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The spatial distribution of groundwater quality in the region of Derna, Libya

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This article analyzes the groundwater contamination and its spatial distribution in Derna region, North-east Libya. Fourteen groundwater samples were collected and analyzed for pH, electrical conductivity (EC), total dissolved salts (TDS), total hardness (TH), Ca, Mg, Fe, NH_4, Cl, NO_2 and PO_4. Inverse distance weighted (IDW) raster interpolation technique of spatial analyst module in ArcGIS software was used to generate the spatial distribution of water pollutants of constituents. The results has revealed that the TDS, TH, Cl and PO_4 have exceeded the permissible limit in several samples, and their values were 8000, 1700 and 1140 mg/L germ per 100 cm^3 respectively. Geographic information systems (GIS) zonation maps prepared for each element is self-explanatory. The groundwater quality parameters distribution maps have indicated that most of the parameters are concentrated on northern and northwestern parts of the region except pH and iron. The quality decreases gradually in the southward and eastward directions due to the high population and urban density and the associated activities in the northern and northwestern parts of the study area, and reflects the existence of correlation among some measurements.

Key words: Derna region, groundwater sources, groundwater quality parameters, spatial distribution, geographic information systems.

INTRODUCTION

Groundwater is one of the major and important water resources of exploitation in arid and semi -arid regions (Mehrjardi et al., 2008). However, the groundwater sources are by long period of aridity, human and agricultural activities (Sharaf and Subyani, 2001). Therefore, it is significant to analyze the data on spatial and temporal distribution, to protect the quality of groundwater. The knowledge of potable groundwater recovery should be given special considerations in quality-deteriorated regions, due to the scarce presence of surface water and unfavorable climatic conditions (Mehrjardi et al., 2008). According to Sharaf and Subyani (2001), the adverse activities of human beings, impact and natural processes on groundwater quality, becomes one of the major environmental problems affecting sustainable development. However, groundwater is generally polluted by natural and anthropogenic factors. The impact of these factors varies from one place to the other; therefore, we have found that there is a spatial difference in the water quality and the concentration of pollutants.

The Derna region of Libya lacks surface water and

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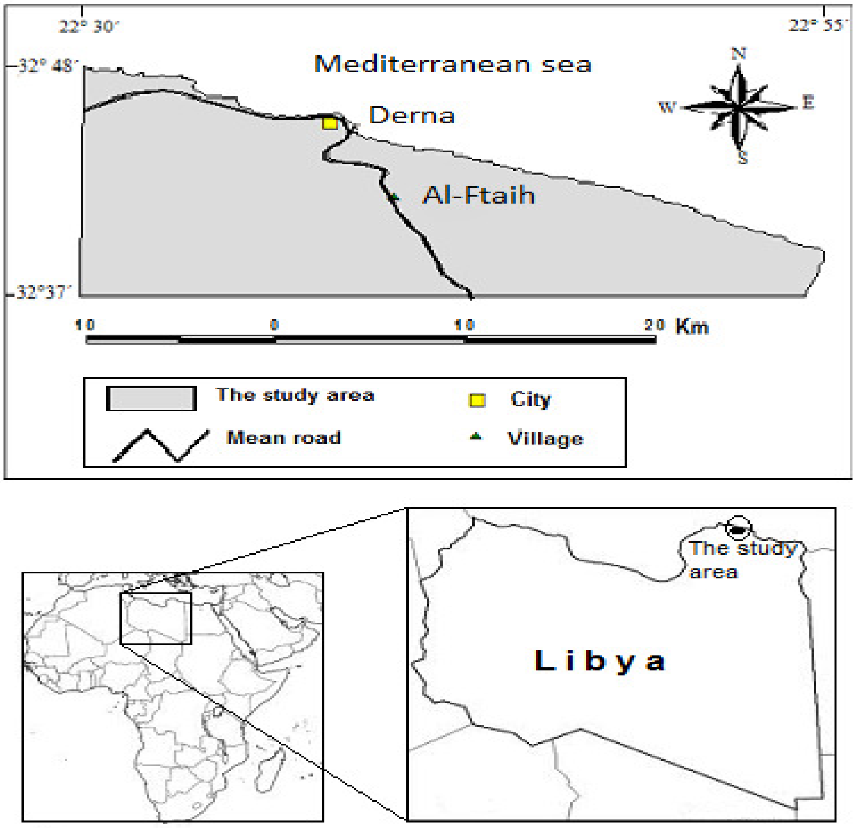

Figure 1. The study area location.

therefore relies on groundwater as the main source for domestic use. The huge urbanization and population growth in this region has resulted in the decrease of groundwater level and considerable physical, as well as chemical pollution. Eventually, 70 tons of waste is generated daily, which are dumped in open places close to residential areas. Ultimately, the accumulated garbage contaminates the groundwater as they are absorbed by the ground along with rain water (Elgali, 2006). The contamination has a very serious effect on environmental as well as health status of the people.

