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# Studying the Probability of Using Groundwater in Baghdad City for Human, Animal, and Irrigation Use

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## Abstract

Groundwater is an important source of fresh water especially in countries having a decrease in or no surface water; therefore itis essential to assess the quality of groundwater and find the possibility of its use in different purposes (domestic; agricultural; animal; and other purposes). In this paper samples from 66 wells lying in different places in Baghdad city were used to determine 13 water parameters, to find the quality of groundwater and evaluate the possibility of using it for human, animal and irrigation by calculating WQI, SAR, RSC and Na% and TDS indicators. WQI results showed that the groundwater in all wells are not qualified for human use, while SAR and RSC indicated that most samples are suitable for irrigation use, and TDS showed that 74% of samples are suitable for animal use especially for sheep and meat-livestock animals.

***Keywords:*** *Groundwater quality, WQI, SAR, RSC, Na%.*

## 1. Introduction

Ground water originates as infiltration from precipitation, 40 percent of the precipitation falling on the earth's land masses does not evaporate, but collects on the surface, flows into streams and rivers and empties into the oceans, while some seeps into the soil to become underground water that slowly moves toward the seas [1, 2, 3].

Almost all of the world water (97 %) is located in the oceans, but the high concentration of salts renders the ocean virtually unusable as source of water for municipal; agricultural or most industrial needs, 2% of water is in the form of ice caps and glaciers. Only 1% is available as fresh water which is the main source of water for human consumption and other uses. This 1% is available as fresh water lakes, rivers, and streams which account 0.0072 percent of the world's stock of water, while ground water accounts 1.7 percentage of world supply water [1, 3].

As population grows and development proceeds, rising demands for water increase the potential for internal disruption within countries and external conflict with other countries. Many countries depend on local rivers for their water supply, but their upstream neighbors control the flow. Iraq depends on about 66% of the surface water supply of rivers while its neighbors control almost all of the rivers total flow. Some countries use ground water as a source of water supply, in USA about 50% of its population depend on ground water as a source of drinking water, with 30% delivered by community systems and 20% from domestic wells [1, 2].

Quality of ground water is equally important to its quantity owing to the suitability of water for various purposes [4]. As other sources of water, ground water is threatened with pollution from different sources such as domestic wastes; industrial wastes; agricultural wastes; runoff from urban areas; soluble effluent; earthen septic tanks; leaching and downward movement of pollutants; waste water treatment lagoon [5, 6]. Ground water chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of various rock types, quality of recharge water and inputs from sources other than water-rock interaction, such factors and their interaction result in a complex ground water quality [4], therefore monitoring and conserving this important resource is essential.

The aim of this study is to show the possibility of using ground water of Baghdad city for domestic, irrigation and animal purposes .

## 2. Description of the Study Area

Raw water samples were taken from wells drilled in different places of Baghdad City by the Ministry of Water Resources of Iraq. Baghdad City lies 43m above see water level, 33º 19' 33" latitude and 44º 26' 19" longitude within the Tigris River [7], with overall area of 4555 $Km^2$ (about 1.5% of Iraq overall area), and a population of about 7.2 million people (about 24% of Iraq population) [8]. Fig.1 shows the locations of the wells in Baghdad city (45 well in AL-Karkh side and 21 in AL-Rusafa) using ArtGIS 9.

