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Using GIS for Assess the Groundwater Quality in Southwest Side of Basrah City

Ammar Salman Dawood[a*] , Ahmed Naseh Ahmed Hamdan[b]

Department of Civil Engineering,College of Engineering, University of Basrah.

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Abstract

In order to evaluate the quality of groundwater for drinking suitability purposes, a total of 27 groundwater samples from wells in southwest of Basrah city have been analyzed for various geochemical parameters. The aim of this research was to find the physicochemical quality of ground water in the southwest of Basrah. The results show that the quality of groundwater regarding the physical and chemical parameters of southern Basrah is unsuitable for drinking purposes. The total hardness (TH) was very high and it was in the ranged (740-6950) mg/l, also the electrical conductivity (EC) was very high and ranged (1720- 18030) µS/cm, while the World Health Organization (WHO) recommends a value less than 100 mg/l for (TH) and 750µs/cm for (EC). According to the international and national standards the allowable concentration of total dissolved solids (TDS) should not exceed 500 mg/l, while the groundwater samples of the study area shows a range of (1200-10790) mg/l, therefore it is considered very high. Moreover, the other physicochemical properties of groundwater were analyzed and compared with those of drinking water standards recommended by the WHO. Groundwater for irrigation has been studied by using the rating of water samples in relation to salinity and sodium hazard graph. As a result of the study, only one sample was accepted for irrigation.

استخدام نظم المعلومات الجغرافية لتقييم نوعية المياه الجوفية في جنوب غرب مدينة البصرة

الكلمات المفتاحية

المياه الجوفية،تعداد نوعية المياه

الخلاصة

من أجل تقييم نوعية المياه الجوفية لغرض ملائمتها للشرب ، فقد تم تحليل مجموعه من 27 عينة من المياه الجوفية للابار في جنوب غرب مدينة البصرة لمختلف المعاملات الجيوكيميائية. وكان الهدف من هذا البحث هو تحديد النوعيه الفيزيوكيميائيه للمياه الجوفيه في جنوب غرب البصرة. نتائج هذا العمل قد بينت أن نوعية المياه الجوفية اعتمادا على المعاملات الفيزيائية والكيميائية لجنوب غرب البصرة لا تصلح لأغراض الشرب. ان العسره الكليه كانت عالية جدا و تراوحت بين(740-6950) ملغم / لتر ، وان التوصيل الكهربائي (EC) عالي جدا وتراوح بين (1720- 18030) مايكروموز / سم ، في حين توصي منظمة الصحة العالمية (WHO) قيمة لاتتجاوز 100 ملغم / لتر بالنسبة للـ (TH) و 750مايكروموز / سم بالنسبه للـ(EC). ووفقا للمعايير الدولية والمحليه للتركيز المسموح به لمجموع المواد الصلبة الذائبة (TDS) يجب ان لاتتجاوز 500 ملغم / لتر، في حين أن عينات المياه الجوفية في منطقة الدراسة ظهرت بحدود (1200-10790) ملغم / لتر وبالتالي فانها تعتبر عاليه جدا . علاوة على ذلك، فان بقية خصائص المعاملات الفيزيوكيميائيه للمياه الجوفية قد تم تحليلها وقورنت مع تلك المعايير لمياه الشرب التي أوصت بها منظمة الصحة العالمية.

وقد تم دراسة المياه الجوفية لأغراض الري وذلك باستخدام مخطط تقييم عينات المياه بالنسبة للملوحة وخطرالصوديوم، وكنتيجة لهذه الدراسة، تم قبول عينة واحدة فقط لأغراض الري.

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*Corresponding author.
E-mail addresses: ammars.dawood@yahoo.com

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Introduction

The upper part of Dibdiba formation is predominate at south of Iraq. Dibdiba formation has a large extension over large area in the southern part of Iraq addition some areas in the middle west of Iraq. It is a part of the alluvial fans deposits of the stable shelf at tectonic map in Iraq. Dibdiba formation age is upper Miocene–Pliocene, and it is consisting of sand, gravel with pebbles of igneous rocks and white quarts somewhere cemented into a hard grit. The studied area is about 700 square kilometers of Dibdiba plain, Groundwater resides in the porous media of alluvial quaternary deposits and the Dibdiba formation. see **Fig.1**.

The Dibdiba aquifer is set by two horizontal aquifer formations. The first formation, which is generally unconfined and has a saturated thickness of about 20m. The second formation makes up the rest of the aquifer thickness. A consolidated, silty, clay bed with gypsum, locally referred “Chauchab”, usually separates the two formations. The first upper portion of the aquifer is the one thought to be naturally rechargeable and that presently plays the most significant role as a resource for groundwater–based agriculture in the Safwan, Al Zubair, and JebalSanam regions west of Basrah.

The quality of the groundwater is, in general, brackish to saline. It varies greatly laterally and vertically. Two salinity layers can be distinguished. The upper layer is normally lower in salinity than the lower layer, the salinity of groundwater found in the second layer normally exceeds 15,000 mg/l. The separation between the two layers may be a less permeable layer or just a transitional interface whereby less saline water is floating over more saline water. The TDS of the upper water layer is generally caused by dissolved calcium or sodium carbonate. The TDS of the deeper layer is likely from sodium chloride.

Rainfall is the sole source of groundwater recharge in this area. The average annual rainfall in the region is close to 100 millimeters per year (mm/year) varying usually between 50 mm/year and 150 mm/year.

Many technological advances have been achieved during the past century to develop the protection of water sources and the treatment of water for drinking purposes; but, many countries still have the problem of the littleness of safe drinking water [1-3]. There is a significant incensement in the demand for fresh water throughout the world because of the population growth. A measure that can assess the usage of water for different purposes using several parameters such as physical, chemical, and biological is called water quality. These different purposes of water quality include drinking, irrigation, industrial, and others. Water quality changes based on climate, location, time, and presence of pollution sources. General health and life expectation of the people in many developing countries affected by the lack of clean drinking water. Therefore, the quality of groundwater acts as a major role in water quality management, planning water supply, and environmental management. Several researchers such as Heath (1998) [4] classified the groundwater suitability for domestic usage depending on hydrogen ion concentration (pH), total hardness (TH), and total dissolved solids (TDS). However, one of the most serious problems in the arid and semi-arid area is the finding of the concentration of the salt zone limits in groundwater aquifers. Poor quality of water adversely affects the plant growth and human health [5-8].

The aim of this study is to examine and characterize the groundwater quality in southwest side of Basrah city for drinking use. The results of this study will greatly contribute to a better understanding of water quality in Basrah city.

Materials and methods

Sampling sites

Groundwater samples were collected at the city of Basrah, located in the southwest part of Iraq. Basrah city is located between longitude 47°40’ and 48°30’ east and latitudes in 29°50′ and 31° 20’in the north. The study area (**Fig. 2**) in this research located within semi-arid zone with prevailing climate of hot in summer with little rainfall in winter. The study area includes Um Qaser, Safwan, Khour Al Zubair and Al Zubair districts, where the study area is the bigger and important part of Basrah city, and include very important resource of crops for Iraq.

Physicochemical analysis of water

A total of 27 samples of groundwater were collected in the study area by the general authority for the groundwater-Basrah branch. Physicochemical parameters such as hydrogen ion concentration (pH), total dissolved salt (TDS), electrical conductivity (EC), and temperature (C°) of the water samples were measured immediately according to standard methods guidelines from Examination of Water and Wastewater [9]. Sodium and Potassium were analyzed using flame spectrometry apparatus. The method of titration with EDTA was used to find the concentrations of calcium, magnesium, and total hardness. Titration with $AgNO_3$ method was used to determine the concentration of chlorides.

