Ground Water Hydrochemical Assessment at Rifai-Nasiriya district, Thi Qar Governorate- South Iraq

Moutaz A. Al-Dabbas¹, Kareem G. Mhajej², Weam H. Kadum³
¹Department of Geology, College of Science, University of Baghdad,  
²Department of Biology, College of Science, University of Al-Qadisiyah  
³Department of Chemistry, College of Science for Women, University of Baghdad, Iraq.

profaldabbas@yahoo.com  
Weamhh99@yahoo.com

Abstract. The climate parameters (rainfall, Number of rainy days and temperature) data for the period from 1941 to 2009 for Nasiriya were investigated. The output reflect minimizing the numbers of rainy days and means yearly precipitation in the Nasiriya station, with the maximizing the yearly mean temperature. The chemical properties of sixteen samples of the shallow groundwater of the Quaternary sediments at Rifai-Nasiriya district are examined. Groundwater analysis indicates that the values of pH, electrical conductivity (EC) and total dissolved solids (TDS) are in the range of (6.9 to 7.8), (1645 to 68509) μS/cm, and (1158 to 47956) mg/l respectively. The results of groundwater analyses show brackish to salty water classes and indicate slightly mineralized to mineralized water. The groundwater is of two categories Sulphate group with three families (Na - SO₄) and (Mg - SO₄), while the second is Chloride group having two families, (Ca - Cl) and (Na - Cl). The evaporation and dissolution of the evaporate rocks (gypsum and anhydrite) are the main factors affecting the groundwater as well as the weathering of the carbonate rocks. The water is not good because of the high salinity for any usage.

Keywords. Climate change, Ground water Hydrochemistry, Rifai-Nasiriya district, Iraq.

1. Introduction
The hydrological system, at Rifai-Nasiriya district, Thi Qar Governorate- South Iraq, has endured dramatic change over the last 30 years as a result of rising demand for a resource of progressively more limited supply. The climate changes have diversely affected the Tigris River and consequently the Garraf River that pass through the area. These rivers are representing the primary source of water, have fallen to less than a third of normal capacity with deterioration of its water quality.

Moreover, the quantity of water is deteriorated for their high soluble salts that developed due to various improperly drilled wells and increasing the population [1, 2]. The shallow groundwater of the Quaternary sediments at Rifai-Nasiriya district southwestern part of Iraq is situated between 46° 00 ′ – 46° 30 ′ E and 31° 00 ′ – 32° 00 ′ N within Thi Qar governorate, (Figure 1) [3, 4].

2. Geological Setting
The chosen area is a relatively flat surface with low Relief and covered with Quaternary sediments which overlie a complete Mesozoic and Cenozoic section [5].

The upper part of the Quaternary deposits sequence comprises fluviatile flood silts and Aeolian silts which are palaeontologically difficult to differentiate from Pre-Quaternary deposits. The Quaternary sediments are unconsolidated and usually finer grained than the underlying formations. The Quaternary deposit distributed to Pleistocene deposits and Holocene deposit [5].

3. Pleistocene deposits
Pleistocene deposits cover all parts of the study area and the upper limit of this sediment could be up to (1.5 m) below the surface of the ground and up to a thickness of (174 m) and consists of sand, silt, and clay that interbedded with each other [6].

4. Holocene deposits
Sediment of Holocene age comprises fluvial and lacustrine deposits of sand, silt and clay, silty is the dominant facies. The boundary between the Pleistocene and Holocene deposits is based on lithological criteria since age diagnostic fossils are absent. It is alluvial plain deposit which comprises from River Deposit, a deposit of Shallow Depression and Marshes Deposits [5, 6].

The quality groundwater is deteriorated due to intensive pumping, mixed with fertilizes and waste disposal [5, 6].