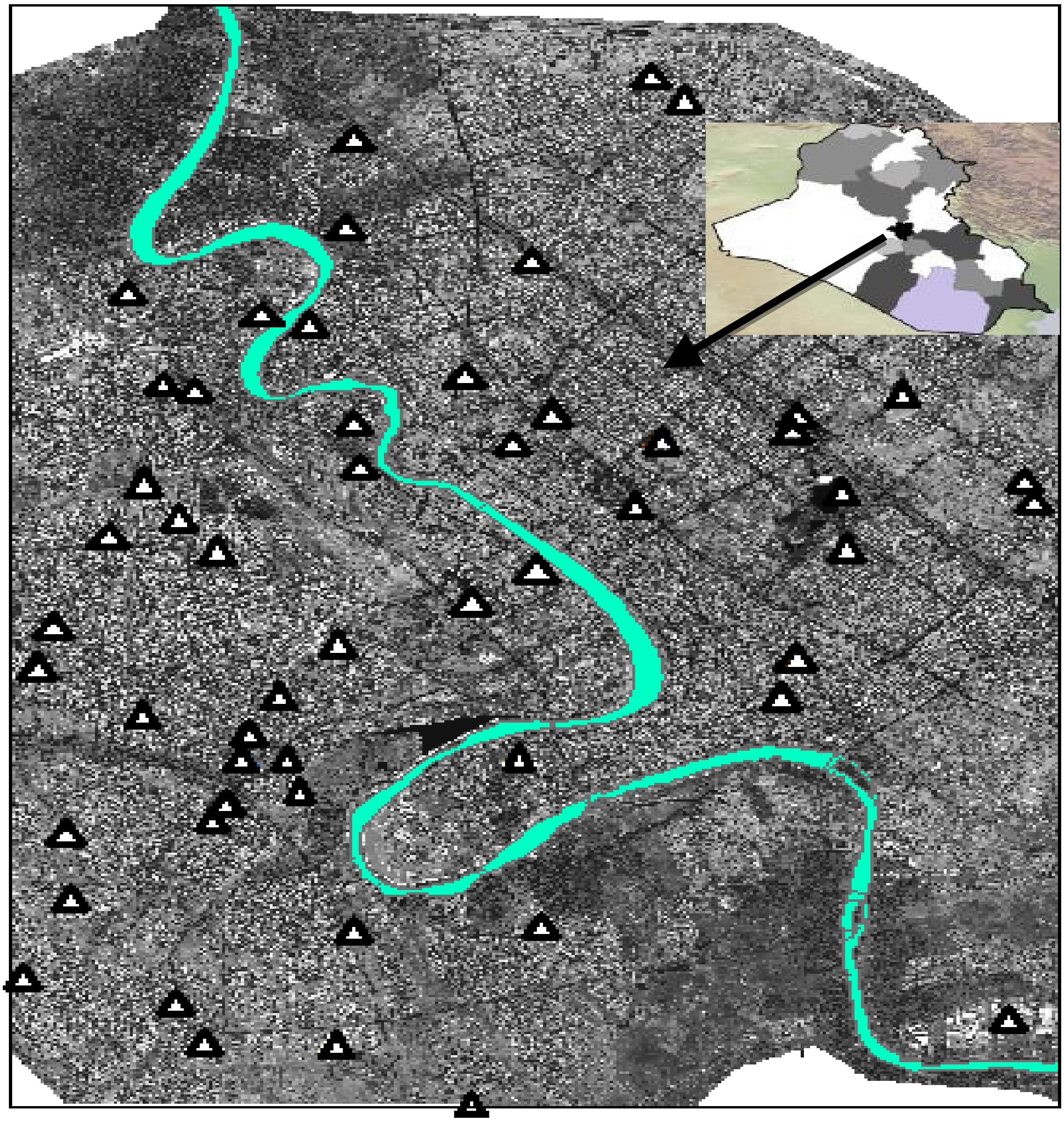

**Fig.1. Wells Drilled in Different Places in Baghdad City.**

## 3. Samples Collection

The data used in this paper were taken from 66 wells lying in different places in Baghdad City from 33º10'00" to 33º30'00" in latitude and from 44º15'00" to 44º30'00" in longitude; and within 25m in depth by the ministry of water resources of Iraq. One sample of ground water from each well was already analyzed physically and chemically and parameters of EC, pH, T.D.S, TH, Cl, $CO_3$, $HCO_3$, $SO_4$, $NO_3$, Ca, Mg, Na and K were determined for the 66 samples by the same ministry. Table 1 shows the max., min., average and standard deviation values of these parameters for the ground water samples. These data were taken and used to evaluate the probability of water use for human, animal and agriculture by calculating WQI (water quality index), SAR (sodium adsorption ratio), RSC (residual sodium carbonate) and Na% (sodium percentage) indicators.

**Table 1,**
**Minimum, Maximum, Average and Standard Deviation Values of Physical and Chemical Parameters of Ground Water Samples.**

| Parameter | Min. value | Max. value | Mean value | Sd. value |
|---|---|---|---|---|
| pH | 7.2 | 8.7 | 7.8 | 0.3788 |
| EC | 1100 | 29600 | 7179.8 | 5746.9 |
| T.D.S | 864 | 19064 | 4735.3 | 3672.8 |
| TH (as $CaCo_3$) | 696.4 | 10664 | 2337.7 | 3249.11 |
| Cl | 107 | 8724 | 1477.5 | 1616.1 |
| $CO_3$ | 0 | 70 | 7.6364 | 15.66 |
| $HCO_3$ | 33 | 491 | 163.62 | 105.74 |
| $SO_4$ | 40 | 3110 | 688.18 | 502.77 |
| $NO_3$ | 0.1 | 17.5 | 2.3689 | 3.3617 |
| Ca | 72 | 1100 | 407.65 | 252.11 |
| Mg | 67 | 1924 | 542.21 | 449.96 |
| Na | 101 | 6405 | 1386.8 | 1254.3 |
| K | 2 | 60 | 12.944 | 11.82 |

All parameters are in mg/l except pH has no unit and EC in µS/cm.

## 4. Drinking Water Parameters

Thirteen water parameters were determined and compared with the Iraqi drinking water standards and also using the WHO and US public health service drinking standard values if any absence in the Iraqi standards as shown in table 2.

**Table 2,**
**Water Quality Standard [6, 15].**

| Parameters | Iraqi Drinking Standard |
|---|---|
| pH | 6.5 – 8.5 |
| EC | 1500 * |
| TDS | 1000 |
| TH (as $CaCo_3$) | 500 |
| Ca | 150 |
| Mg | 100 |
| Na | 200 |
| K | 12 * |
| Cl | 350 |
| $CO_3$ | - |
| $HCO_3$ | 120 ** |
| $SO_4$ | 400 |
| $NO_3$ | 50 |

All parameter are in mg/l except pH has no unit and EC in µS/cm. * WHO standard [6]. ** US public health service value [6].

### 4.1. pH

pH values for the samples vary between 7.2 and 8.7 with a standard deviation of 0.3788. All of the samples were within the Iraqi standard range except for one sample. pH usually has no direct impact on consumers, but it is one of the most important operational water quality parameters [9]. Fig. 2 shows the cumulative percentage for no. of samples vs. pH values indicating that all of the samples are within the drinking standards.

