Viability of the ground of Shithatha, western Iraqi plateau, for industrial and commercial uses via hydrochemistry analysis

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Abstract. Iraqi western plateau is considered as one of the most resourceful areas of the middle east, that is not yet well explored, due to the many political disturbances and security issues. The viability of underground water for the various industrial, municipal, commercial and agricultural uses is examined for Shithatha, Karbala governorates as a representative for the western plateau via chemical and physical analysis of water samples that are taken from 9 wells and 3 springs all-around the study area during the wet and dry periods. Hydrochemical and statistical analysis for the field samples have proved that groundwater of the studied area is classified as slightly-brackish water and water hardness is very high. Also, the results of the analyses of trace elements in the groundwater of the study area have confirmed the contamination of groundwater with some elements such as (Fe, Cd, Pb, Ni) in concentrations that have exceeded the WHO and Iraqi national standards IQS, permissible limits. The application of Hydro-chemical formulae of Kurlov and Piper, Schoeller, Stiff classifications have demonstrated that most samples of the study area have water type of (Na2SO4) while other samples have ranged between (MgSO4), and (NaCl) water type. The quality of groundwater is unsuitable for drinking and industrial purposes and it is almost suitable for irrigation purposes, but it is suitable for livestock, building and agricultural purposes because the salinity of the water is within the permissible limits when considering the nature of the soil.

1. Introduction
The groundwater plays an important role in human living and land development in many parts of Iraq, particularly those, which are remote from fresh surface water supplies, like perennial rivers and streams, or those of unsuitable topography to use surface water, therefor; the groundwater is considered as the main source of water in areas of the Western Desert which are characterized by low rainfall and far away from sources of surface water supply. Accordingly, the groundwater is used for domestic, agricultural and industrial purposes. The quality of groundwater is of nearly equal importance to quantity. The quality required of groundwater supply depends upon its purpose, thus, the needs for drinking water, industrial water, and irrigation water vary widely [1]. The study of groundwater quality involves a description of the occurrence of its various constituents and the relation between these constituents to the materials which exist in the aquifer. The data on groundwater quality give important clues to the geological history of the rocks and indications of groundwater recharges, discharges, movement, and storage [2]. The studied area is located in the middle part of Iraq in Karbala governorates, it is represented the west of the western shore of the Al-Razzaza lake and the area extending from Shithatha city to the Qasr Al-Ekhedhur between longitudes (43°25′ - 43° 40′) eastern and latitudes (32° 25′ -32° 40′) northern, (Figure 1).
Figur e 1. Locations of water samples in the studied area.

2. Materials and methods
The water samples were collected from (9) wells and (3) springs in two periods; the first period during of April (2013) which represent the wet period , and the second period was during October (2013) which represent the dry period, (Figure 1) and (table 1). These wells take water from the confined bed belonging to the Dammam formation. The samples were kept in plastic bottles of one liter size. Every sample was taken from the well after (10-15) minutes from the operation of well’s pump to remove the remains of water from the pipe of the pump. The plastic bottle was washed by distilled water and hydro-chloric acid before taking them to the field and also washed by samples water before using . The bottle was filled to the end of the neck to remove air; the presence of air with the sample affects the concentration of the hydrogen (pH) and stability of carbonate and bicarbonates and Bactria growth [3]. The GPS (Global Positional System) was used to determine the locations (Longitude, Latitude, Elevation a.s.l.) for each well and spring. The temperature (C°) and electrical conductivity (EC) of the water samples were measured direct in the field by using HANA (HI 9811). Hydro chemical study of groundwater included measuring the concentration of cations (K +, Na +, Mg 2+, Ca 2+) and anions (Cl-, HCO3-, SO42-, NO3-) and trace elements (Fe, Cd, Co, Cu, Ni, Pb, Mn and Zn) , as well as measuring of pH and the total dissolved soled (TDS).

