University of Baghdad
College of Engineering
JE
JOURNAL OF ENGINEERING

**Journal of Engineering**
journal homepage: www.jcoeng.edu.iq
Number 8 Volume 24 August 2018

***Water Resources and Surveying Engineering***

# GIS Approach for Spatial Distribution Analysis of Groundwater Quality at South-West Part of Basrah

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## ABSTRACT

Water is necessary for sustainable development and healthy society. Groundwater, often, is not sufficient and protected for direct human consumption. Due to increase in the density of population the requirement of water is increasing. In this work, the assessment of groundwater quality was conducted in the south-west part of Basrah province. Spatial variations in the quality of groundwater in the study area have been analyzed utilizing GIS technique. The geochemical parameters of groundwater samples including pH, EC, TDS, Ca, Mg, Na, Cl, $HCO_3$, $SO_4$, and $NO_3$ were assessed in this study. Information maps of the study area have been actually prepared to make use of the GIS spatial interpolation approach for all the parameters. The current study reveals that most of the parameters are observed to be beyond permissible limit as per WHO and Iraqi standards. Thus, it is concluded from this work that results acquired in this research and the spatial database founded in GIS will be useful to monitor and manage the groundwater pollution in the study area.

**Keywords:** spatial distribution, GIS, groundwater, assessment, Basrah.

# منهج نظم المعلومات الجغرافية لتحليل التوزيع المكاني لجودة المياه الجوفية في الجزء الجنوبي الغربي من البصرة

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## الخلاصة

ان المياه ضرورة لنمو وصحة المجتمع. فالمياه الجوفية غالبا ما تكون غير كافية وغير صالحة للاستهلاك البشري المباشر وذلك بسبب الزيادة المستمرة بالتلوث. رغم ان الحاجة الى هذه المياه اخذة بالازدياد. قد تم في هذه الدراسة تقييم جودة المياه الجوفية في الجزء الجنوبي الغربي من محافظة البصرة ولهذا تم تحليل الاختلافات المكانية في نوعية المياه الجوفية في منطقة الدراسة باستخدام تقنية نظم المعلومات الجغرافية. حيث تم فحص عينات المياه الجوفية بالنسبة الى مجموعة من المعلمات الفيزيائية والكيميائية مثل الاس الهيدروجيني والموصلية الكهربائية والاملاح الكلية المذابة وايون الكالسيوم وايون المغنيسيوم وايون الصوديوم وايونات الكلوريدات وايونات البيكاربونات وايونات الكبريتات وايونات النترات. وقد أعدت خرائط المعلومات لمنطقة الدراسة للاستفادة من نهج الاستيفاء المكاني لنظام المعلومات الجغرافية لجميع المعلمات. وتكشف الدراسة الحالية أن معظم المعلمات قد لوحظ أنها تجاوزت الحدود المسموح بها وفقا لمنظمة الصحة العالمية والمعايير العراقية. وهكذا،

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https://doi.org/10.31026/j.eng.2018.08.07

Article accepted: 28/11/2017

يستنتج من هذا العمل أن النتائج المكتسبة في هذا البحث و قاعدة البيانات المكانية التي تأسست من تطبيق نظم المعلومات الجغرافية ستكون مفيدة لرصد وإدارة تلوث المياه الجوفية في منطقة الدراسة.

## 1. INTRODUCTION

Water is the fundamental demand of all life on a world. Both of surface water and groundwater tend to be the significant sources of water. Groundwater is actually a required resource that is necessary for previous decades because of the rise in its consumption for drinking, irrigation, water supply, and industrial uses, etc. The rise in population and urbanization requires increases in the agricultural and industrial sectors which need more fresh water.

Nevertheless, complete dependence upon human are not satisfied through the surface water just, therefore, they have to depend on the groundwater that may or may possibly not be potable. Nowadays, the dedicated issue is the contamination of drinking water by some activities such as human and industrial.

Evaluation of the quality of water for drinking purpose means the dedication of the chemical composition of groundwater and the correlated measures for the recovery of the quality of water in case of its degeneration demand the recognition of possible sources that contributed to the contamination of groundwater. It is crucial to investigate the geochemistry of groundwater used as potable water. Consequently, appropriate treatment of contaminated groundwater is important before consuming it.

Geographic Information System (GIS) provides an essential tool for the efficient management of groundwater resources. GIS helps in developing a scientific database for the resource and furthermore helps in updating the data. GIS-based models assist in understanding the yearly distribution and produce a database for future use.

Indistinctive use of groundwater degrades the quantity and quality of water. The quality of water was evaluated with regards to geochemical parameters and compared to WHO and Iraqi standards. This study is certainly current to the evaluation of the physical-chemical properties of the groundwater in the study area that is certainly situated in a semi-arid region wherein the people is depending on the groundwater for their needs. This work also provides an evaluation regarding the suitability associated with the groundwater for drinking purposes. Groundwater samples were collected from all around the study area, and the strategically analyzed results presented in the GIS-based water quality mapping recommending remedial actions in the study area. Many researchers used chemical characteristics of groundwater to evaluate the groundwater quality of drinking such as **Subramani, et al., 2005**, **Nagarajan, et al., 2010**, **Barbooti, et al., 2010**, **Jassas and Merkel, 2005**, **Al-Mussawi, 2014**, and **Al-Mezori and Hawrami, 2011**. This paper relates to the application of GIS as a tool for comprehending distribution among these studied variables.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Basrah province is situated in the south part of Iraq. Basrah province is bordered in the south by Kuwait, in the north by Maysan province, in the east by Iran, and in the west by Dhi-Qar and Muthanna provinces. It covers the southwest area of the alluvial plain. The province is situated in a climate that is semi-arid which can be hot and dry in summer due to the irregular distribution of rainfall throughout the eight months The study area is located in the south-west part of Basrah province, **Fig.1**. Geomorphologically, this study area shows a smooth plain with small linear structural hills and valleys. The direct infiltration of precipitation recharges the Dammam aquifer of the study area, which is the main source of groundwater recharge. The composition of Dammam aquifer is mainly limestone and dolomite.

## 2.2 Sample Collection and Analysis

In the present study, the groundwater samples were collected from sixteen wells of the unconfined aquifer and analyzed for different chemical parameters. **Table 1** shows the characteristics of the wells located within the study area. The analytical data were taken into the GIS environment. In GIS, a number of spatial distribution maps were prepared for the selected parameters, which show significant variation and the evaluation of water samples was carried out according to standard methods of water analysis. The chemical analysis was carried out to determine pH, TDS, EC, and ions for each of Ca, Mg, Na, $HCO_3$, Cl, $SO_4$, as well as $NO_3$ ions, and contrasted with standard values suggested by Iraqi and WHO standards. **Table 2** contains the statistics of physicochemical data of the sixteen groundwater samples in the current study.

## 2.3 Hydrogeological situation

The hydrogeological attributes of any area depend on its structures and geological nature, kinds of formation, topographic of the area, and the nature of the rocks in that area. Dammam aquifer is regarded as one of the groundwater storage that is essential in the west area of the Basrah province. This aquifer could be the main regional aquifers in the southern part of Basrah. The Dammam aquifer in the study area is an unconfined type, **Al-Basrawi, 2006**, and it depends mainly on the rainfall that falling in its widespread western area.