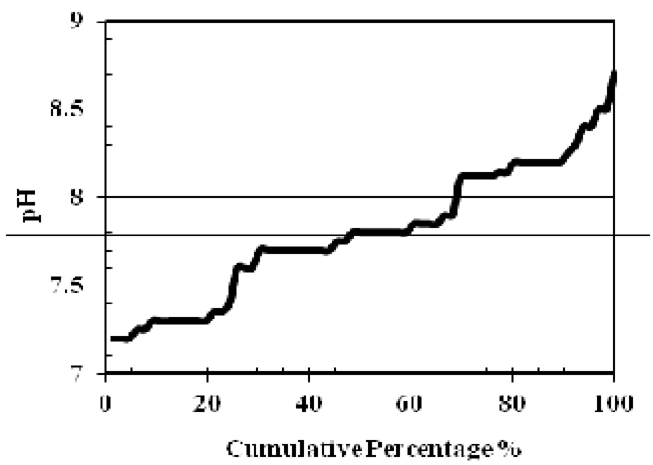


**Fig. 2. pH Values vs. Cumulative Percentage of the Samples.**

## 4.2. Chloride (Cl)

The maximum value of Cl was 8724 mg/l and the minimum 107 mg/l with a standard deviation of 1616.1. No health-based guideline value is proposed for chloride in drinking water. However, chloride concentration in excess of about 250 mg/l gives water detectable or salty test which is objectable to many people [9, 10].

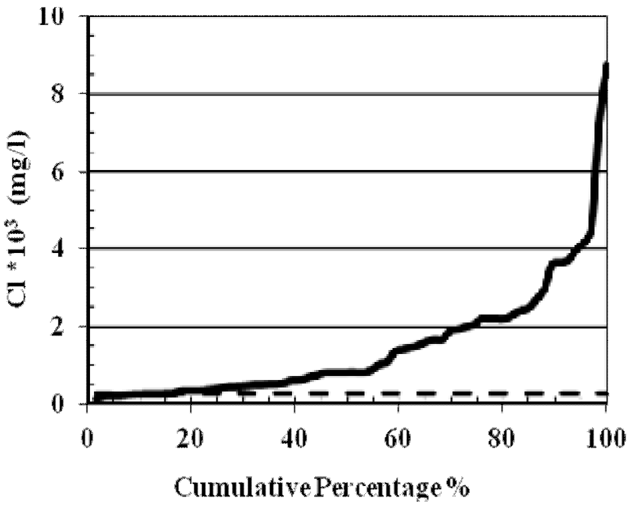


**Fig. 3. Cl Values vs. Cumulative Percentage of Samples.**

In ground water the high concentration of chloride may be attributed to the presence of soluble chloride from rocks and saline intrusion [10]. Also high chloride concentration may be an indication of pollution from sewage leakage. Fig. 3 shows that 23% of samples are within the Iraqi standard for drinking water which is 350 mg/l.

## 4.3. Total Hardness (TH)

Hardness of water is defined as the inhabitation of soap action in water which is due to the precipitation of Mg and Ca salts [11, 14]. TH is calculated from the formula [11];

$$TH\ (CaCO_3)\ mg/l = 2.497\ Ca + 4.115\ Mg \quad \ldots(1)$$

TH of water limits are used for industrial purposes, it causes scaling in pots and boilers, closure in pipes, and may cause health problems to human, such as kidney failure and some evidence indicates its role in heart diseases [6, 11]. However, no health-based guideline value is proposed for hardness, also the degree of hardness in water may affect its acceptability to the consumer in terms of taste and scale deposition [9].

Iraqi standard proposed a value of 500 mg/l for drinking water standard [15], Fig.4 shows that all the samples are out of the permissible limit.

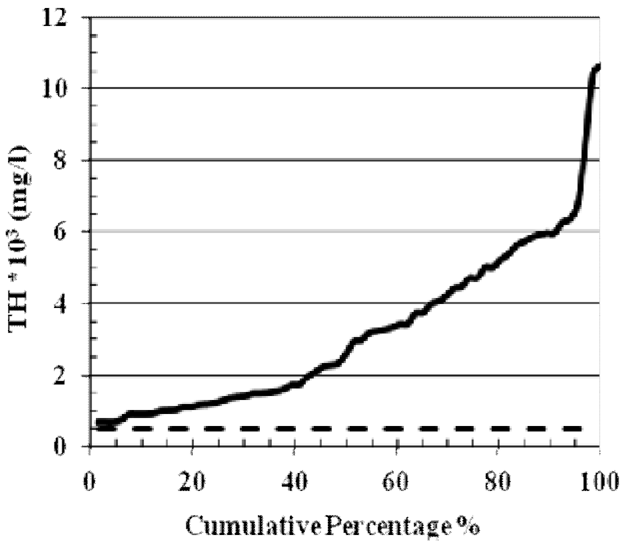


**Fig. 4. TH Values vs. Cumulative Percentage of Samples.**

## 4.4. Sodium (Na)

Sodium concentration ranged from 101 mg/l to 6405 mg/l with a standard deviation of 1254.3. As shown in Fig. 5 only 9% of the samples are within the permissible limit. Concentration in excess of 200 mg/l of Na gives rise to unacceptable (salty) taste [9]. Na salts are not actually toxic substances to human because of efficiency with which mature kidneys excrete Na [10].

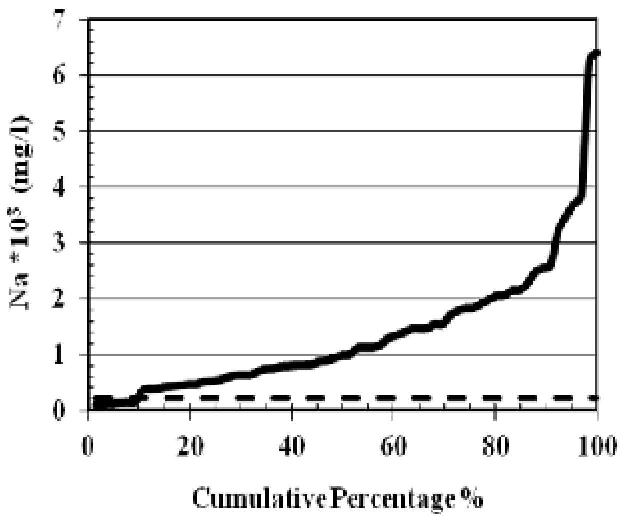


**Fig. 5. Na Values vs. Cumulative Percentage of Samples.**

Sodium concentration is important in irrigation water but high concentration is an issue in irrigated areas when the ratio of soluble sodium to calcium and magnesium ions in water is high this can cause low permeability soil and become salty [14].