Table 1. Geographic location of selected wells and springs in the studied area.

| Wells No. | Latitude   | Longitude  | Elev. (m) |
|-----------|------------|------------|-----------|
| W1        | 32°33' 34.7" | 43°31' 43" | 55        |
| W2        | 32°33' 57"   | 43°31' 0.5" | 50        |
| W3        | 32°33' 47"   | 43°29' 27.6" | 62        |
| W4        | 32°34' 32"   | 43°31' 14.5" | 50        |
| W5        | 32°27' 49.1" | 43°34' 36.7" | 65        |
3. Results and discussions

The Physical analysis of water samples:

The physical properties for the water samples in wet and dry periods in the studied area are shown in (Table 2). The odor, color, and taste are important properties of ground water. All the water samples in the studied area (both for the wet and dry periods) do not give any color but give the odor of (H₂S) gas in the samples (W8,9,11) which unlovely smell. As for the hydrogen ion concentration (pH) values of water samples in the study area for wet period ranges between (7.15–7.61), average (7.30), and for dry period ranges between (7.10–7.40), average (7.24). Generally the pH value in dry period is higher than those of wet period because of increasing dilution as a result of rain reaction with CO₂, which leads to release the bicarbonate ion and increase alkalinity. The low recharge and high discharge in dry period are reinforce the concentration of hydrogen ion inside the groundwater system.

Table 2. Physical properties for the water samples in studied area.

| Wells No. & springs | Wet Period | Dry Period |
|---------------------|------------|------------|
|                     | PH | Temp. (°C) | TDS (ppm) | EC (µs/cm) | T.H (ppm) | PH | Temp. (°C) | TDS (ppm) | EC (µs/cm) | T.H (ppm) |
| W1                  | 7.61 | 26 | 1932 | 2550 | 687.2 | 7.36 | 26 | 2238 | 3670 | 1032.8 |
| W2                  | 7.16 | 27 | 1700 | 2560 | 687.2 | 7.40 | 27 | 2200 | 3670 | 366.4 |
| W3                  | 7.31 | 30 | 1919 | 2650 | 652.6 | 7.20 | 27.6 | 2260 | 2750 | 852.1 |
| W4                  | 7.15 | 27 | 1872 | 2540 | 772.9 | 7.20 | 26 | 2228 | 2700 | 979.6 |
| W5                  | 7.34 | 29 | 1723 | 2560 | 604.3 | 7.30 | 27 | 2000 | 2750 | 632.4 |
| W6                  | 7.34 | 30 | 2000 | 2670 | 320.9 | 7.22 | 27.2 | 2450 | 3480 | 972.5 |
| W7                  | 7.31 | 27 | 2420 | 3000 | 685.8 | 7.25 | 27.5 | 2750 | 3260 | 813.7 |
| W8                  | 7.21 | 27 | 1812 | 3020 | 620 | 7.25 | 25 | 2113 | 2750 | 802 |
| W9                  | 7.19 | 27 | 2172 | 2920 | 320.9 | 7.11 | 25.4 | 2476 | 3260 | 389.6 |
| S1                  | 7.17 | 27 | 1872 | 2540 | 772.9 | 7.20 | 27 | 2230 | 2700 | 979.7 |
| S2                  | 7.40 | 27 | 1204 | 2058 | 656.7 | 7.10 | 29 | 2139 | 3658 | 851.4 |
| S3                  | 7.41 | 29.7 | 1933 | 2650 | 655.1 | 7.25 | 28 | 2371 | 3310 | 948.4 |

The temperature values of water samples in the study area for wet period ranges between (26°-30°), average (27.8°), and for dry period ranges between (25°-29°), average (26.89°). The TDS values of water samples in the study area for wet period ranges between (1204-2420), average (1879.9), and for dry period ranges between (2000-2750), average (2271.3). It is clear that the salinity in the dry period is more than it is for the wet period and that is due to the dilution which happens in the wet period as a result of rainfall. Comparison of TDS values for both periods with three classifications of water [4], [5], [6], it is clear that the groundwater in the studied area is classified as slightly-brackish.
water. The Electrical Conductivity (EC) values of water samples in the study area for wet period ranges between (2058 -3020), average (2643.2), and for dry period ranges between (2700 -3670), average (3163.2). It is clear that the electrical conductivity in the dry period is more than in the wet period and that is due to the dilution resulted from rainfall recharge to the ground water which leads to decrease ion concentration in water. When comparing EC values for both periods with[7], it can be concluded that the type of groundwater in the studied area is as excessively mineralized water due to the salinity.

