard specifications. The values of TDS were ranged between (937 – 8676) ppm, while T.H values were between (590 – 3700) ppm.
2. For drinking Total Coliform Bacteria results showed that some of groundwater wells were needed disinfection only, other were needed partial and complete treatment.

3. Groundwater was unfit for all industries (except groundwater of W_{23} was suitable for chemical industry and refinery) because of very high concentrations of hardness, calcium, magnesium, chloride and sulfates. The concentrations of Ca^{+2} and Mg^{+2} were between (162.4 – 1080) ppm and (27.5 – 412.4) ppm, respectively. The Sulfate concentrations were ranged between (256.9 – 2666.3) ppm were as the Chloride concentrations were between (135 – 2150) ppm.
4. Groundwater was fit for animal consumption because the concentrations of positive and negative ions, total hardness and total dissolved solid were within the permitted limits for animal drinking.
5. Water form W_{21} and W_{23} only was suitable to agriculture all crops because of its low salinity.
6. Most of groundwater of the study area was suitable to agriculture vegetable crops and field crops which resist moderate and high concentrations of EC in water.
7. According to Todd classification of irrigation water based on salinity (EC), the test results showed that the EC values fall within the water class unsuitable because of all the values were greater than (3000 µS /cm) except values of (W_{21} and W_{23}) fall within doubtful and permissible classes respectively.
8. Based on the classification of (TDS) values which stated by the American Salts Laboratory, the test results showed that the groundwater of the study area is outside the limitation of the classification except (W_{23}) fall within C3 and (W_4, W_5, W_7, W_9, W_{13}, W_{17} and W_{21}) fall within C4.
9. Based on the Richard classification for (SAR) values, there was no harmful effects from sodium on plants because all the values of (SAR) (except value of W_7) were less than ten. SAR values varied from (0.305 – 17.18) in groundwater.
10. Most of the water samples were within the classes (poor and very poor) which index (C4S1, C4S2 and C4C4) for agriculture use.
11. According to chloride Mass classification (28%) of samples show injury to moderately tolerant plant and (69 %) of samples can cause severe problems.
12. For irrigation Total Coliform Bacteria results showed that all groundwater samples (except W_{29}) were used in general irrigation.

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Table (1) Average Monthly Temperature, Relative Humidity % , Rainfall and Evaporations Values in Najaf for The period (1980 _ 2014) (Al- Kelabbee, 2016)

Months	j.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N	D.
Temperature (C^0)	10.8	13.4	17.9	23.9	29.9	33.7	35.7	35.4	32	26.4	18.2	12.65
Relative Humidity %	70	60.3	51.4	43.7	33.4	27.8	27	29	33.2	43.3	29.2	70.1
Rainfall (mm)	20.7	15.1	13.5	10.2	4.1	0	0	0	0	4.2	14.8	17.5
Evaporation (mm)	72.7	122.9	201.3	285.7	409	531.4	579.5	538.3	403.1	268.2	144.1	87.6

Table(2) Wells Locations and Depths

Well Symbol	Location	Wells Depths (m)	Well Symbol	Location	Wells Depths (m)
W_1	Najaf City	30	W_{16}	Kufa	_
W_2	Najaf City	50	W_{17}	Najaf Sea	90
W_3	Najaf City	50	W_{18}	Najaf Sea	45
W_4	Najaf City	50	W_{19}	Najaf Sea	15
W_5	Najaf City	20	W_{20}	Kufa	30
W_6	Najaf City	160	W_{21}	Kufa	30
W_7	Najaf City	10	W_{22}	Kufa	25

W_8	Najaf City	10	W_{23}	Kufa	20
W_9	Najaf City	25	W_{24}	Kufa	35
W_{10}	Najaf City	12	W_{25}	Kufa	_
W_{11}	Najaf – Karbala Road	35	W_{26}	Kufa	_
W_{12}	Najaf – Karbala Road	35	W_{27}	Kufa	30
W_{13}	Najaf – Karbala Road	10	W_{28}	Kufa	20
W_{14}	Najaf City	48	W_{29}	Kufa	25
W_{15}	Najaf City	50	_	_	_

Table(3) Methods of Testing The Concentration of The Ions in Groundwater

Parameter	Method of Testing	Unit
EC	EC- Meter	µmohs/cm
TDS	Method of Drying (or Weight Method)	ppm
pH	pH - Meter	-
Ca , Mg and TH	Titration with the Na_2 – EDTA	ppm
Na	Flamephotometer	ppm
Cl	Titration with the $AgNo_3$	ppm
SO_4	Burning	ppm
NO_3	Spectrophotometer	ppm