Several studies were achieved that concerning with the chemistry of water [1, 2, 3] but no one investigate the hydrochemistry of ground water at Rifai-Nasiriya area together. Therefore, the Rifai-Nasiriya area is selected for utilization and analyses of the water of the unconfined aquifer figure 1 [4]. The area is with yearly mean precipitation about 129 mm, yearly mean evaporation about 2995 mm, yearly mean relative humidity% of 41% and with yearly mean temperature of 25 °C [5]. The objectives of the research are to examine the chemical properties of groundwater and to assess the suitability of water for various purpose uses at the shallow groundwater of the Quaternary sediments at Rifai-Nasiriya district southwestern part of the Mesopotamia during October 2016 and the suitability of the groundwater for different uses.

Figure 1. The map of the chosen wells locations and Garraf River [4, 7].

5. Methodology

5.1. Climatic factors investigation
The Nasiriya climatic data for the period between years 1941 to 2009 were investigated, as mean annual temperature, mean annual rainy days and mean annual rainfall [8].

5.2. Hydrochemistry
The shallow aquifer is studied within the Quaternary sediments (Figure 1). The analyzed hydrochemical parameters such as pH, electrical conductivity, total dissolved solids as well as cations and anions are used to describe groundwater quality and its suitability for different purposes. According to hydrochemical investigation of the unconfined aquifer twenty six water wells were sampled during October 2016 that represent the water deficit periods (Figure 1). The cations K+, Na+, Mg2+, Ca2+ and anions Cl-, HCO3-, SO42- as well as electric conductivity EC, total dissolved salts TDS and pH were examined in the laboratories of the Ministry of Water Resources - General Commission for Groundwater. The outputs are shown in Tables 1.

6. Results

6.1. Climate:
The mean annual temperature (°C) of Nasiriya for the period from year 1941 to 2009 with their best fit line was indicated. Direct relationship between temperature and time is reflected (Fig. 2). While, the average yearly precipitation (mm) for the same period indicates inverse relationship between rainfall and time as well as indirect relationship between rainy days and time (Fig. 2).

Figure 2. The trend of yearly precipitation (A), yearly rainy days (B) and yearly mean temperature (C), for Nasiriya between year 1941 to year 2009 [8].

7. Hydrochemistry
The groundwater of the shallow groundwater of the Quaternary sediments at Rifai-Nasiriya district southwestern part of the Mesopotamia is characterized by their variation in TDS during October 2016 are range between 1158 to 47956 ppm (Tables 1). The EC are range between 1654 to 68509 μs/cm. Comparison of TDS values with three classifications of water [9, 10, 11, 12], the water is classified as range between slightly-brackish water to salty water; accordingly the water is not suitable for drinking
and with pH values range between 6.9 to 7.8, the shallow groundwater of the Quaternary sediments at Rifai-Nasiriya district indicates weakly to Mineralized water according to [13].

Applying Sulin’s [14] classification, the ground water samples fall in the zone of A< 1 that represent diluted marine water in unconfined to semi confined aquifer and in the zone of B<1 that represent meteoric origin of Na+K - Sulphate and some samples belong to NaHCO3. The groundwater samples shows that the group are SO4 and Cl with the families of Na-SO4, Mg-SO4, Na -Cl and Ca-Cl according to Schoeller, [15] classification. While according to Piper’s [16] classification the groundwater samples fall in (c –class) which represents normal earth alkaline water with prevailing sulphate and chloride and some of these samples fall in (e – class). The result of using combined Sulin’s [14] - Schoeller, [15] (SS) method that proposed by Hassan, et al. [17], reflect that the sulphate group with two families (sulphate -sodium and sulphate- magnesium) the first family with two water types rNa> rCa> rMg; SO4> rCl, with 43.7% and rMg>rCa > rNa ; rSO4> rCl with 6.3% (Table 2). The chloride of two families (chloride -sodium and chloride - calcium) and two water types which are rNa >rMg> rCa; rCl>rSO4 water type with 13.3 % and rCa >rNa> rMg; rCl>rSO4 water type with 18.7% (Table 2).