Results and discussion

Physicochemical analysis

The physicochemical water analysis were determined and the results are presented in histogram **Fig.s (3- 14**) also using GIS software [10], with Geographic Coordinate System, GCS_WGS_1984 the samples location and contour lines has been created in **Fig.s.(15-26).**

As shown in the **Fig. (3)**, pH generally has no direct affect on users, it is one of the almost significant parameters in water quality, with the optimum pH required frequently being in the range of 6.5–8.5 [11]. There was only one well (Well F1) in the study area which the pH exceeds the WHO standards. The spatial distributions of pH values are shown in **Fig. (15)**. It is shown that the high pH values noticed south-west of the study area and within the center to the west. The maximum and minimum values of pH were measured as 6.8 and 8.7, respectively.

In contrast, the electrical conductivity (EC) of the groundwater samples were ranged from 1720 to 18030 µs/cm, while WHO recommended a value not more than 750 µs/cm. all groundwater samples in the study area exceeding the allowable limit state by WHO for drinking purpose as shown in **Fig. (4)**. The spatial distribution map of EC in the study is shown in **Fig. (16),** EC concentrations increase from east to north-west and south-west .

TDS concentration varies between 1200 mg/l and 10790 mg/l in the waters of the study area samples, while WHO recommended a value not more than 1000 mg/l, High concentration of TDS in the groundwater sample is due to leaching of salts from aquifer matrix and domestic sewage that may percolate into the groundwater. The highest level of TDS was noticed in the well no. F24 and well no.F3 as shown in **Fig. (5)**, from above it can be noticed that all wells were above the allowable limits. The spatial distribution map of TDS distribution in the study area is shown in **Fig. (17)**.

The highest level of Cl is found in well no. F24 which was 4248.7 mg/l and the lower concentration was noticed in well no.F9 which was 249.6 mg/l. In all natural waters, chloride is most widely varying concentrations. When the mineral content increases, chloride concentration normally increased . When the concentration of Cl be high, water will have a salty taste [12]. Most of Cl concentration in the waters of the study area **Fig.(6)** are exceeded the allowable limits state by which that not more than 250 mg/l. As pointed by **Fig. (18)**, chloride concentration increased from northeast to south-west and north-west in the study area.

For total hardness (TH), all waters samples have TH level higher than the standard of 100 mg/l as recommended by WHO as shown in **Fig.(7)**. The increase in the high level of hardness may affect water supply system and it is due to leaching of minerals. The spatial variation of groundwater total hardness is mapped in **Fig. (19)**.

The sulfate (SO_4) concentration ranged (290-4408 mg/l) in the waters of study area samples **Fig.** (**8**) . But, the maximum concentration level of sulfate state by WHO (250 mg/l) is exceeded in all wells of the study area. It can be seen in **Fig. (20)** which shows the spatial distribution map of sulfate, that the sulfate concentration increases in the west, south and north sides of the study area.

Similarly, all analyzed groundwater samples are rich in nitrate (NO_3) concentration because their concentration exceeded 10 mg/l as state by WHO except two wells (well no.F9 and well no.F14) as shown in **Fig. (9)**. During last years, the problem of contamination of groundwater by nitrates has been studied by several researchers all over the world [13-17]. The spatial distribution of nitrate in the study area are shown in **Fig. (21)** which reflects the high concentrations were noticed in the south and north-west sides of the study area.

The maximum concentration level of Bicarbonate (HCO_3) is given as 200 mg/l by the WHO for drinking water. The HCO_3 concentrations vary between 61 mg/l and 296 mg/l in the waters of study area samples. The highest level of bicarbonate is found in the wells no. F4,F5,F9,F13,F17,F23, and F24, The higher concentration of HCO_3 in the groundwater points indicate the dominance of mineral dissolution, **Fig. (10)**and **Fig. (22)**, shows the spatial distributions of bicarbonate concentrations in waters of the study area.

Through the alkaline earth, the concentrations of magnesium (Mg) and calcium (Ca) as shown in (**Fig.(11)**and **Fig.(12)**) were in the range of 3.9 to 365.5 mg/l and 257 to 1002 mg/l, respectively. For 27 samples, 92.6 %, and 100 % respectively showed higher magnesium and calcium contents in comparison to their corresponding WHO permissible limits of 30 and 75 mg/l. The spatial distribution map of both Mg and Ca in the study area were shown in **Fig. (23)** and **Fig. (24)**, respectively.

Among the alkalies, potassium (K) and sodium (Na) concentrations (**Fig.(13)** and **(Fig. (14)**) were ranged from 4.6 to 267.2 mg/L and 12.2 to 763.0 mg/L, respectively. For 27 samples, 77.8 % have high sodium contents above the permissible limit of 200 mg/L [12], while 74.1 % of groundwater samples for potassium concentration was within the permissible limit of 100 mg/L. **Fig. (25)** and **Fig. (26)**, show the spatial distribution map of K and Na in the study area.

Correlation analysis

A correlation analysis is applied to show how well one variable predicts the other. In this study, the relationship between various elements has been analyzed using the spearman rank coefficient which is established on the ranking of the data and not based on their absolute values [18-20].

The correlation matrices for 13 variables were designed for various elements and it is shown in **Table (1)** . Besides the excellent correlation (r = 0.95) between TDS and EC, also , a strong correlation existed between the following elements: TDS–Na, EC–Na, TDS–SO_4, Na–SO_4 and TDS–Cl. CO_3 showed a negative correlation with most of the variables. Ca did not establish any significant relation with any parameter in the study area. EC showed good correlation with the following elements: Cl, NO_3, and SO_4. However, EC shows negative correlation with CO_3. Particularly, Mg not only showed relatively strong correlation with Na but also had a moderate correlation with SO^4, among the heavy metals. Overall, in the study area, EC–Mg, Mg–TDS, Mg–Na, Na–NO_3, and TDS–Mg exhibited a correlation of more than 0.5 while Cl–Ca pairs had a correlation from 0.4 to 0.5 in the groundwater samples of the study area. CO_3 and pH presented a negative correlation with most of the variables and EC–HCO_3, TH–HCO_3, Na–K, K–NO_3, K–SO_4, and SO_4–HCO_3 exhibited no significant correlation in the matrixes of the study area.

Groundwater for drinking quality

Groundwater chemistry has been employed as a tool for the expectation of water quality for drinking and irrigation purposes [21]. WQI is a significant parameter for demarking groundwater quality and its suitability for drinking purposes [22-24]. WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption. WQI summarizes large amounts of water quality data into very simple terms. The standards of drinking purposes that recommended by WHO [11] has been studied for the calculation of WQI. For calculating WQI three steps are followed. In the first step, each of the 10 parameters (TDS, NO_3, HCO_3 ,SO_4, Cl, Mg, Ca, Na, and K) has been assigned a weight (w_i) granting to its relative importance in overall quality of water for drinking purposes (**Table 2**). The maximum weight of 5 has been assigned to the parameters like total dissolved solids and nitrate due to their major importance in water quality assessment [25]. Other parameters like pH, chloride, and sodium were given a weight of 3.Calcium and magnesium have been assigned a weight of 2 depending on their importance in water quality definition. Next step, the relative weight (W_i) is computed from the following equation:

$$W_i = w_i \Big/ \sum_{i=1}^{n} w_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where,

W_i is relative weight.

w_i is the weight of each parameter.

n parameter's number.

The calculated values of relative weight (W_i) for each parameter are shown in **Table 2**. In the last step, a quality rating scale (q_i) for each parameter is given by dividing the parameter concentration in each groundwater sample by its particular standard according to the WHO guide lines and the result is multiplied by 100. Now, the SI is determined for each chemical parameter as

$$SI_i = W_i \times q_i \quad \text{……………………………(2)}$$

Which is then utilized to determine the WQI as per the equation:

$$WQI = \sum SI_i \quad \text{…………………..………(3)}$$

Where,

SI_i is the sub-index of ith parameter.

q_i is rating depending on the concentration of the ith parameter.