Table(4) Results of Chemical Analysis of Groundwater of Selected Wells

Ele. Well No.	EC (µmohs/cm)	TDS (ppm)	pH	Ca^{+2} (ppm)	Mg^{+2} (ppm)	Na^{+} (ppm)	Cl^{-} (ppm)	SO_4^{-2} (ppm)	NO_3^{-} (ppm)	TH (ppm)	SAR
W_1	5547	3327	6.7	600	73.2	453.5	450	1430.4	61.7	1800	4.641
W_2	5397	3588	7.0	624	131.7	262	590	1876	62.28	2100	2.481
W_3	5531	3597	6.9	640	117.12	228	660	1047.4	58.38	2080	2.169
W_4	4160	2716	7.5	550	101	298.5	658	2261.5	56.7	1790	3.063
W_5	4574	2973	7.3	656	56.12	118	310	1333.1	21.7	1870	1.185
W_6	7236	4342	7.3	376	197.6	406	143	685	5.49	1750	4.204
W_7	4282	2782	6.3	504	124.4	1666.4	350	1100	3.27	1770	17.18
W_8	5168	3362	5.1	595	149	209.1	600	1202	63.6	2020	1.98
W_9	4400	2860	5.2	520	130	282	300	904	44.7	1833	2.857
W_{10}	5064	3290	8.5	585	146	216.5	348	1118.6	3.8	2060	2.069
W_{11}	7443	4837	6.5	800	170.8	850.5	1350	1192.5	17.09	2700	7.101
W_{12}	7400	4820	6.9	872	185.4	860	1685	1547.5	18	2940	6.881
W_{13}	4021	2813	6.6	520	122	142	226	1728.4	8.3	1800	1.452
W_{14}	11900	7140	7.4	780	195.2	584.5	1616	2380.5	77.9	2750	4.834

W_{15}	14460	8676	7.5	740	156.16	762.5	405.6	2380	92.9	2490	6.629
W_{16}	7666	5568	7.0	544	412.4	858	2116	2300	80	3050	6.724
W_{17}	3595	2340	6.4	388.8	150	250	644	1000	3.23	1572	2.73
W_{18}	7065	4593	7.1	416	222	347	1150	1352	7.13	1950	3.403
W_{19}	7489	4867	6.8	448	212.2	362	1000	1409.2	73.2	1990	3.516
W_{20}	11170	5650	7.5	1040	268.4	90	2150	2004	27.2	3700	0.642
W_{21}	2529	1646	7.8	240	53.4	20.14	280	642.5	23.2	820	0.305
W_{22}	9111	5913	7.3	660	27.5	620.2	1400	2666.3	124.7	2200	6.419
W_{23}	1464	937	7.8	162.4	44.8	102.1	135	256.9	5.44	590	1.823
W_{24}	8090	4060	8.1	1080	239.1	1040	223.5	2128.4	3.45	2680	7.437
W_{25}	7970	5455	6.8	560	341.6	994	2058	1500	50	2800	8.133
W_{26}	8150	5583	6.8	800	226.9	1064	1666	1400	60	2930	8.524
W_{27}	5020	3263	7.4	656	209	250	540	1523.6	63.7	2500	2.169
W_{28}	5700	3455	7.0	600	73.2	248	400	1961	58.2	1800	2.538
W_{29}	6713	3963	6.9	624	107.3	254.6	475	2214	10.32	2000	2.471

Table(5) Results of Microbiological Analysis of Groundwater of Selected Wells

Well No.	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9	W_{10}	W_{11}	W_{12}	W_{13}	W_{14}	W_{15}
T.C /100ml	_	8	4.6	23	240	_	0	46	70	23	_	0	8	_	_
Well No.	W_{16}	W_{17}	W_{18}	W_{19}	W_{20}	W_{21}	W_{22}	W_{23}	W_{24}	W_{25}	W_{26}	W_{27}	W_{28}	W_{29}	
T.C /100ml	_	_	5.1	23	_	23	23	7.8	_	_	_	920	31	1600	

Table(6) Standard Specifications for Drinking Water (Jaber, 2014)

Parameter	TDS	pH	Ca	Mg	Na	Cl	SO_4	NO_3	TH
Units	ppm	_	ppm	ppm	ppm	ppm	ppm	ppm	ppm
(IQS)	1500	6.5-8.5	150	50	200	250	250	_	500
(WHO)	1000	6.5-8.5	200	150	200	250	400	_	500

Table(7) Water Quality Criteria for Microbiological Indicators (Warrnigton, 2001)

Water Use	Escherichia	Enterococci	Pseudomonas	Fecal coliforms

			aeruginosa	
Raw Drinking Water – no treatment	0 / 100 ml	0 / 100 ml	0 / 100 ml	0 / 100 ml
Raw Drinking Water – disinfection only	Less than or equal to 10 / 100 ml 90^{th} percentile	Less than or equal to 3 / 100 ml 90^{th} percentile	None applicable	Less than or equal to 10 / 100 ml 90^{th} percentile
Raw Drinking Water – partial treatment	Less than or equal to 100 / 100 ml 90^{th} percentile	Less than or equal to 25 / 100 ml 90^{th} percentile	None applicable	Less than or equal to 100 / 100 ml 90^{th} percentile
Raw Drinking Water – complete treatment	None applicable	None applicable	None applicable	None applicable

Table(8) Proposal Limits for Water Using in Different Industries (Jaber, 2014)

Industries	pH	TH (ppm)	Ca^{++} (ppm)	Mg^{++}	Cl^{-} (ppm)	$SO_4^{=}$ (ppm)
Canning Food	6.5 – 8.5	310	120	_	300	250
Chemical Industry	6 - 9	1000	200	_	500	863
Cement	6.5 – 8.5	_	_	_	250	250
Refinery	6 - 9	900	220	85	1600	570
paper	6 - 9	475	20	12	199	_

Table (9) Water Specification for Animal Consumption (Altoviski, 1962)

Element (ppm)	V. good water	Good water	acceptable use	Can be use	Maximum 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
TDS	3000	5000	7000	10000	15000
TH	1500	3200	4000	4700	54000

Table (10) Acceptable Limits of Salinity in Irrigation Water for Various Crops Based on EC Values (Al-Maliki, 2013)