The study aims to provide information on the characteristics of groundwater quality and identify the spatial distribution of water quality parameters in the region of Derna, Libya.

Study area

The study area is stretches between latitudes 32˚37´ and 32˚48´ north, and between longitudes 22˚30´ and 22˚55´ east. It is located on the north-eastern slopes of Al Jabal Al Akhdar area, in the north-eastern part of Libya. The region, bordered by the Mediterranean Sea from the north, and extends from An-Naqah valley in the west to Al-Khaleej valley in the east, includes Derna city and Al-Ftaih agricultural region. It is 90 km west and 175 km east of Al-Bayda and Tobruk, respectively (Figure 1). This region is one of the most populated urban centers in the eastern region of Libya. Increased economic activities of the area are ascribed to the presence of a seaport (Aziz, 1973).

METHODOLOGY

Data collection

In order to evaluate the suitability of groundwater for human use in Derna region, a total of fourteen water samples were collected, and their coordinates were carried out using the global positioning system (GPS) survey. A map of the region of Derna (on 1:250,000) was used as basic information for the GIS database.

Data analysis

A laboratory analysis has been carried out for measuring the concentration of standard set of constituents including pH, electric conductivity (EC), total dissolved salts (TDS), total hardness (TH as $Ca CO_3$), calcium (Ca^{2+}) (magnesium (Mg^{2+}), iron (Fe), ammonia (NH_4), chlorides (Cl), nitrate (NO_2) and phosphate (PO_4). The Arc View software of GIS approach was employed as a tool to produce the maps for the special distribution and concentration of groundwater quality parameters. The location points of the wells

Table 1. Chemical parameters of groundwater quality.

Parameter / Samples no.	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Fe	NH_4	C1	NO_2	PO_4
1	7.0	1638	982	400	64	58	0	0	140	0	0
2	7.7	1900	950	380	96	34	0.1	0.2	180	0.2	1
3	7.3	790	640	320	64	64	0	0	160	0	0
4	-	12050	8000	1700	280	243	0	0	1140	0	-
5	6.8	3380	2028	900	186	116	0	0	360	0	0
6	7.0	1570	942	380	88	38	0	0	180	0	0
7	7.4	2950	2183	750	160	92	0	0	260	0	0
8	7.0	1777	1200	560	136	53	0	0	160	0	0
9	7.8	2340	1684	640	112	87	0	0	240	0	0. 5
10	-	-	4000	-	-	-	0	0	-	0	1
11	-	1300	750	340	56	32	0	0	80	0	0
12	-	1933	1300	360	88	34	0.1	0	180	0	-
13	-	4650	3100	300	104	10	0.2	0	300	0	0
14	-	1518	920	550	88	31	0.1	0	120	0	-

All parameters expressed in mg/l except pH and EC, where EC in µS/cm and pH has no units.

were digitized and the corresponding location numbers were assigned. The obtained water quality data forms the attribute database and it is stored in excel format and converted into dbase file (dbf) to transport data to arc view project. It is then linked with the spatial data by the join option in Arc View. The spatial and the attribute database formed are integrated for the generation of spatial distribution maps of the water quality parameters. In the present study, the spatial interpolation technique through inverse distance weighted (IDW) approach in GIS has been used to delineate the spatial distribution of groundwater quality parameters.

RESULTS AND DISCUSSION

Chemical properties of groundwater

It is vital to consider the chemical properties of water before it is used for domestic, agricultural or industrial purposes (Ashraf et al., 2011). Fourteen groundwater supplies were examined to determine their chemical properties. The chemical analysis results have indicated some variations among the chemical properties of water. Evaluation of the results is presented in Table 1.

The spatial distribution of groundwater quality parameters

A spatial analysis of the pollutants and their associated impact on groundwater quality is essential for understanding the present environmental problems. The GIS zonation maps prepared for each element is self-explanatory and helps in future management of water resources in the area. The groundwater quality distribution maps have shown that most of the parameters are concentrated on the northern and northwestern parts of the region.

The total hardness (TH) measure illustrates the concentration of calcium and magnesium in water and is usually expressed as the equivalent of CaCO3 concentration. Hard water causes scaling and reduces the effectiveness of soap, while soft water in general, is acidic and corrosive (Swarna and Nageswara, 2010). The spatial distribution of TH varied from 320 to 1700 mg/l. The highest values of TH are concentrated in the northwestern part of the study area (Figure 2), which exceeded the allowed maximum limit. In groundwater quality, the hardness is usually due to carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium (Venkateswara et al., 2009). However, the land use pattern in this part is still under development practice.

The pH is one of the most important operational water quality parameters, but it usually has no direct impact on consumers. For effective disinfection with chlorine, the pH should be preferably less than 8.0; however, lower-pH water is likely to be corrosive (WHO, 2008). The desirable limit of pH usually ranges from 6.5 to 8.0, which is a safe range for drinking (WHO, 2008). The pH level of ground water is affected by inhabited area and buffering capacity of water. In the present study, pH values have ranged from 6.8 to 8.1. In majority of the samples, the pH value ranged from 7.0 to 7.8. The GIS map of spatial distribution indicates that the higher value of pH (8.1) is observed in southern part of the region in the Spring of Abu-Mansour (Figure 3). Its acceptable value is based on the WHO standard desirable limit, which ranges between 7 and 8.5 (WHO, 2008).