The Total Hardness (TH) values in water samples of the study area in wet period ranges between (320.9-772.9) ppm with average (619.7) ppm, while in dry period ranges between (366.4-1032.8) ppm with average (801.7) ppm. TH values for both periods were compared with classifications of water hardness [4],[6],[8] and as a result the groundwater in the studied area is classified as very hard water due to wide exposures of limestone in the recharge area, also according to [6] where the lithology consists of limestone and dolomite mostly which is rich in calcium and magnesium.

Chemical analysis of water samples:

The chemical properties of water samples in the wet and dry periods in the studied area is given in (Table 3) which consist of major cations (Ca$^{2+}$ - Mg$^{2+}$ - Na$^{+}$ - K$^{+}$), major anions (Cl$^{-}$ - SO$_4^{2-}$ - HCO$_3^{-}$) and Minor compounds of nitrate (NO$_3^{-}$). The trace elements are analyzed for all water samples of two periods and these elements are (Fe, Cd, Pb, Ni and Zn).

The calcium ion (Ca$^{2+}$) concentration in water samples of the study area in wet period ranges between (71 -163) ppm with average (128.6) ppm, while in dry period ranges between (81 -241) ppm with average (159.9) ppm. The decreases of (Ca$^{2+}$) concentration in wet period due to dilution process by rainfall. The decreases of (Ca$^{2+}$) concentration in dry period probably refers to the mixing of ground water with the rainwater accumulated in subsurface caves or hard evaporation leads to precipitation CaCO$_3$ according the equation [9]:

$$\text{Ca}^{2+} + 2\text{HCO}_3^- \rightarrow \text{CaCO}_3 + \text{CO}_2(g)\uparrow + \text{H}_2\text{O}$$

The magnesium ion concentration in water samples of the study area in wet period ranges between (35-91) ppm with average (72.75) ppm, while in dry period ranges between (45- 123) ppm with average (87.9) ppm. The sodium ion concentration in water samples of the study area in wet period ranges between (130 - 425) ppm with average (243.16) ppm, while in dry period ranges between (130-429) ppm with average (273.1) ppm. The potassium ion concentration in water samples of the study area in wet period ranges between (7- 16) ppm with average (11.26) ppm, while in dry period ranges between (6- 15) ppm with average (10.95) ppm. The decreases of captions concentration in wet period due to dilution process by rainfall.

The chloride ion concentration in water samples of the study area in wet period ranges between (240-530) ppm with average (320.9) ppm, while in dry period ranges between (240- 614) ppm with average (370.1) ppm. The sulfate ion concentration in water samples of the study area in wet period ranges between (512-572) ppm with average (544.9) ppm, while in dry period ranges between (515- 907) ppm with average (620) ppm. High concentrations of (SO$_4^{2-}$ ) in the water samples of the study area may be attributed to the available gypsum and anhydrite minerals within the aquifer lithology of the area, or due to using chemical fertilizers and human activity in the recharge region[10].