Kinds of Crops	Crops resisting low concentrations of EC in water	Crops resisting moderate concentrations of EC in water	Crops resisting high concentrations of EC in water
Fruit Crops	**< 3000 µS /cm** Lemon , Strawberry , Peach , Apricot , Almond , Orange , Apple , Pear	**≥ 3000 - < 4000 µS /cm** Olive , **Fig**ure , Pomegranate	**≥ 4000 – 10000 µS /cm** Date Palm
Vegetable Crops	**3000- < 4000 µS /cm**	**≥ 4000 - < 10000 µS /cm** Cucumber , Feas , Onion ,	**≥10000 –12000 µS /cm** Spinach , Kale , Beet

	Green bean , Celery , Badish	Carrot , Potato , Lettuce , Cauliflower , Tomato	
Field Crops	**4000 - < 6000 µS /cm** Field bean	**≥ 6000 - < 10000 µS /cm** Sun flower , Flax , Corn , Rice , Wheat	**≥10000 –16000 µS /cm** Cotton , Sugar Beet ,Barley

Table (11) Limitation of Salinity for Irrigation Water Based on (EC) Values (Tood, 2005)

Water Class	EC (µS /cm)
Excellent	< 250
Good	≥ 250 - < 750
Permissible	≥ 750 - < 2000
Doubtful	≥ 2000 - < 3000
Unsuitable	> 3000

Table(12) American Salts Laboratory Classification of Irrigation Water Based on (TDS) Values (Al-Saffy, 2010)

Water kind	TDS (ppm)	Water suitability
C1 – less salt	0 - < 160	The water is suitable to most plants and soils with a little possibility of soil saltiness
C2 – moderate salt	≥ 160 - < 480	The water is suitable to plants that can undergo salts increase where there is moderate draining for the soil .
C3 – high salt	≥ 480 - < 1440	Water is suitable for plants that resist salts , and on well – drained lands. It is essential to have a fine draining structure for the soil.
C4 – very high salt	≥ 1440 - <3200	The water is suitable to plants that are highly resistance to salts , and on pervasive well – drained soils and deep washing for salts.

Table (13) Richard Classification for Irrigation Use (Abdulrazzaq, 2010)

Water Class	SAR	Index	EC (ds / m)	Index
Excellent	≤ 10	S1	0.1 – 0.25	C1
Good	10 - 18	S2	0.25 _ 0.75	C2
Fair	18 - 26	S3	0.75 _ 2.25	C3
Poor	≥ 26	S4	≥ 2.25	C4

Table (14) Groundwater Classification According to Richard Classification for Irrigation Use

Index	Water Class	No. of Well	Index	No. of Well	Water Class
C1S1	Excellent		C3S1	W_{23}	Appropriate
C1S2	Good		C3S2		Acceptable
C1S3	Appropriate		C3S3		Acceptable
C1S4	Poor		C3S4		Poor

C2S1	Good		C4S1	W_5, W_9, W_{13}, W_{17}, W_{21}	Poor
C2S2	Good		C4S2	W_4	Poor
C2S3	Acceptable		C4S3		Very Poor
C2S4	Poor		C4S4	W_7	Very Poor

Table (15) Chloride Classification of Irrigation Water (Mass, 1990)

Chloride (ppm)	Effect on crops
Below 70	usually harmless for all plants
70 – 140	Sensitive plants show harm
141 – 350	Moderately tolerant plants show harm
Above 350	Can cause severe troubles

Table (16) Microbiological Indicators Criteria (Warrnigton, 2001)

Water Use	Escherichia	Enterococci	Pseudomonas aeruginosa	Fecal coliforms
Irrigation – crops eaten raw	Less than or equal to 77 / 100 ml Geometric mean	Less than or equal to 20 / 100 ml Geometric mean	None applicable	Less than or equal to 200 / 100 ml Geometric mean
Irrigation - public access - livestock access	Less than or equal to 385 / 100 ml Geometric mean	Less than or equal to 100 / 100 ml Geometric mean	Less than or equal to 10 / 100 ml 75^{th} percentile	None applicable
Irrigation - general irrigation	Less than or equal to 1000 / 100 ml Geometric mean	Less than or equal to 250 / 100 ml Geometric mean	None applicable	Less than or equal to 1000 / 100 ml Geometric mean