## 2.4 Type of groundwater

There are various geological and hydrochemical factors such as porosity and permeability of the rocks and the presence of cracks, as well as, the movement of groundwater is working to arrange and discover any elements dissolved in water. Several techniques and categories were hydrochemablleistry implemented in the classification of groundwater such as **Schoeller, 1977**, and **Piper**, **1944**, diagrams. Piper’s trilinear diagram, **Piper, 1953**, was used to classify the groundwater hydrochemistry on the basis of dominant ions of the groundwater. As it is shown in **Fig.2**, the piper’s diagram divided into small triangles. Each triangle shows different groundwater type. There are two types of water depending on the cation or anion ions in that water.

## 3. RESULTS

Groundwater quality is highly degraded as a result of human activities and/or natural processes. Analysis of groundwater quality for drinking establishes its suitability for various purposes depending upon the requirements which are specified by different agencies including the drinking water standards prepared by **WHO, 2011**. The physical parameter values of the groundwater samples in the study area show that pH varies within the standard limits which suggest the alkaline nature of the groundwater samples in the study area. On the basis of the **WHO, 2011** standards, all the groundwater samples can be used for human consumption because its values fall within the recommended limit (6.5 to 8.5). The concentration of TDS in the groundwater samples of the study area is high and it varies from 453 to 7174 mg/l with an average value of 2923.7 mg/l, **Table 2**. As per TDS category, 68.75 % of the wells water types are brackish because its TDS is more than 1,000 mg/l, meanwhile, 31.25 % of water wells type is fresh due to its TDS was less than 1,000 mg/l, **Freeze and Cherry, 1979**. The EC of groundwater samples is ranged from 697 to 8668 µS/cm with a mean of 3832.2 µS/cm. Nearly all the groundwater samples exceeded the desirable limit of 1000 µS/cm for EC for drinking water (as per WHO). A gastrointestinal agitation in humans may be caused by higher EC. Even though the big difference in EC is especially related to Geochemical process such silicate weathering, reverse exchange, ion exchange, evaporation rock, water interaction, oxidation processes and sulphate reduction, **Ramesh, 2008**. The spatial distribution of TDS and EC is shown in **Figs.3** and **Figs.4** respectively. **Table 3** shows the standard values of water quality parameters according to WHO and Iraqi standards.

The Ca concentration of groundwater samples in the study area ranged from 52 to 500 mg/l with a mean value of 220 mg/l. The major source of Ca in the groundwater is a result of ion exchange of minerals from rocks of the study area. As per WHO standards, 87.5 % of the groundwater from the study area is not safe to use for drinking purposes due to its values is more than the desirable limit specified as 75 mg/l by **WHO, 2011**. The spatial distribution of Ca is illustrated in **Fig.5**. The concentration of Mg in the groundwater samples of the study area is higher and varying from 15 to 292 mg/l with an average value of 91.1 mg/l. The spatial distribution of Mg is illustrated in **Fig.6**. It could be seen from **Table 2**, that Mg concentration in the groundwater samples from the study area is very high and unacceptable for some applications such as drinking, **WHO, 2011**. Mg may probably have been produced by the precise resource that is same as that of Ca. Na concentration of groundwater samples ranged from 51 to 1339 mg/l with an average value of 600.4 mg/l. As per WHO recommendations, the maximum allowable limit is 200 mg/l. For the current study, 68.75% of groundwater samples showed a concentration of Na above permissible limit stated by **WHO, 2011**. The spatial distribution of Na is shown in **Fig.7**. Hypertension and congenital diseases caused by excess in Na concentrations. **Hem, 1985,** reported that the groundwater with high values of Na may be either as a result of the over-exploitation of groundwater resources or the chemical weathering of feldspars.

The concentration of Cl in groundwater samples of the study area is varied from 57 to 2378 mg/l with a mean value of 774. mg/l. For the drinkithe ng water, the desirable limit of Cl concentration is specified as 250 mg/l according to **WHO 2011**. From this study, it is noticed that 68.75 % of the groundwater samples were above a specified limit for Cl concentration. The spatial distribution of Cl is illustrated in **Fig.8**. The higher levels of chloride concentration above 250 mg/l cause salty taste and odor aside from aggravating heart-related illnesses and causing high levels of blood pressure. It absolutely was discovered that the $SO_4$ concentration of the groundwater samples in the study area ranged from 96 to 2724 mg/l with an average value of 946.6 mg/l. It really is mentioned that 81.25 % of groundwater samples in this study are above the maximum permissible limit of 250 mg/l that stated by **WHO, 2011**. **Fig.9** showed the spatial distribution of $SO_4$ concentration in the study area. In drinking water, the higher concentration of $SO_4$ connected with respiratory issues, **Subramani, et al., 2010**. The concentration of $NO_3$ in the groundwater samples of the study area has varied from 4 to 130 mg/l with an average value of 39.6 mg/l. It is observed that 25 % of the groundwater samples are not amongst the permissible limit of 45 mg/l for drinking water and 50 mg/l for irrigation purposes as per **WHO, 2011** and Iraqi standard, respectively. The spatial distribution of $NO_3$ is clarified in **Fig.10**. The sewage, decaying organic matter, and fertilizer that came from agricultural runoff, increases the concentration of $NO_3$, **Karnath, 1987**. Some diseases, such as Methaemoglobinaemia, goiter, gastric cancer, and hypertension and birth malformation are caused by higher concentrations of $NO_3$ in the drinking water. The concentration of HCO3 in groundwater samples of the study area has ranged from 85 to 256 mg/l with a mean value of 157.4 mg/l. **Fig.11** shows the spatial distribution of $HCO_3$ in the wells of the study area. The permeability of some wells in the aquifer is ranged between 0.7 m/day and 6 m/day. The movement of groundwater is directed as shown in **Fig.1.**

To determine the groundwater type, the concentrations of major ionic constituents of groundwater samples were plotted in the Piper diagram of the study area as shown in **Fig.12**. From the fields of cationic and anionic triangular in Piper's diagram, it is noticed that the type of water in the groundwater samples in the study area was shown in **Table 4**. There are 12 wells in the study area with a sodium type of the cation ion water type. Furthermore, it is noticed that there are 4 wells of sulfate type and 5 wells of chloride type in the study area of anion ion water type. Schoeller diagrams for the groundwater samples in the study area are shown in **Fig.13**. The classification of water in the study area of Dammam aquifer, according to its Schoeller diagram **Fig.13**, shows that there are three different groups. The first group which is rich with Na-$SO_4$ is shown in seven samples in the aquifer. The second group which is rich with Ca-$SO_4$ is shown in two samples. While the third group which is rich with Na-Cl, is shown in the rest of seven samples in the study area.

