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تحليل توزيع جودة المياه الجوفية في مدينة سبها باستخدام نظم المعلومات الجغرافية

Analysis of The Distribution of Groundwater Quality in Sabha City Using the Geographic Information System

مبروكة محمد ضو
الهادي رمضان علي
Mabroka Mohamed Daw
Elhadi Ramadan Ali

جامعة سبها
University of Sabha

mabr.mohamed6@sebhau.edu.ly
0000-0001-6873-4914
e.abdulhadi@wau.edu.ly
0009-0008-9940-5310

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الملخص

تقوم هذه الدراسة بتقييم التوزيع المكاني لمعايير جودة المياه الجوفية وتحديد الأماكن ذات الجودة الأفضل للشرب في مدينة سبها بليبيا. تعتمد هذه الدراسة على التحليل المكاني المتكامل للمتغيرات الفيزيائية والكيميائية للمياه الجوفية باستخدام نظام المعلومات الجغرافية (GIS) وحساب مؤشر جودة المياه (WQI). يتم استخدام نظم المعلومات الجغرافية في هذه الدراسة لتقييم التوزيع المكاني لجودة المياه الجوفية وتحديد المواقع داخل منطقة سبها ذات نوعية المياه الجوفية الصالحة وغير الصالحة للاستخدام. تعتمد نتائج هذه الدراسة على المعايير الفيزيائية والكيميائية التي تم الحصول عليها من الدراسة الميدانية، وذلك باستخدام نظم المعلومات الجغرافية والمسافة العكسية المرجحة (IDW). وتوصل البحث إلى أن غالبية عينات المياه التي تم فحصها تجاوزت توصيات منظمتي الصحة العالمية والليبية ونتيجة لذلك، أصبحت نوعية المياه في هذه المنطقة سيئة، حيث إن 85 % من العينات التي تم جمعها كانت ملوثة وتتطلب معالجة خاصة قبل استخدامها. وتوصي الدراسة بالاهتمام بمصادر المياه الجوفية في منطقة الدراسة حيث تبين أن بعض المواقع بها تركيزات تتجاوز بكثير معايير منظمة الصحة العالمية والمواصفات الليبية لمياه الشرب.

الكلمات المفتاحية: المياه الجوفية، التباين المكاني، الخصائص الفيزيائية والكيميائية، استخدام الأراضي، نظم المعلومات الجغرافية.

Abstract

This study assesses groundwater quality parameters' spatial distribution and identifies places with the best quality for drinking in the Sabha city of Libya. The study based on integrated spatial analysis of physical-chemical parameters using Geographical Information System (GIS) and Water Quality Index (WQI) calculation. GIS is utilized in this study to evaluate the spatial distribution of parameters for groundwater quality and identify sites within the Sabha area with useable and unusable groundwater quality. The findings of This study are based on the physicochemical parameters obtained from the field study, using GIS and Inverse Distance Weighted (IDW). The research found that most water samples examined had amounts that exceeded the World and Libyan Health Organizations' recommendations. Since a result, the water quality in this area is poor, as 85 percent of the collected samples were contaminated and required special treatment before being used. The study recommends that attention be paid to the groundwater resource in the study area because some of the locations were found to have concentrations far exceeding the WHO and Libyan drinking water standards.

KEYWORDS: Groundwater, Spatial Variation, Physic-Chemical Parameters, Land Use, Geographic Information System

Introduction

Water is an abundant natural resource but critical for the survival of all living organisms. For various well-known factors, groundwater is crucial for society (Chowdhary et al., 2020). The capacity to supply a direct healthy source for drinking water, agricultural, industrial and domestic purposes is one of the most significant reasons (Malthess, 1990). Pure water contains only the water's essential chemical elements, such as chloride, sodium, nitrate, and so on. Drinking water typically contains minerals such as calcium, magnesium, and sodium, which are derived from its source, treatment, storage facility, distribution, and household plumbing conditions. These minerals and elements are typically found at very low concentrations and pose no significant risk to health.

Unfortunately, pollution-prone groundwater is becoming increasingly vulnerable to manmade pollution sources, including urbanization and its associated activities, which is a major factor influencing the quality of groundwater systems (Calder et al. 1993; Appelo & Postma, 2005). Anthropogenic activities such as indiscriminate waste disposal, the spread and use of pit toilets and septic tanks, agricultural activities, industrial effluents, siltation, toxic and thermal pollutants, and so on place significant strain hydrogeological systems on both temporal and spatial scales. The pathway consists primarily of contaminants being introduced into the underlying aquifers.

The environment of Sabha, a Libyan province, is characterized by natural and manmade problems resulting from the unregulated chromogenic activity and rapid land use and cover changes, which result in desertification, erosion, induced soil sterility, and degradation. Through such activities, which are necessary for life, groundwater becomes contaminated with heavy metals and toxins. If uncontrolled, this situation will result in poor water quality, which is hazardous to human and animal health. It becomes imperative. Therefore, that groundwater quality is assessed periodically for possible quality standardization using the GIS method. As a result, based on an integrated spatial analysis of physical-chemical parameters using a Geographical Information System and the calculation of the Water Quality Index, this study aims to assess groundwater quality parameters' spatial distribution and identify places within the study area with the best quality for drinking. Research, analysis, and groundwater explorations for sustainable management have increased in recent decades. The Geographic Information System (GIS) has been extremely useful in determining the spatial distribution of anthropogenic groundwater contamination.

Literature Review

Water quality is determined by established physical and chemical parameters closely related to the intended use of the water (Akujieze et al., 2003; Babiker et al., 2007If it does not match these requirements, it must be treated before being used (Cordoba et al., 2010). In the last century, extreme human activities, including industrialization, urbanization, mining, agriculture, and others, have resulted in distinct and obvious changes to the water quality in many landscapes (Bronstert, 2007). Growing populations have been under pressure for a greater need for food, fodder, and fuel. In contrast, industrial activity in an emerging country, Libya, has led to significant changes in land usage patterns.

Hepatitis, dysentery, typhoid, and other diseases have been linked to drinking groundwater contaminated by septic tank seepage. Poisoning can be caused by toxins that have leached into well water supplies. Contaminated groundwater, on the other hand, could affect wildlife. Some malignancies can develop due to drinking dirty water, and there are additional long-term risks (Trevisan et al., 2003). Contaminants in water supplies have remained a major environmental problem in many parts of the world, particularly in developing countries like Libya, where some people are still without safe drinking water (Ijeh & Onu, 2013; Brika, 2019). Low-income areas are the most vulnerable to the effects of poor water quality because they rely on untreated groundwater for home and agricultural purposes and often lack the infrastructure to monitor water quality and execute mitigation efforts (Ayoko et al., 2007; Fayomi et al., 2019; Ali, Hasan & Alharbi, 2020**).**).

The Study Area

Sabha is a district in the southwest of Libya in the Fezzan region. The capital city of Sabha, which is situated at 27.04 latitude and 14.43 longitude (Figure 1), stands at 421 meters above sea level (Pradhan, Moneir & Jena, 2018). Sabha spans around 17,066 sq. km and the district of Sabha borders on the districts of Al-Shati valley to the north, the Al-Jufrah to the east, the Murzuq district to the south, and the Al Hayat Wadi to the west (Abulugmah & Algaziry, 1995).