### 4.5. Sulfate ($SO_4$)

The maximum concentration was 3110 mg/l and the minimum was 40 mg/l with standard deviation equal to 502.77, about 36% of the samples were within the Iraqi standard [15] which is 400 mg/l as shown in Fig. 6.

Studies with human volunteers indicate a laxative effect at sulfate concentration of 1000-1200 mg/l but no increase in diarrhea, dehydration or weight loss. The presence of sulfate in drinking water may also cause noticeable taste and may contribute to the corrosion of distribution systems [9].

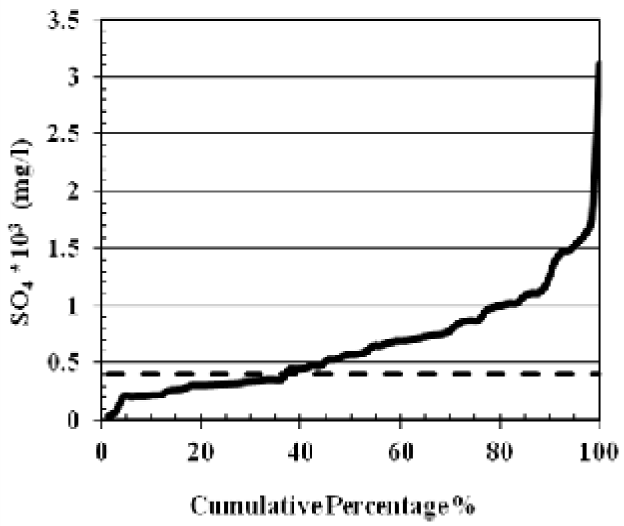


**Fig. 6. $SO_4$ Values vs. Cumulative Percentage of Samples.**

### 4.6. Total Dissolved Solid (TDS)

The TDS concentration ranged from 864 mg/l to 19064 mg/l with a standard deviation of 3672.8; all samples except one exceeded the permissible limit 1000 mg/l as shown in Fig. 7. No health based guideline value is proposed. However, the presence of high levels of TDS in drinking water may be objectionable to the consumer [9].

TDS is a general indication of the amount of water salty and its originally and kind, knowing that the kind and concentration of dissolved salt in water depend on the environment of the study area, kind of existing rocks and velocity of ground water runoff [14].

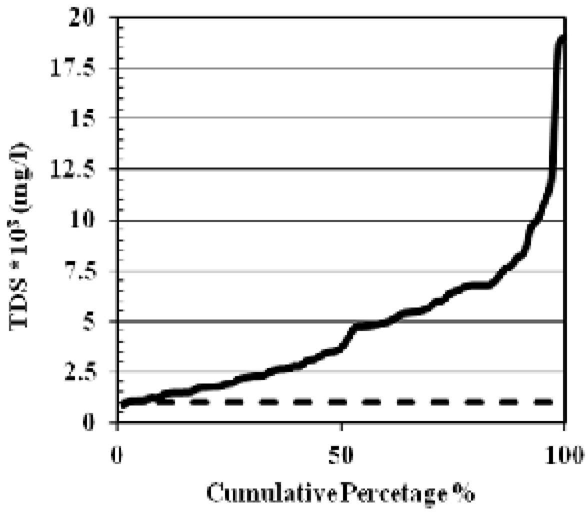


**Fig. 7. TDS Values vs. Cumulative Percentage of Samples.**

### 4.7. Electrical Conductivity (EC)

Values of EC ranged from 1100 μS/cm to 29600 μS/cm with standard deviation equal to 5746.9, EC is an indication of the total dissolved salt content in water consequently it indicates the capacity of an electrical current that passes through the water, which in turn is related to the concentration of ionized substance present in it [10]. Fig. 8 shows the cumulative percentage for no. of samples vs. EC values.

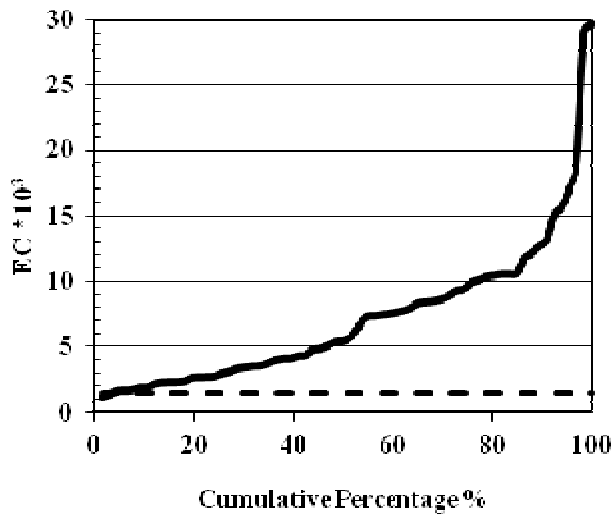


**Fig. 8. EC Values vs. Cumulative Percentage of Samples.**

The maximum limit of EC in drinking water is prescribed as 1500 μS/cm by WHO [6], the interpreted water quality with respect to EC indicates that 2 samples only lies in the good range for drinking water purposes.