## 4. CONCLUSIONS

This study has proven that GIS application in groundwater quality is effective in addition to the understanding of the spatial distribution of many Geochemical parameters of groundwater in the area of the study. Thus, the spatial distribution maps of particular parameters such as EC, TDS, Ca, Mg, Na, Cl, $HCO_3$, $SO_4$, and $NO_3$, arrived at in this study are proven to form a useful notification for groundwater evaluation. It is concluded in this study that contamination in groundwater should be taken into consideration when analyzing groundwater quality. It has been found out that the quality of groundwater in the area of the study decreases due to the continuity environmental pollution. For this reason, monitoring and controlling of groundwater is essential. The current work has presented a guideline for evaluating groundwater quality in Basrah. The analysis of physical and chemical parameters of the groundwater samples of this study was compared with the standard guideline for drinking (WHO) to assess the suitability of the groundwater for drinking purposes. Consequently, the collected groundwater samples in this study are almost not suitable for human use according to these study parameters, except the pH parameter.

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**Table 1.** Total depth and the water level of wells in the study area.

| Well No. | Total Depth (m) | Water Level (m) |
|---|---|---|
| 1 | 200.0 | 170.0 |
| 2 | 61.0 | 41.0 |
| 3 | 66.5 | 40.0 |
| 4 | 158.0 | 122.7 |
| 5 | 165.0 | 130.0 |
| 6 | 170.0 | 122.0 |
| 7 | 210.0 | 130.0 |
| 8 | 112.0 | 78.0 |
| 9 | 174.0 | 124.0 |
| 10 | 173.0 | NS |
| 11 | 175.0 | 130.0 |
| 12 | 215.7 | 163.5 |
| 13 | 62.3 | 40.5 |
| 14 | 180.0 | 170.0 |

| | | |
|---|---|---|
| 15 | 60.0 | 40.3 |
| 16 | 222.0 | 164.0 |

NS : Not specified.

**Table 2.** Statistics of Physico-Chemical water parameter.

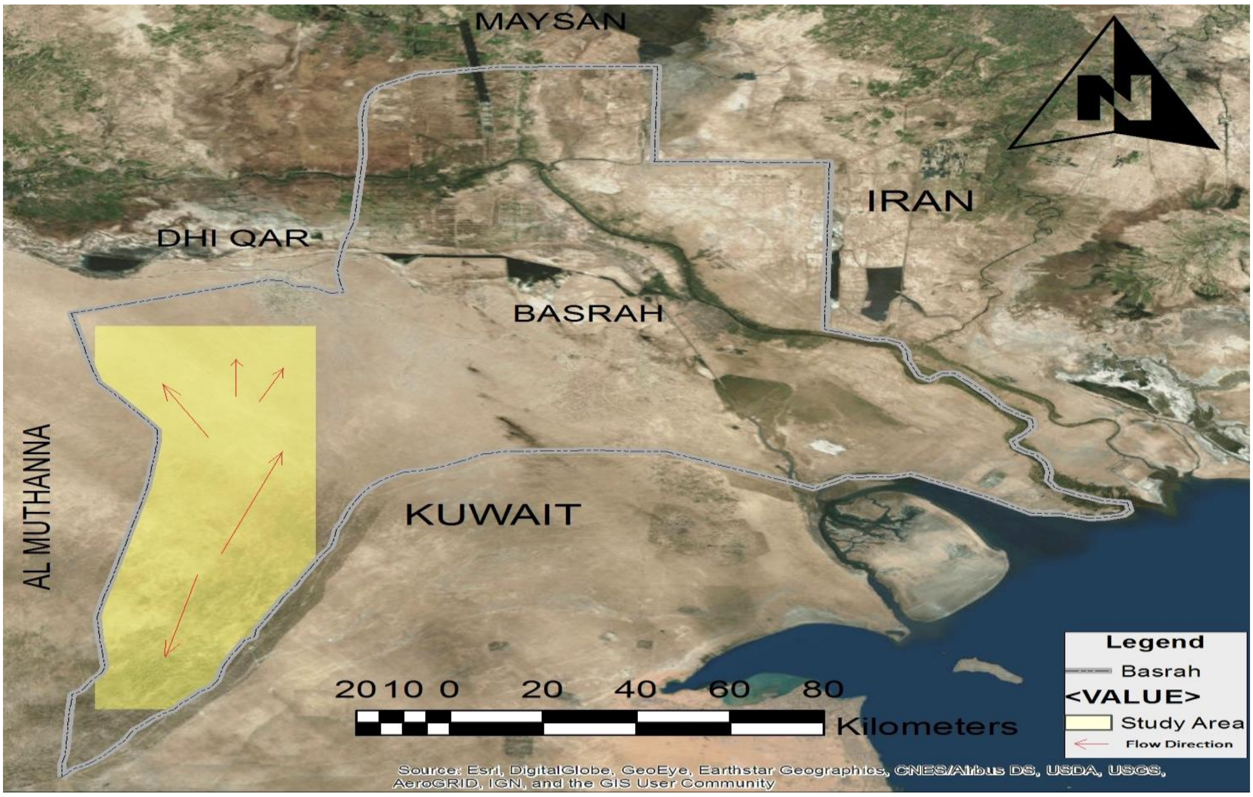
| Parameter | Min. | Max. | Mean | Standard Deviation |
|---|---|---|---|---|
| TDS | 453 | 7174 | 2923.7 | 2358.70 |
| EC | 697 | 8668 | 3832.2 | 2813.39 |
| Ca | 52 | 500 | 220 | 158.67 |
| Mg | 15 | 292 | 91.1 | 90.29 |
| Na | 51 | 1339 | 600.4 | 465.55 |
| Cl | 57 | 2378 | 774.9 | 687.47 |
| $SO_4$ | 96 | 2724 | 946.6 | 859.80 |
| $NO_3$ | 4 | 130 | 39.6 | 30.93 |
| $HCO_3$ | 85 | 256 | 157.4 | 40.37 |

**Table 3.** Standard values of water quality parameters (Standard specification no. 417, 2009) and (WHO, 2011) for drinking and irrigation purposes.

| Parameter | Mean value | The standard for Drinking water | | The standard for Irrigation water | |
|---|---|---|---|---|---|
| | | WHO | Iraqi | WHO | Iraqi |
| TDS (mg/l) | 2923.7 | 500 | 1500 | 2000 | 2500 |
| EC (µS/cm) | 3832.2 | 1000 | 2000 | 2000 | 250 |
| Ca (mg/l) | 220 | 75 | 200 | 20 | 450 |
| Mg (mg/l) | 91.1 | 50 | 150 | 50 | 80 |
| Na (mg/l) | 600.4 | 200 | 200 | 4 | - |
| Cl (mg/l) | 774.9 | 250 | 200 | 300 | 250 |
| $SO_4$ (mg/l) | 946.6 | 250 | 400 | 20 | 200 |
| $NO_3$ (mg/l) | 39.6 | 45 | 10 | - | 50 |

**Table 4.** Piper field classification of groundwater type in the study area.

| **Water type** | **Total number of samples** |
|---|---|
| Cation Ions | |
| A. Magnesium type | - |
| B. Calcium type | - |
| C. Sodium type | 12 |
| D. No dominant type | 4 |
| **Total number of samples** | **16** |
| Anion Ions | |
| E. Sulfate type | 4 |
| F. Bicarbonate type | - |
| G. Chloride type | 5 |
| H. No dominant type | 7 |
| **Total number of samples** | **16** |



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Figure 1.** Basrah province location map and Study area map.