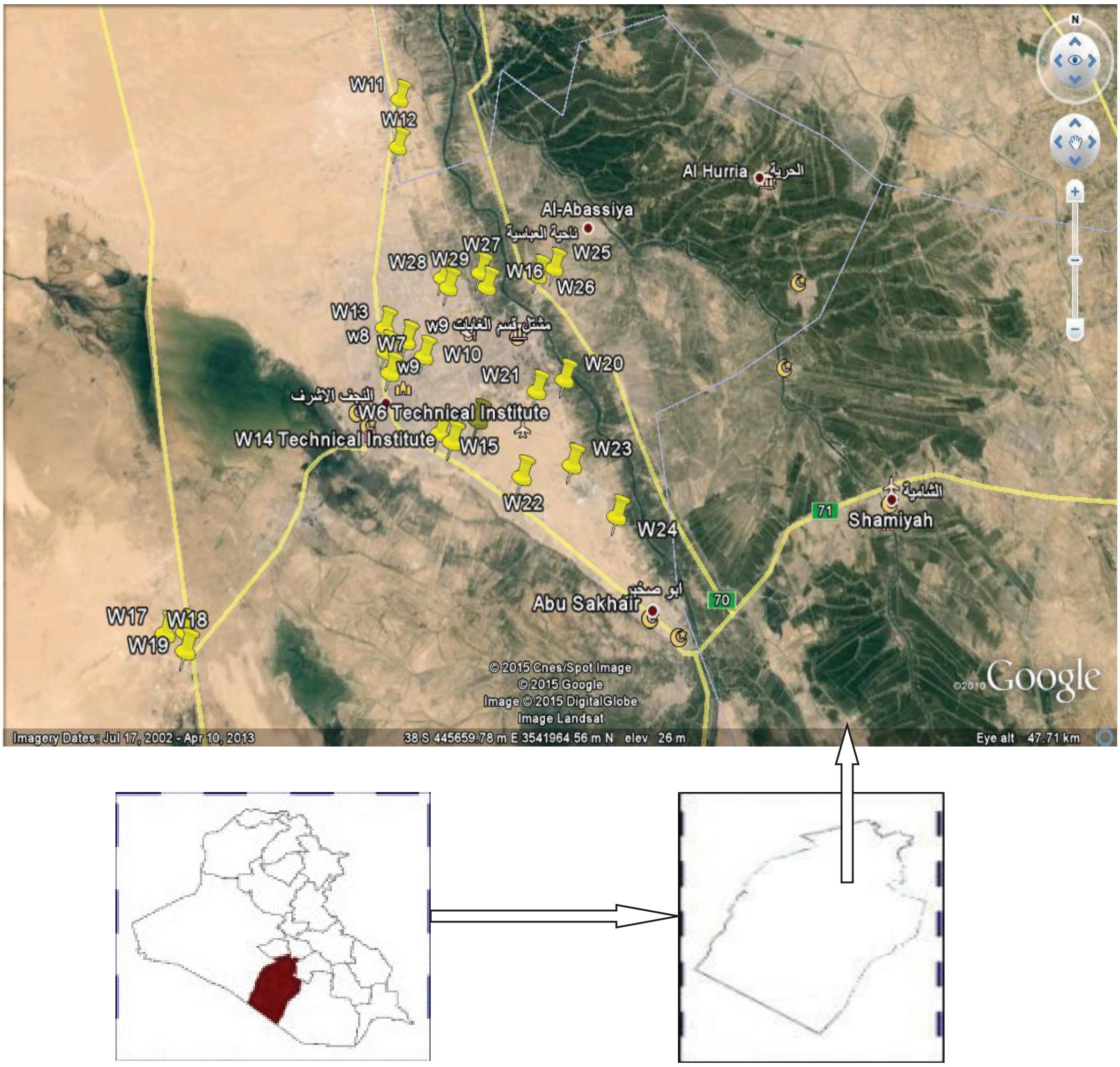

Figure (1) Location of The Study Area in Iraq and Sampling Locations

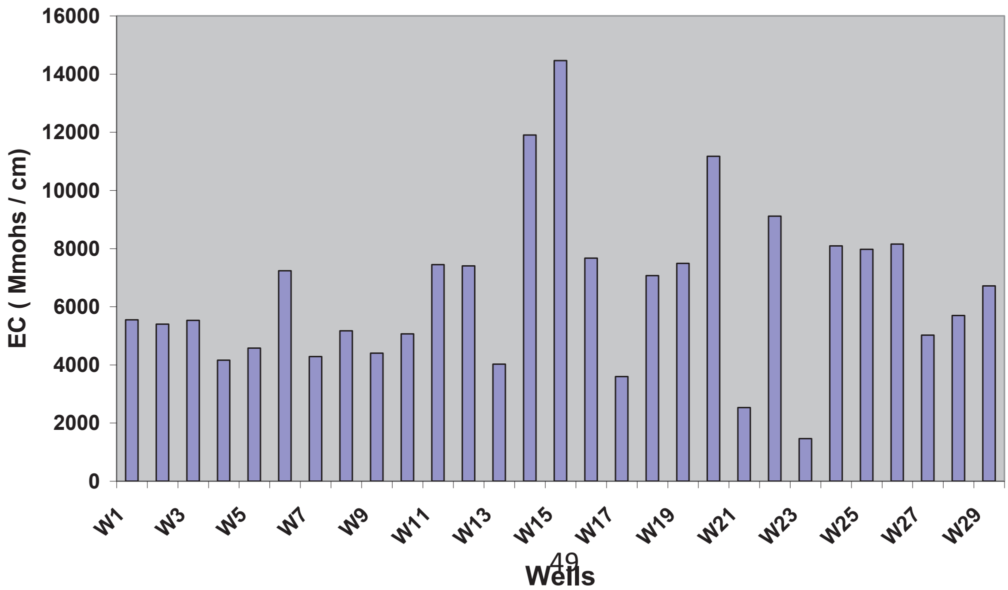

Figure 2: EC values for the studied wells

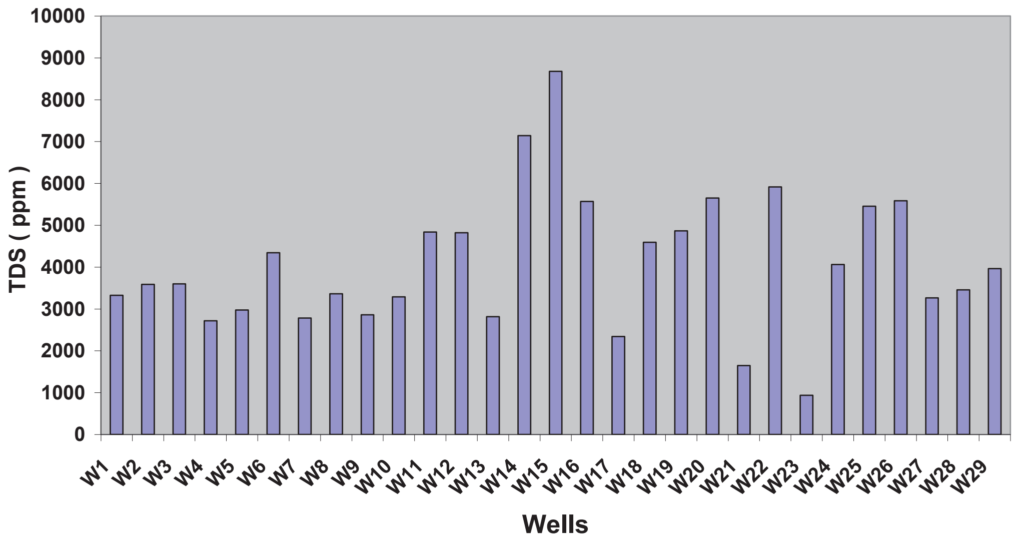

