Impact of climate change on the hydrochemistry of Debaga unconfined aquifer, Kurdistan region, Iraq

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Abstract. The available climate parameters data of the rainfall and temperature for the Iraqi meteorological stations: Mosul, Kirkuk, Baiji, Tuz, Tikrit, and Debaga were investigated. The findings indicate profound document of change in climateshown by the noticeable increase of the average mean annual temperature with the remarkable decrease of the yearly precipitation in the investigated meteorological locations. The impact of the climatic change on the hydrochemistry of Debaga unconfined aquifer was noticeable in increasing the water salinity as studied during the year 2014 and compared with the years before 2001. The Debaga unconfined aquifer has indicated two groups’ sulphate (79%) and chloride (21%) for the year 2014. It is clear that the climate change conditions increase the sulphate group in Debaga basin during 2014. It is recommended to overcome the water shortage by choosing an economical method of irrigation rather than the local traditional methods.

Keywords: Debaga unconfined aquifer, Climatic changes, hydrochemistry, Iraq.

1. Introduction:

The operation of any system of water resources should take into consideration the changes in rainfall and temperature. As it is expected that there are shortage of rainfall due to the global climate changes, therefore, there will be a shortage of the surface water resources and the groundwater will be important for people living. Accordingly the need of more groundwater resources may lead to the deterioration of the quality of the groundwater[1][2]. Many researches mentioned the vital challenges and alarming groundwater decreases in quantity and quality with in the Tigris and Euphrates Rivers basins due to the Global climatic warming that will therefore effect the expected sustainable development[3][4][5].

The Bai Hassan Formation in general and the Debaga unconfined aquifer in particular has more exploitation in groundwater resources for municipal activities and agricultural activities due to the surface water shortage [6], [7]. Groundwater in this layer is replenished from an average annual rainfall of approximately 400mm through gravels in dendritically-shaped valleys [8]. Many researches were carried out dealing with the aquifer properties, whereas few investigations are taking into consideration the global warming on the ground water development in Iraq [9][10][11]. The aquifer of Debaga that of silt, gravel and sand composition, is believed to supply vital groundwateramounts. The impact of the climatic change on the hydrochemistry of Debaga unconfined aquifer for the year 2014 and the comparison with their hydrochemical properties before 2001 was investigated as novelty of this research.

Many types of ionic relations could be used, chemical classification of the dominant cations and anions concentration and their interrelationships may throw light on the water quality changes with time[12]. The aims of this research are to indicate the evidence of climatic change in Iraq by studying the available historical climate parameters, rainfall, temperature, for the Iraqi meteorological stations (Mosul, Kirkuk, Baiji, Tuz, Tikrit, and Debaga). It also aims to investigate the effect of the global warming on the hydrochemistry of Debaga unconfined aquifer for the year 2014 with comparison to the hydrochemistry of the same wells for the years before 2001.
2. Location

Debaga watershed lies on the right side of Lesser Zab River between Avana and Qarachuq mountains, it has a longitudinal shape, its length is about 65 km while its width is about 22 km, and its total area is about 1500 km².

The area depends on groundwater for irrigation due to absence of any irrigation project in the area. It also depends on the rain fed. After 1991, the area suffered from demographic changes and this led to ignoring the groundwater exploitation until the year 2001 after the large campaign for wells drilling in the area. In that year, about 60 wells were drilled for agricultural purposes. The wells were mostly drilled in the older alluvium and BaiHasan formation. The Quaternary deposits (as older alluvium) thickness ranges between 50-130 m. The best water bearing layer belongs to BaiHasan formation, its thickness and its lithology let the formation has an importance to have a good quantity of water. The Debaga basin is situated between latitude 35°30'00"–36°07'30"N and longitude43°22'30"–44°15'00"E.