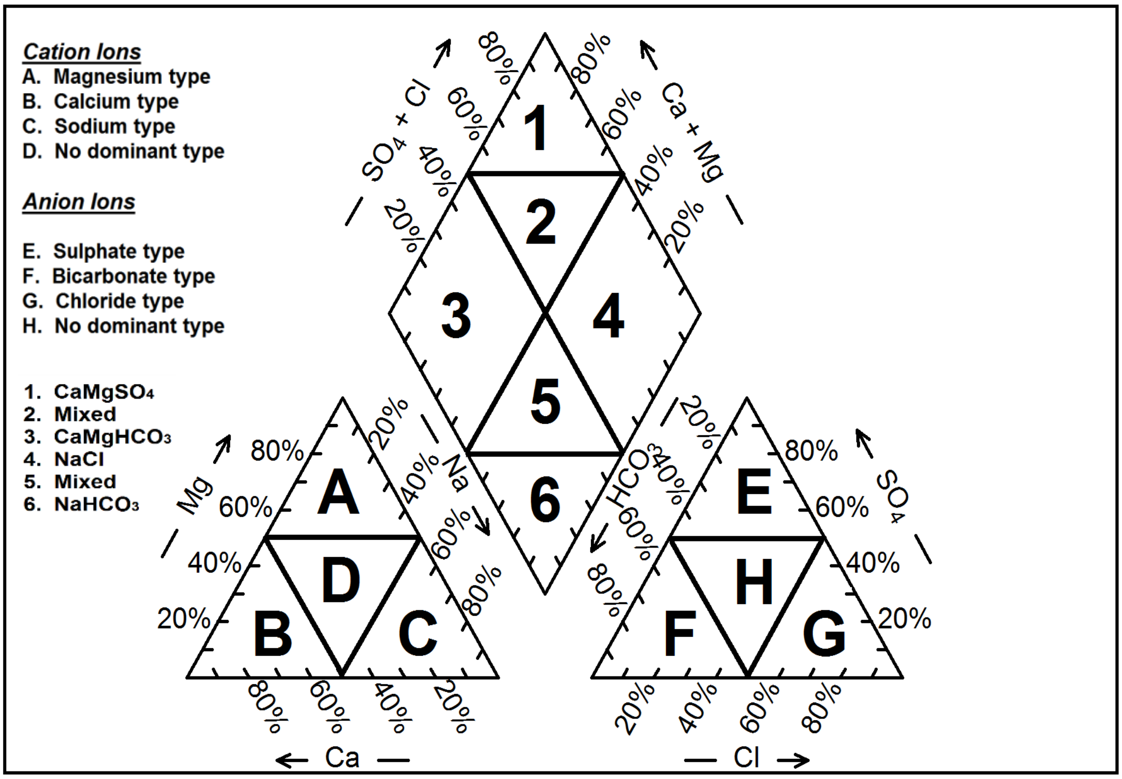


**Figure 2.** Piper diagram showing the relative cation and the anion composition, **Piper, 1953**.

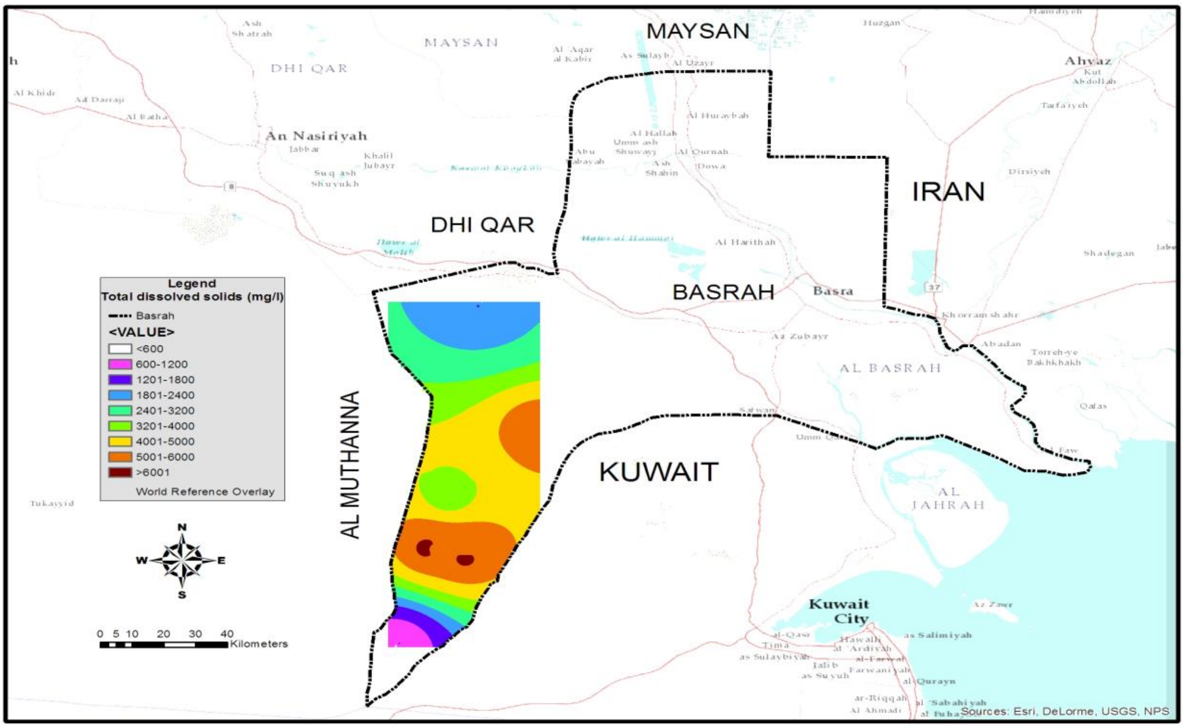


**Figure 3.** Digital map explains the spatial distribution of TDS concentrations in the study area.

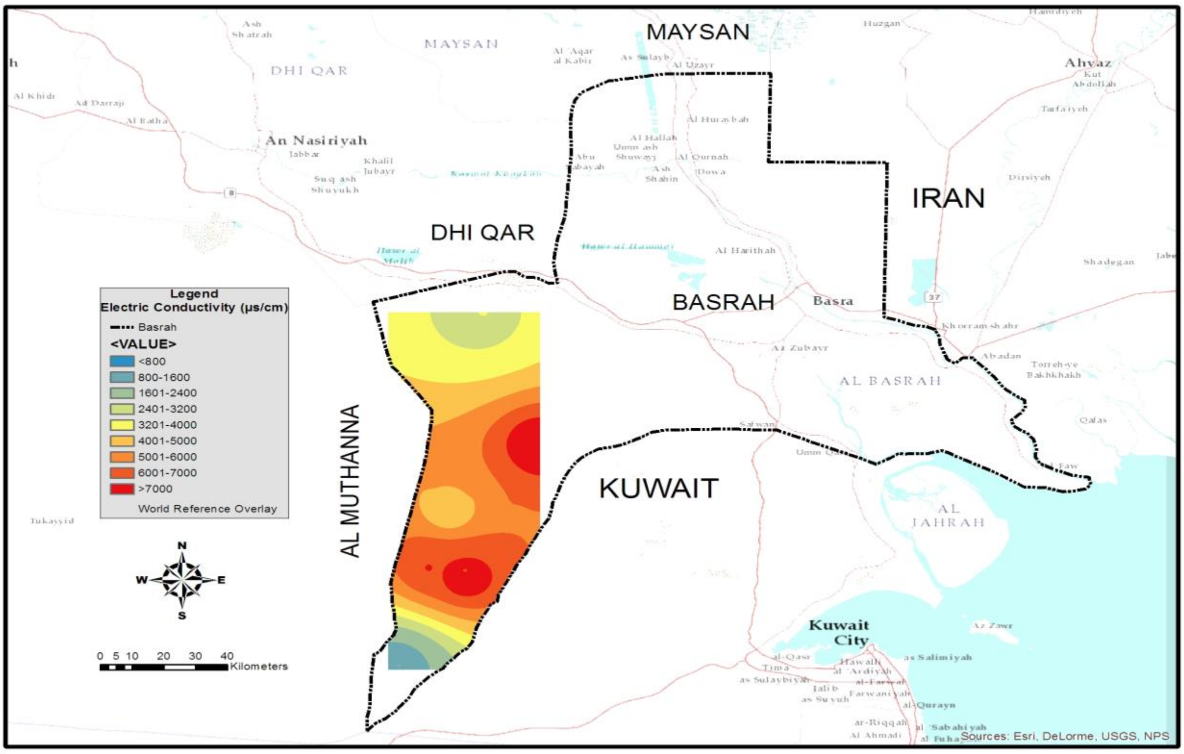