### 4.8. Bicarbonates and Carbonate ($HCO_3$ & $CO_3$)

Bicarbonate and carbonate ions are the main resource for alkalinity in water which give an unpleasant taste to water. The main resource of bicarbonate ion ground water is from the infiltration water containing dissolved carbon-dioxide [14].

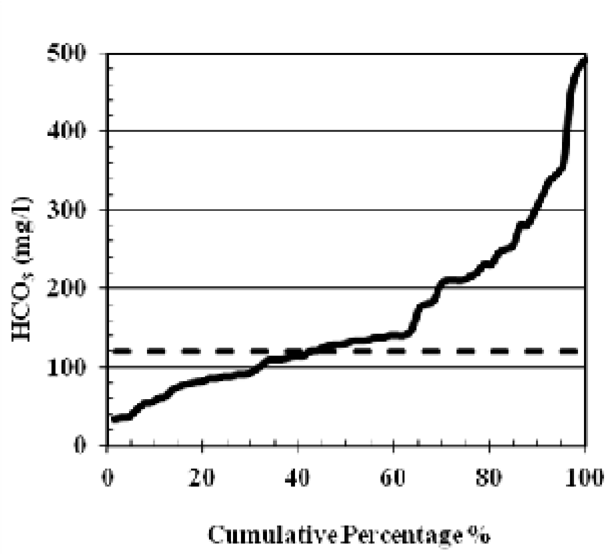


**Fig. 9. $HCO_3$ Values vs. Cumulative Percentage of Samples.**

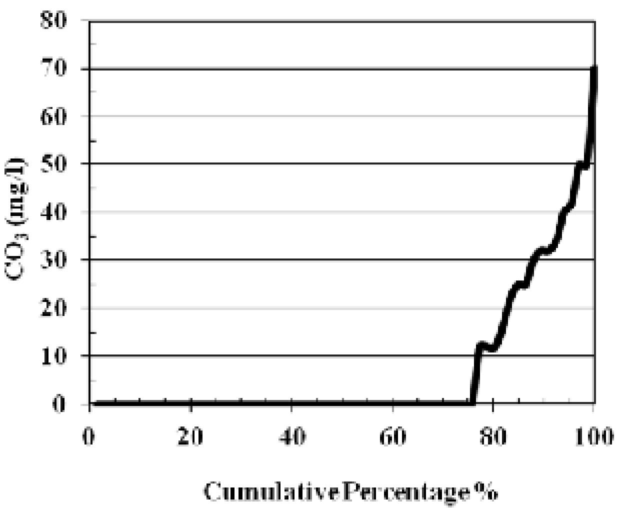


**Fig. 10. $CO_3$ Values vs. Cumulative Percentage of Samples.**

Fig. 9 shows that 42% of samples are within the permissible limit for $HCO_3$ which is 120 mg/l depending on US public health service value [6]. While fig.10 shows the cumulative percentage for no. of samples vs. $CO_3$ values

### 4.9. Nitrate ($NO_3$)

It is an important ion for agriculture that decreases the usage of nitrogen for fertilization but with excessive concentrations it becomes toxic to human [14]. The maximum value of $NO_3$ was 17.5 mg/l and the minimum was 0.1 mg/l with a standard deviation of 3.362 which is within the acceptable limit of 50 mg/l depending on the Iraqi standard for drinking water [15]. As shown in Fig. 11, all the samples are within the acceptable limits.

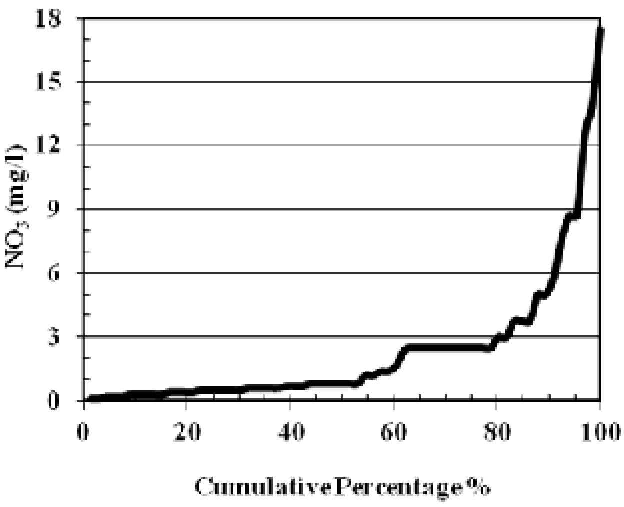


**Fig. 11. $NO_3$ Values vs. Cumulative Percentage of Samples.**

### 4.10. Calcium (Ca)

Calcium concentration of the tested samples ranged from 72 mg/l to 1100 mg/l with a standard deviation of 252.11, As shown in Fig. 12, 12% of the samples were within the acceptable value of 150 mg/l (Table 2) [15]. Ca is presented in ground water as suspension where calcium bicarbonate is the prime cause for the hardness in water [10, 14]. Excessive calcium in drinking water is linked to the formation of concretions in the body and may cause gastro intestinal diseases and stone formations [10].