The groundwater samples are divided into two types’s diluted marine water and meteoric water. The differences of the water types are because of the geological and geochemical variations of the sedimentary facies, sedimentation and dissolution of different minerals.

8. Usage of the Groundwater

The groundwater chemical analyses indicated that they are unsuitable for human drinking purposes according to Iraqi standard [18] and World Health Organization standard [19]. While, they are ranging from good for animal drinking to acceptable for poultry according to [9], Crist and Lowery [20] and Ayers and Westcot [21] classifications. It is clear that all water samples are suitable for building purposes according to Altoviski [9] and located within the permissible limits except some samples are located within the doubtful limits according to Ayers and Westcot [21], and Don [22] classifications for irrigation purpose.

| Sample | pH | EC (μS/cm) | TDS (ppm) | Unit | Ca2⁺ | Mg2⁺ | Na+ | K⁺ | SO4⁻ | HCO3⁻ |
|--------|----|------------|-----------|------|------|------|-----|-----|------|-------|
| 1      | 7.3| 13150      | 28995     | ppm  | 834  | 793  | 786 | 244 | 104  | 741   |
|        |    |            |           | epm% | 9.1  | 66.1 | 341.9 | 6.3 | 299  | 154.1 |
| 2      | 7.5| 58500      | 40400     | ppm  | 300  | 1213 | 5539 | 897 | 7384 | 1017  |
|        |    |            |           | epm% | 29.2 | 19.6 | 66.1 | 4.5 | 40   | 40.5  |
| 3      | 6.9| 68509      | 47956     | ppm  | 914  | 88   | 16293| 99  | 201  | 9161  |
|        |    |            |           | epm% | 45.7 | 7.3  | 708.4 | 2.5 | 576  | 190.1 |
| 4      | 7.7| 12745      | 23096     | ppm  | 649  | 88   | 8050 | 70  | 127  | 118.1 |
|        |    |            |           | epm% | 32.5 | 7.3  | 350  | 1.8 | 364  | 24.7  |
| 5      | 7.4| 6692       | 4927      | ppm  | 354  | 172  | 621  | 58  | 852  | 1305  |
|        |    |            |           | epm% | 17.7 | 14.3 | 27   | 1.5 | 24   | 27.2  |
| 6      | 7.8| 7560       | 5807      | ppm  | 570  | 160  | 711  | 200 | 138  | 131   |
|        |    |            |           | epm% | 28.5 | 13.3 | 30.9 | 5.1 | 39   | 27.4  |

Table 1. Hydrochemical parameters of the present groundwater samples of low flow conditions (October 2016).
Table 2. Schoeller- Sulin’s 1981 classification of the groundwater samples of low flow conditions (October 2016).

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 7.5 | 10295 | 26060 | ppm | 521 | 1507 | 6142 | 123 | 102 | 596 | 336 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 8 | 7.3 | 14910 | 34064 | ppm | 637 | 1849 | 8919 | 113 | 1491 | 7234 | 225 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 9 | 7.6 | 8170  | 5400  | ppm | 501 | 292  | 710  | 20  | 1250 | 1818 | 511 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 10| 7.4 | 6771  | 4740  | ppm | 337 | 187  | 926  | 40  | 781  | 235  | 132 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 11| 7.3 | 4390  | 2910  | ppm | 261 | 129  | 430  | 8   | 685  | 944  | 228 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 12| 7.1 | 2380  | 1640  | ppm | 192 | 59   | 270  | 3   | 107  | 945  | 114 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 13| 7.5 | 1654  | 1158  | ppm | 100 | 122  | 112  | 3   | 178  | 515  | 231 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 14| 7.3 | 9985  | 25429 | ppm | 502 | 150  | 7812 | 128 | 627  | 9253 | 310 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 15| 7.8 | 10187 | 25712 | ppm | 866 | 528  | 7178 | 110 | 944  | 6192 | 390 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 16| 7.4 | 13890 | 298819| ppm | 970 | 782  | 8224 | 68  | 101  | 8305 | 289 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 17| 6.9 | 1654  | 1158  | ppm | 100 | 59   | 112  | 3   | 107  | 515  | 114 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 18| 7.8 | 6850  | 4795  | ppm | 300 | 1213 | 7864 | 897 | 7384 | 101  | 610 |
|   | ppm |       |       |     |     |     |     |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