**Table 3.** Chemical properties of water samples in studied area.

| Wells No. & spring s | Wet Period |
|----------------------|------------|
|                      | Ca$^{2+}$ ppm | Mg$^{2+}$ Ppm | Na$^{+}$ ppm | K$^{+}$ ppm | Cl ppm | SO$_4^{2-}$ ppm | HCO$_3^{-}$ ppm | NO$_3^{-}$ ppm | Fe ppm | Cd ppm | Pb ppm | Ni ppm | Zn ppm |
| W1                   | 129         | 89          | 139          | 10          | 246      | 561       | 62          | 1.3            | 0.017 | 0.006 | 0.045 | 0.10   | 0.002 |
| W2                   | 129         | 89          | 138          | 10          | 247      | 562       | 63          | 1.3            | 0.017 | 0.004 | 0.044 | 0.11   | 0.001 |
| W3                   | 125         | 83          | 150          | 11          | 240      | 545       | 65          | 3              | 0.023 | 0.002 | 0.046 | 0.13   | 0.0015 |
| W4                   | 160         | 91          | 256          | 7           | 389      | 572       | 210         | 3              | 0.019 | 0.006 | 0.043 | 0.11   | 0.002 |
| W5                   | 160         | 50          | 246          | 10          | 360      | 520       | 208         | 2.2            | 0.063 | 0.010 | 0.042 | 0.11   | 0.001 |
| W6                   | 71          | 35          | 423          | 16          | 360      | 515       | 266         | 3              | 0.025 | 0.009 | 0.051 | 0.14   | 0.001 |
The bicarbonate ion concentration in water samples of the study area in wet period ranges between (62- 266) ppm with average (158.6) ppm, while in dry period ranges between (65- 440) ppm with average (195) ppm. The nitrates ion concentration in water samples of the study area in wet period ranges between (1.3- 6) ppm with average (2.81) ppm, while in dry period ranges between (1.4- 9) ppm with average (3.73) ppm. No carbonates were detected in the water samples of the study area, because carbonates are usually found in water where its pH value exceeds 8.3, where bicarbonates are associated with water in which its pH is less than 8.3, and this is the case of the study area [11]. The decrease of anions concentration in wet period due to dilution process by rainfall.

Trace elements (Heavy elements) It defines as a metallic elements of atomic number that exceeds twenty. It comes from weathering rocks or from human activities [5]. The concentration of heavy elements is affected by many factors like pH, Redox potential, Transitivity degree, Surface absorption and clay minerals [12]. The iron element is essential in the life processes of plants and animals [13]. Iron is essential for human, but it becomes toxic when the concentration increases [14]. The Fe concentration in water samples of the study area in wet period ranges between (0.017- 0.063) ppm with average (0.028) ppm, while in dry period ranges between (0.23- 0.37) ppm with average (0.294) ppm. The Cd concentration in water samples of the study area in wet period ranges between (0.002- 0.020) ppm with average (0.009) ppm, while in dry period ranges between (0.016- 0.042) ppm with average (0.031) ppm. The pb concentration in water samples of the study area in wet period ranges between (0.040- 0.190) ppm with average (0.058) ppm, while in dry period ranges between (0.067- 0.245) ppm with average (0.160) ppm. The Ni concentration in water samples of the study area in wet period ranges between (0.10- 0.17) ppm with average (0.13) ppm, while in dry period ranges between (0.15- 0.23) ppm with average (0.19) ppm. The zinc concentration in water samples of the study area in wet period ranges between (0.001- 0.004) ppm with average (0.0016) ppm, while in dry period ranges between (0.015- 0.051) ppm with average (0.030) ppm.

**Groundwater Classification**

The types of water are connected with the chemical and physical properties which change relatively with respect time and place. These changes are slow in groundwater comparing with surface water [15]. The water type is very important to determine its suitability for the different uses (human, agricultural and industrial). All these classifications depend on the main cations and anions concentrations by unit equivalent weight of ion (epm) or milli equivalent per liter (meq/L).