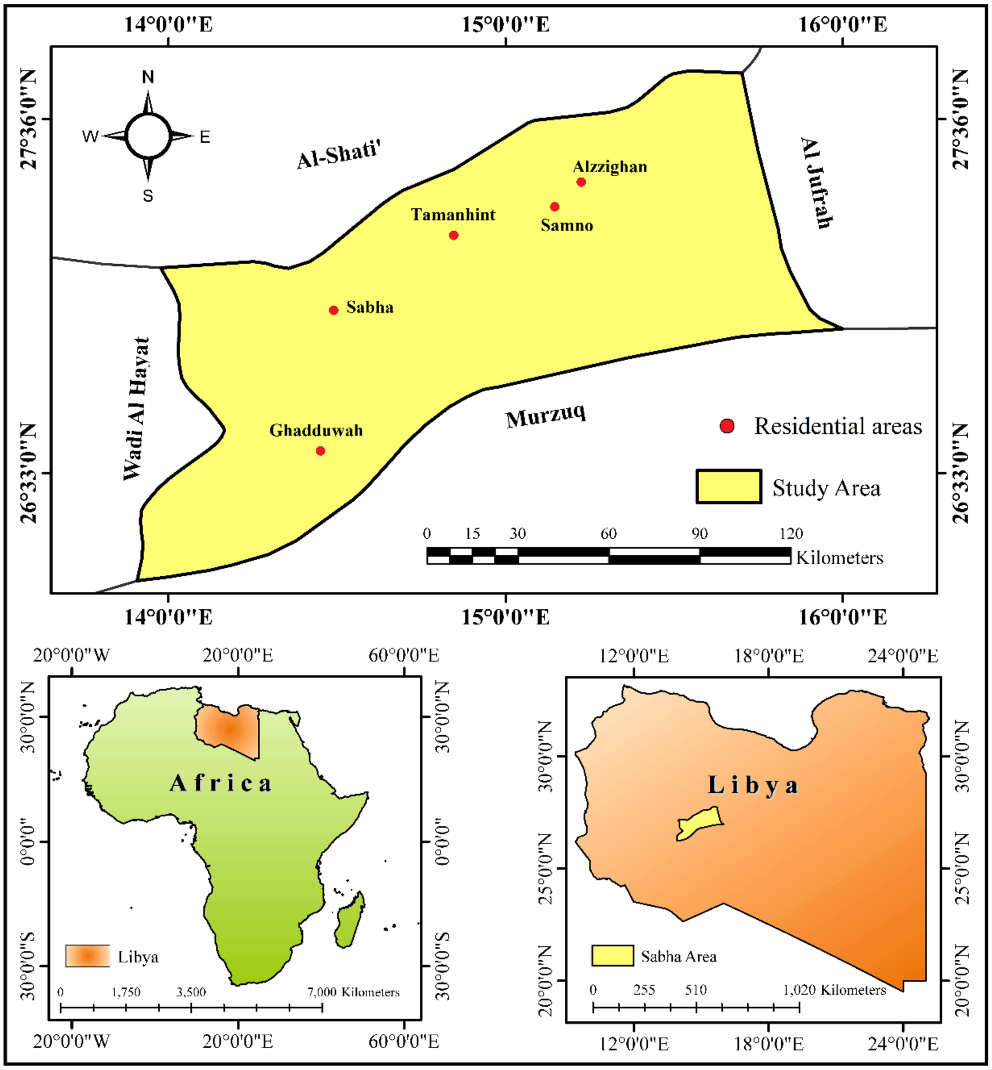

Figure 1. Map of the study area

Sabha district is the first city in the Fezzan region in terms of population; it had only about 28,714 inhabitants in 1973; in 1984, the figure reached 70,905 persons. This number reached 111,795 persons in 1995, rising to a total of 133,254 in 2006 and 154,441 persons in 2018. Population growth is the most important element that causes huge pressure on environmental resources; also, population growth causes deterioration among these resources. At the same time, when the population increases, the pressure on agriculture increases.

Sabha is located in the southwestern part of Libya and occupies the northern part of the great Sahara region. This affects the climate as there are only two seasons, winter and summer. The lowest monthly temperature is "January", with maximum temperature averaging at 18.8˚C. The temperature begins to rise gradually until it reaches the maximum in "July" at 39.4˚C. The average annual rainfall is not more than 0.5 mm3 per year; the highest average monthly rainfall ever recorded in the study area was 15.7 mm3 in March 1995.

The study area is one of the driest areas, and the highest average relative humidity was recorded in January at 48.6%. The monthly average of evaporation reaches 9.6 mm. It reaches its maximum in June when the average evaporation reaches 23.7 mm. The lowest monthly average of evaporation is in January. The rate reaches 6.7 mm, and the annual rate is 15.8 mm. From the above, it is clear that the region's climate is continental, namely hot, dry, dry summer, and cold winter, in which during the dry season, the humidity is relatively low. The rate of evaporation increases dramatically, especially in the summer (Abdulhadi, 2009).

The soils in the study area are considered from the soils of special areas, and they fall into two ranks, namely soils of newly formed "Entisols" and dry soils "Airdisols". These soils suffer from many problems in the study area, as they are characterized by an apparent rise in percentages of sand in the soil, which is offset by a decrease in the percentage of clay, in addition to the drought that leads to a decrease in the ability of these soils to retain moisture.

Methods

This section focuses on the materials and methods employed in collecting, analyzing, and presenting the various data used in the study.

Types and Sources of Data: GPS data of certain locations in the Sabha area were collected during fieldwork with the aid of the GPS (Etrex Garmin Version 16.0). GPS was used to capture the coordinates and altitudes of borehole water sampling points in the area to assess the undulating nature and elevation of Sabha and its environment. Datasets of the physicochemical parameters of the sampled boreholes from different locations in Sabha were acquired from analyzing the samples collected in the laboratories of Sabha University.

Methods of Data Collection: The major data given above was gathered through fieldwork and the use of a hand-held GPS to coordinate some of the research area's positions. This was used to create a map of the study region that included the sampling points. Polythene bottles were used to collect well water samples that were free of air bubbles. To achieve the results, the data analysis stage was completed after the data collection stage. The gathered water samples were analysed chemically and microbiologically at Sabha University's central laboratory and the General Company's Central Laboratory of Water. The results were then compared to water standard criteria from around the world and in Libya. Samples were examined for 13 parameters and the date and time of collection were recorded. A Hanna auto-ranging microprocessor EC/TDS/°C metre was used to test the water's electrical conductivity, temperature, and total dissolved solids on the spot. The pH was measured using a Beckman pH meter; the other water parameters were analyzed in the laboratory. Total alkalinity, total hardness, and chloride were determined using the Hanna freshwater analysis kit following the APHA (1989) procedures. The Hanna multiparameter bench photometer was used to analyze the other water parameters. Electrical connection (EC), pH, Total Dissolved Salts (TDS), Magnesium (Mg++), Sodium (Na), Potassium (K), Chlorides (CI), Total Hardness as Ca Co3 (TH), Nitrate (No3), Sulfate (So4), Calcium (Ca++), Phosphate (PO4), and Iron (Fe), are the parameters studied and methods used (listed in brackets). They were calculated using the values of various water parameters as a comparison, with the hardness of water as a reference (Srinivas et al., 2000).

Data Analysis Instruments: To meet the study's goals, the following devices and software were used: 10.0 ArcGIS: To construct the study area map, ArcMap was used to vectorize and digitize the photos. The personal geo-database was created with ArcCatalogue, and the overlay was done with a shapefile. Aside from that, Microsoft Office Word and Excel 2013 are examples of supplementary software.

Data Analysis Methods and Geographic Information System: Geographic Information System (GIS) and Remote Sensing techniques were used to model the spatial distribution of the physicochemical parameters. The location of each sampled borehole was mapped using GPS, and the findings of each of the parameters examined were then added to the attribute of the corresponding coordinate. In this study, the spatial analysis tool in ArcMap of ArcGIS was used. The spatiotemporal behavior of groundwater quality parameters was determined using an extended spatial analysis model. The various thematic layers on pH, conductivity, total dissolved solids, salinity, nitrate, phosphate, and other concentrations were created using an Inverse Distance Weighted Interpolation technique (IDW). In the current study, this contouring method was used to delineate the locational distribution of the water parameters. This method estimates the value of the cell grid with a set of sample points defined or selected. The cell values are calculated using a linear weighted combination of a set of sample points and by controlling the importance of known values based on the distance from their output point and the generation of a surface grid. Groundwater quality classification maps for thematic layers' parameters are based on WHO and Libya drinking water standards, as shown in Table 1.

Table 1 Drinking water standards

Parameters	Ratings
PH	< 6.7- > 9.2
TDS	> 1000
EC*	100
Mg	>150
Na	>100
K	>12
Cl	>150
TH	>500
No3	>10
So4	>150
Ca	>200
Po	>0.1
Fe	>0.030
PH	> 9.2

Libyan drinking water standards 2016, *WHO 2006

Results

The following results are reported for the physicochemical examination of groundwater samples collected. A study area quality assessment was made using water samples collected from 36 randomly selected boreholes from the research region. The samples were examined for chemical quality, and the results were acquired from Sabha University’s laboratories. This data was processed geospatially to create quality maps of groundwater exhibiting spatial variations in the electrical conductivity, sulfate, phosphate, total dissolution solids (TDS), salinity, and nitrate.