In general, the TDS in groundwater are not harmful to human health, but high concentration of these may affect persons suffering from kidney and heart diseases. Water containing high solids may cause either laxative or

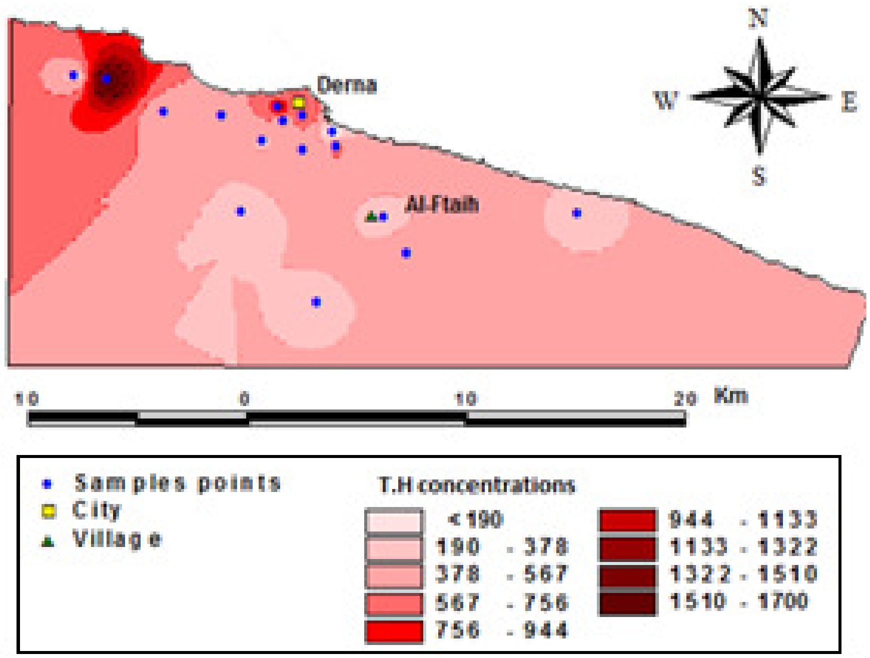

Figure 2. The spatial distribution TH.

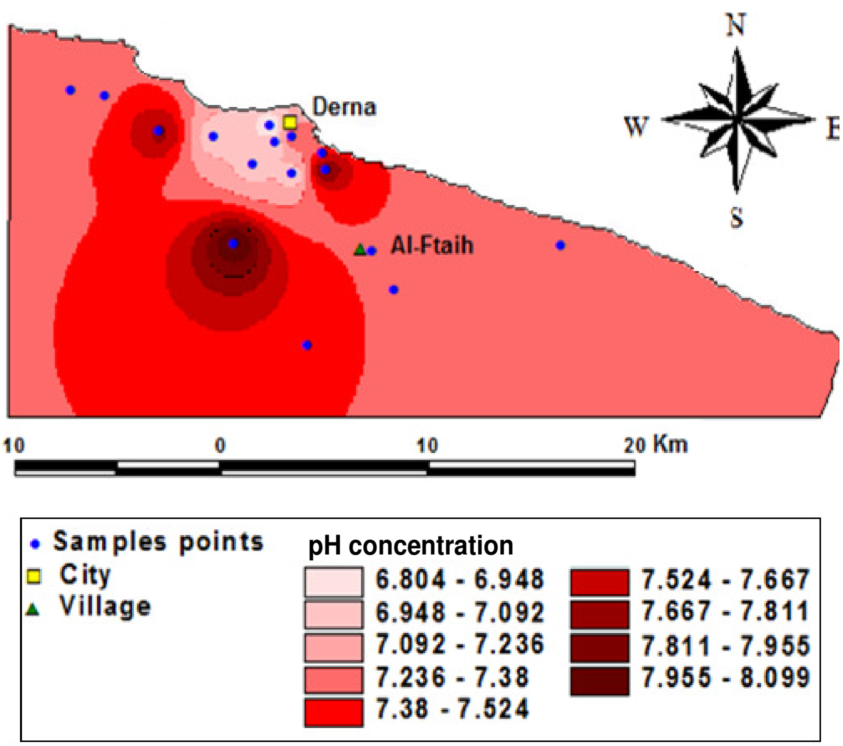

Figure 3. The spatial distribution of pH.

constipation effects (Ramakrishnaiah et al., 2009). In this study, most of the groundwater samples have moderate concentrations of TDS, which ranged between 640 and 1300 mg/L, and the TDS content was higher than permissible limit in 35.5% of the samples. The highest concentration of TDS values which exceeded the permissible limit of drinking water was also observed in the north-western part with 8000 mg/l and some other