There are different water quality types when determined on the basis of WQI. The computed WQI distributed map for the groundwater sample of the study area is shown in **Fig. 27**. The WQI type and range of water can be classified as follow (**Table 3**).

The chemical analysis of groundwater indicates that majority of the sample exceeds the permissible limit set by WHO for drinking purposes. From the calculation of WQI for the study area groundwater sample, 3.7% of groundwater samples represent “poor water”, 3.7% indicate “very poor water”, and 92.6% shows “unsuitable water for drinking”.

The water quality index was tested with EC and chloride selected as pollution indicators. The noticed high values of EC and chloride correspond to the same WQI, indicating the groundwater in the study area is not suitable for drinking. Poor quality water is observed in well F14 along the north part of the study area. Very poor water quality is noted in well no.20 along the north part of the study area near to well F14. The quality of water that is not suitable for drinking was noticed in the other rest of wells as shown in **Fig. 27**.

Groundwater suitability for irrigation

The importance of evaluation irrigation water is coming from effects of the quality of used water on plants, soil and crops. The productivity of any crop is depending on the quality of plants, environmental conditions, properties of soil structure, the content of organic materials, methods of irrigation, crop type and climate conditions. The evaluation of groundwater for irrigation can be determined by the minerals constituents and the type of plant and soil [26].

In Safwan and Um Qaser area, the upper part of the groundwater is isolated by clay layer, while in Al-Zubairarea at the west side of studied area, the clay layer either absent or within the aquifer (**Fig.28**).

Salinity Hazard

Salinity hazard is the most influential water quality guideline on crop productivity as measured by electrical conductivity, it reflects the total dissolved solid (TDS) in water The amount of water transpired through a crop is directly related to yield; therefore, irrigation water with high EC reduces yield potential and can result in a physiological drought condition. That is, even though the field appears to have plenty of moisture, the plants wilt because the roots are unable to absorb the water.

SodiumHazard

EC is estimation for all dissolved salts in water. Sodium hazard is defined separately because of it has destructive effects on soil physical properties. The sodium hazard is typically expressed as sodium adsorption ratio (SAR), it is a measure of the suitability of water for use in agricultural irrigation , as calculated from the ratio of sodium to calcium and magnesium by this formula:

$$\boldsymbol{SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}}} \quad \text{……………………..(4)}$$

Where,

Na^{+}, Ca^{+2} and Mg^{+2} are in meq /l.

Continued use of water with high SAR value leads to a breakdown in the physical structure of the soil caused by excessive amounts of colloidally adsorbed sodium. The soil then becomes hard and compact when dry and increasingly impervious to water penetration.

SAR in all samples ranged from 0.0.114 to 6.238, as shown in **Fig. 29**.

In this respect, the US salinity diagram (**Fig. 30**) which is based on the integrated effect of EC (salinity hazard), and SAR (alkalinity hazard), has been used to assess the water suitability for irrigation.

When the analytical data of EC and SAR plotted on the US salinity diagram, it is illustrated that water samples of F14 fall in the class of C3-S1 indicating high salinity with low sodium water, which can be used for irrigation on almost all types of soil, with only a minimum risk of exchangeable sodium. This type of water can be suitable for plants having good salt tolerance but restricts its suitability for irrigation, especially in soils with restricted drainage, while water samples of F7,F9,F10,F12,F13,F15,F16,F17,F18,F19,F20,F22 and F27 wells fall in the class of C4-S1 and the rest fall in the class C4-S2 indicating very high salinity with low to medium sodium water, generally very high salinity water (C4) is not suitable for irrigation.

Conclusion

1. The calculated WQI results show that the groundwater in these districts was not suitable for drinking purposes except in two wells which were poor and very poor water type for drinking.
2. The study show that only one sample was accepted for irrigation which was F14.
3. The groundwater in the study area need to be some degree of treatment before using for drinking or irrigation purposes.

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Table 1: Correlation coefficient matrix for water quality parameters (n=13)

	EC	**TH**	**pH**	**TDS**	**Cl**	**Mg**	**Ca**	**CO_3**	**Na**	**K**	**NO_3**	**SO_4**	**HCO_3**
EC	**1.00**												
TH	**0.23**	**1.00**											
pH	**0.34**	**-0.04**	**1.00**										
TDS	**0.95**	**0.22**	**0.31**	**1.00**									
Cl	**0.78**	**0.05**	**0.16**	**0.83**	**1.00**								
Mg	**0.54**	**0.37**	**0.23**	**0.52**	**0.28**	**1.00**							
Ca	**0.31**	**0.37**	**-0.18**	**0.32**	**0.47**	**-0.10**	**1.00**						
CO_3	**-0.08**	**0.02**	**-0.14**	**-0.04**	**-0.20**	**0.27**	**-0.14**	**1.00**					

Na	**0.85**	**0.33**	**0.22**	**0.83**	**0.72**	**0.60**	**0.35**	**-0.07**	**1.00**				
K	**0.11**	**0.12**	**0.15**	**0.06**	**-0.01**	**0.09**	**0.37**	**-0.23**	**0.00**	**1.00**			
NO_3	**0.70**	**0.19**	**0.24**	**0.75**	**0.66**	**0.36**	**0.30**	**-0.06**	**0.67**	**0.01**	**1.00**		
SO_4	**0.77**	**0.29**	**0.21**	**0.83**	**0.63**	**0.50**	**0.34**	**-0.25**	**0.81**	**0.01**	**0.70**	**1.00**	
HCO_3	**0.02**	**0.02**	**-0.19**	**0.04**	**-0.08**	**0.16**	**0.18**	**0.23**	**-0.08**	**0.33**	**-0.22**	**0.00**	**1.00**

Table 2: Relative weight of chemical parameters

Chemical parameters	WHO Standard	Weight (wi)	Relative Weight (Wi)
pH	**8.5**	**3**	**0.103**
TDS mg/L	**500**	**5**	**0.172**
Cl mg/L	**250**	**3**	**0.103**
So_4 mg/L	**250**	**3**	**0.103**
NO_3 mg/L	**45**	**5**	**0.172**
HCO_3 mg/L	**120**	**2**	**0.069**
Na mg/L	**200**	**3**	**0.103**
Ca mg/L	**75**	**2**	**0.069**
Mg mg/L	**50**	**2**	**0.069**
K mg/L	**12**	**1**	**0.034**
Total		**29**	**1.000**

Table 3: Types and ranges of water according to WQI values

Type of water	Range
Excellent water	**< 50**
Good water	**50-100**
Poor water	**100-200**
Very poor water	**200-300**
Unsuitable water for drinking purpose	**>300**