These parameter maps permit rapid evaluation of their relative concentrations of variation in the groundwater quality of the different locations within the study zone. Inverse Distance Weighted (IDW) Interpolation maps of the above-stated parameters' spatial variation were also developed.

Total Dissolved Solids Concentration

TDS levels in groundwater are generally not detrimental to human health. However, persons with renal and cardiovascular problems may be affected by excessive TDS levels. Constipation or laxative effects may be caused by drinking a lot of solid water (Ramakrishnaiah et al., 2009). Most groundwater samples in the study location have moderate TDS concentrations ranging between 640 mg/L and 1300 mg/L. The TDS content was higher than the permissible limit in 32.3% of the samples. The highest concentration of TDS values that exceeded the permissible drinking water limit was observed in the north-western part with 5500 mg/L and some scattered areas in the north and south-west of the region (Figure 2). TDS levels are likely to be high due to wastewater pollution in pits, ponds, and septic tanks, which travel down the water table (Nair et al., 2006). The increase in TDS concentration in groundwater in most sections of the region, on the other hand, could be attributed to increased withdrawal of water and a lack of rain, resulting in a lack of water (Taira, 2004).

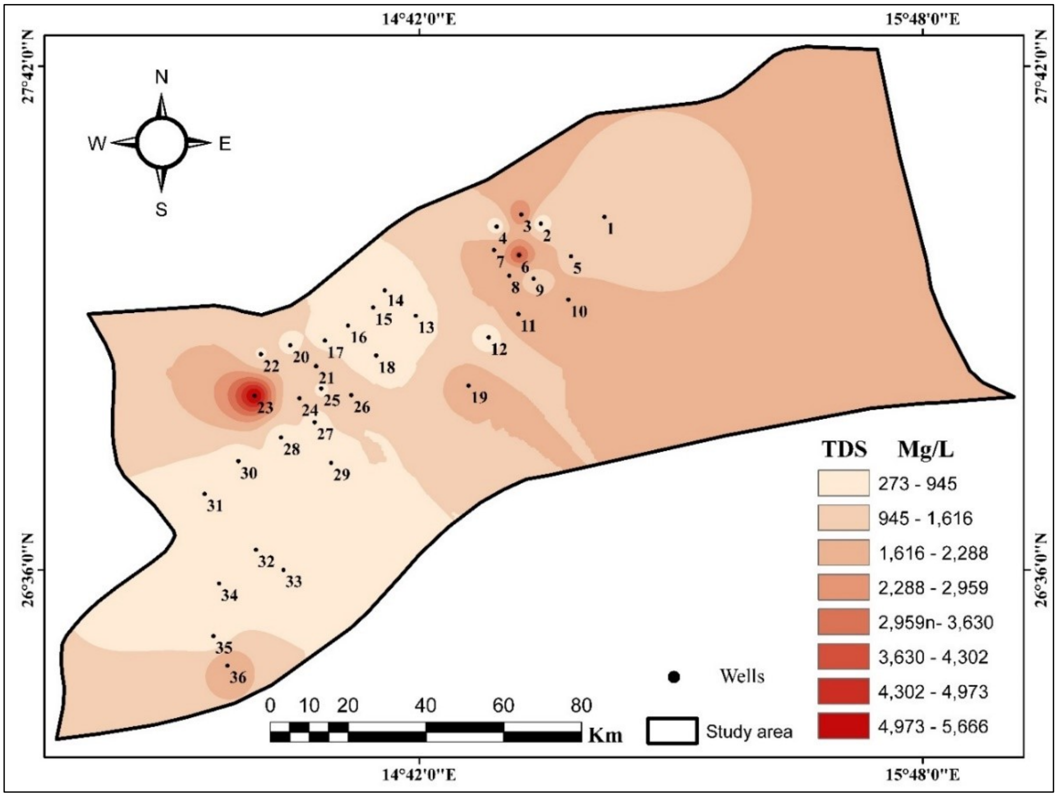

Figure 2: Spatial variation in total dissolved solids of the water sample in the area

Electrical Conductivity

The map of the spatial variation of Electrical Conductivity is shown in Figure 1. The conductivity of a sample reflects how salt-free, ion-free, or impurity-free it is; the lower the conductivity, the purer the water (the higher the resistivity). Water's electrical conductivity (EC) is a TDS-related metric. As a result, the EC serves to measure the overall concentration of dissolvable salts in water (Ramakrishnaiah et al., 2009). The conductivity of pure, salt-free water is low. The importance of EC and TDS stems from their effects on water corrosivity and the solubility of marginally soluble molecules like CaCO2 (Nas & Berktay, 2010). The presence of salts, acids, and alkalis in the water will increase its electrical conductivity. Therefore, this is used to identify the number of dissolved salts in the water (Ghraibh & Al-Frhan, 2000). The highest values of EC are found in the north-western parts in Well No. 22 and the lowest in the east and southwest, as shown in Figure 3. The EC values ranged between about 410 to over 8500 µS/cm.

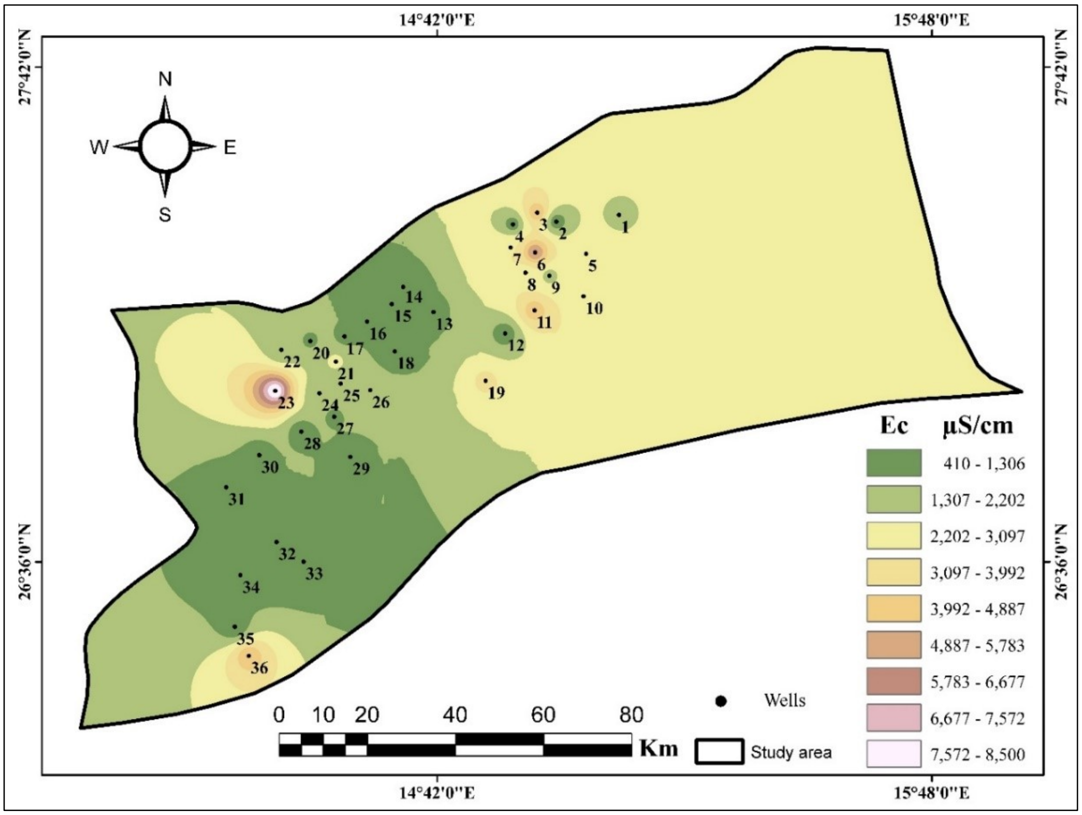

Figure 3. Spatial variation in total electrical conductivity of the water sample in the area

Nitrates Concentration

The NO3 comes from anthropogenic sources such as agricultural fields, domestic sewage, and other waste effluents (Das & Acharya, 2003). The EPA set a maximum contamination level (MCL) of 10 milligrams per liter (10ppm) nitrate-nitrogen in drinking water to provide the best protection to neonates. Nitrate-nitrogen refers to the amount of nitrogen in the form of nitrate. The amount of nitrogen in the form of nitrate is referred to as nitrate-nitrogen. Levels of nitrate more significant than ten ppm may pose substantial health hazards for children and pregnant women. Some people can drink water beyond the normal standards and have no negative consequences. However, levels over this limit are regarded to be potentially dangerous (Chen et al., 2017). In Figure 4, we find that the nitrate rate increases dramatically in the western region at Well No. 31 to reach 176 mg/L. This may be due to the use of agricultural land in the area surrounding the well and the spread of urea fertilizers significantly.