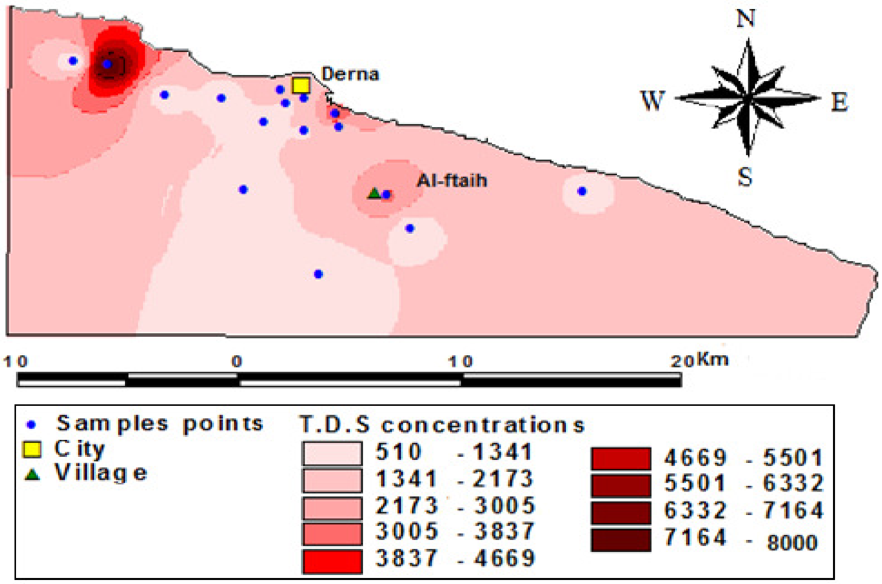

Figure 4. The spatial distribution of TDS.

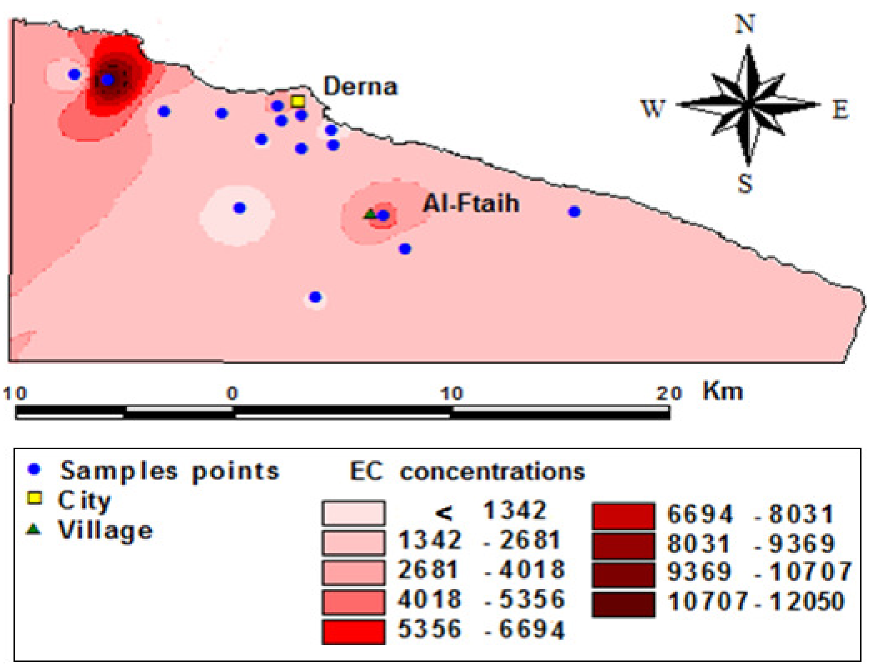

Figure 5. The spatial distribution of EC.

sporadic parts of north and east of the region (Figure 4). High values of TDS may be due to groundwater pollution by waste waters, which is discharged into pits, ponds and septic tanks, and migrate down the water channels (Nair et al., 2006).

According to the positive relationship between TDS and EC, pure water that is free from salts has bad conductivity. Presence of salts, acids and alkalis in the water increase its electrical conductivity. Therefore, this fact is used to identify the amount of dissolved salts in water (Ghraibh and Al-Frhan, 2000). The highest values of EC are concentrated in the north-western parts of the region and the lowest in the south and east as is shown in Figure 5. In this study, the EC values have ranged between 790 and 12000 µ S/cm. Calcium is one of the most important and abundant element in the human body