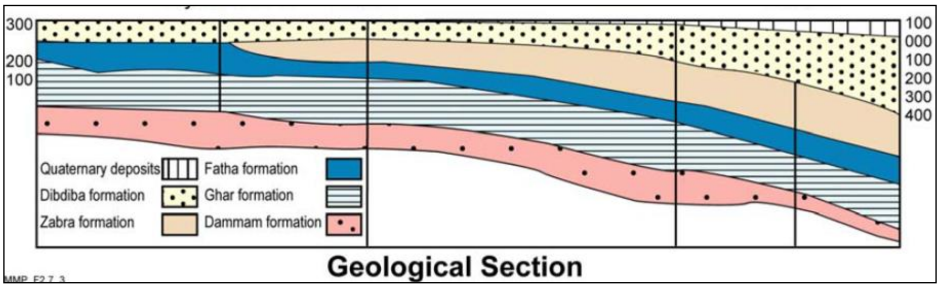

Fig.1 : Geological cross section in Dibdiba

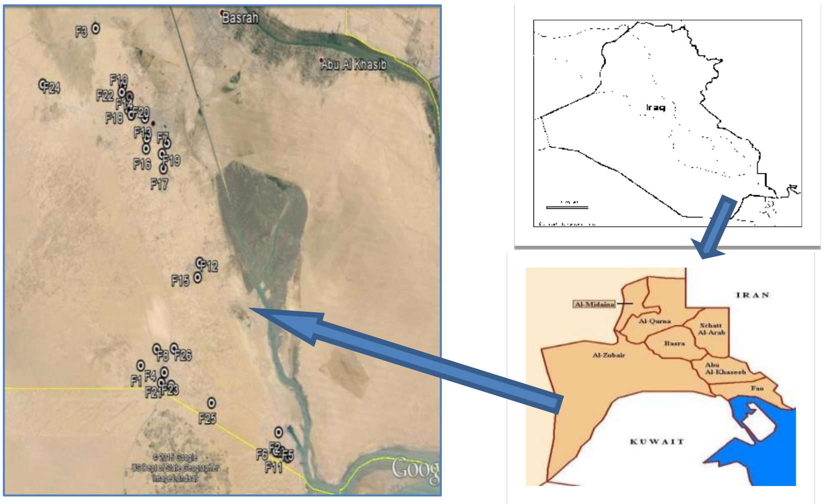

Fig.2: Groundwater samples location and map of the study area

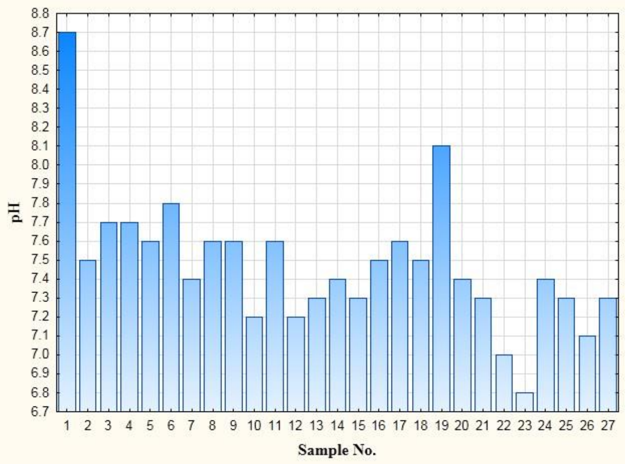

Fig.3 Histogram of pH values of groundwater analysis.

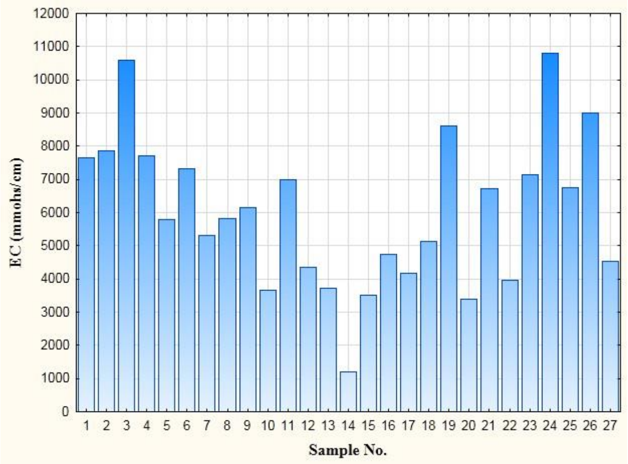

Fig. 4 Histogram of electric conductivity values of groundwater analysis.

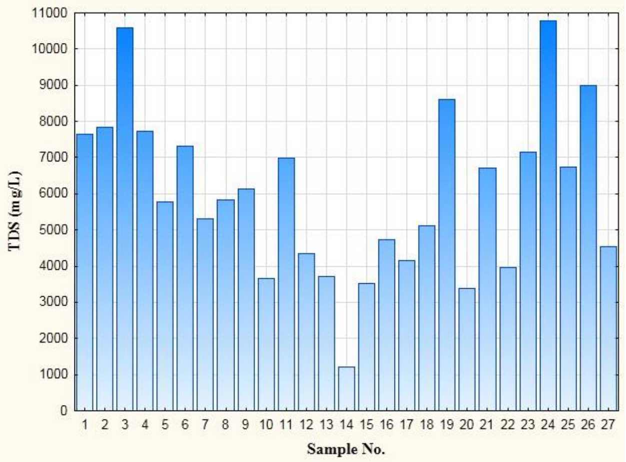

Fig.5 Histogram of total dissolved salt values of groundwater analysis

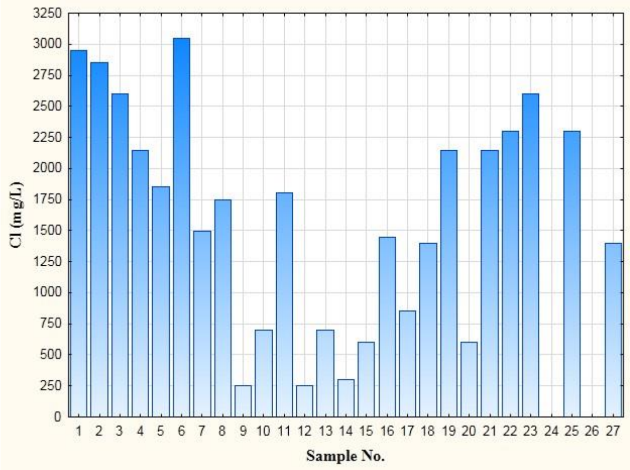

Fig.6 Histogram of chloride values of groundwater analysis.

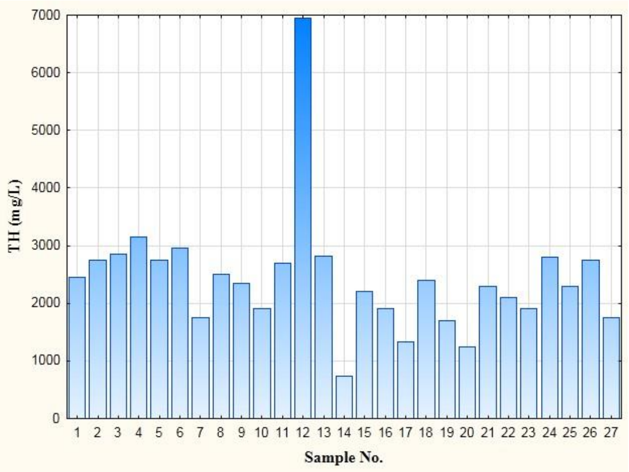

Fig.7 Histogram of total hardness values of groundwater analysis

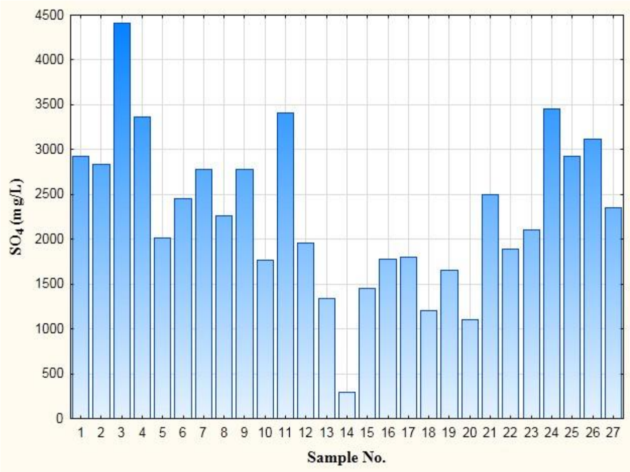

Fig.8 Histogram of sulfate values of groundwater analysis.