It is a high undulated terrain bounded by two geological structures (the Avana and the Qarachuk mountains) and two rivers, The Lower Zab and The Upper Zab. The plain area has rectangular shape (20*65) Km² oriented southeast to North West along the general direction of the major fold sin the north east corner of Iraq (Figure 1). The plain is higher in the middle slopping in opposite directions towards the two rivers The Upper (or Greater) Zab in the North West and The Lower (or Leaser) Zab in the southeast.

In addition, agriculture is the most common profession among the residents of the Debaga basin who in the last decade has augmented water wells drilling activities [12]. The Debaga basin lies in the low fold region in northern Iraq. Its topography is announced with variation in altitude between a low of 233 and a high of 875 m.a.s.l. The plain area is an undulated terrain cut by a parallel drainage system type [13].The center line of Debaga basin corresponds to annual average rainfall of 375 mm, (Figure 1) [9].

3. General Geological Setting

As can be seen, the Quaternary deposits (older alluvium) is a heterogeneous deposit of lenticular and commonly elongated bodies of sand, clay, secondary gypsum, and poorly sorted gravels mostly derived from topographic heights in the region. Younger alluvium is however a flood plain stream deposit composed of gravel and sand with considerable silt and clay. Pliocene underlies the Quaternary deposits represented here by the Bai Hassan formation which consists of brown mud stone and coarse poorly consolidated conglomerates. It overlies conformably an Upper Miocene formation of pebbly sand and clay beds named locally Al-Mukdadiaformation (Figure 2)[14].
4. Hydrogeological setting
The conglomerates of the Pliocene epoch of the Bai Hassan formation may be considered the most permeable horizon in the lithological column of the clastics sediments in the study area. The course sandstone and pebbly sandstone beds of the Upper Miocene-Pliocene sediments of the Mukdadiaare
the next ground water bearing horizon in the sequence. However, the formation contains important impermeable mudstone horizons. The fine sandstone beds of the Upper Miocene have the largest extent in the basin. They occur normally at several horizons separated by impermeable beds of siltstone and claystone which compose the Injana formation. More clay stone as well as gypsum beds are found with depth as the Fatha formation of the Middle Miocene is encountered. The shallow unconfined aquifer was recognized of the permeable beds of the Tertiary formations BaiHassan2003; [11][13].

The first unconfined aquifer has a variable saturated thickness ranging from 25 m to about 50 m. Groundwater generally flows to the southwest, and less relief is distributed with areas of permeability and effective porosity of gravel and sand of the Bai Hassan Formation and the Quaternary sediments (see Figure 3).

![Figure 3: Ground water flow pattern in the Debaga unconfined aquifer [13].](image)

5. **Groundwater quality**
Groundwater quality is variable in the Debaga basin spatially and vertically. This is probably due to the fact that the shallow aquifer is affected by the drainage water of the agricultural activities which take place in the low plain areas.

6. **The effect of carbon dioxide in Iraq**
The level and source of carbon dioxide in Iraqi is distributed from several ways, as burning of the liquid, solid, and gas fuel, flaring and the cement industry [15]. As it is known, the primary cause of global warming is elevation in the concentration of CO₂ in the atmosphere. This increase in surface temperature is called greenhouse effect. So, because CO₂ blocks heat from escaping much as the glass panes of a greenhouse does, a considerable increase in CO₂ level witnessed in Iraq between 1950 and 2018 had been detected. CDiac shows the relatively higher temperature between 1960 and 2018, which, it is believed to indicate the role of CO₂ in climate changes [16].
7. Materials and Methods

7.1. It is vital to consider the latitudes which is important for Climatic parameter analysis in Iraq. Accordingly the general climatic elements for Mosul, Kirkuk, Baiji, Tuz, and Tikrit, Debag meteorological stations were selected. The available data for the climatic elements were studied for the average mean annual temperature, and the average mean annual rainfall.