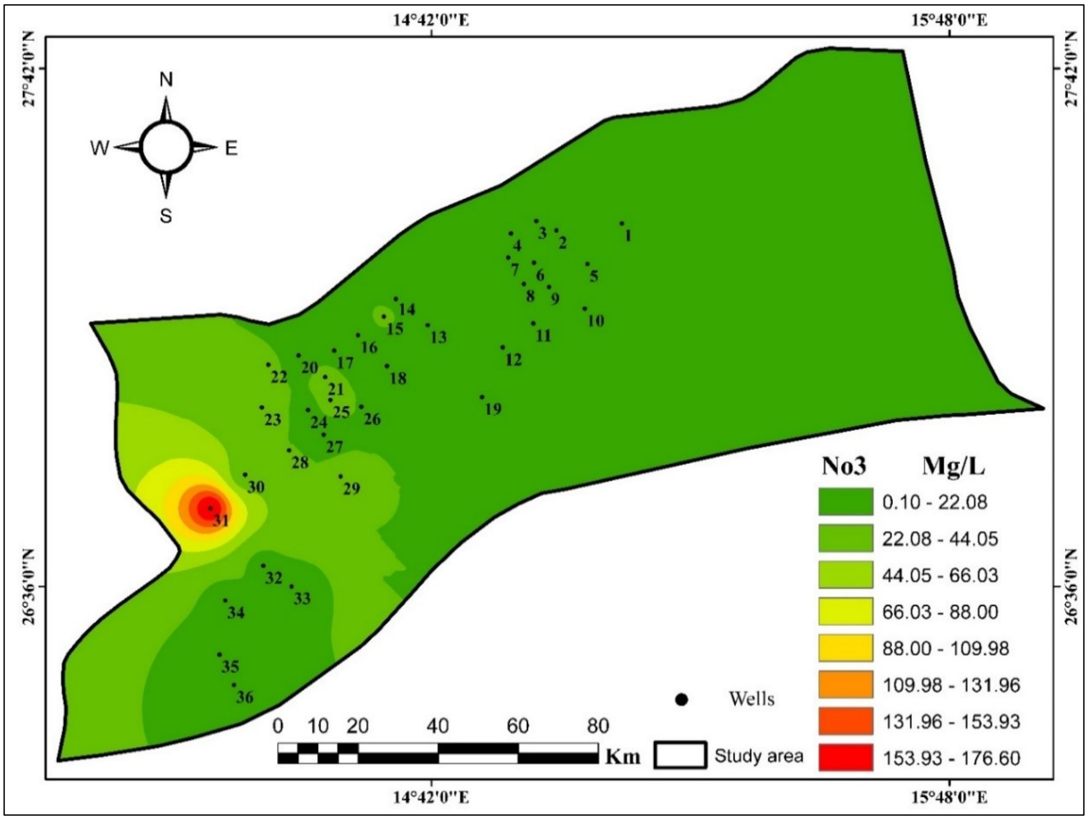

Figure 4. Spatial variation in nitrates concentration of the water sample in the area

Phosphate Concentration

Phosphate is widely used as an agricultural fertilizer and is a critical component of detergents, especially household usage. Phosphorus contributes to surface waters from runoff and sewage discharges (Phillips et al., 2007). PO4 concentrations map (Figure 5) shows that its values range between 0 to 0.5 mg/L. The maximum is concentrated in the middle part, in Well No. 11 near Samano, whereas the lowest concentrations were observed in the southern part of the region. The high concentrations of phosphates can indicate pollution, such as domestic wastewater, industrial effluents, and fertilizer runoff (Yisa & Jimoh, 2010). A high percentage of Po4 was found in the eastern region, with the highest percentage in Well No. 11 in Samno. It reached 0.5 mg / l, followed by Well No. 25 in the Sabha region, which reached 0.2 mg/L. Moreover, the land used near Well No. 11) is agricultural, as irrigated farms are spread in that area, while Well No. 25 is located in Sabha, where sewage water overflows in large areas near the well.

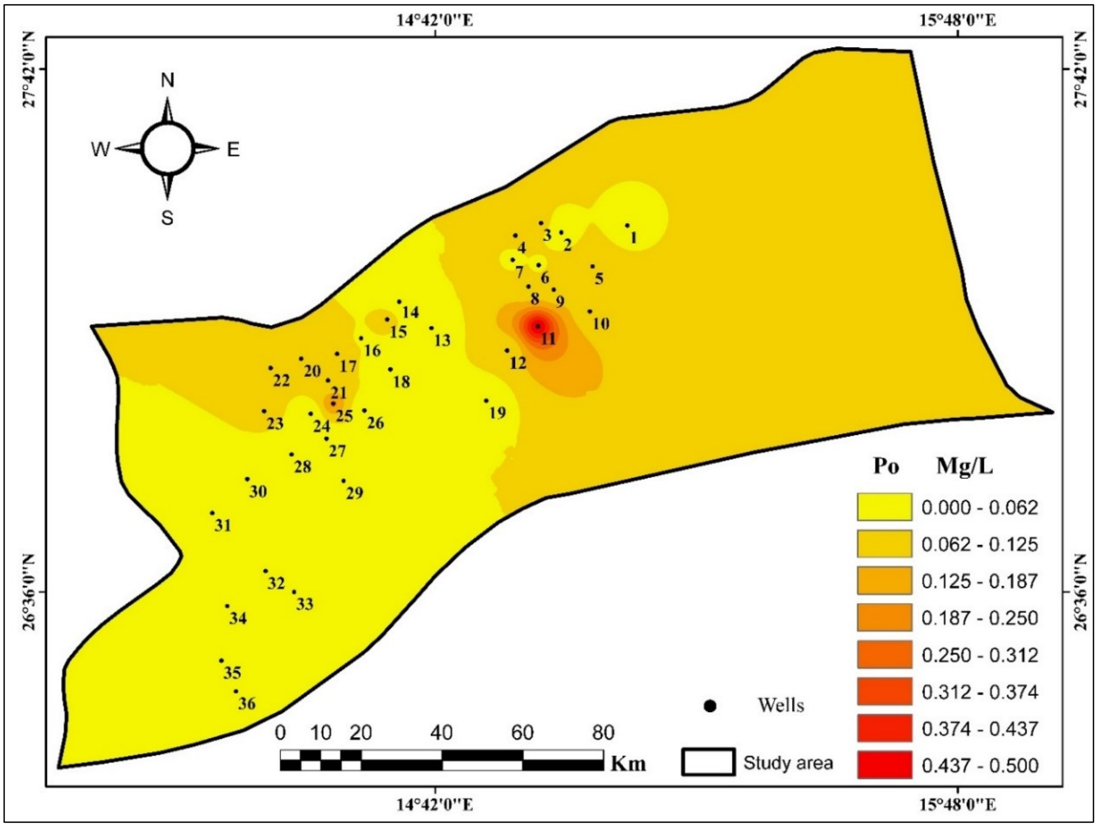

Figure 5. Spatial variation in phosphate concentration of the water sample in the area

Ph Concentration

The pH is the most significant operational water quality measure, although it does not directly affect the customer. The pH should preferably be less than 8.0 for successful chlorine disinfection; nevertheless, lower-pH water is susceptible to corrosion. The desirable pH limit usually ranges from 6.5 to 8.0, safe for drinking (WHO, 2008). The pH of groundwater is influenced by the geology of the catchment region and the water's buffering capability. The pH values in the bulk of the samples in this investigation ranged from 6.2 to 7.5. (Figure 6).