Figure 3:TDS values for the studied wells

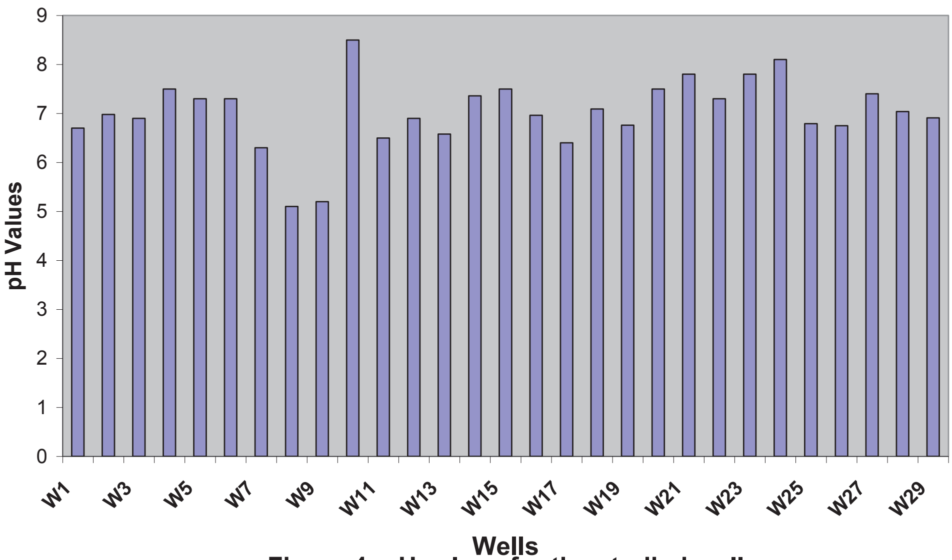

Figure 4: pH values for the studied wells

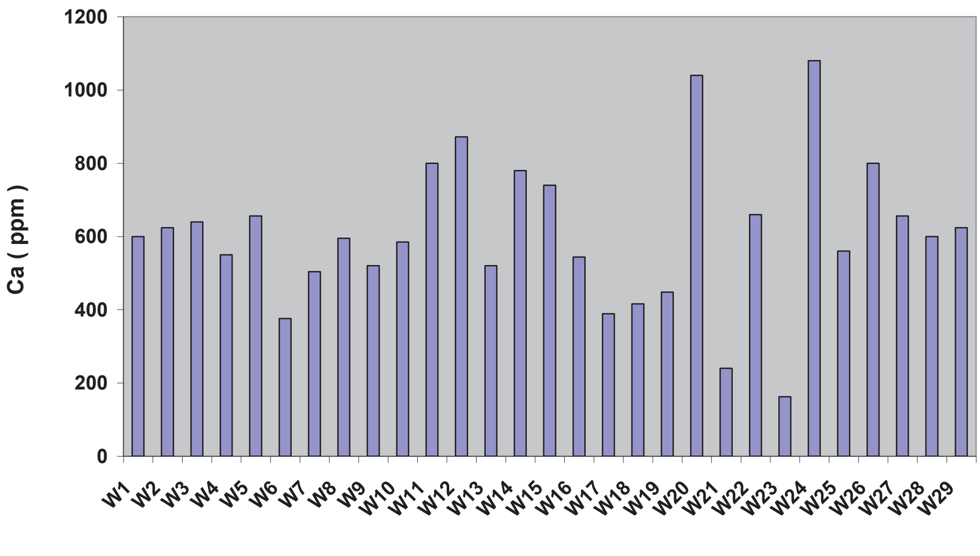

Figure 5: Calcium values for the studied wells

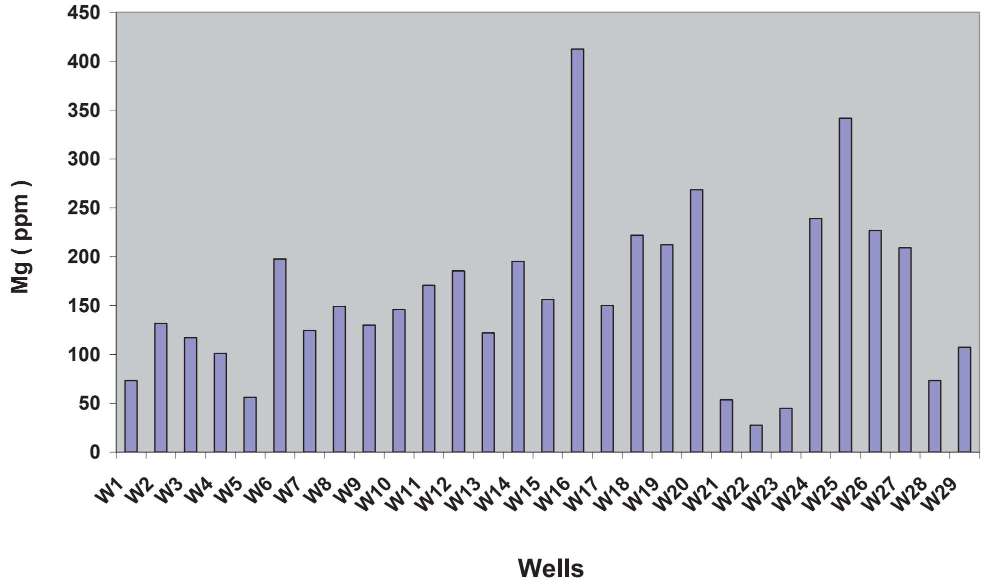