According to Hydro chemical Formula (Kurolov formula) which is depend on the ratio of the main ions, (cations and anions) expressed by (epm %) that are arranged in descending order which have more than (15%) ratio of availability [16]. The hydro chemical formula and water type for water samples of study area for wet and dry periods are shown in (Table 4). The predominant salts in water

| Dry Period | W1 | 241 | 103 | 372 | 11.5 | 485 | 907 | 245 | 1.4 | 0.27 | 0.026 | 0.245 | 0.16 | 0.025 |
| W2 | 81 | 90 | 423 | 11 | 360 | 515 | 266 | 3 | 0.26 | 0.034 | 0.154 | 0.15 | 0.041 |
| W3 | 185 | 95 | 240 | 11 | 341 | 547 | 67 | 2.5 | 0.23 | 0.029 | 0.166 | 0.15 | 0.051 |
| W4 | 190 | 123 | 280 | 14 | 614 | 576 | 170 | 4 | 0.29 | 0.016 | 0.173 | 0.2 | 0.032 |
| W5 | 125 | 78 | 165 | 9 | 240 | 545 | 65 | 3 | 0.37 | 0.019 | 0.162 | 0.21 | 0.041 |
| W6 | 225 | 100 | 317 | 10 | 422 | 851 | 225 | 9 | 0.25 | 0.029 | 0.181 | 0.17 | 0.021 |
| W7 | 186 | 85 | 340 | 15 | 330 | 696 | 440 | 8.5 | 0.29 | 0.033 | 0.067 | 0.2 | 0.018 |
| W8 | 193 | 78 | 289 | 6 | 411 | 622 | 252 | 1.9 | 0.33 | 0.039 | 0.076 | 0.18 | 0.019 |
| W9 | 82 | 45 | 429 | 15 | 365 | 518 | 266 | 3.5 | 0.30 | 0.042 | 0.098 | 0.22 | 0.015 |
| W10 | 160 | 93 | 256 | 7 | 389 | 572 | 210 | 3 | 0.29 | 0.036 | 0.177 | 0.21 | 0.022 |
| W11 | 125 | 84 | 130 | 10 | 242 | 545 | 68 | 2 | 0.31 | 0.032 | 0.210 | 0.19 | 0.045 |
| W12 | 126 | 83 | 135 | 12 | 242 | 546 | 66 | 3 | 0.34 | 0.038 | 0.211 | 0.23 | 0.029 |
samples in the both period are (Na$_2$SO$_4$), (NaCl), (MgSO$_4$), and (CaSO$_4$). The variation in the existing water types points due to the interaction between factors such as lithology, recharge, the geochemistry of the aquifer and depths of the well [17].

According to [18] classification the groundwater samples of the study area fall in (e class) which represents earth alkaline water with increase portion of alkali with prevailing sulfate and chloride, and some of these samples fall in (g class) which represents alkaline water with prevailing sulfate and chloride (Figure 2). The predominant salts in water samples in the both period are (Na$_2$SO$_4$), (NaCl), (MgSO$_4$), and (CaSO$_4$).

**Table 4.** Hydro chemical Formula of water samples in studied area.

| Sample | Hydro chemical formula | Water type |
|--------|------------------------|------------|
| W1     | Na$_2$SO$_4$            | 7.61       |
| W2     | Na$_2$SO$_4$            | 7.16       |
| W3     | MgSO$_4$                | 7.31       |
| W4     | MgSO$_4$                | 7.15       |
| W5     | Na$_2$SO$_4$            | 7.34       |
| W6     | Na$_2$SO$_4$            | 7.34       |
| W7     | Na$_2$SO$_4$            | 7.31       |
| W8     | MgSO$_4$                | 7.21       |
| W9     | MgSO$_4$                | 7.19       |
| S1     | MgSO$_4$                | 7.17       |
| S2     | MgSO$_4$                | 7.40       |
| S3     | MgSO$_4$                | 7.41       |