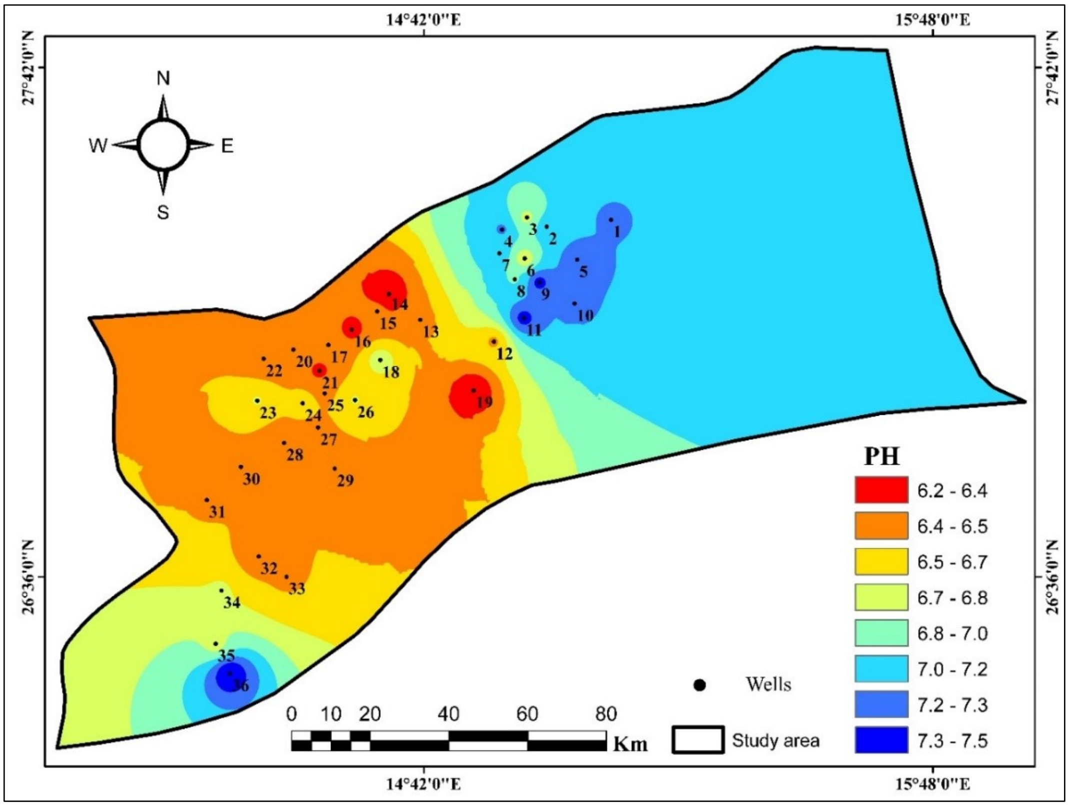

Figure 6. Spatial variation in PH concentration of the water sample in the area

Total Hardness

The dissolved calcium and magnesium salts, commonly stated as the equivalent calcium carbonate quantity, account for the total hardness. Scale deposition can occur when the hardness concentration in the water exceeds 200 mg/liter. Soft waters with a hardness of less than 100 mg/liter, on the other hand, have a low buffering capacity and may be more corrosive to pipes (WHO, 2008). Carbonates, bicarbonates, sulfate, and calcium, and magnesium chlorides are the most common causes of hardness in groundwater (Venkateswara et al., 2009). The spatial distribution of total hardness (TH) in the study area using the stiffness rate ranges from 28-1039 mg / L. Based on Figure 7, the highest rate is found in Well No. 23, reaching 1039 mg/L. It is located in the city of Sabha near the areas where the sewage network floods in the city, and the wells in the next ranks are Wells No. 36, 11, 3, and 6, with values of 956, 955, 905, and 818 mg/L, respectively. They are located in agricultural areas where fertilizers are used in large quantities. Several environmental and analytical research suggest that the hardness of drinking water and cardiovascular diseases have a statistically significant inverse relationship. Some evidence suggests that particularly soft waters can affect the mineral balance (Calderon & Craun, 2005).

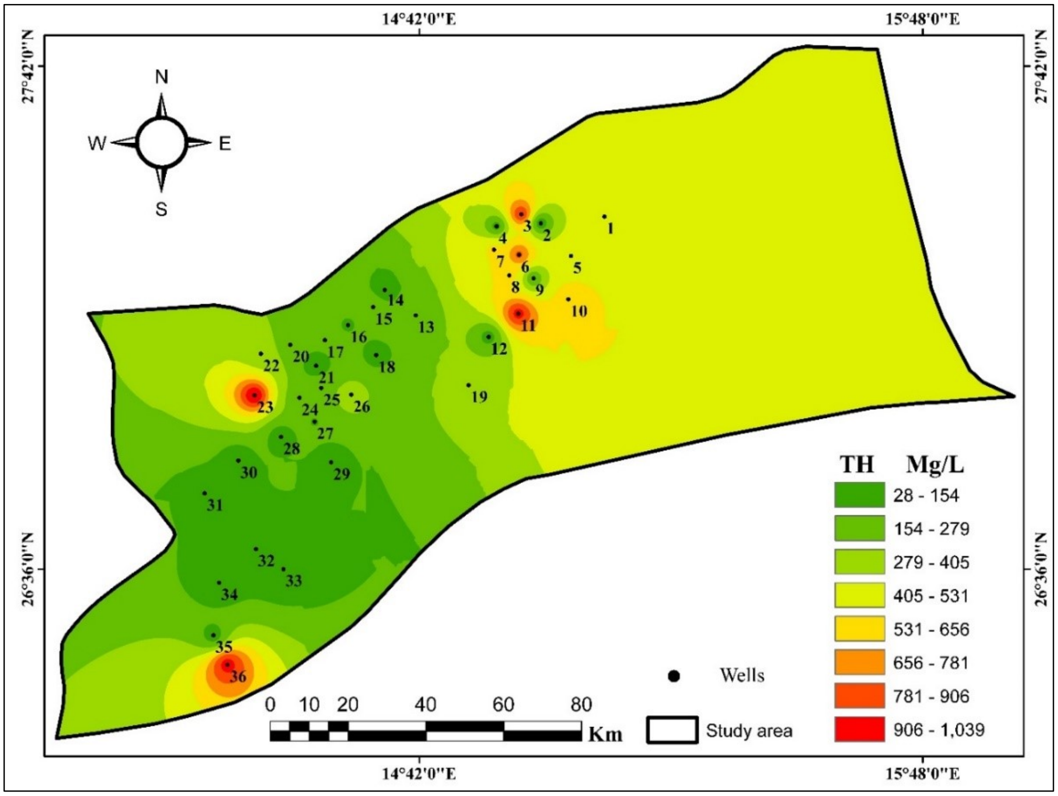

Figure 7. Spatial variation in total hardness of the water sample in the area

Sulfate Concentration

There have been studies on the effects of sulfate in drinking water and anecdotal accounts and case studies that suggest people have gastrointestinal problems after drinking water with high sulfate levels (Backer 2000). The sulfate rate is higher than the permissible limit in the Libyan specifications in 41.6% of the region's wells, and it is less than 150 mg / L (Figure 8). The sulfate rate rises significantly in the eastern part of the Sabha, and the highest levels are in Well No. 4, reaching 2839 mg. Sulfur is a vital fertilizer element such as nitrogen, which requires converting it to a form of "sulfate"; it must be oxidized in the soil for a plant to benefit from it (Degryse et al., 2016). Thus, the excessive use of chemical fertilizers may cause the increase of sulfate in the water of the study area.