9. Discussion
The chemical composition of the samples reflects the predominance of chloridic water type in most of the Quaternary sediments aquifers (flood plain aquifers). The bicarbonate water type with low TDS is restricted to a local scale, especially along river courses and irrigation channels, where the seepage from the river dilute groundwater salinity. Generally, the groundwater of chloridic type is characterized by salty groundwater and even Salty groundwater (TDS >40000 mg/l), especially in depressions near the marshes. This can be explained by the soil waterlogging and the high potential evaporation (Pan Evaporation =3250 mm/year), where the salt accumulates near the surface, as salt crust, then dissolves by the infiltrated rainfall water, leading, with time, to salt accumulation in the groundwater. On the other hand, the slightly brackish groundwater Highly Brackish Water and Salty Water in the Quaternary sediments aquifers may be found in the areas where influent seepages from the rivers and irrigation channels occur, especially along Al-Gharraf River, with Ca (Mg) – Bicarbonate water type. Generally, the chloridic water is not useful for any purpose (human drinking, animals drinking, agriculture and industrial uses).

The study area is mainly covered by Quaternary sediments which are generally composed of alternation of clay, silt, and sand. The layers of sand and silt which represent the oldest part of these sediments represent aquifers, while those of silty clay and clay represent aquitards. The distribution of aquifers and aquitards differs significantly from one place to another, but in general some regional regularity can be followed in the Mesopotamia Plain. The upper part of the sediment sequence is usually formed by aquitards with thickness ranging from 10 m to 20 m, while the extensions of aquifers are generally downward below the depth of (20 – 25) m. During winter and spring, the rainfall is the main source of recharge, as well as, water in the form of influent seepage from rivers and streams and irrigation channels. the water level in Al-Gharraf River is higher than the groundwater level in the surrounding areas, so that the river is considered as a recharge source to the groundwater in these areas. This can explain the relatively lower salinity of groundwater along Al-Gharraf River.

The main factor affecting the groundwater quality in the Quaternary sediments aquifers is the evaporation under the arid condition and the low recharge rate, where the salt accumulates in groundwater through washing of the salt crust by infiltrated rainfall and returned irrigation water. The groundwater in these aquifers is of high salinity and not suitable for any use, except in the area along Al- Gharraf River, where the river is feeding the groundwater and the groundwater is turned into brackish water.

During the dry season the water level of the, the water level in Al-Gharraf River is higher than the surrounding groundwater level, so the river is feeding the unconfined aquifer along the river course and dilutes its salinity.

The significant spatial variation in the hydrochemical properties of the Quaternary aquifers may be attributed to the lateral variation in lithology which is a feature of the flood plain sediments.

**Conclusion**

1- The results of analyzing the climatic variable for of Nasiryia show decrease of the average means annual rainfall; average number of rainy days per year, with the increase of the mean yearly temperature.

2- The groundwater is classified as brackish and can be concluded that the water reflect mineralized water.

3- The groundwater is of two groups, the first is mixed Mg and Na - SO4 group having two families which are (Na2SO4) and (MgSO4). While the second is Chloride group having two families, (Ca- Cl) and (Na - Cl).

4- The results reflect that the groundwater is divided into diluted marine water and meteoric water.

5- The ground water is not recommended for drinking and industrial purposes because of high salinity and it is (Doubtful to unsuitable-Unsuitable) for irrigation.

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