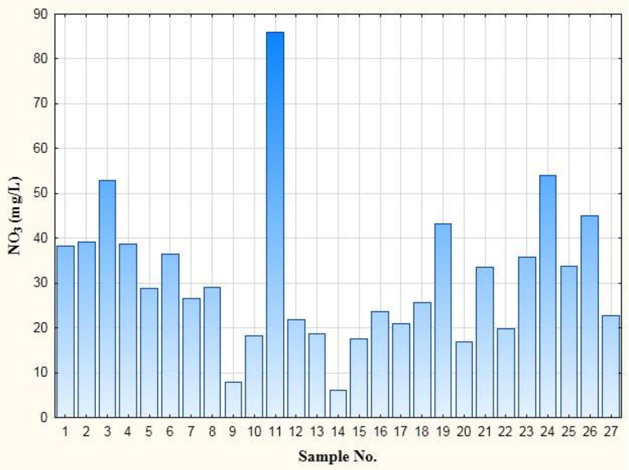

Fig. 9 Histogram of nitrate values of groundwater analysis

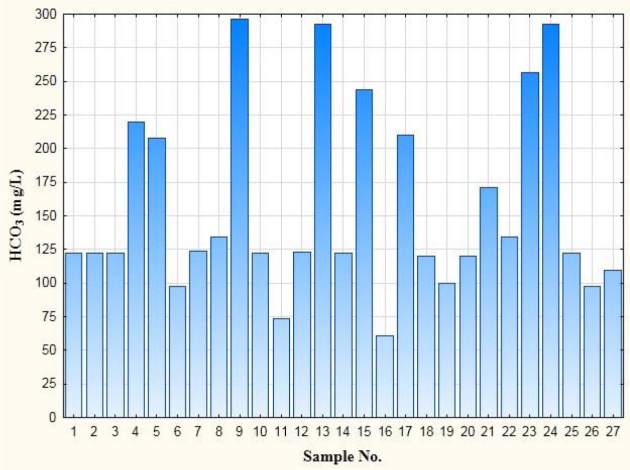

Fig.10: Histogram of bicarbonatevalues of groundwater analysis.

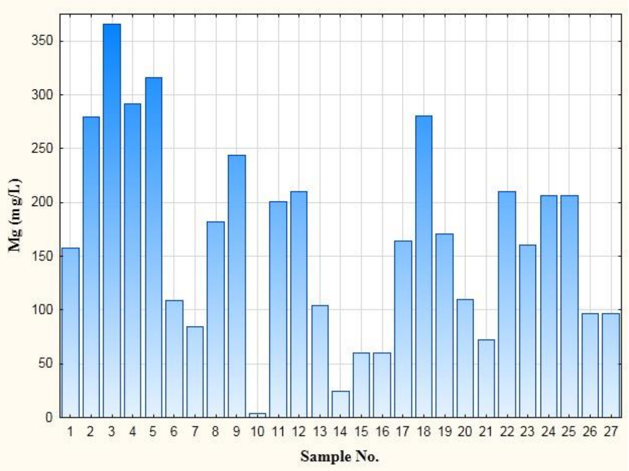

Fig. 11 Histogram of magnesium values of groundwater analysis

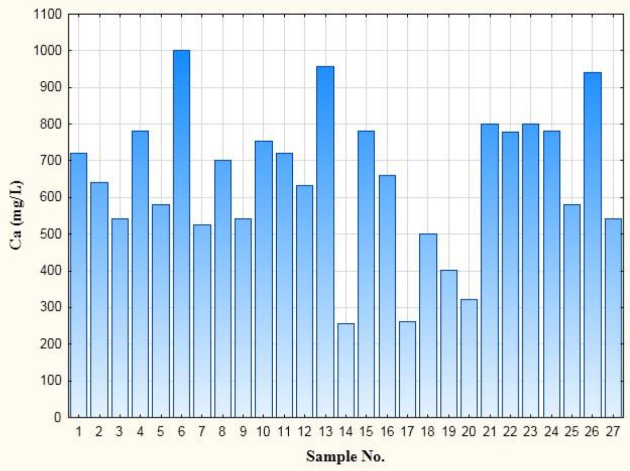

Fig. 12 Histogram of calcium values of groundwaterr analysis.

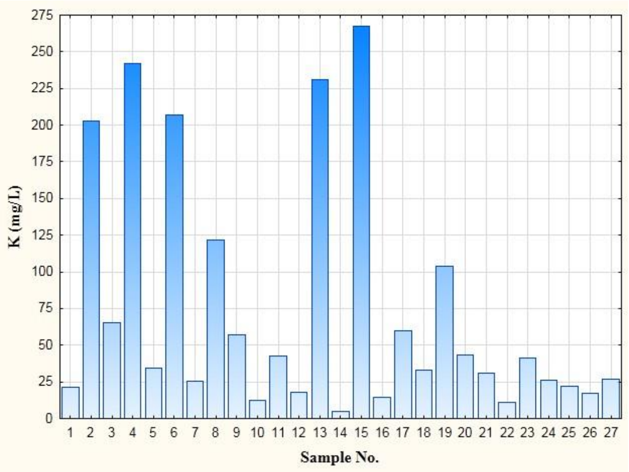

Fig.13 Histogram of potassium values of groundwater analysis

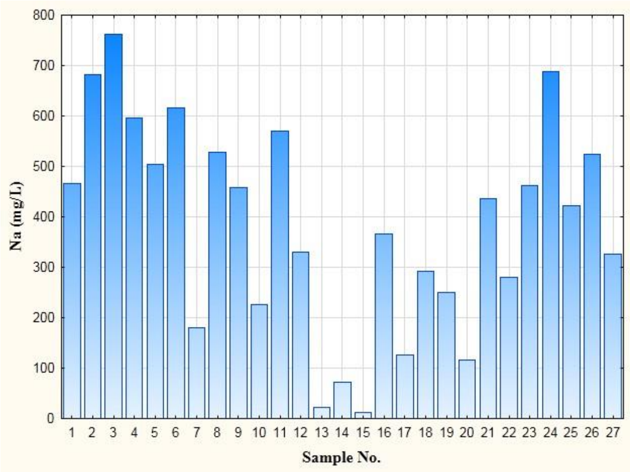

Fig. 14 Histogram of sodium values of groundwaterwater analysis.