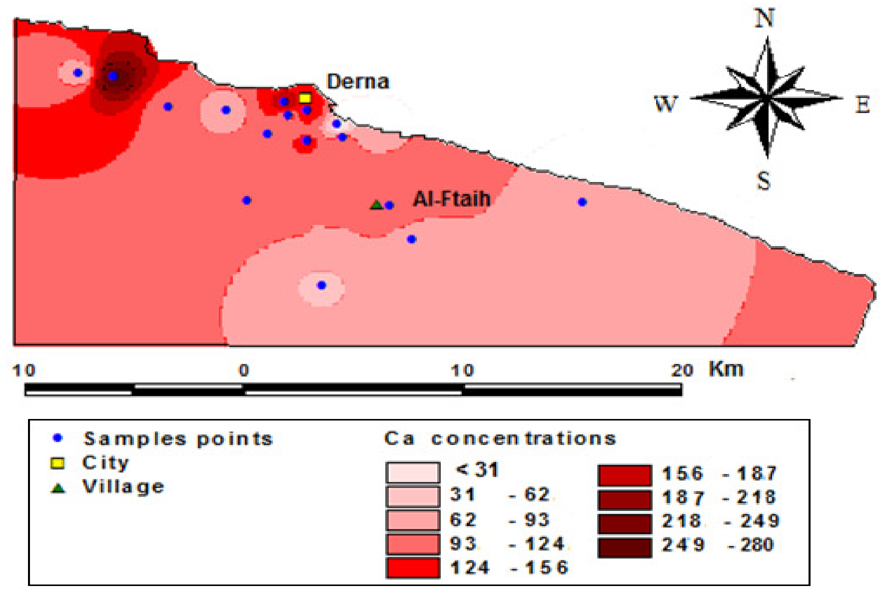

Figure 6. The spatial distribution of Ca.

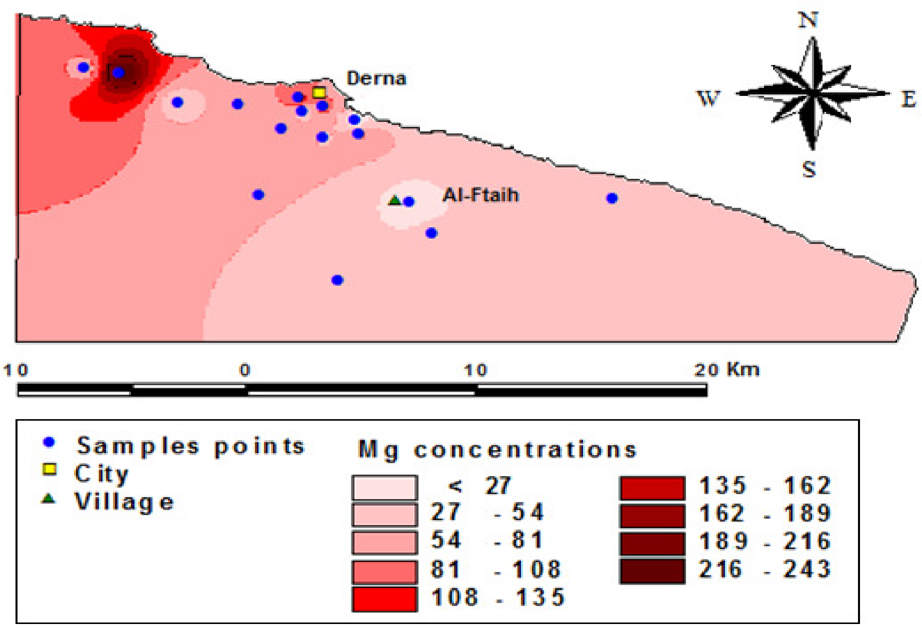

Figure 7. The spatial distribution of Mg.

and an adequate intake is essential for normal growth and health. High concentrations may be beneficial and waters with rich calcium are very palatable. Despite the potential health benefits of the abundance of calcium, there are problems associated with hardness (Environmental Protection Agency, 2001). The Ca^{++} map in Figure 6 also indicates the presence of highest value in the north-western part of the region with a range of 124 to 280 mg/L. The next highest range of Ca^{++}, with 93 to 187 mg/l, has been found in the central part of the city.

Magnesium is abundant, and is a major dietary requirement for humans (0.3 to 0.5 g/day). It is the second major constituent of total hardness with calcium (Environmental Protection Agency, 2001). Mg content (Figure 7) in the study area ranged from 10 to 243 mg/L. According to the National Center for Standards