7.2. The hydrochemical analysis

Nineteen ground water samples were collected during summer season of year 2014, from Debaga unconfined aquifer according to Todd[17] procedure, as in Figure 4. These samples compared with historical analysis of ground water samples that were collected almost from the same locations during the summer season before year 2001 Following Hassan [18] hydrochemical classification [11]. The major ions (K\(^+\), Na\(^+\), Mg\(^{2+}\), Ca\(^{2+}\), Cl\(^-\), HCO\(_3\)\(^-\), SO\(_4\)\(^{2-}\), NO\(_3\)\(^-\)) in addition to Electric conductivity EC, Total dissolved salts TDS and pH were carried out. The analyses were done in the College of Science-University of Baghdad chemical laboratory according to Todd [17] procedure. EC, pH, Major ions and TDS, of Debaga unconfined aquifer water samples for years before 2001 and 2014 were shown in Tables 1 and 2 respectively.

Table 1: The groundwater samples Hydrochemical parameters of high flow conditions for Debaga unconfined aquifer before 2001.

| S. No. | pH | EC  | TDS | Ca\(^{2+}\) | Mg\(^{2+}\) | Na\(^+\) | K\(^+\) | HCO\(_3\)\(^-\) | SO\(_4\)\(^{2-}\) | Cl\(^-\) | NO\(_3\)\(^-\) |
|--------|----|-----|-----|-------------|------------|--------|-------|--------------|-------------|--------|-------------|
| 1      | 7.9| 722 | 499 | 25          | 22         | 106    | 0     | 184          | 197          | 18     | 7           |
|        | 1.25 | 1.8 | 4.61 | 0         | 3.0        | 4.1    | 0.5   | 6.44         | 3.0          | 0.5    | 6.44        |
| 2      | 7.5 | 935 | 726 | 74          | 22         | 31     | 1     | 138          | 161          | 35     | 19          |
|        | 3.7 | 1.8 | 1.35 | 0.03       | 2.26       | 3.4    | 1     | 0.31         | 2.26         | 3.4    | 1.35        |
|        | 53.6 | 26.54 | 19.52 | 0.38       | 32.68      | 48.45  | 14.45 |             |              |        |             |
| 3      | 8   | 1151 | 789 | 153         | 56         | 37     | 0     | 355          | 320          | 28     | 44          |
|        | 7.65 | 5.67 | 1.61 | 0          | 5.8        | 6.67   | 0.8   | 4.72         | 0.8          | 0.8    | 4.72        |
|        | 54.9 | 33.5 | 11.55 | 0          | 41.6       | 47.6   | 5.72  |              |              |        |             |
| 4      | 7   | 2825 | 2300 | 80          | 49         | 450    | 3     | 162          | 742          | 326    | 6           |
|        | 4   | 4.1 | 19.57 | 0.08       | 2.66       | 15.46  | 9.6   | 0.1          | 2.66         | 15.46  | 9.6         |
|        | 14.43 | 14.7 | 70.57 | 0.28       | 9.55       | 55.58  | 34.52 |              |              |        |             |
| 5      | 7.7 | 1830 | 1582 | 91          | 84         | 153    | 0     | 255          | 550          | 30     | 106         |
|        | 4.55 | 7   | 6.65  | 0          | 4.18       | 11.46  | 0.86  | 1.7          | 4.18         | 11.46  | 0.86        |
|        | 40.5 | 16.3 | 42.5 | 0.7        | 16.1       | 24.7   | 50.7  |              |              |        |             |
| 6      | 6.8 | 1988 | 1569 | 52          | 81         | 184    | 1     | 188          | 461          | 165    | 2           |
|        | 2.6 | 6.75 | 8     | 0.03       | 3.1        | 9.6    | 4.7   | 0.03         | 3.1          | 9.6    | 4.7         |
|        | 15.0 | 38.85 | 46.0 | 0.15       | 17.7       | 55.1   | 27.0  |              |              |        |             |
| 7      | 7.2 | 1142 | 780  | 39          | 60         | 64     | 4     | 245          | 215          | 35     | 24          |
|        | 1.95 | 5   | 2.78  | 0.1        | 4.0        | 4.5    | 1     | 0.39         | 4.0          | 4.5    | 1           |
|        | 19.8 | 50.8 | 28.3  | 1.0        | 40.6       | 45.3   | 10.1  |              |              |        |             |
| 8      | 7.5 | 2810 | 2420 | 83          | 20         | 100    | 3     | 100          | 121          | 181    | 54          |
|        | 4.2  | 1.7 | 4.35  | 0.08       | 1.64       | 2.5    | 5.2   | 0.87         |              |        |             |