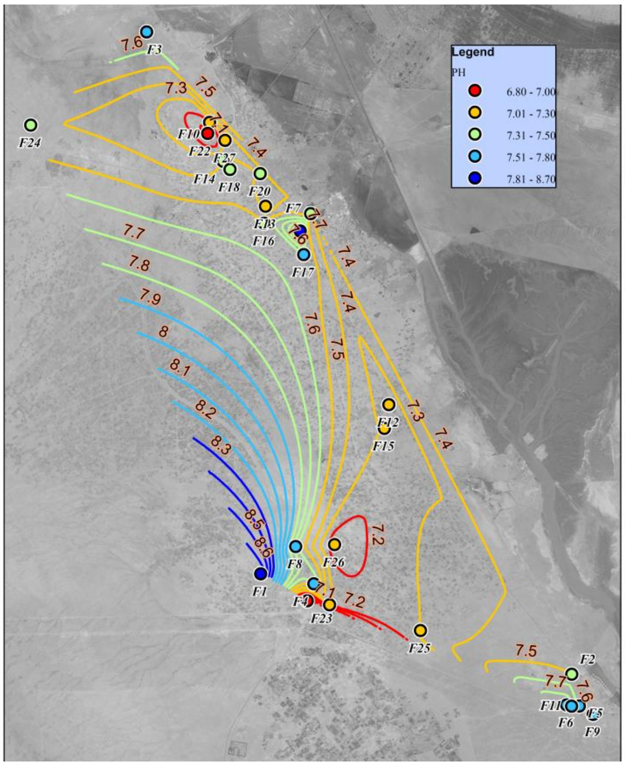

Fig. 15 Spatial distribution of pH in the study area

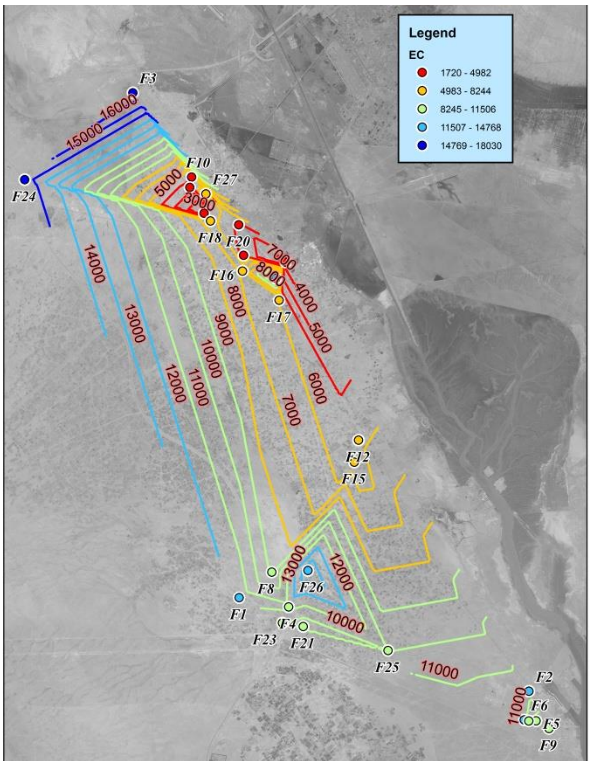

Fig. 16 Spatial distribution of EC in the study area

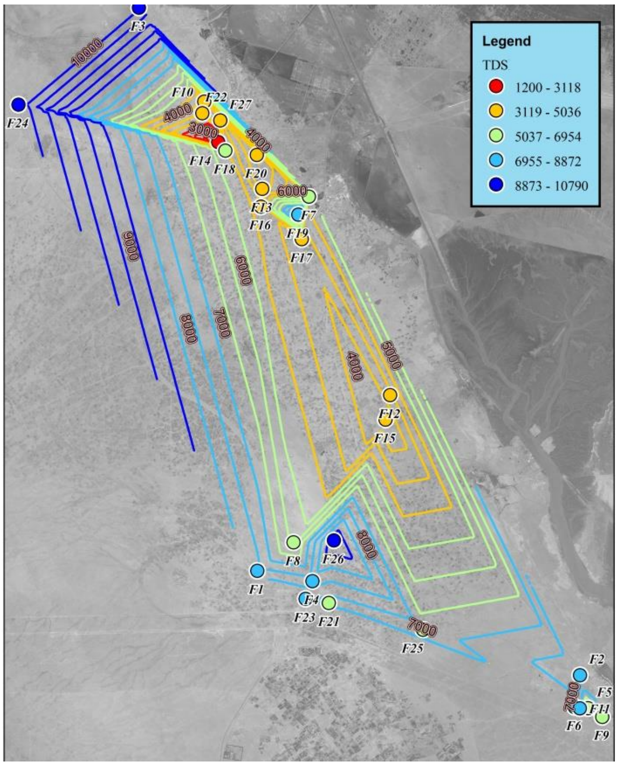

Fig. 17 Spatial distribution of TDS in the study area

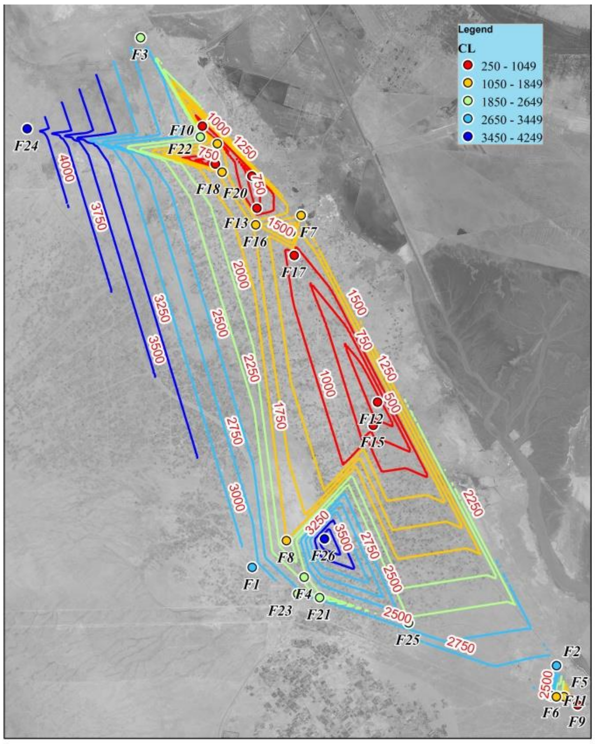

Fig. 18 Spatial distribution of Cl in the study area.

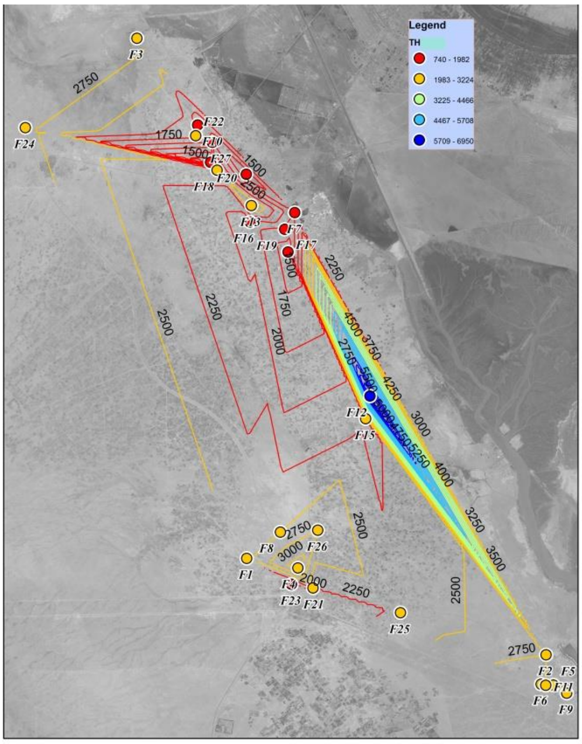

Fig. 19 Spatial distribution of TH in the study area

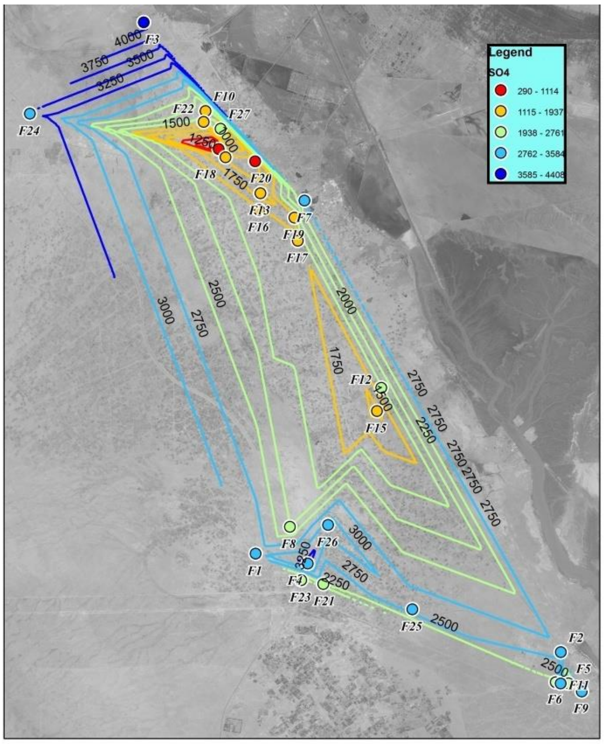

Fig. 20 Spatial distribution of SO_4 in the study area.