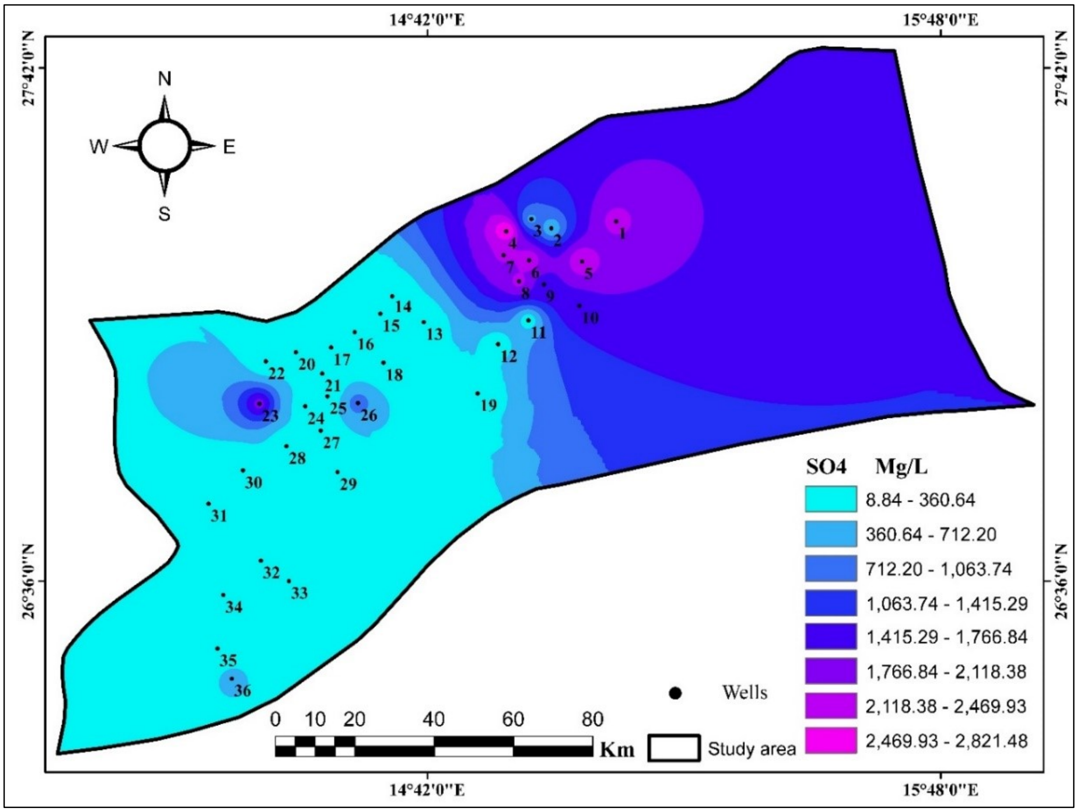

Figure 8. Spatial variation in sulfate concentration of the water sample in the area

Calcium Salts

Calcium salts help the body meet part of its need for building bones and teeth, but they also add to the hardness of the water. Potassium levels that are too high can cause a heart attack or even death. Unfortunately, many people do not realize they have excessive potassium levels until it is too late, and their heart health deteriorates (Thomsen et al., 2018). In the study area, 58.3% of the wells were contaminated with potassium. The Libyan specifications for drinking water are considered less than 12 mg / l as the safe rate for drinking. Based on Figure 9, the most considerable rate of potassium is located in agricultural lands from Wells No. 19, 36, and 11, with a value of 98, 89.6, and 89 mg/L, respectively. Thus, agrochemicals may be the cause of this increase.

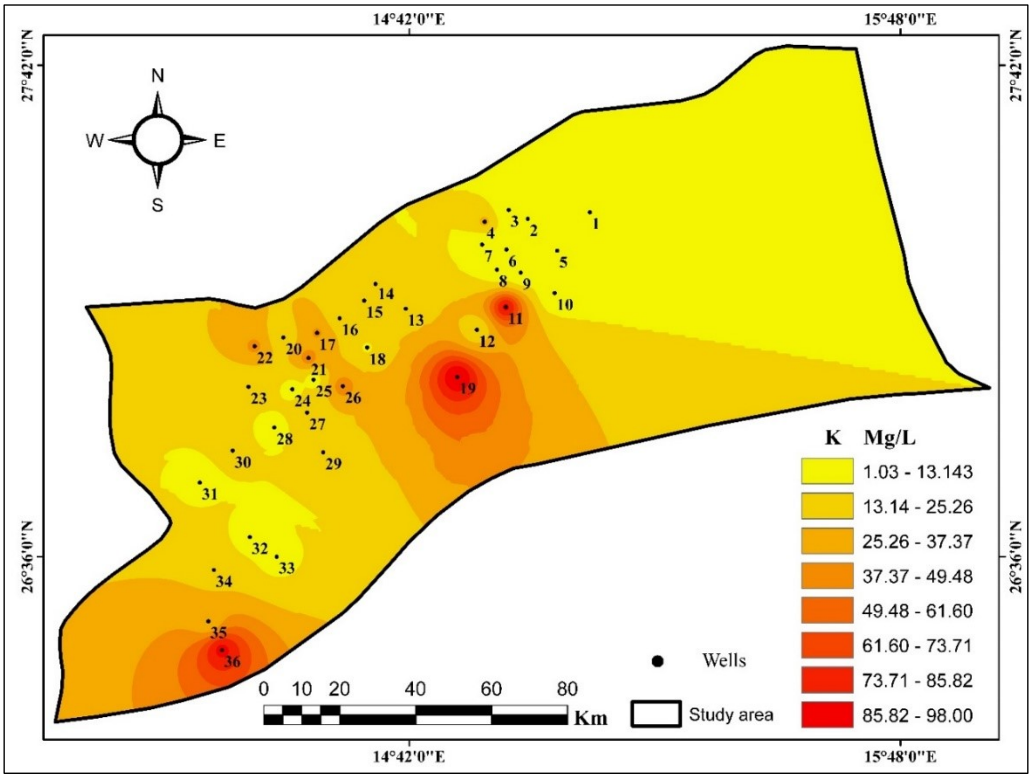

Figure 9. Spatial variation in calcium salts of the water sample in the area

Chlorides

On a wide scale, chlorides can be found in all-natural fluids in various quantities. As the mineral concentration rises, the chloride content rises as well (Nas & Berktay, 2010). The concentrations in the CI ranged from 36 to 2883 mg/L. It was higher than the permissible limit in about 33% of the study samples. The maximum value of CI was observed in the western part of the region (Figure 10). The Libyan National Centre for Standards Specification has set the permissible limit of Cl in potable water from 200 to 300 mg/L. In natural water, concentrations of chloride vary widely, and it is related to the mineral content of the water. As is well known, the surface salty water intrusion is caused by abnormal concentrations of chloride.