Figure 6: Magnesium values for the studied wells

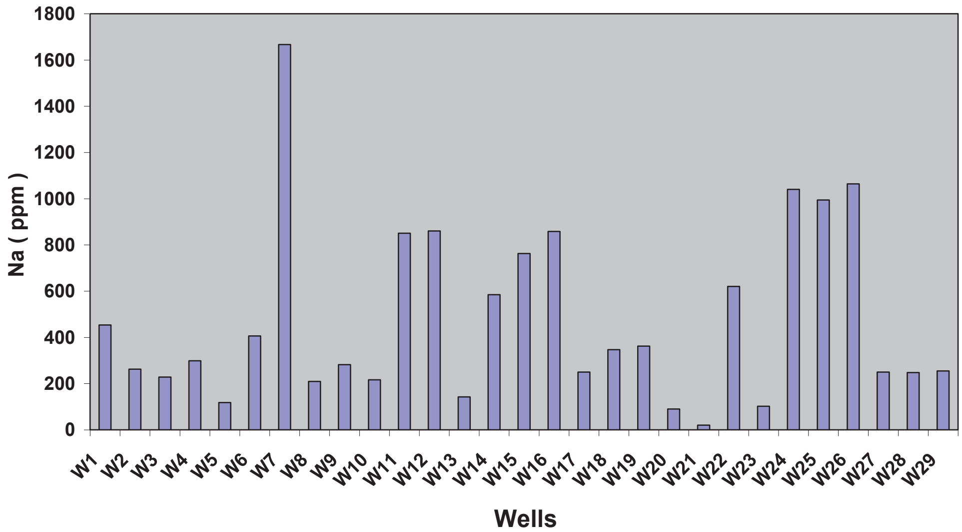

Figure 7: Sodium values for the studied wells

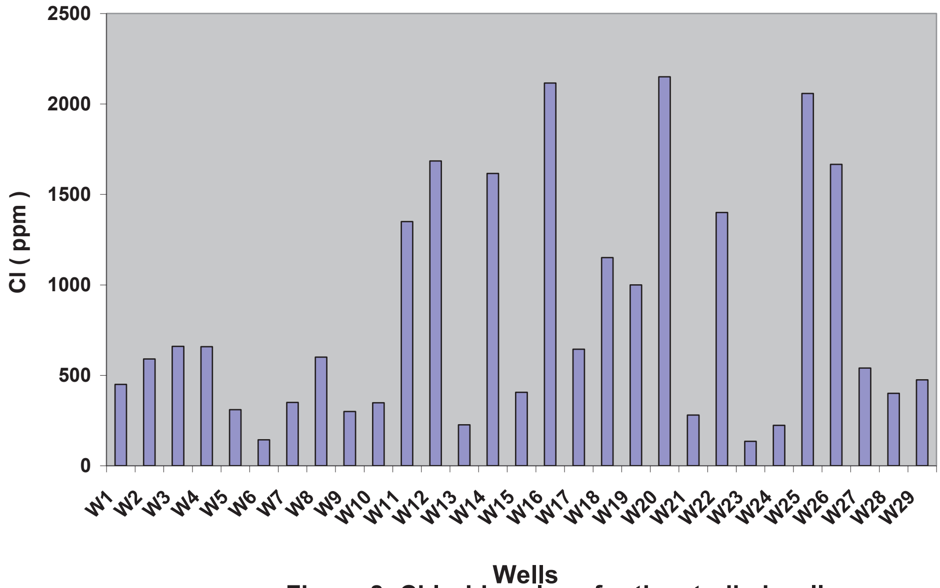

Figure 8: Chloride values for the studied wells