**Figure 4.** Digital map explains the spatial distribution of EC concentrations in the study area

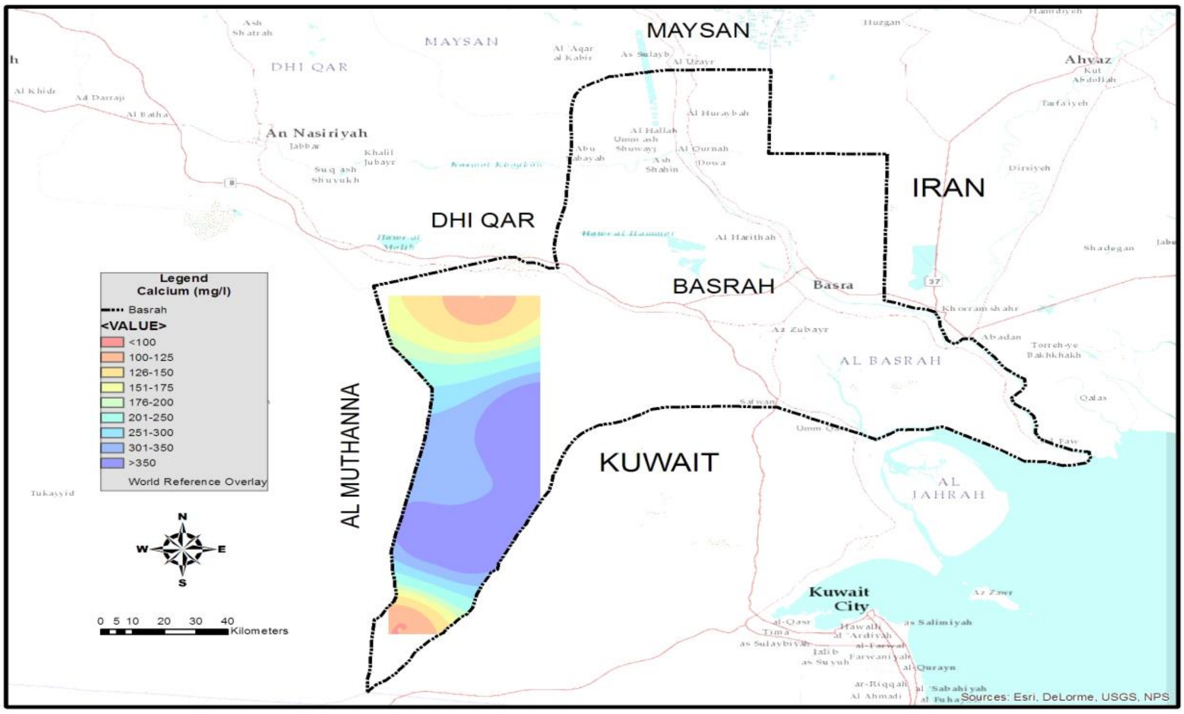


**Figure 5.** Digital map explains the spatial distribution of Ca concentrations in the study area

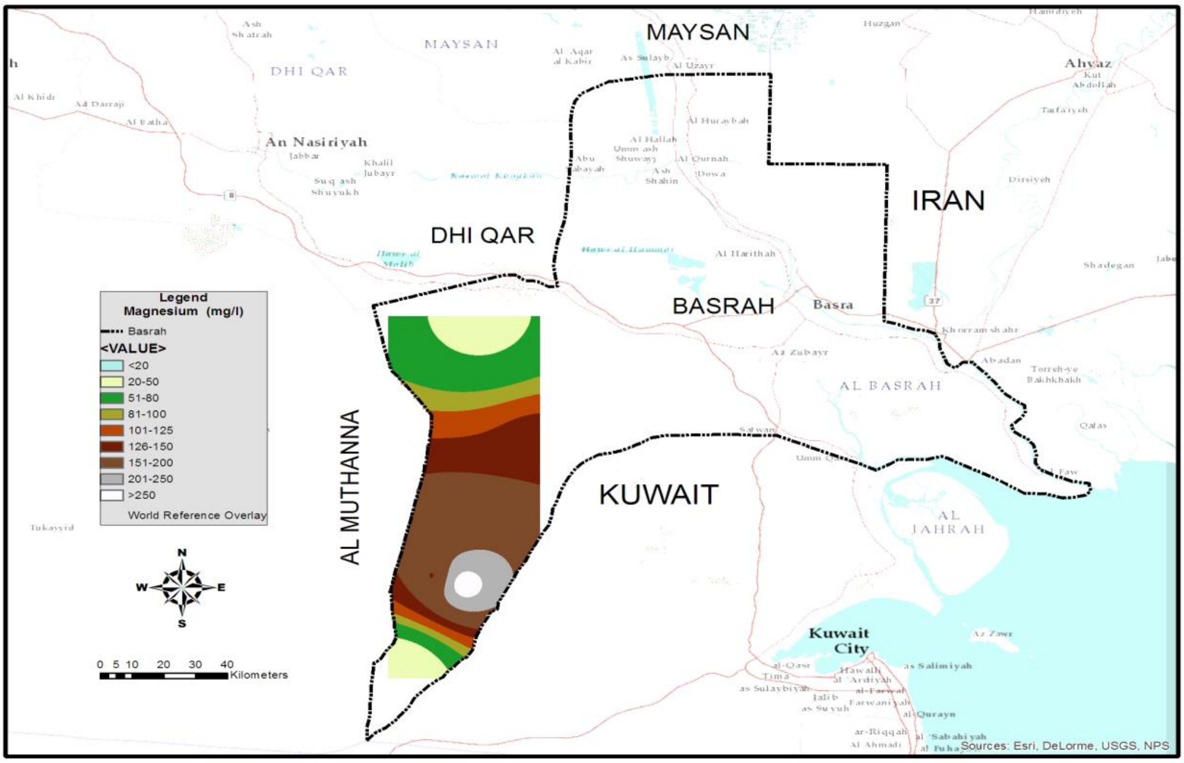


**Figure 6.