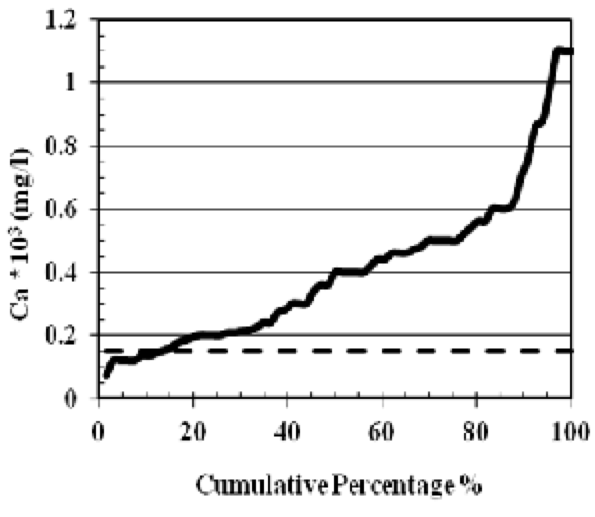


**Fig. 12. Ca Values vs. Cumulative Percentage of Samples.**

## 4.11. Magnesium (Mg)

The concentration of Mg ranged from 67 mg/l to 1924 mg/l with a standard deviation of 449.96, 91% of the samples (Fig.13) exceeded the acceptable limit of 100 mg/l depending on the Iraqi standard [15].

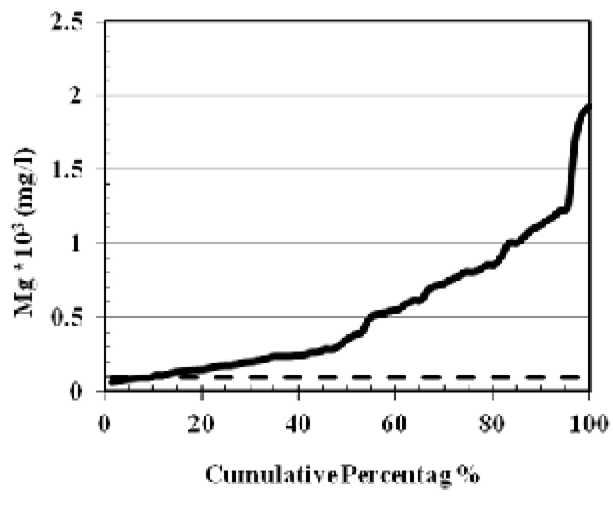


**Fig. 13. Mg Values vs. Cumulative Percentage of Samples.**

## 4.12. Potassium (K)

Potassium concentration of the samples ranged from 2 mg/l to 60 mg/l with standard deviation 11.82. Potassium is an essential element for plants and animals. The elements present in the plant material and are lost from agricultural soil by crop harvesting and removal as well as leaching and runoff on organic residues [10]. Fig.14 shows that 64% of samples are within the acceptable range of 12 mg/l depending on WHO standard [6].

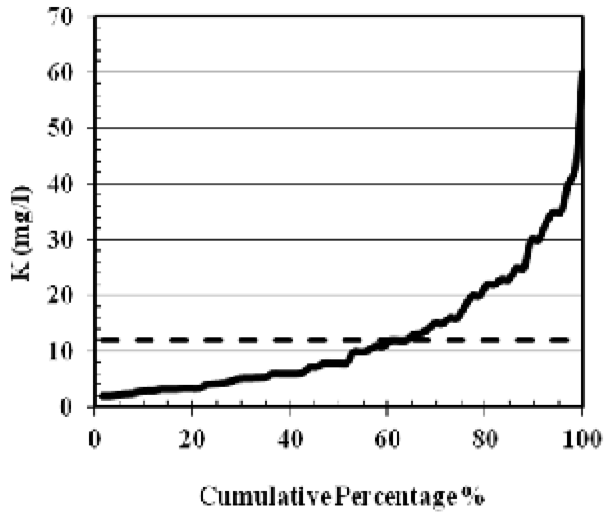


**Fig. 14. K Values vs. Cumulative Percentage of Samples.**

## 5. Results and Discusion

### 5.1. Water Quality Index (WQI)

WQI is used to reduce the large amount of water quality parameters to a single numerical value [10]. The importance of various parameters depend on the intended use of water [12]; here, water quality parameters are used to evaluate the suitability of groundwater for human consumption.

To calculate WQI the following steps were used [6, 10, 11, 12, 13];

1. Each of the 13 parameters (EC, pH, T.D.S, TH, Cl, $CO_3$, $HCO_3$, $SO_4$, $NO_3$, Ca, Mg, Na and K) has been given an assigned weight (wi) according to its relative importance in the overall quality of water for drinking purposes as shown in Table 3 ranging from 1 to 5. A maximum weight of 5 is given to the parameters $SO_4$, $NO_3$, Cl, and TDS for their importance in water quality assessment, while a minimum value of 1 is given to the parameters TH, k, and $CO_3$ that play an insignificant role in the water quality assessment [11].
2. Second step is finding the relative weight depending on the following equation;

$$Wi = wi / \sum_{i=1}^{n} wi \quad \ldots(1)$$

where Wi = relative weight, wi = weight of each parameter, n = number of parameters.

**Table 3,**
**Water Quality Standard, Assigned and Relative Weight Value Needed to Calculate Water Quality Index.**

| Parameters | Drinking standard mg/l | Assigned weight wi | Relative weight Wi |
|---|---|---|---|
| pH | 6.5 – 8.5 * | 2 | 0.05 |
| EC | 1500 ** | 3 | 0.075 |
| TDS | 1000 | 5 | 0.125 |
| TH (as $CaCo_3$) | 500 | 1 | 0.025 |
| Ca | 150 | 3 | 0.075 |
| Mg | 100 | 3 | 0.075 |
| Na | 200 | 4 | 0.1 |
| K | 12 | 1 | 0.025 |
| Cl | 350 | 5 | 0.125 |
| $CO_3$ | - | 1 | 0.025 |
| $HCO_3$ | 120 | 2 | 0.05 |
| $SO_4$ | 400 | 5 | 0.125 |
| $NO_3$ | 50 | 5 | 0.125 |

* pH has no unit, ** EC in µS/cm.