| Sample | Hydro chemical formula | Water type |
|--------|------------------------|------------|
| W1     | Na$_2$SO$_4$            | 7.36       |
| W2     | Na$_2$SO$_4$            | 7.4        |
| W3     | CaSO$_4$                | 7.20       |
| W4     | NaCl                   | 7.20       |
| W5     | Na$_2$SO$_4$            | 7.30       |
| W6     | Na$_2$SO$_4$            | 7.22       |
| W7     | Na$_2$SO$_4$            | 7.25       |
| W8     | Na$_2$SO$_4$            | 7.25       |
|   |   |   |   |   |
|---|---|---|---|---|
| W9 | 2476 | SO₄ (42.69) Cl (40.46) Na (69.51) Ca (15.14) | 7.11 | NaSO₄ |
| S1 | 2230 | Cl (53.56) SO₄ (31.31) Na (37.89) Mg (51.80) Ca (59.49) | 7.20 | NaCl |
| S2 | 2139 | NO₃ (49.17) Mg (26.91) Ca (13.74) SO₄ (49.17) Cl (18.72) | 7.10 | NaSO₄ |
| S3 | 2371 | NO₃ (45.68) Ca (31.28) Mg (24.17) SO₄ (49.17) Cl (18.72) | 7.25 | NaSO₄ |

1.

**Figure 2.** Piper diagram of the water samples in the wet and dry periods.
2. According to [19] classification the groundwater samples of the study area shows that the group are SO$_4$ and Cl and the families are Na-SO$_4$, Mg-SO$_4$, Ca-SO$_4$, Na-Cl for wet and dry periods are shown in (Table 5).

**Table 5.** Water quality for the water samples in studied area by schoeller method.

| Sa. No | Type       | Family | Group   |
|-------|------------|--------|---------|
|       | Wet period | Anion  | Cation  |
| W1    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Mg$>$Ca$>$K | Na-SO$_4$ | SO$_4$ |
| W2    | rSO$_4$Cl$>$HCO$_3$ | rMg$>$Ca$>$Na$>$K | Mg-SO$_4$ | SO$_4$ |
| W3    | rSO$_4$Cl$>$HCO$_3$ | rMg$>$Na$>$Ca$>$K | Mg-SO$_4$ | SO$_4$ |
| W4    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W5    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W6    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W7    | rCl$>$SO$_4$HCO$_3$ | rNa$>$Mg$>$Ca$>$K | Na-Cl | Cl |
| W8    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W9    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| S1    | rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| S2    | rSO$_4$Cl$>$HCO$_3$ | rMg$>$Ca$>$Na$>$K | Mg-SO$_4$ | SO$_4$ |
| S3    | rSO$_4$Cl$>$HCO$_3$ | rMg$>$Ca$>$Na$>$K | Mg-SO$_4$ | SO$_4$ |
|       | Dry period | Anion  | Cation  |
| W1    | 3. rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W2    | 6. rSO$_4$Cl$>$HCO$_3$ | 7. rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W3    | 10. rSO$_4$Cl$>$HCO$_3$ | 11. rCa$>$Mg$>$Na$>$K | Ca-SO$_4$ | SO$_4$ |
| W4    | 14. rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-Cl | Cl |
| W5    | 17. rSO$_4$Cl$>$HCO$_3$ | rNa$>$Mg$>$Ca$>$K | Na-SO$_4$ | SO$_4$ |
| W6    | 20. rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W7    | 23. rCl$>$SO$_4$HCO$_3$ | 24. rNa$>$Ca$>$Mg$>$K | Na-Cl | Cl |
| W8    | 27. rSO$_4$Cl$>$HCO$_3$ | rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| W9    | 30. rSO$_4$Cl$>$HCO$_3$ | 31. rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
| S1    | 34. rSO$_4$Cl$>$HCO$_3$ | rNa$>$Mg$>$Ca$>$K | Na-Cl | Cl |
| S2    | 37. rSO$_4$Cl$>$HCO$_3$ | 38. rNa$>$Mg$>$Ca$>$K | Na-SO$_4$ | SO$_4$ |
| S3    | 41. rSO$_4$Cl$>$HCO$_3$ | 42. rNa$>$Ca$>$Mg$>$K | Na-SO$_4$ | SO$_4$ |
According to [20] classification the groundwater samples of the study area for two periods (wet and dry) have water type of \( \text{Na}_2\text{SO}_4, \text{MgSO}_4, \text{CaSO}_4 \) and \( \text{NaCl} \). It appears to be almost fit with the hydrochemical formula results.