Table 1: to be continued
Table 2: Hydrochemical parameters of the present groundwater samples of high flow conditions for Debaga unconfined aquifer during 2014.

| S.No | pH  | EC  | TDS | Ca²⁺ | Mg²⁺ | Na⁺ | K⁺ | HCO₃⁻ | SO₄²⁻ | Cl⁻ | NO₃⁻ | Na/Cl molar ratio |
|------|-----|-----|-----|------|------|-----|-----|-------|-------|-----|------|-----------------|
| 1    | 7.8 | 772 | 502 | 82   | 23   | 66  | 0   | 189   | 188   | 50  | 50   | 0.39            |
| 2    | 7.3 | 1160| 789 | 66   | 77   | 74  | 0   | 238   | 300   | 55  | 55   | 1.38            |
| 3    | 7.9 | 1285| 991 | 98   | 76   | 80  | 0   | 70    | 540   | 32  | 32   | 0.87            |
| 4    | 7.5 | 3260| 2300| 69   | 37   | 417 | 16  | 255   | 480   | 361 | 361 | 1.29            |
| 5    | 8   | 1916| 1569| 100  | 136  | 196 | 0   | 128   | 800   | 67  | 67   | 1.00            |
| 6    | 7.2 | 2216| 1898| 181  | 95   | 218 | 8   | 170   | 482   | 460 | 460 | 1.25            |
| 7    | 7.7 | 2058| 1599| 120  | 69   | 98  | 0   | 298   | 293   | 150 | 150 | 0.73            |

Table 2: to be continued
|   | 6   | 5.8 | 4.3 | 0   | 4.9 | 6.1 | 4.3 | 0.8 | 1 |
|---|-----|-----|-----|-----|-----|-----|-----|-----|---|
|   | 37.5 | 35.9 | 26.6 | 0   | 30.4 | 38.0 | 26.7 |     |   |
| 8 | 7.5 | 4040 | 3616 | 254 | 65  | 327  | 0   | 607 | 503 |
|   | 12.7 | 5.47 | 14.2 | 0   | 10   | 10.5 | 11.4 | 0.5 | 1.25 |
|   | 39.3 | 16.8 | 44   | 0   | 30.8 | 32.5 | 35.2 |     |   |
| 9 | 7   | 2565 | 2180 | 50  | 16   | 462  | 1   | 157 | 606 |
|   | 2.5 | 1.3  | 20.1 | 0.03 | 2.57 | 12.63 | 7.9 | 0.8 | 2.54 |
|   | 10.44 | 5.57 | 83.9 | 0.11 | 10.77 | 52.82 | 33.1 |     |   |
| 10 | 7.5 | 2448 | 1932 | 89  | 64   | 269  | 3   | 181 | 815 |
|   | 4.45 | 5.3  | 11.7 | 0.08 | 2.97 | 17   | 1   | 0.6 | 11.7 |
|   | 20.6 | 24.7 | 54.3 | 0.36 | 13.76 | 78.76 | 4.64 |     |   |
| 11 | 7.2 | 2077 | 1898 | 99  | 61   | 315  | 1   | 570 | 525 |
|   | 4.95 | 5.1  | 13.7 | 0.03 | 9.3  | 10.94 | 3   | 0.4 | 4.6 |
|   | 20.84 | 21.4 | 57.66 | 0.1 | 39.4 | 46.2 | 12.67 |     |   |
| 12 | 8   | 1049 | 643  | 165 | 17   | 127  | 0   | 164 | 263 |
|   | 8.25 | 1.42 | 5.5  | 0   | 2.7  | 5.5  | 6.7 | 0.3 | 0.82 |
|   | 54.32 | 9.33 | 36.36 | 0   | 17.7 | 36.1 | 44.3 |     |   |
| 13 | 8   | 1855 | 1569 | 66  | 56   | 223  | 1   | 146 | 593 |
|   | 3.3  | 4.67 | 9.7  | 0.03 | 2.4  | 12.35 | 2.63 | 0.3 | 3.7 |
|   | 18.66 | 26.4 | 54.8 | 0.15 | 13.55 | 69.9 | 14.88 |     |   |
| 14 | 7.4 | 1699 | 1179 | 140 | 60   | 164  | 1   | 158 | 607 |
|   | 7   | 5    | 7.1  | 0.03 | 2.6  | 12.65 | 2.23 | 1.7 | 3.2 |
|   | 36.5 | 26.1 | 37.2 | 0.14 | 13.5 | 66   | 11.63 |     |   |