3. Third step is calculating the quality rating Qi using the equation;

$$Qi = \left(\frac{Ci}{Si}\right) * 100 \qquad \ldots(2)$$

Except for pH where Qi is calculated from the fallowing equation;

$$Qi = \left(\frac{Ci-7}{Si-7}\right) * 100 \qquad \ldots(3)$$

where Qi = quality rating, Ci = concentration of each water parameter in mg/l, Si = standard value for each water parameter.

Qi = 0 when pollutant is totally absent in the water sample and Qi = 100 when the value of the parameter is just equal to its miscible value, thus the higher the value of Qi is, the more polluted is the water [12, 13].

4. Last step is computing WQI using the following equation;

$$WQI = \sum_{i=1}^{n}(Wi * Qi) \qquad \ldots(4)$$

where WQI = water quality index, Qi = rating based on the concentration of $i^{th}$ parameter, Wi = relative weight of $i^{th}$ parameter.

In the end of the last step WQI is computed for each sample (for each well), it ranged from 51 to 1242 as shown in fig.15. According to the WQI the water can be classified as shown in table 4. From this table the water from these well are classified unsuitable for drinking purposes.

**Table 4,**
**WQI Range and Type of Water Classification [6].**

| Range | Type of water |
|---|---|
| < 50 | Excellent water |
| 50 - 100 | Good water |
| 100.1 - 200 | Poor water |
| 200.1 – 300 | Very poor water |
| > 300 | Water unsuitable for drinking purposes |

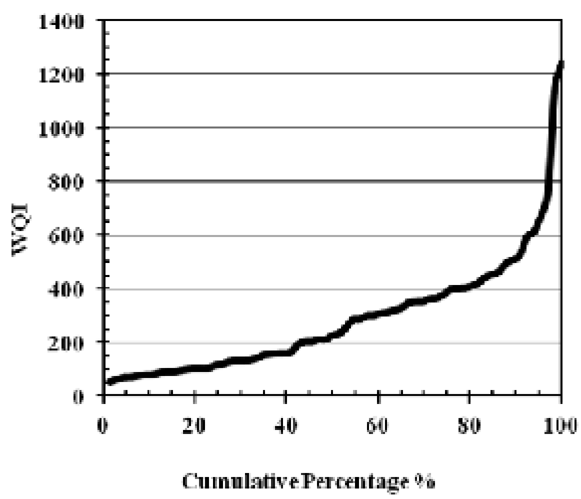


**Fig. 15. WQI Values vs. Cumulative Percentage of Samples.**

## 5.2. Water Quality for Irrigation Purposes

### 5.2.1. Sodium Adsorption Ratio (SAR)

SAR and EC are used to evaluate water quality for irrigation. SAR is a measure of alkali/sodium hazard to crops [4] and is calculated using the fallowing equation [4, 11];

$$SAR = Na^{+}/\left[\sqrt{(Ca+Mg)/2}\right] \qquad \ldots(5)$$

all ionic concentration are expressed in meq/l. SAR ranged from 1.16 to 28 (Fig.16) and according to Table 5, 56% of the samples were under the category of excellent water for irrigation and 33% of samples were under the category of good water for irrigation.

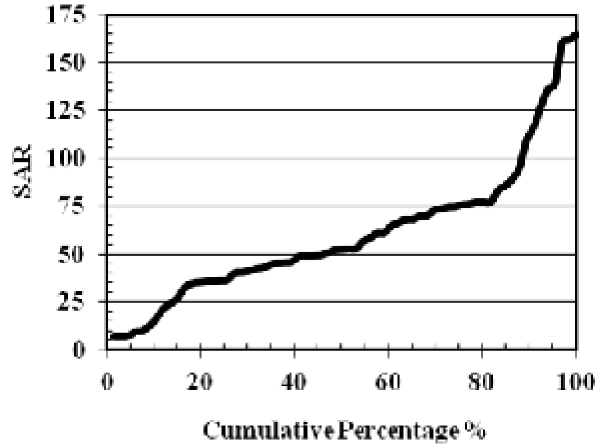


**Fig. 16. SAR Values vs. Cumulative Percentage of Samples.**

**Table 5,**
**Classification of Ground Water for Irrigation Based on SAR [4].**

| Quality of water | Sodium adsorption ratio (SAR) |
|---|---|
| Excellent | < 10 |
| Good | 10-18 |
| Doubtful | 18-26 |
| unsuitable | >26 |

## 5.2.2. Residual Sodium Carbonate (RSC)

RSC is an indicator to the hazards effect of carbonate and bicarbonate on irrigation water, and is calculated using the formula [4, 11];

$$RSC = [(HCO_3 + CO_3) - (Ca + Mg)] \quad \dots(6)$$

where RSC and all ionic are expressed in meq/l. Based on table 6, fig.17 shows that all samples are good for irrigation.