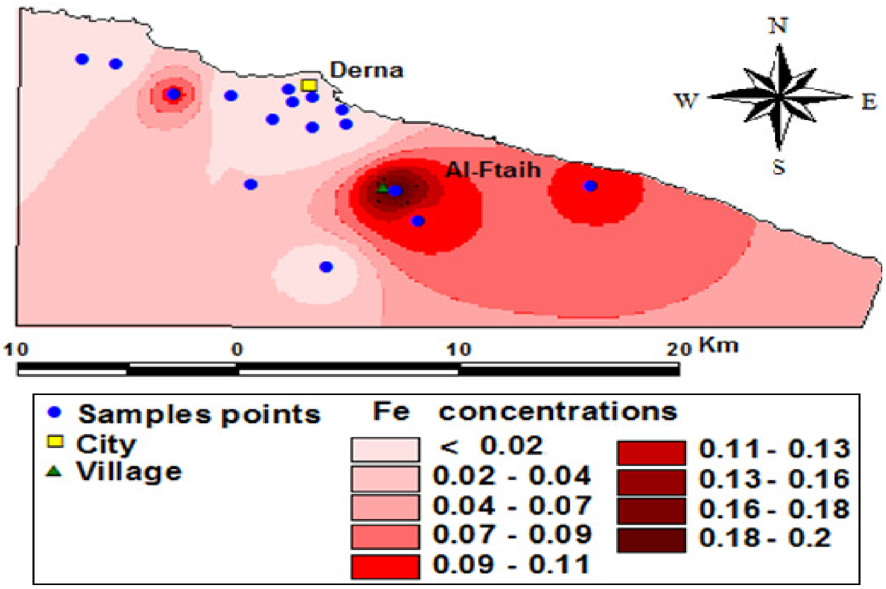

Figure 8. The spatial distribution of Fe.

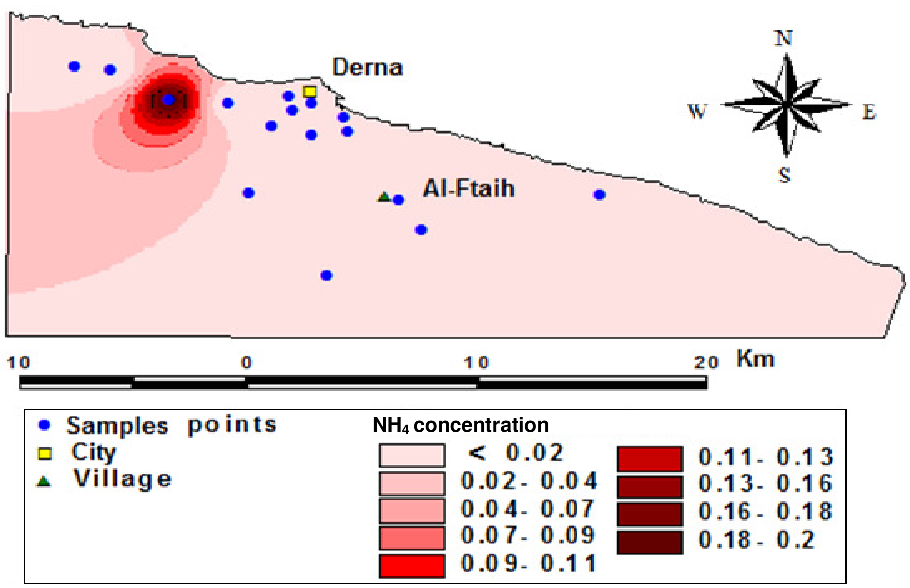

Figure 9. The spatial distribution of NH_4.

Specification in Libya, only 7% of samples have showed Mg above the permissible limit, and concentrated in the northwestern section of the region, whereas the other samples were within the optimum limit.

Iron exists in large quantities in the soil and rocks, mainly in the insoluble forms (Environmental Protection Agency, 2001). Iron is biologically an important element, which is essential to all creatures and present in hemoglobin system. Its high concentration causes slight toxicity (Swarna and Nageswara, 2010). A slightly high concentration of the iron is found in the central and eastern part of the region (Figure 8). The Fe values ranged between 0 and 0.2 mg/l.

Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramines. Its natural levels in groundwater and surface water are usually below 0.2 mg/l (WHO, 2008). Based on Figure 9, a slightly high concentration of NH_4 has been identified in the west of the central part of the study area, where, a site of solid waste dumping is

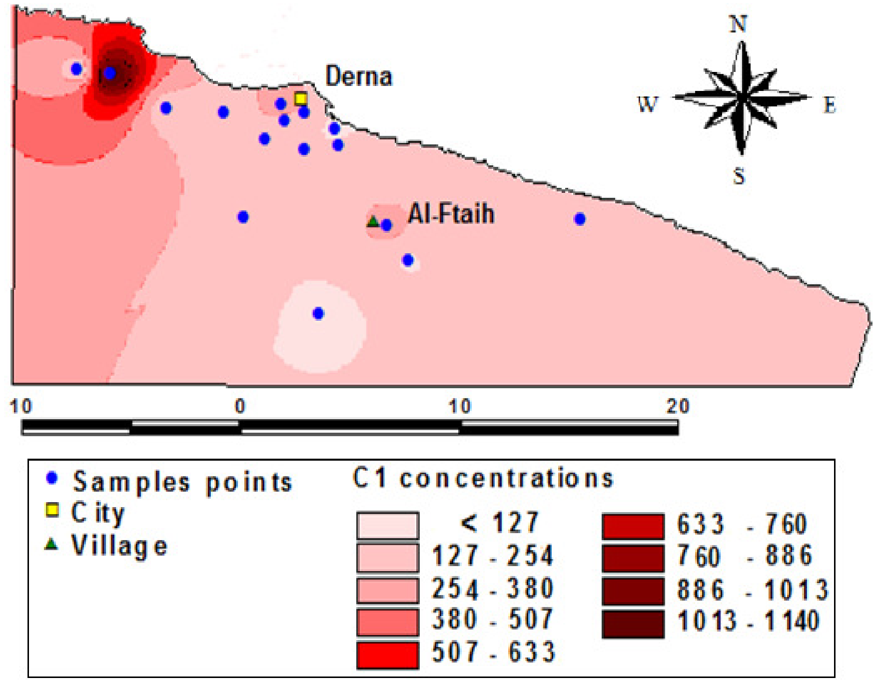

Figure 10. The spatial distribution of Cl.

situated. The values of NH_4 varied from 0 to 0.2 mg/L.