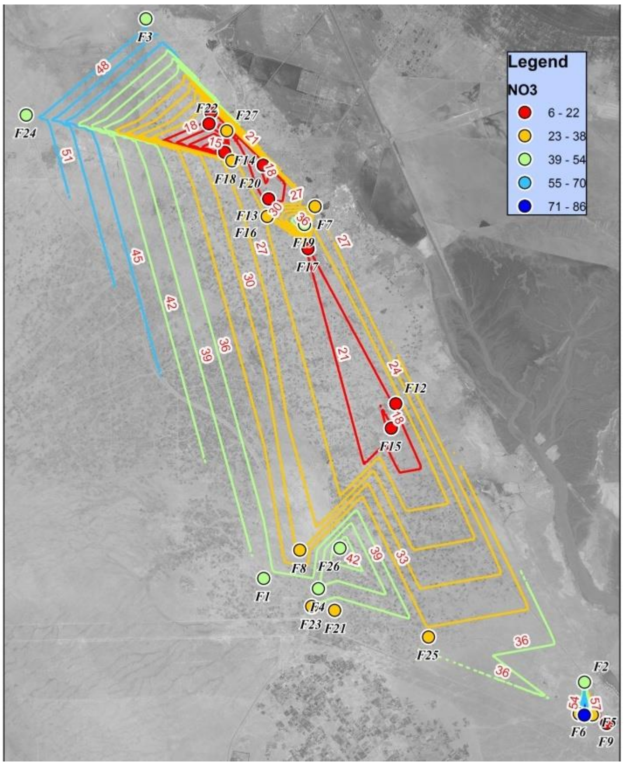

Fig. 21 Spatial distribution of NO3 in the study area

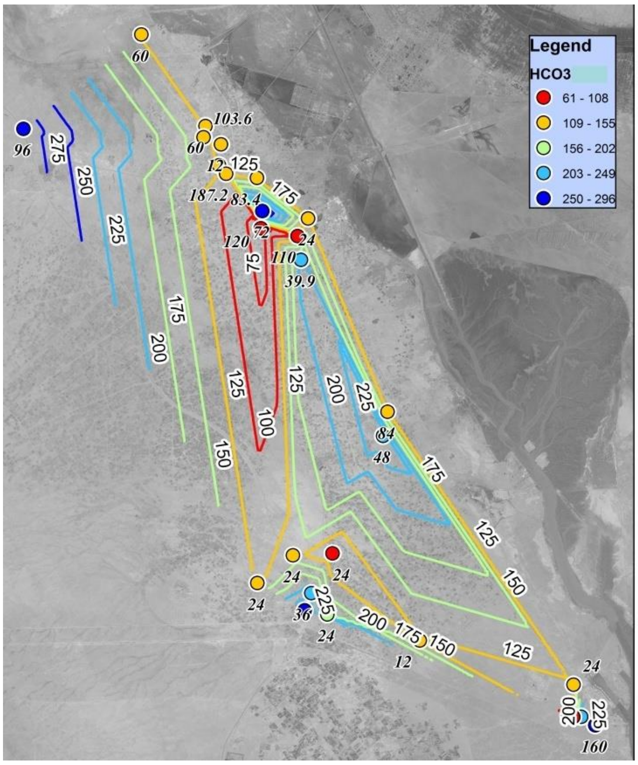

Fig. 22 Spatial distribution of HCO3in the study area.

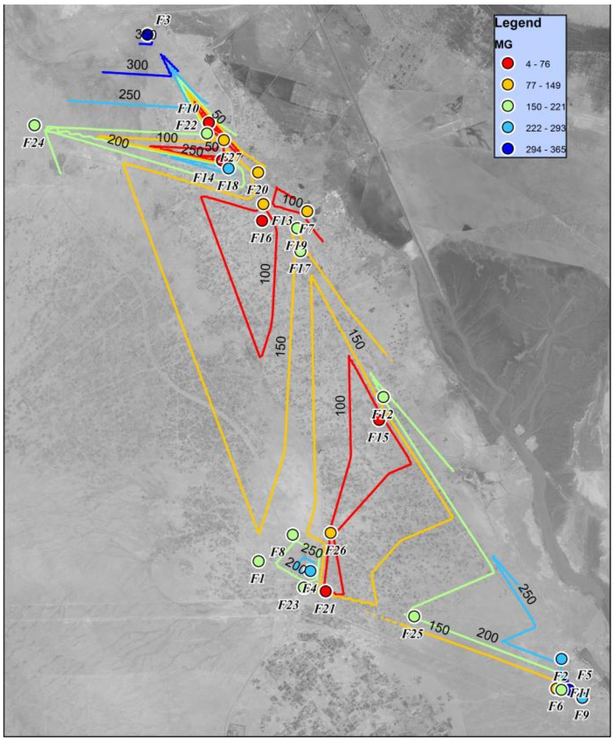

Fig. 23 Spatial distribution of Mg in the study area

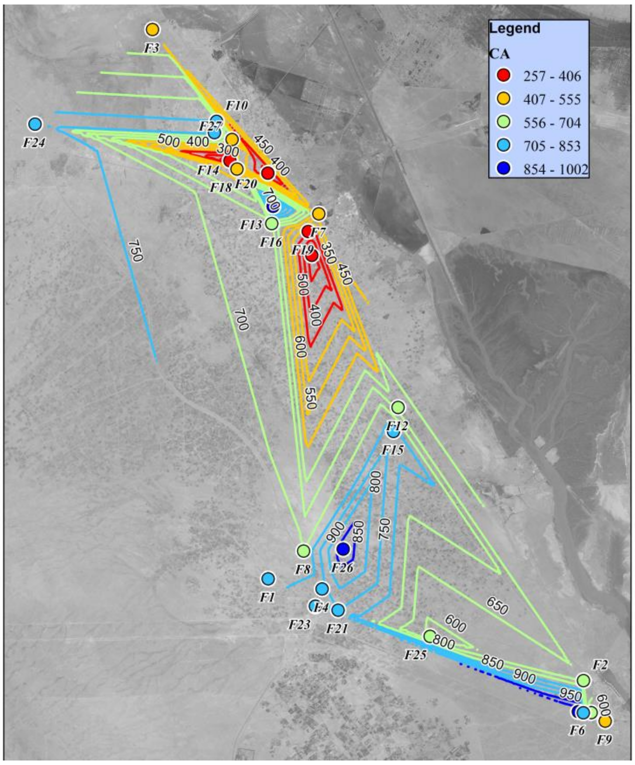

Fig. 24 Spatial distribution of Cain the study area.