Min. PPM  | 7   | 772  | 502  | 50  | 16   | 66   | 0   | 70  | 188 |
Max.PPT   | 8   | 4040 | 3616 | 254 | 136  | 462  | 16  | 570 | 815 |

**Figure 4:** Location of groundwater sampling for Debaga unconfined aquifer.
8. Results and Discussion

8.1. Climate

8.1.1. The mean annual temperature. The relationship between the averages means annual temperature (°C) frequency curves and time seems positive in Kirkuk, and Debaga (Figure 5). Noticeable degrees of temperature were identified from the general trend line for these meteorological stations.

8.1.2. Rainfall Analysis. The relationship between the averages means annual rainfall and time-frequency curves seem negative in Mosul, Kirkuk, Baiji, Tuz and Tikrit meteorological stations, for the years 1981–2011 (Figure 6). A remarkable decrease in rainfall amounts was indicated from the general trend line for these meteorological stations.

Moreover, comparing the average mean annual rainfall (mm) for the years 1970-1980 and for the years 2000-2012 reflects that the higher average rainfall during the seventies was about 350 mm for the periods 1970-1980 and decreased to about 300 mm for the periods 2000-2012[19]. Mulder[20] concluded that the overall applied model shows that natural variation of groundwater and soil moisture have a share of about 25% of the total water mass decline in northern Iraq. Adamo [11], concluded in their investigation that the Climate Change affects lesser Zab River Basin, and that all applied models showed a decrease in mean annual precipitation in which the basin will see varying decreases in precipitation at different rates, reaching a reduction up to 30%. The results of this research are in agreement with Mulder[20], and [11]. They conclude that the climate change affect the groundwater due to decline of the annual rainfall and the reduction in the recharge water in northern Iraq in general and Debaga area in particular as it is a part of the Lesser Zab River Basin.

![Figure 5: The average means annual temperature (°C) frequency curves of Kirkuk and Debaga stations.](image)

![Figure 6: The annual rainfall data from 1980 to 2011 were obtained from Mosul, Kirkuk, Baiji, Tuz and Tikrit meteorological stations [21].](image)
8.2. The hydrochemistry of the Debaga unconfined aquifer

The Debaga unconfined aquifer water has noticeably showed that the Bicarbonate, Sulphate, and Chloride groups are of higher distribution before year 2001. According to Hassan[18] classification, the major group is the sulphate group that represent 57.12 %, with three families (sulphate-sodium, sulphate-calcium and sulphate-magnesium) the first family with three water types are Na > Mg > Ca; rSO4 > rCl > rHCO3, rNa > rMg > rCa; rSO4 > rHCO3, and rNa > rMg > rCa; rSO4 > rHCO3, the second family with only one major water type rCa > rMg > rNa; rSO4 > rHCO3 while the third family with one major water type as well which is rMg > rNa > rCa; rSO4 > rHCO3. The dominant groundwater facies indices are 13:33, 63:52 and 33:52. The second group is the Bicarbonate group that represent 21.42 %, which is with three families (Bicarbonate-Sodium, Bicarbonate-Calcium, Bicarbonate-Magnesium) each has only one water type, these are rNa > rMg > rCa; rHCO3 > rCl , rCa > rNa > rMg; rHCO3 > rSO4, and rNa > rMg > rCa; rHCO3 > rSO4 respectively. There is not dominated facies index within this group. The third group is the Chloride group that represent 21.42 %, which is with two families (Chloride-Sodium, Chloride-Calcium) each has only one water type, these are rNa > rMg > rCa; rCl > rSO4 > rHCO3 and rCa > rMg > rNa; rCl > rSO4 > rHCO3 respectively. The dominant groundwater facies index of this group is 23:13.