Chloride is the second dominant ion in the groundwater and higher content of chloride gives salty taste to water (Venkateswara et al., 2009). The C1 values ranged between 80 and 1140 mg/l, and it was higher than permissible limit in about 28% of the study samples. The maximum level of C1 was observed in the western part of the region and in the center of Derna city and the village of Al-Ftaih (Figure 10). The Libyan National Center for Standards Specification has prescribed the permissible limit of C1 in the potable water from 200 to 300 mg/l. In natural water, concentrations of chloride vary widely and are related to mineral content of the water. It is well known that the sea water intrusion results in abnormal concentration of chloride and the presence of soluble chloride from rocks can also increase the Cl concentration in the groundwater. At concentrations above 250 mg/l, water gets a salty taste, (Swarna and Nageswara, 2010).

Nitrite is not usually present in significant concentrations except in a reducing environment. It can reach surface water and groundwater as a result of agricultural activities, wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (WHO, 2008). The spatial distribution map of NO_2 in Figure 11 shows that the NO_2 values ranged between 0 and 0.2 mg/l. The high concentration was observed in the western part of Derna city, it decreases gradually from southward to eastward directions, where the value reaches 0 in most southern and eastern parts of the region. Phosphate is considered an essential nutrient for living organisms, which is found in water as dissolved and particulate species (Swarna and Nageswara, 2010). It is widely used as an agricultural fertilizer and considered as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are the important contributors of phosphorus to surface waters (Environmental Protection Agency, 2001). PO_4 concentrations map in Figure 12 shows that its values ranged between 0 and 1 mg/l. The maximum concentrations of PO_4 is found in the west of the central and eastern parts of Derna city (locality of Al-Maghar and Al-Sahil), whereas the lowest concentrations were observed in the southern part of the region.

The spatial distribution of *Escherichia coli* count varies from 0 to 100 in each 100 cm^3. The highest number of *E. coli* in the groundwater are concentrated in the central and western part of the Derna city, while the *E. coli* count in the southern and eastern part of the region ranged between 0 and 33 in 100 cm^3 (Figure 13). The high spread of *E. coli* counts in the central and western part of the city is related to weakness of the sewage network and the frequent presence of sewage tanks, thus overflowing the sewage and seeping into groundwater reservoirs.

Conclusion

The study discussed the characteristics of groundwater quality and identified the spatial distribution of water

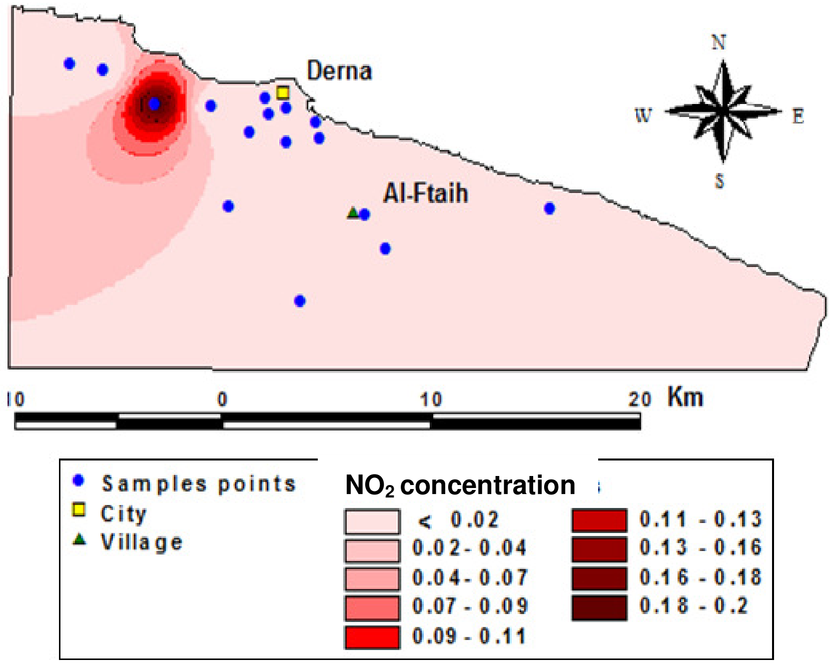

Figure 11. The spatial distribution of NO_2.