** Digital map explains the spatial distribution of Ca concentrations in the study area

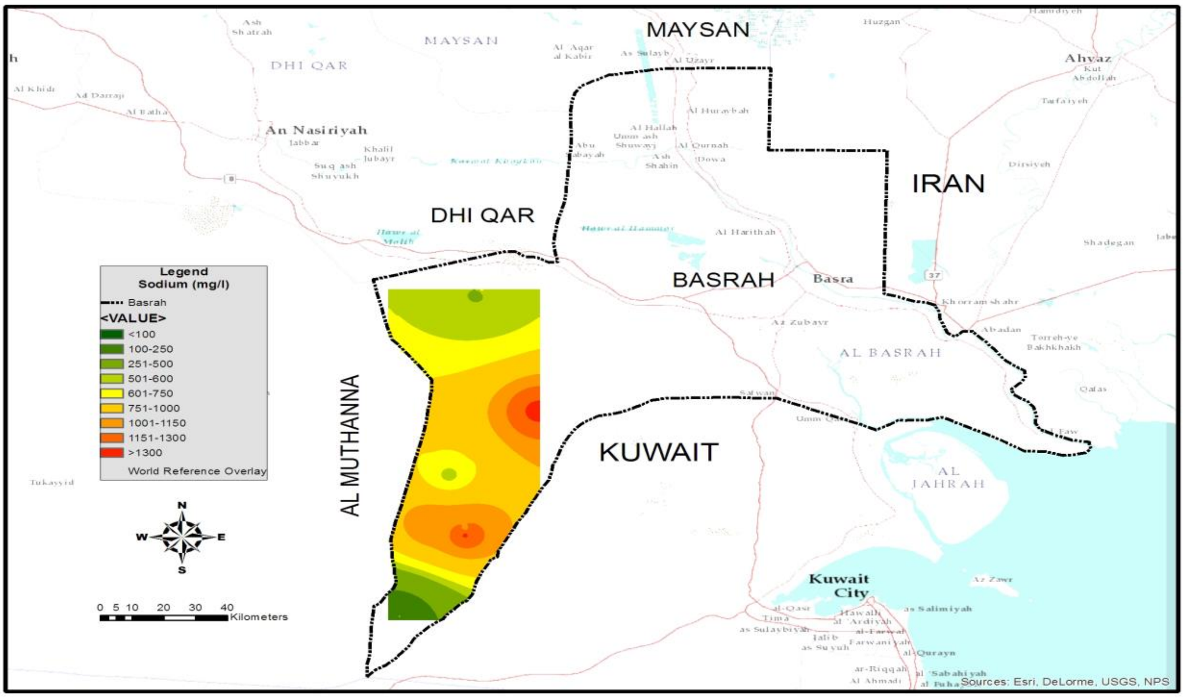


**Figure 7.** Digital map explains the spatial distribution of Na concentrations in the study area

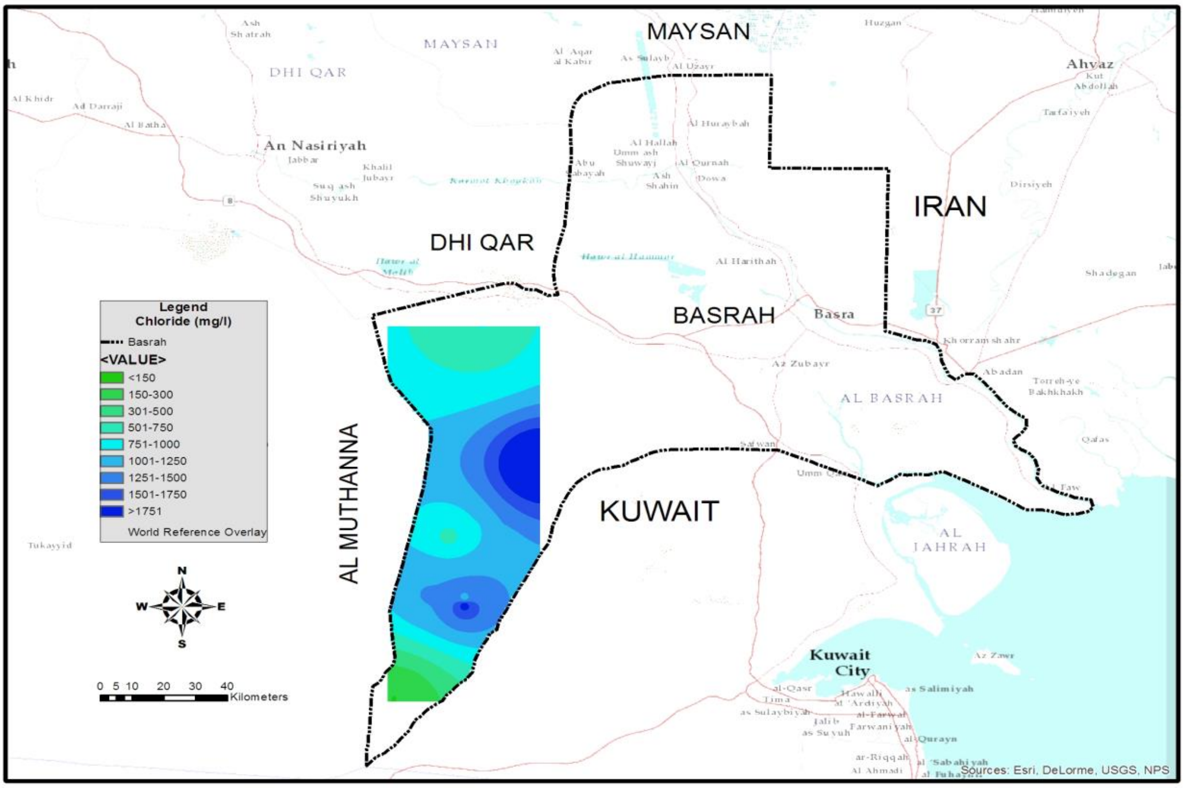


**Figure 8.** Digital map explains the spatial distribution of Cl concentrations in the study area.

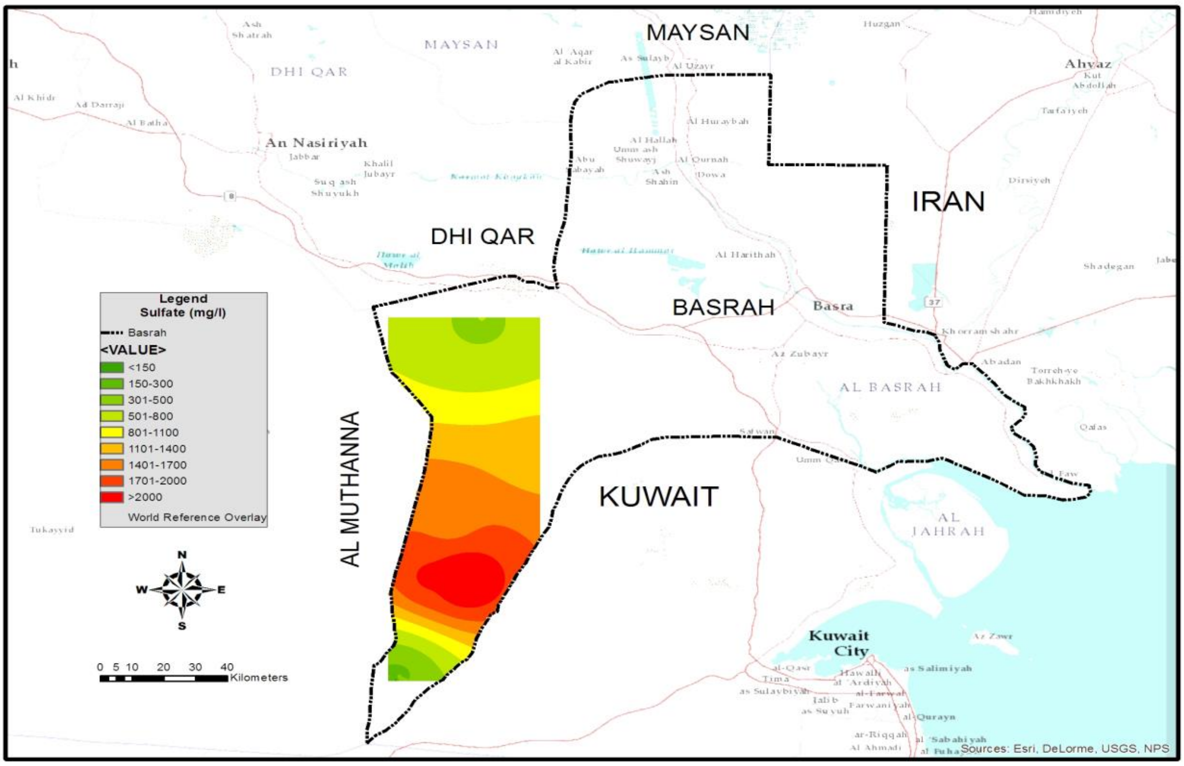