Two water groups are existed during 2014 survey that are: the sulphate, and chloride groups. The major group is the sulphate group that represent 78.58 %, with three families (sulphate-sodium, sulphate-calcium and sulphate-magnesium) the first family with four water types are Na > rMg > rCa; rSO4 > rCl > rHCO3, rNa > rMg > rCa; rSO4 > rHCO3, and rNa > rMg > rCa; rSO4 > rHCO3. The second family with two major water type rCa > rMg > rNa; rSO4 > rHCO3 > rCl and rCa > rNa > rMg; rSO4 > rHCO3 while the third family with one major water type which is rMg > rCa > rNa; rSO4 > rHCO3. The dominant groundwater facies indices are 13:52, 23:33 and 53:52. The second group is the Chloride group that represent 21.42 %, which is with two families (Chloride-Sodium, Chloride-Calcium) each has only one water type, these are rNa > rMg > rCa; rCl > rSO4 > rHCO3 and rCa > rNa > rMg; rCl > rSO4 > rHCO3 respectively. The dominant groundwater facies index of this group is 23:13.

8.3. Geochemical Control of Groundwater:

The Na/Cl molar ratio was applied to indicate the evaporation process in groundwater as well as if it is more than one reflects the continental origin of the groundwater [22]. The EC plot was applied against the molar ratio of Na/Cl to unravel the local geochemical processes in the Debaga unconfined aquifer water of during 2014. A straight lineindicated from the plot of EC means against Na/Cl ratio via evaporation (Figure 6) [23].

Therefore, electrical conductivity versus the molar ratio of Na/Cl displays a special trend that may indicate the effect of evaporation on geochemistry of groundwater in the Dammam unconfined aquifer [24].

Therefore, the variation of groundwater with time can be attributed to the impact of the climatic change on the hydrochemistry of Debaga unconfined aquifer that may indicated by increasing the sulphate water group percent to 78.58 % for year 2014 than 57.12% during the survey before 2001 and the extinction of the Bicarbonate group.

8.4. Suitability of Groundwater

The groundwater quality of 2014 sampling period reflect that they are unsuitable for human drinking purposes [25]. The low water quality of some wells was attributed to the impact of the climatic change on the hydrochemistry of Debaga unconfined aquifer. While, the groundwater hydrochemistry is ranging from very good to good for animal drinking according to Altoviski[26] classification. The groundwater is very satisfactory for all types of livestock and poultry, according to the classification given by Ayers and Westcot (1989)[27]. It is clear that the groundwater is good for building [26]. Moreover; the groundwater is located within the permissible limits [27]. However, the suitability of the groundwater for irrigation standard is affected by several agricultural factors such as soil and
crop types as well as the climate change conditions increase the sulphate group in Debaga basin during 2014 and deteriorate the water quality than before two decades. Therefore, it is recommended to overcome the water shortage choosing an economical method of irrigation rather than the local traditional methods.