**Table 6,**
**Classification of Irrigation Water Based on RSC [15, 4].**

| Quality of Irrigation Water | Residual Sodium Carbonate (RSC) in meq/l |
|---|---|
| Good | < 1.25 |
| Unsuitable | >2.5 |

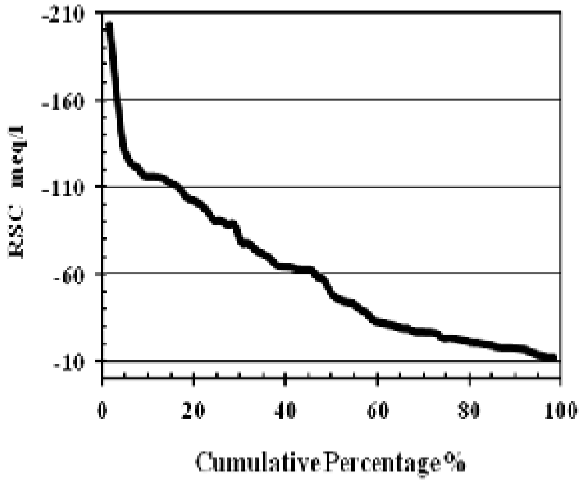


**Fig. 17. RSC Values vs. Cumulative Percentage of Samples.**

## 5.2.3. Sodium Percentage (Na%)

Na reacts with soil to reduce its permeability and support little or no plant growth so it is considered vital for determining ground water suitability for irrigation and is usually expressed in terms of percentage sodium calculated using the formula [4];

$$Na\% = (Na + K) * 100 / (Ca + Mg + Na + K) \quad \dots(7)$$

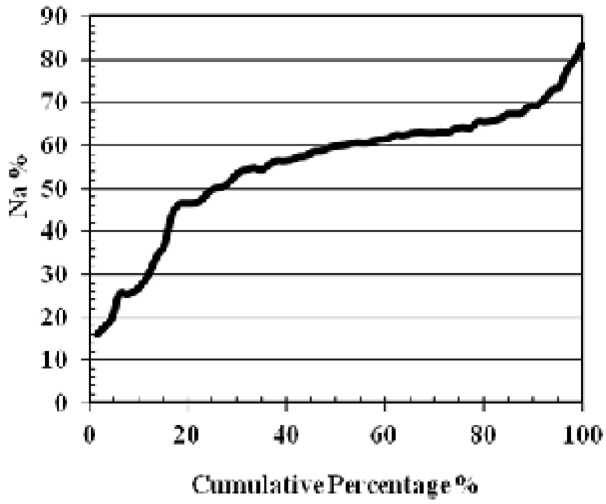


**Fig. 18. Na% Values vs. Cumulative Percentage of Samples.**

all ionic concentration are in meq/l, based on Na% < 35 in ground water is suitable for irrigation purposes [4], with Na% ranging from 18.43 to

85.67 (Fig.18), only 14% of samples are suitable for irrigation purposes depending on Na%.

## 5.3. Water Quality for Animal Use

Tables 7 and 8 show the range of TDS in drinking water for animal use.

**Table 7,**
**TDS Range and Type of Animal Classification [14].**

| TDS Range (mg/l) | Type of animal |
|---|---|
| < 1000 | Domestic Animals |
| 1000 - 3000 | Horses |
| 3000 - 5000 | Milk-Livestock |
| 5000 – 7000 | Meet-Livestock |
| > 7000 | Sheep |

**Table 8,**
**Classification of Ground Water Depending on TDS [14].**

| TDS Range (mg/l) | Type of water |
|---|---|
| 2860 | Excellent water |
| 6435 | Good water |
| 7150 | Poor water |
| 10000 | Very poor water |
| 12900 | Water unsuitable for drinking purposes |

On basis of Table 8 classification, Fig.٧ shows that 41% of samples are within excellent ground water for animal use, while 33% are within good water category. Then 74% of samples are suitable for animal use especially for sheep and meet-livestock animals.

## 6. Conclusion

### 6.1. Using the Groundwater as Drinking Water for Human

Depending on WQI values which are more than 50, all samples are not to be used for drinking water, because of the high concentrations of one or more of the water parameters which are above the permissible limitation (depending on Iraqi and WHO drinking water standards) this cause increasing in the WQI value, which means decreasing in water quality.

### 6.2. Using the Groundwater for Irrigation

Depending on SAR and RSC values, the groundwater samples could be used for irrigation but this water may affect the physical properties of the soil because of the high value of sodium percentage in most of the samples. High sodium percentage will reduce the permeability of the soil and water infiltration slows to near zero which effects plant growth. An application of gypsum ($CaSO_4 2H_2O$) to the soil will reduce the effect of this problem because sodium will react with sulfate to form sodium sulfate ($Na_2SO_4$) which is a highly water soluble material that is leached from the soil.

### 6.3. Using the Groundwater for Animals

The study showed that depending on TDS values of the groundwater samples, that the water is suitable to be used for animals especially for sheeps and meet livestock animals.

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# دراسة مدى ملائمة المياه الجوفية لمدينة بغداد للاستهلاك البشري والحيواني والزراعي

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**الخلاصة**

المياه الجوفية تعتبر احد المصادر المهمة للمياه خاصة للبلدان التي تعاني من شحة او انعدام المياه السطحية ، لذلك من الضروري دراسة نوعية المياه الجوفية والوقوف امام امكانية اسخدامها للاستهلاك البشري او الحيواني او لاغراض الزراعة. ويتم ذلك باستخدام عدة مؤشرات مثل WQI, SAR, RSC, Na%, TDS من خلال هذا البحث تم دراسة خواص 66 نموذج لمياه جوفية اخذت من ابار تم حفرها بمناطق مختلفة من مدينة بغداد، حيث اظهرت النتائج ان WQI يشير الى عدم ملائمة هذه المياه للاستحدام البشري بينما بين مؤشري SAR, RSC ان مظم المياه الجوفية صالحة للزراعة، ومن خلال TDS نلاحظ ان 74% من النماذج يمكن استخدامها للاستهلاك الحيواني وبالاخص الاغنام ومواشي اللحوم.