**Figure 9.** Digital map explains the spatial distribution of $SO_4$ concentrations in the study area

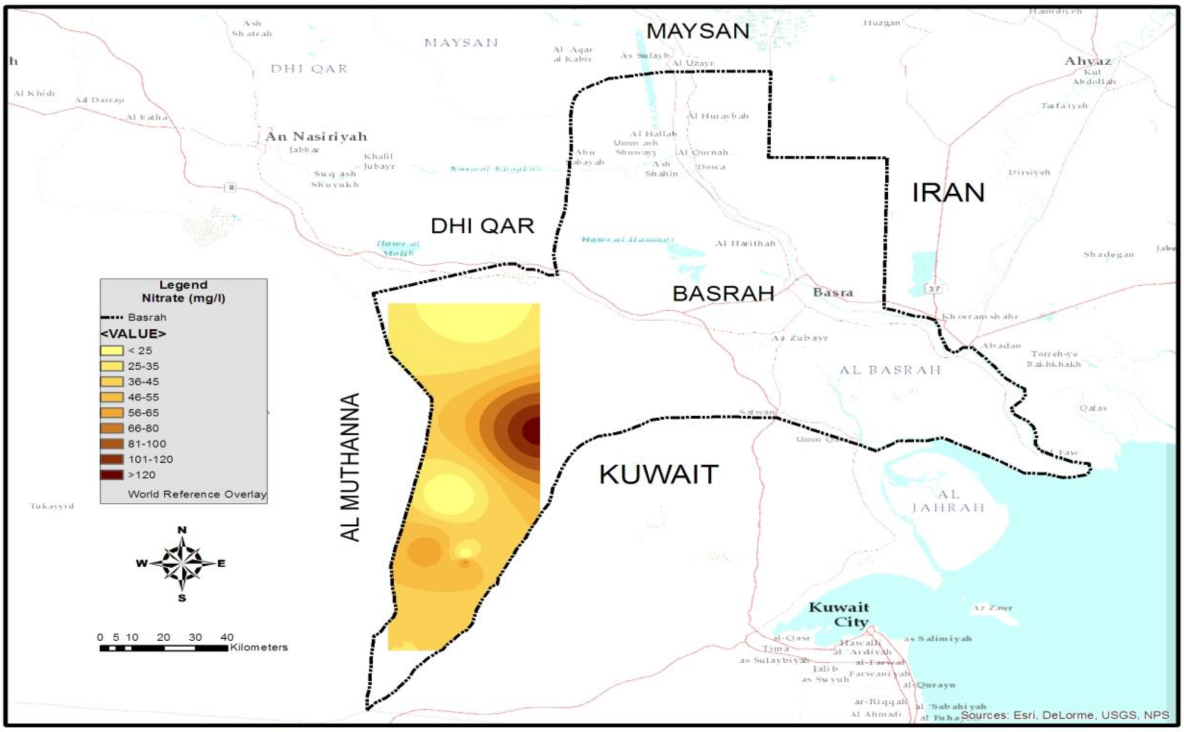


**Figure 10.** Digital map explains the spatial distribution of $NO_3$ concentrations in the study area

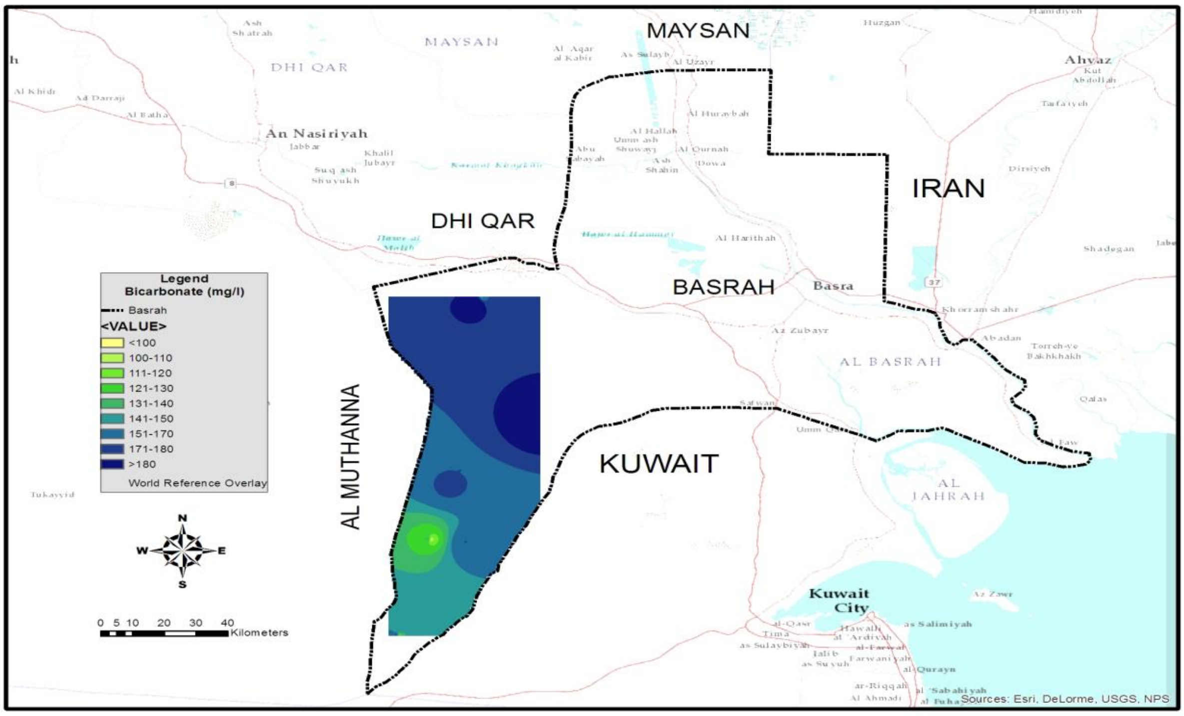