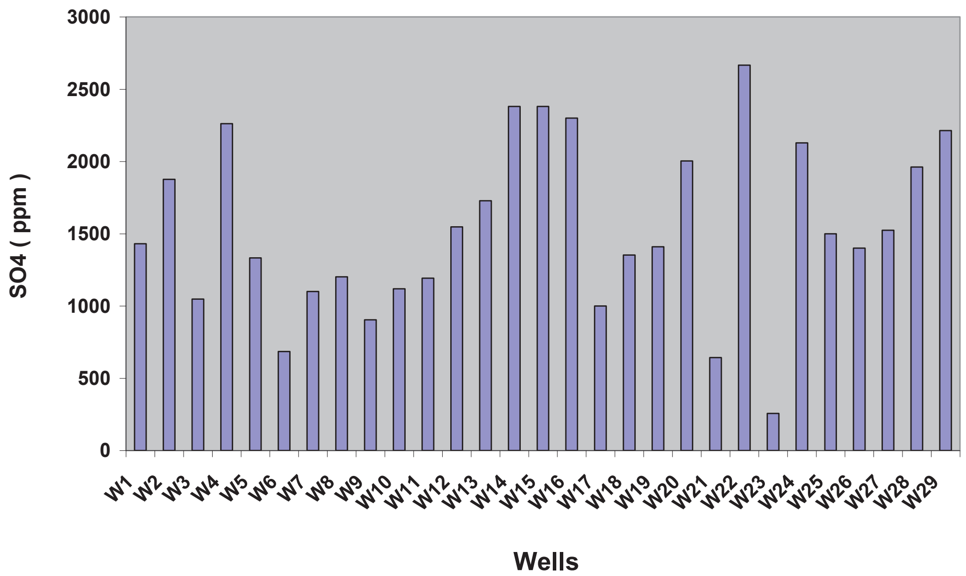

Figure 9: Sulphate values for the studied wells

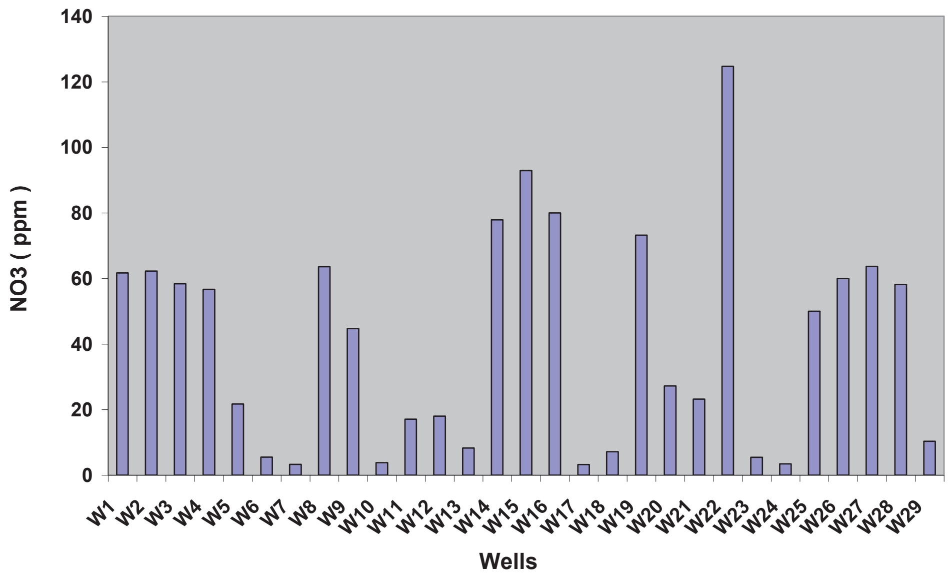

Figure 10: Nitrate values for the studied wells

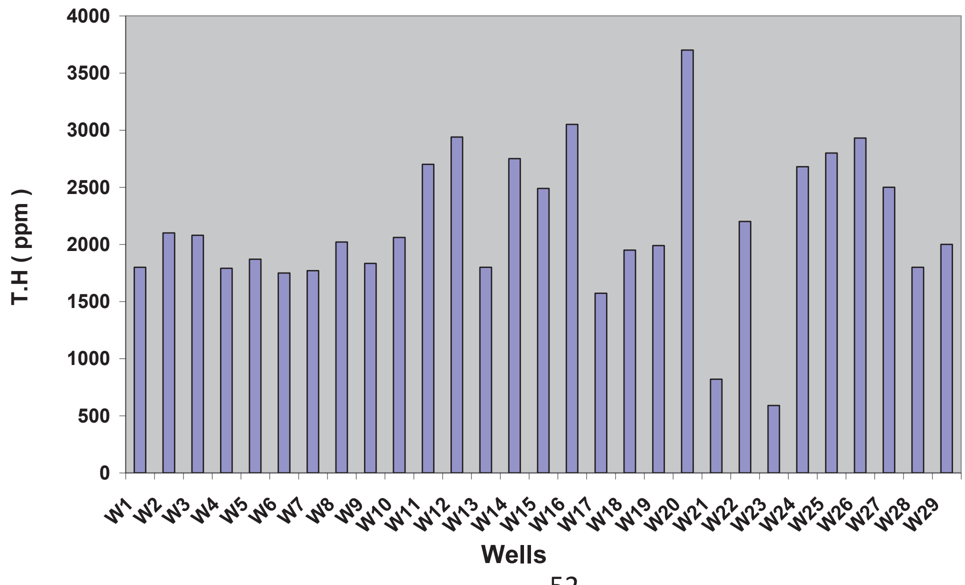

Figure 11: Total hardness values for the studied wells