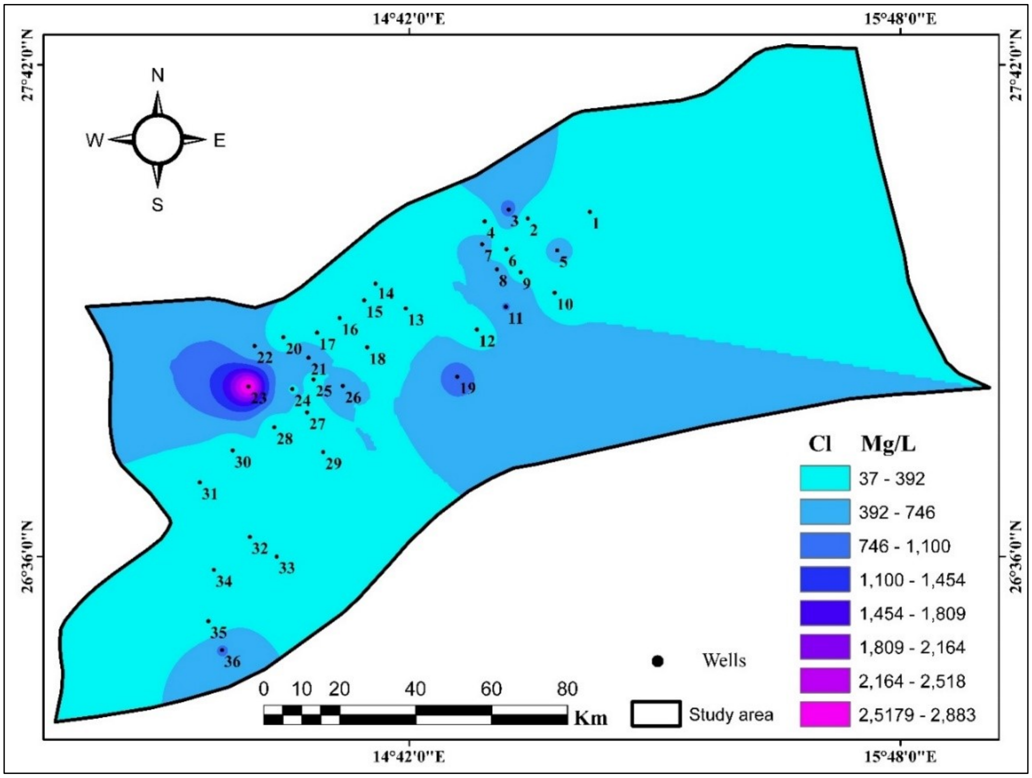

Figure 10. Spatial variation in chlorides of the water sample in the area

Magnesium

Magnesium is widespread and highly nutritional (0.3-0.5 g/day) to humans and is the second primary constituent of total calcium hardness (Environmental Protection Agency, 2001). Our content map (Figure 11) indicates the presence of the highest values in Well No. 23 at about 92mg/L, Wells No. 36 and 12 at 69.7mg/L, and in Well No. 11, it reaches

65 mg/L. Thus, all parameters are within safe drinking limits, estimated at Libyan standards of <150Mg/L.

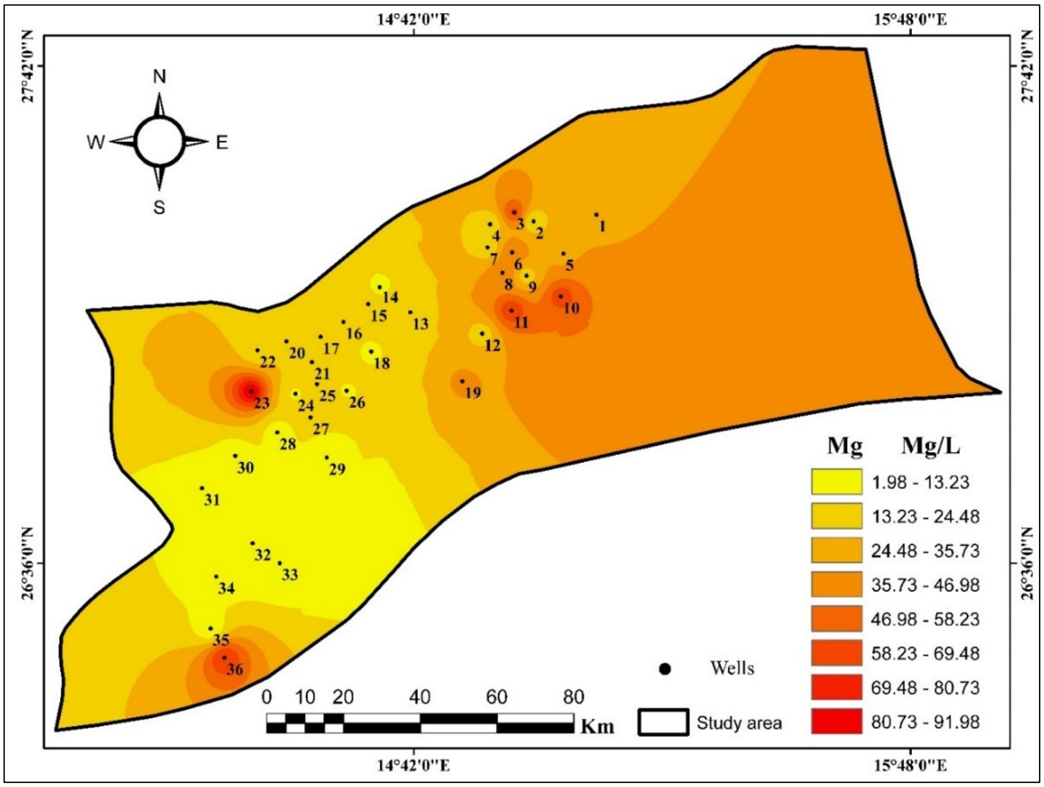

Figure 11. Spatial variation in magnesium of the water sample in the area

Calcium

Calcium is an important and abundant element in the human body that is required for proper growth and health. High calcium levels are beneficial, and calcium-rich water tastes great. Although an abundance of calcium may have health benefits, there are worries about hardness (Santi & Masters, 2001). The Ca++ map (Figure 12) indicates the presence of a higher value also in the northeastern part of the region with a range of 11 - 350 mg/L. In the north central, Well No. 3 reached more than 350 mg/L, and those close to it, namely Wells No. 6, 7, 8, 10, and 11, were at 320, 222, 220, 241, and 265 mg/L, respectively.

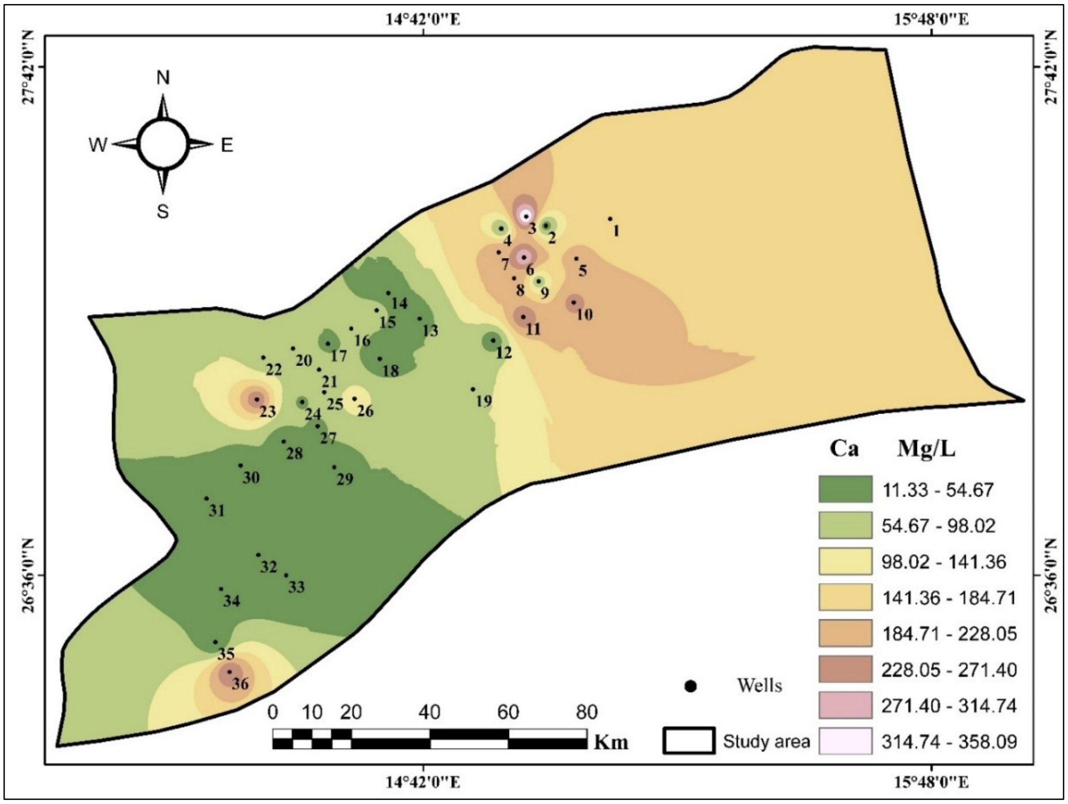

Figure 12. Spatial variation in the calcium of the water sample in the area

Sodium

Sodium is introduced into drinking water by a range of human and natural activities. High sodium levels in drinking water may be damaging to one's health, according to evidence. The amount of salt in drinking water that humans are exposed to should be reduced. According to WHO and Libyan drinking water specifications, the safe percentage of sodium is less than 100 mg/L. The percentage of sodium-contaminated wells is 72.2 percent among all the wells. The highest rates are found in the region's center, at Wells No. 26 and 19, which reached 608 and 400 mg/l, respectively (Figure 13).