**Groundwater uses for human drinking purposes**

For the purpose of evaluating the suitability of groundwater for human drinking [14] and [21] standards were used to determine its suitability as drinking water in the study area. The average of two periods (wet and dry) for the analyzed water samples is unsuitable for human drinking purposes.

**Groundwater uses for livestock purposes**

The [4], [22] and [23] criterion are used to determine its suitability for livestock and poultry purposes. It is clear that all water samples in the study area are:

- Very good for animal drinking according to [4] classification.
- Acceptable for all types of animals and poultry according to [23] classification.
- Very satisfactory for all types of livestock and poultry, according to [24] classification.

**Groundwater uses for industrial purposes**

The analyzed samples results of the study area for two periods (wet and dry) are evaluated for industrial purposes by using classification suggested by [24]. It is clear that all water samples are not suitable for industrial purposes and the reason related to the high values of hardness and high salts concentrations as well as it exceeded the permissible limits.

**Groundwater uses for building purposes**

Suitability of groundwater in the study area is evaluated for building purposes by using [4] classification. It is clear that all water samples in the study area are suitable for building purposes.

**Groundwater uses for agriculture and irrigation purpose**

The EC values of groundwater samples in the study area for two periods wet and dry are compared with [6] classification. It is clear that all water samples of the study area are suitable for agriculture. The [23] and [25] classifications have been applied to know the suitability of ground water in the studied area for irrigation purposes. By comparing these classifications with the hydrochemical concentrations of the ground water samples, it is clear that all groundwater samples are located within the permissible limits except some samples are located within the doubtful limits.

4. **Conclusions**

- All water samples (both for the wet and dry periods) do not give any color and some give the odor of \( \text{H}_2\text{S} \) gas as in the samples (W1, 2, 4) which unlovely smell.
- The groundwater in the study area is generally of low alkalinity with \( \text{pH} \) average ranging between (7.30) for wet period and (7.24) for dry period.
- Average temperature of groundwater ranging between (27.8°C) for wet period and (26.89°C) for dry period.
- Average EC of groundwater ranging between (2643.2 µS/cm) for wet period and (3163.2 µS/cm) for dry period.
- Average TDS of groundwater ranging between (1879.9 mg/L) for wet period and (2271.3 mg/L) for dry period, and the groundwater classified as slightly brackish water depending on TDS values.
- The average value of total hardness ranging between (619.7 ppm) for wet period and (801.7 ppm) for dry period, and the groundwater is classified as very hard and exceeds the permissible limits due to the wide exposures of limestone and dolomitic limestone in the recharge area, which are rich in calcium and magnesium.
- The results of the analysis of major elements (cations and anions) in the groundwater showed that the predominant ion in the cations is \( \text{Na}^+ \) ion and anions is \( \text{SO}_4^{2-} \) ion as a result for dissolution processes of evaporations rocks and from ionic exchange of clay minerals.
- The average value of nitrate ranging between (2.81 ppm) for wet period and (3.73 ppm) for dry period; no clear nitrate pollution in the groundwater is observed or within the acceptable limits.
• The results of heavy elements analysis in the groundwater confirm that groundwater is polluted with some elements such as (Fe, Pb, Ni, Cd) because their concentrations are higher than the permissible limits.
• The results of hydro chemical formula (Kurolov formula) showed that most water samples of the study area have water type of (Na₂SO₄), (MgSO₄) and (NaCl) for wet period and (Na₂SO₄), (CaSO₄) and (NaCl) for dry period.
• According to Piper classification the groundwater samples of the study area fall in (e class) which represents earth alkaline water with increase portion of alkali with prevailing sulfate and chloride, and some of these samples fall in (g class) which represents alkaline water with prevailing sulfate and chloride. The predominant salts in water samples in the both period are (Na₂SO₄), (NaCl), (MgSO₄), and (CaSO₄).
• According to Schoeller classification the groundwater samples of the study area shows that the group are SO₄ and Cl and the families are Na₂SO₄, Mg₂SO₄, Ca₂SO₄, Na -Cl for wet and dry periods.
• According to Stiff diagram on the water samples for two periods (wet and dry) have water type of Na₂SO₄, MgSO₄, CaSO₄ and NaCl.
• Comparing the quality of groundwater with the standards of different uses shows that it is unsuitable for drinking and industrial purposes. It is almost suitable for irrigation purposes. But it is suitable for livestock, agricultural and building purposes.