Table 3: Hassan [18] hydrochemical classification of the Debaga unconfined aquifer before 2001.

| Family           | Group       | Index | Water type                              | Well No. | %    |
|------------------|-------------|-------|-----------------------------------------|----------|------|
| Sulphate-Sodium  | Sulphate    | 13:33 | rNa>rMg>rCa; rSO4>rCl> rHCO3            | 4,6      | 14.28%|
|                  |             | 23:52 | rNa>rCa>rMg; rSO4>rHCO3                | 14       | 7.14% |
|                  |             | 13:52 | rNa>rMg>rCa; rSO4>rHCO3                | 1        | 7.14% |
| Sulphate-Calcium |             | 63:52 | rCa>rMg>rNa; rSO4>rHCO3                | 2,3      | 14.28%|
| Sulphate-Magnesium |          | 33:52 | rMg>rNa>rCa; rHCO3                     | 5,7      | 14.28%|
| Bicarbonate-Sodium | Bicarbonate | 13:42 | rNa>rMg>rCa; rHCO3>rCl                 | 13       | 7.14% |
| Bicarbonate-Calcium |            | 43:62 | rCa>rNa>rMg; rHCO3>rSO4                | 12       | 7.14% |
| Bicarbonate-Magnesium |      | 53:62 | rMg>rCa>rNa; rHCO3>rSO4                | 11       | 7.14% |
| Chloride-Sodium  | Chloride    | 23:13 | rNa>rCl>rMgCl>rSO4>rHCO3              | 8,9      | 14.28%|
| Chloride-Calcium |             | 63:13 | rCa>rNa>rMgCl>rCl>rSO4>rHCO3          | 10       | 7.14% |

Table 4: Hassan [18] hydrochemical classification of the Debaga unconfined aquifer water of during 2014.

| Family           | Group       | Index | Water type                              | Well No. | %    |
|------------------|-------------|-------|-----------------------------------------|----------|------|
| Sulphate-Sodium  | Sulphate    | 13:33 | rNa>rMg>rCa; rSO4>rCl> rHCO3            | 13       | 7.14% |
|                  |             | 13:52 | rNa>rMg>rCa; rSO4>rHCO3                | 5,10,11  | 21.4%|
|                  |             | 23:53 | rNa>rCa>rMg; rSO4>rHCO3                | 14       | 7.14% |
|                  |             | 23:33 | rNa>rCa>rMg; rSO4>rCl> rHCO3           | 4,9      | 14.28%|
| Sulphate-Calcium |             | 63:53 | rCa>rNa>rMg; rSO4>rHCO3>rCl            | 7        | 7.14% |
| Sulphate-Magnesium |         | 43:53 | rMg>rNa>rMg; rSO4>rHCO3                | 1        | 7.14% |
| Chloride-Sodium  | Chloride    | 23:13 | rNa>rCl>rMgCl>rSO4>rHCO3              | 8,6      | 14.28%|
| Chloride-Calcium |             | 43:13 | rCa>rNa>rMgCl>rSO4>rHCO3              | 12       | 7.14% |

Figure 7: Distribution pattern of (Na / Cl) molar ratio against EC in groundwater of the Debaga unconfined aquifer water of during 2014.
9. Conclusions
a- The analysis of climate parameters for Mosul, Kirkuk, Baiji, Tuz, Tikrit, and Debaga stations show a remarkable increase of the annual temperature with noticeable lower amounts of the rainfall.

b- The impact of the climatic change on the hydrochemistry of Debaga unconfined aquifer was obvious in increasing the water salinity, increasing the sulphate group to 78.58 % and delete the bicarbonate group for 2014 survey.

c- Multi-geochemical ways were influenced the groundwater geochemistry. Fertilizers may provide additional ions to the groundwater aquifer. The source of sulfate is dissolving of evaporate rocks and secondary gypsum. The evaporation is effective process in the Debaga unconfined aquifer water during 2014.

d- The chemical analyses of groundwater during the 2014 survey reflect that they are not good for human drinking, good for animal drinking, within the permissible limits for irrigation purpose and suitable for building purposes.

e- It is recommended to overcome the water shortage choosing an economical method of irrigation rather than applying the local traditional methods, unless a new policy will involve in the area to prevent the deterioration of groundwater.

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