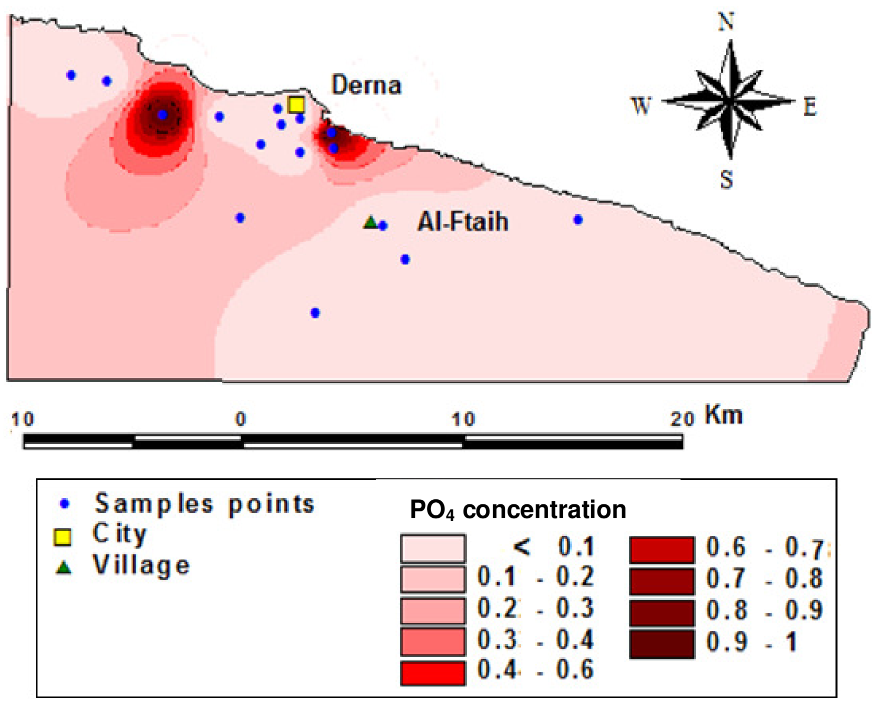

Figure 12. The spatial distribution of PO_4.

quality parameters in the region of Derna. The study found that some chemical parameters were above the permissible limits in drinking water. Groundwater quality distribution maps indicated that the highest values of parameters were concentrated in the northern and northwestern parts of the study area, except pH and iron, which were concentrated on the central parts of the region, and decreased gradually from the southern to eastern parts, due to the increased human activities in the northwestern parts of the region.

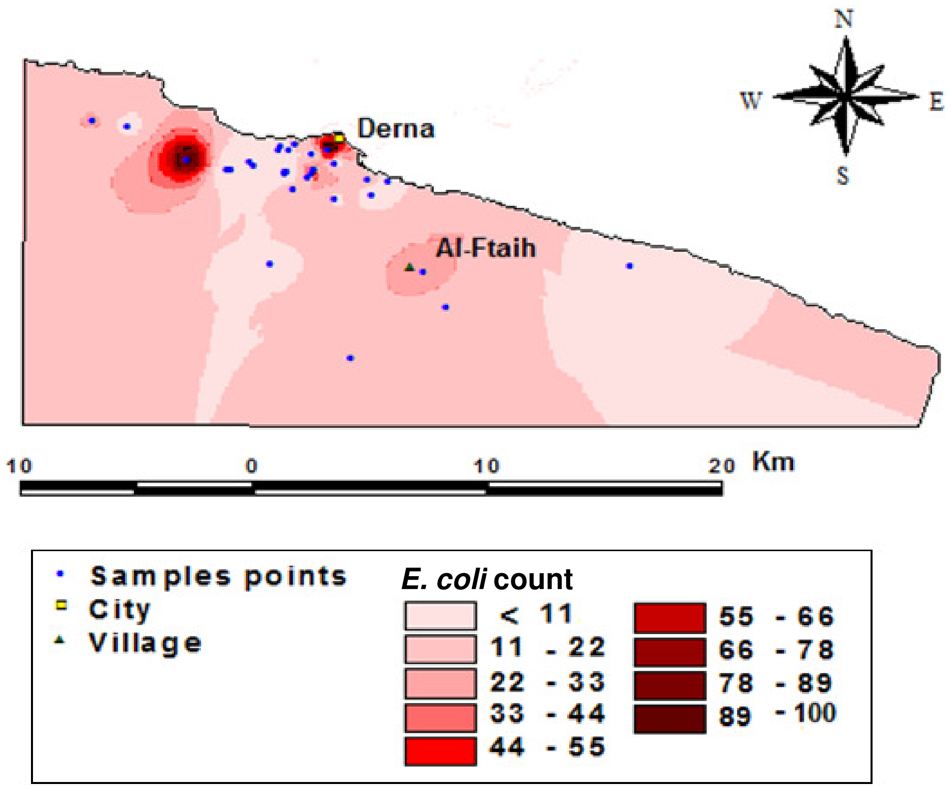

Figure 13. The spatial distribution of *E. coli*.

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