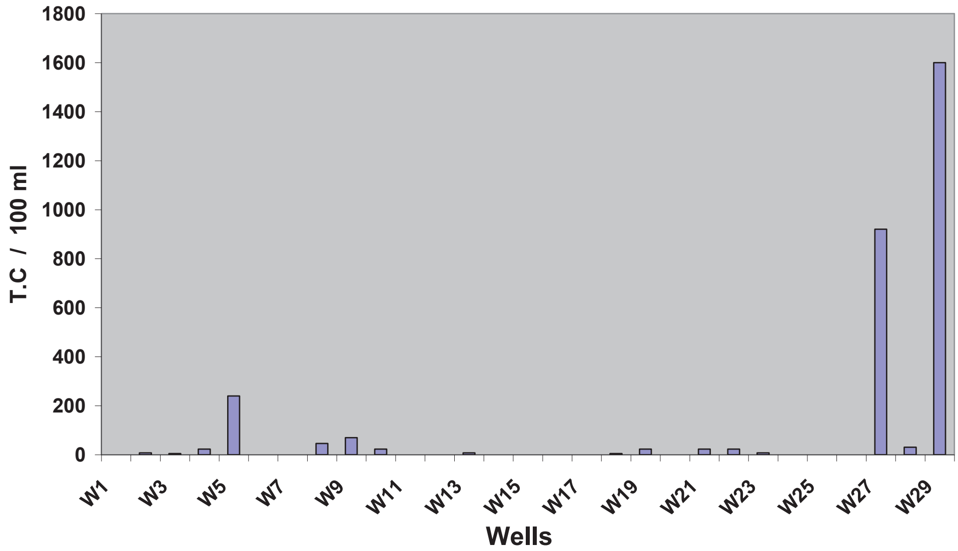

Figure 12: Total Coliform Bacteria for The Studied Wells

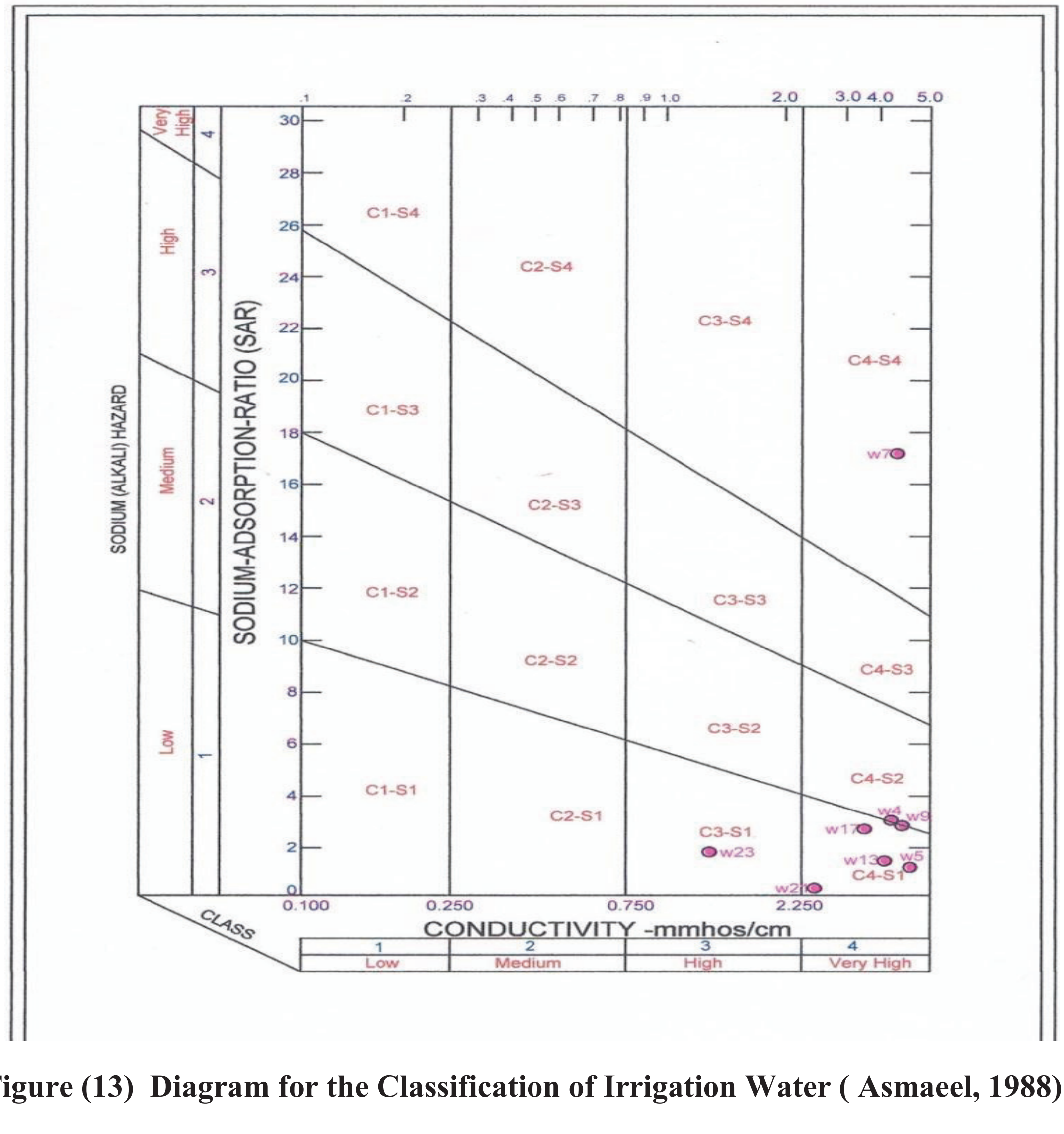

Figure (13) Diagram for the Classification of Irrigation Water (Asmaeel, 1988)