**Figure 11.** Digital map explains the spatial distribution of $HCO_3$ concentrations in the study area

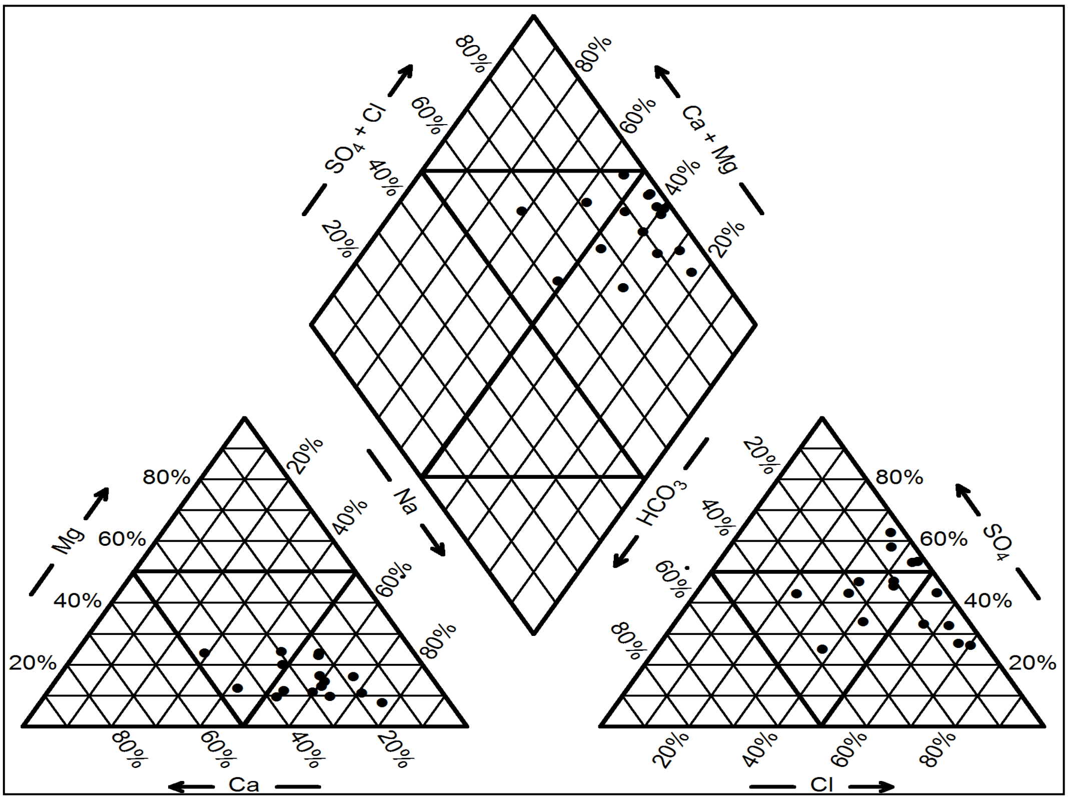


**Figure 12.** Piper diagram for groundwater samples in the study area.

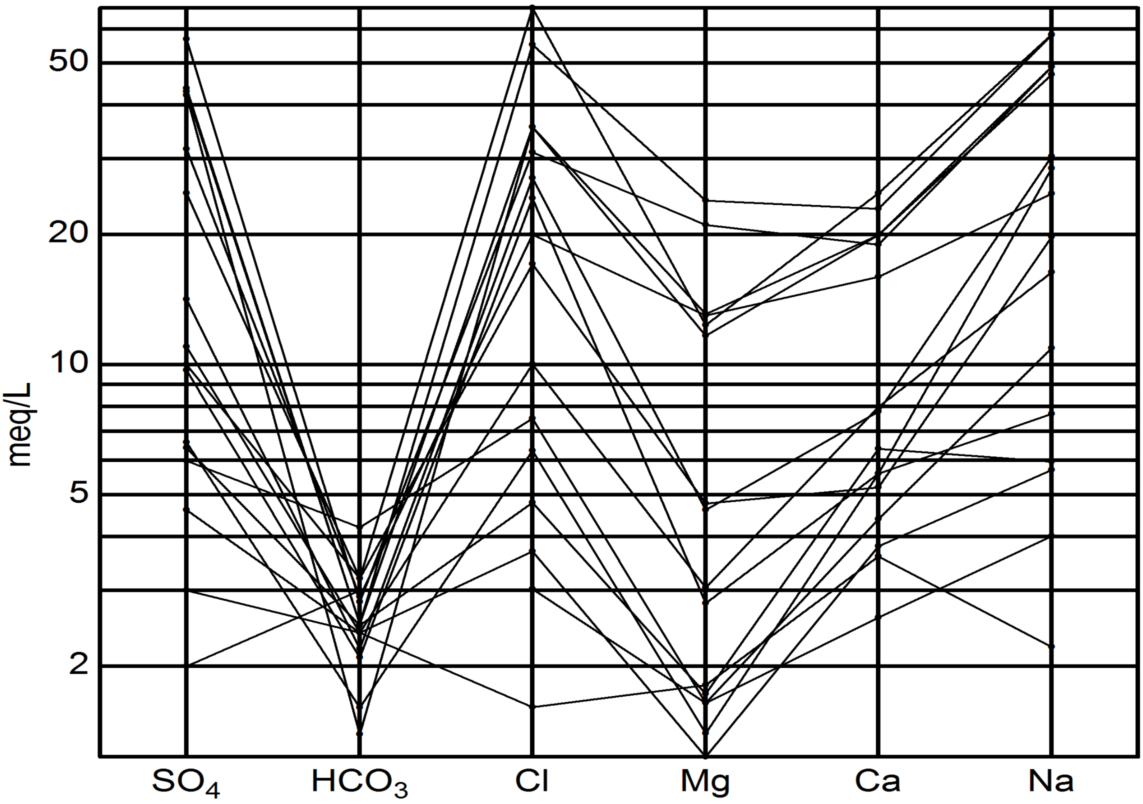


**Figure 13.** Schoeller diagram for groundwater samples in the study area.