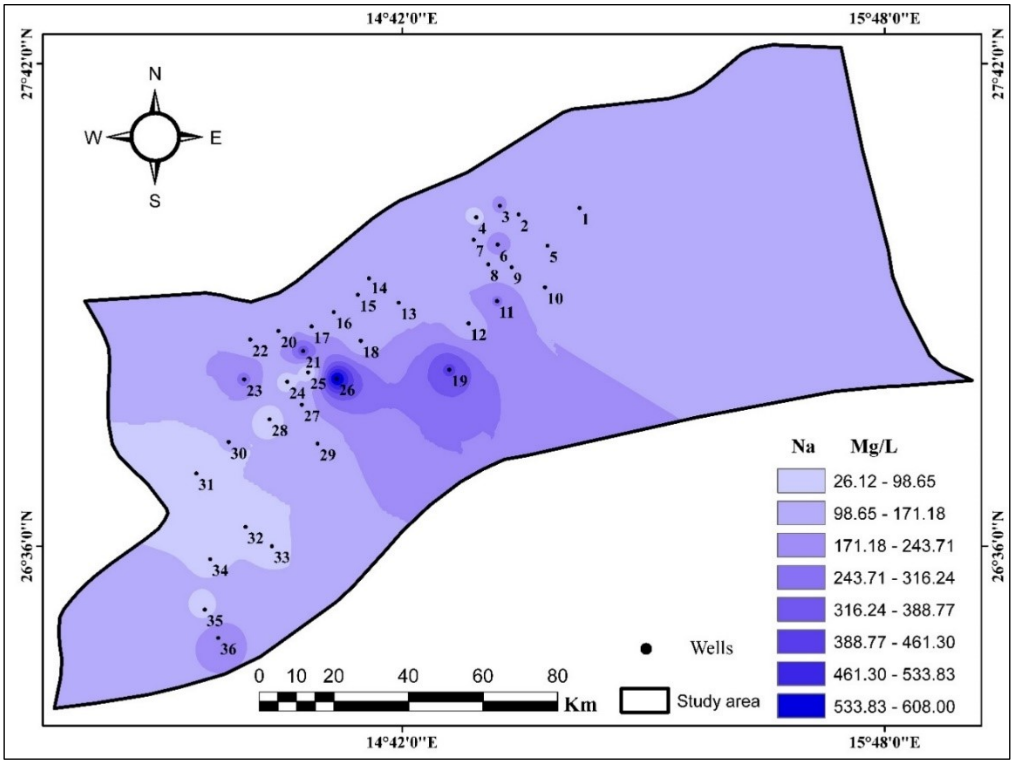

Figure 13. Spatial variation in sodium of the water sample in the area

Iron

Iron can be found in large quantities in soil and rocks, primarily in insoluble forms (Santi & Masters, 2001). Iron is a biologically important element that is required by all living things and is found in hemoglobin. Because of its high concentration, it is slightly toxic (Swarna & Nageswara, 2010). The central and eastern parts of the region have a slightly higher concentration of iron (Figure 14). The Fe concentrations ranged from 0.012 to 6.9 mg/L. We can see that the highest levels of iron are in the eastern region, where it reached 6.9 mg/L in Well No. 9.

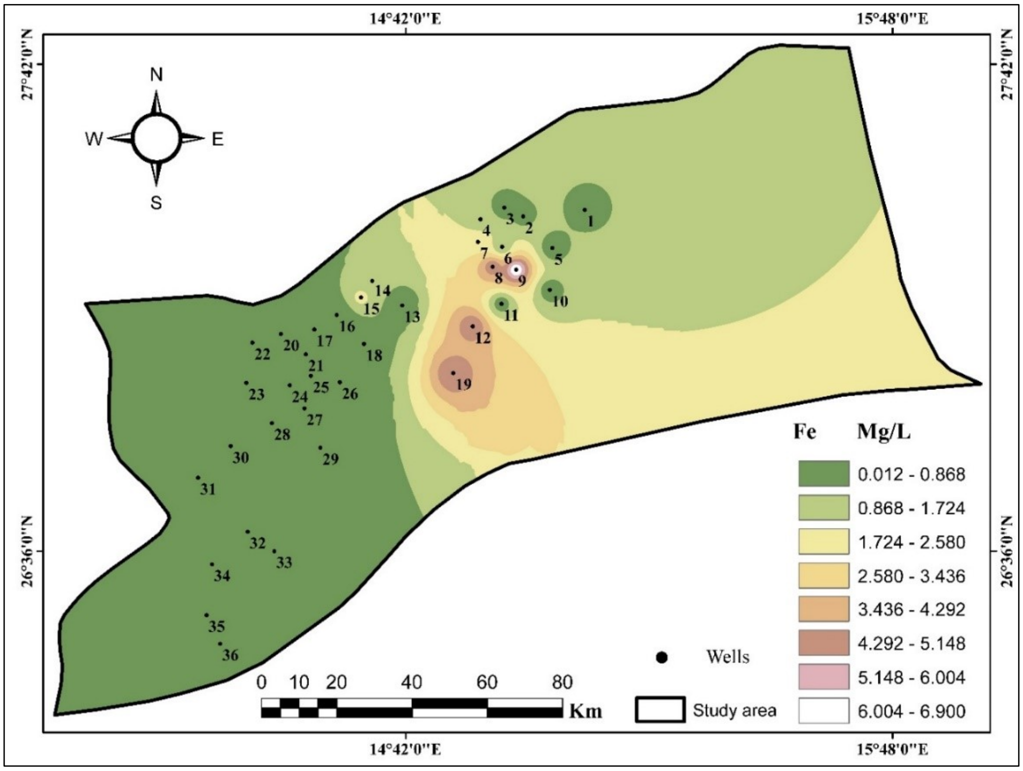

Figure 14. Spatial variation in the iron of the water sample in the area

Discussion

Groundwater pollution happens when manmade items such as gasoline, oil, road salts, and chemicals contaminate the water, rendering it hazardous for human consumption. Surface materials go through the soil and end up in groundwater. Many materials sources contaminate groundwater supplies. This study shows different parameters (elements) of groundwater quality in Sabha, most of which are harmful to human health if the quantity or concentration of the elements is above the given limit. It was found that the majority of groundwater samples in the study location had the highest TDS concentrations - higher than the permissible limit. The student also found the highest values of EC, nitrates, phosphate, magnesium, calcium, and sodium in some parts of the Sabha. And also found the total hardness in groundwater wells. These increased values or concentrations are supposed to be the outcome of the groundwater pollution by wastewater, which is discharged into pits, ponds, and septic tanks and migrate down the water table (Nair et al., 2006; Fayomi et al., 2019). These factors could also result from increased water usage and the lack of rain (Taira, 2004; Ali, Hasan & Alharbi, 2020). Libya is facing critical underground water problems, including excessive groundwater mining, uncontrolled mining of groundwater. There is also overexploitation of groundwater resources to meet irrigation needs has badly affected the country's aquifers. These and many other water-related problems hinder a country's sustainable development (CEDARE, 2014). There are severe implications for the health of using contaminated groundwater. Contamination from septic tank waste can cause diseases, including hepatitis and dysentery. Toxins that have leached into well water supplies may cause poisoning. Contaminated groundwater can potentially impact wildlife. Exposure to dirty water can potentially have long-term consequences, such as some types of cancer. Unfortunately, there are no direct studies in Libya revealing the link between the consumption of contaminated groundwater and human health. Thus, in the future, the research may pay attention to these aspects.

Conclusions

The groundwater quality in the Sabha area was assessed and mapped as part of the study, using the Inverse Density Weighted Interpolation to compare the spatial variation of groundwater quality indicators. The researchers concluded that most waters tested had concentrations higher than those recommended by the World and Libyan Health Organizations. As a result, the water quality in this area is poor since 85 percent of the samples collected were contaminated and required special treatment before they could be used.

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