5. References
[1] Todd D K 1980 Groundwater hydrology second edition Jhon Wiley and Sons Inc. New York p. 535
[2] Walton WC 1970 Groundwater Resource Evaluation McGraw Hill New York p. 664
[3] Sanders L L 1998 A manual of Field Hydrogeology Prentice-Hall p.381
[4] Altovisiki M E 1962 Hand book of hydrogeology Geogolietz Moscow USSR p. 614
[5] Drever J I 1997 The geochemistry of natural water, surface and groundwater environments Prentice Hall USA p. 436
[6] Todd D K 2007 Groundwater hydrology third edition John Wiley and Sons, Third Reprint. p. 535
[7] Detay M 1997 Water Wells- implementation, maintenance and restoration John Wiley and Sons p. 379
[8] Boyd C E 2000 Water quality an introduction Kluwer Academic publisher p. 330
[9] Langmuir D 1997 Aqueous Environmental Geochemistry Prentice Hall p. 600
[10] Al- Qaraghuli S A 2014 Hydrogeological and Hydrochemical Study of Al-Rahaliya –Al-Ekhdhur Area M.Sc. Thesis College of Science Baghdad University Iraq 74p
[11] Appelo C A 1999 Cation and proton exchange, PH variations and carbonate reactions in a freshening aquifer Water Resources Research 30 2793-2805.
[12] Levinson A A 1980 Introduction of exploration geochemistry 2nd ed. Applied publ.Ltd Wilmett Illinois p. 611
[13] Fetter C W 1980 Applied hydrogeology Charles Merrill pub. Co. A. Bell and Howell company 488 p.
[14] WHO 2009 Calcium and magnesium in drinking water public health significance Geneva. Spain p.1
[15] Hem J D 1989 Study and interpretation of the chemical characteristics of natural water U.S geological survey Water supply paper 2254 p. 246
[16] Ivanov V V, Barbanov L N and Plo tinikova G N 1968 The main genetic types of the earth’s crust mineral water and their distribution in the USSR Inter. Geol. Cong. of 23rd. Sessions Czechoslovakia 12 p. 33
[17] Appelo C A J and Postma D 2005 Geochemistry, ground water and pollution Rotterdam: A. A. Balkama p. 536
[18] Piper A M 1944 A graphic procedure in the geochemical interpretation of water analyses, *Transition, American Geophysical Union* 25 914-928.

[19] Schoeller M 1972 Edute Geochemiique De La Nappe Des, Stables in fericurs Du Bassin D.aquitainse *Journal of Hydrology* 15 (4) 317-328

[20] Stiff H A 1951 The interpretation of chemical water Analyses by means of Patterns' *Jour. Petroleum Technology* 3(10) 15-17

[21] IQS Iraqi Quality Standard 2009 Drinking water Standard No. 417, C. O. S. Q. C., Iraq

[22] Crist M A and Lowry M E 1972 Groundwater resource of Natrona county wyming A study of the availability and chemical quality of groundwater *Geological Survey Water Supply p. 92.*

[23] Ayers R S and Westcot D W 1989 Water quality for agriculture *Irrigation and drainage paper 29* (1) FAO 174p.

[24] Hem J D 1985 Study and interpretation of the chemical characteristics of natural water *3rd. ed.U.S.G.S. water supply paper 2254* p. 263.

[25] Don C M 1995 A grows guide to water quality *University college station, Texas* 601-609.