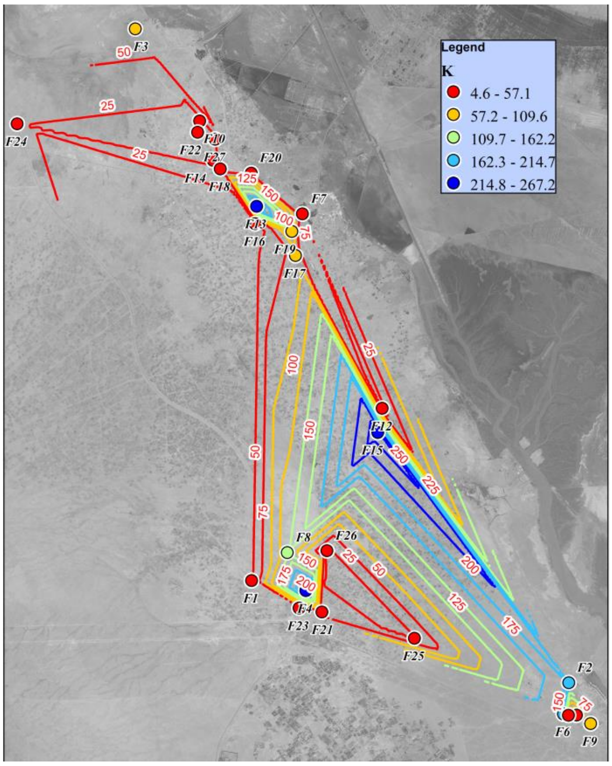

Fig. 25 Spatial distribution of K in the study area

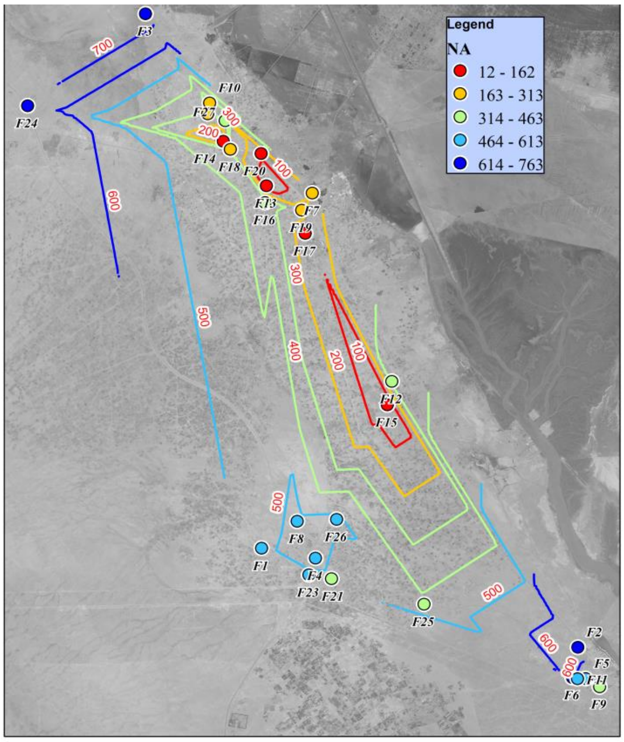

Fig. 26 Spatial distribution of Na in the study area.

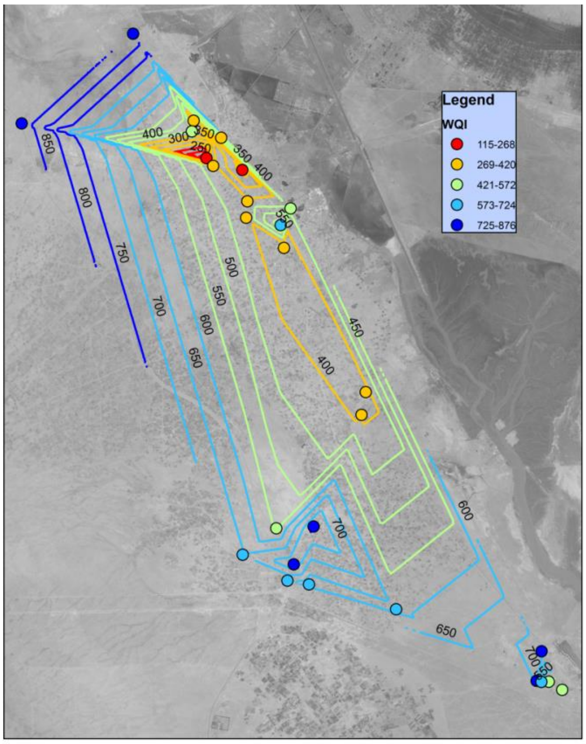

Fig. 27 : Water quality index (WQI) map for the study area samples.

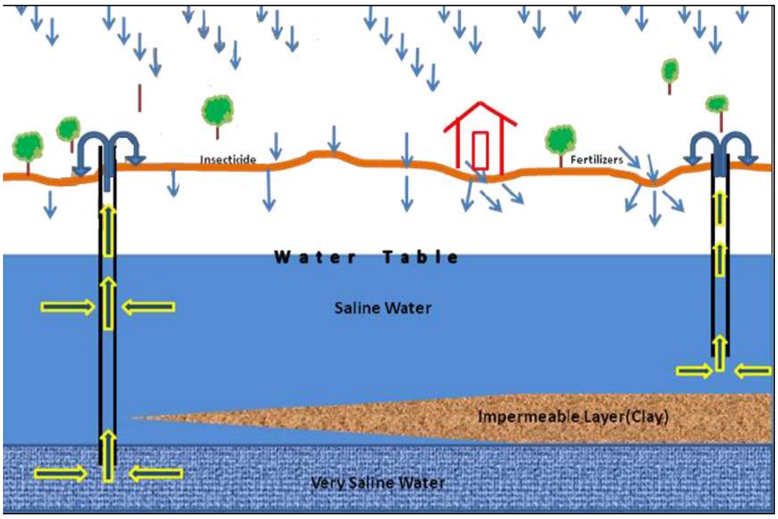

Fig. 28: Human activities and impermeable layer in the study ar
(Aldahaan, 2014).

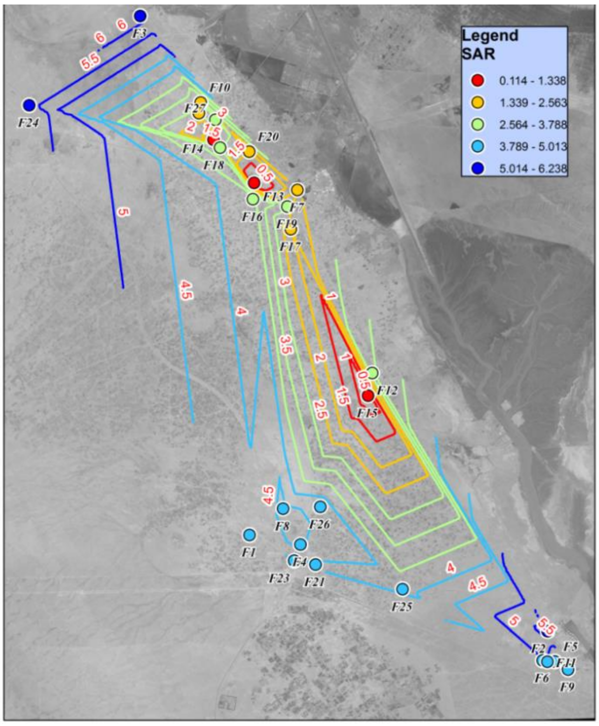

Fig. 29: SAR map for the study area samples.

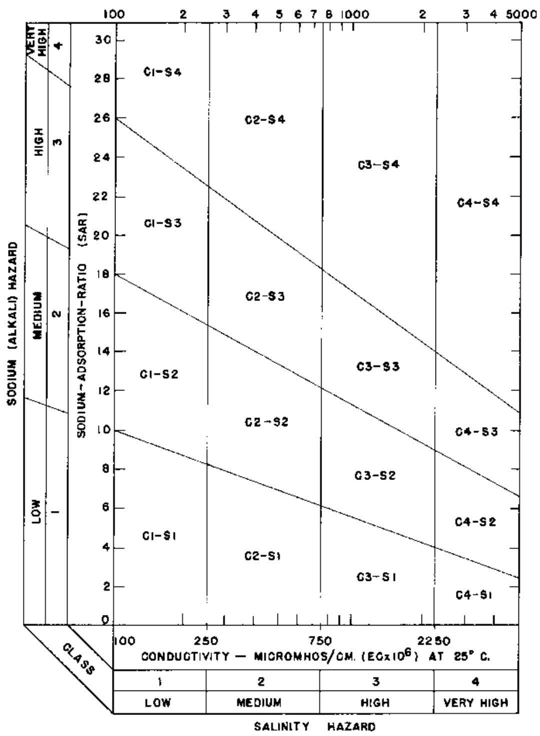

Fig.30 :Rating of water samples in relation to salinity and sodium hazard