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Analyzing Geospatial Trends of Groundwater Quality in Sargodha City, Punjab, Pakistan

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Abstract: Groundwater is a primary source for drinking and domestic use in urban centers of Pakistan. The continuing process of urbanization and the recent rising trend in urban population is leading to overexploitation of groundwater in the study area. Present research explains the groundwater quality status in Sargodha city, Punjab. In this area, the urban population has almost doubled since 2000. Present study focuses on physicochemical parameters of groundwater samples collected from pre-determined boreholes in Sargodha city. One hundred water samples were collected through random proportionate sampling method from the city. The standard laboratory water sample analysis was performed to determine water quality parameters like TDS, EC, PH, alkalinity, turbidity, taste, odor, drinkability, hardness, iron sulfate, nitrate, calcium, magnesium and chloride. The analysis results revealed that the values of turbidity, EC, chloride, sulfate alkalinity, hardness, TDS are higher than the permissible limits of WHO while the magnesium and pH concentrations are below the permissible range for drinking water. The amount of nitrate and iron were found in traces. Geospatial maps for different elements were generated using GIS software in order to delineate zones of high concentrations of these parameters in groundwater of the study area.

Keywords: Physicochemical properties, groundwater quality, GIS, Sargodha, WHO standards.

Introduction

Groundwater is not a renewable water resource. It may take hundreds of thousands of years to replace a gallon of groundwater with a brand-new gallon. In the twentieth century, the rate of water usage accelerated as compared to earlier periods and it seemed that it will not be decreased in upcoming years. The new trends are alarming for us. There will be a stage more likely within next 10 to 40 years, when the global freshwater use may likely level off as a result of physical, environmental, economic and political constraints (Mishra, 2006). The area under stress in 2025 will be 7.9 million square kilometers. The groundwater of Sargodha was contaminated with a high value of turbidity. Previous studies show that 88 percent of water samples were found to be unsafe (Tahir et al. 2010). Another study shows unsafe water in Pakistan (Shahid, 2012).

Study Area

Sargodha is located in Punjab, province of Pakistan at the longitude of 72-38^{o} to 72-43^{o} and latitude of 32-3^{o} to 32-7^{o} (Fig. 1a). This city is famous for citrus fruits. Sargodha is also facing the problem of groundwater quality and the people are complaining about the deteriorating quality of water. The evidence of hard turbid water is found in their study with a high concentration of total dissolved solids (Haydar and Qasim, 2016). The groundwater of Sargodha was contaminated with having a high value of turbidity. Previous studies show that 88% of samples were found unsafe (Water quality, 2002-06).

Materials and Methods

Groundwater samples were collected from Sargodha city for physical and chemical analysis. Samples were taken to the water testing lab within 24 hours of sampling. After completing the analysis following WHO and other standards, the results were spatially interpolated, tabulated and statistically analyzed (Fig. 1b). The measured height above sea level in the study area was found with variations at all sampling points. The height above sea level in 101 samples ranges from 178m to 445m and the average height is 193m. The lowest height was found in an area named 2,3 block in the urban area. While the highest point was found in the area named Islam Pura MC Model School. The central part showed the maximum height. While the northern part was average in height, Eastern and southern parts are also located at average height (Fig. 2).

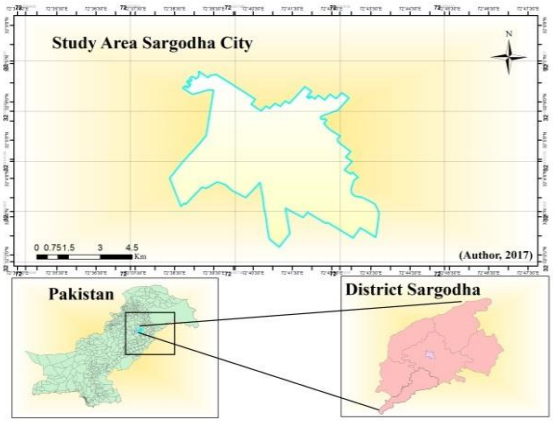

Fig. 1(a) Map of the study area.

▫*This paper was presented in Symposium on Water Contamination Issues and Treatment Techniques, (February, 2018) Abdus Salam School of Sciences, Nusrat Jahan College, Rabwah, Chiniot, Pakistan.*

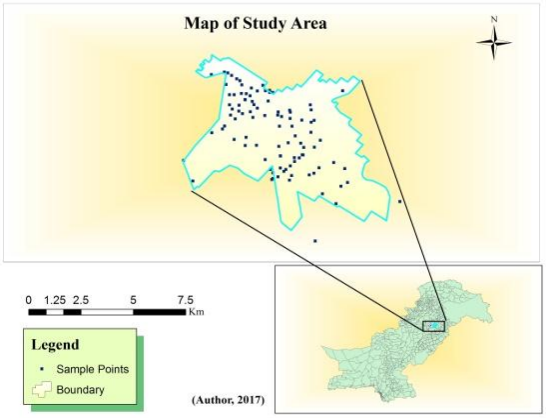

Fig. 1 (b) Sample points for interpolation.

Temperature

The temperature of groundwater of Sargodha city was measured within 24 hours of sampling. The northwestern part was found with 35 to 34°C. The central and southern parts ranged from 19 to 32 °C. The western part was under 35°C and the southern part samples had 36 °C (Fig. 3).

pH Value

The pH value of groundwater determines the alkaline or acidic property of water (Aziz and Tanaka, 2011). The calculated pH values in the groundwater of Sargodha city showed variations in all samples. The pH values in 100 samples range from lowest (0.69) to highest (8.6) and the Median value of 100 samples is 7.3, which is within the permissible limit of WHO standard. Only one sample was found phenomenally low on the pH scale, which was taken from Iqbal Colony Y block due to the adjacent pond at only 20m away from the borehole.

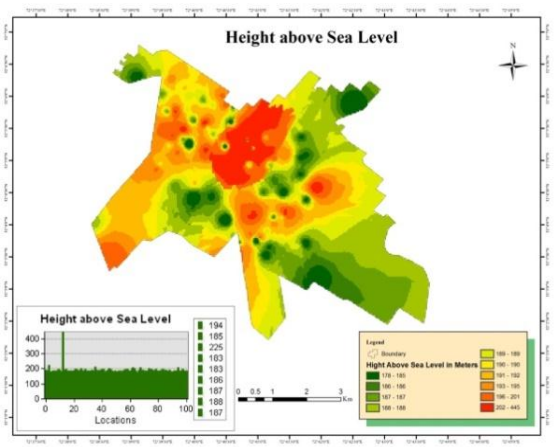

Fig. 2 Height above sea level.

The pH values showed remarkable variations all around the study area (Fig. 4). The northwestern portion of this area is less built up as compared to the surrounding areas (Aziz Bhatti town), where average pH is found, while the value increases on moving from west to east or center. The borehole depth in the highest concentration area was 37 ft and 40 samples were found within the permissible limit of WHO for pH.

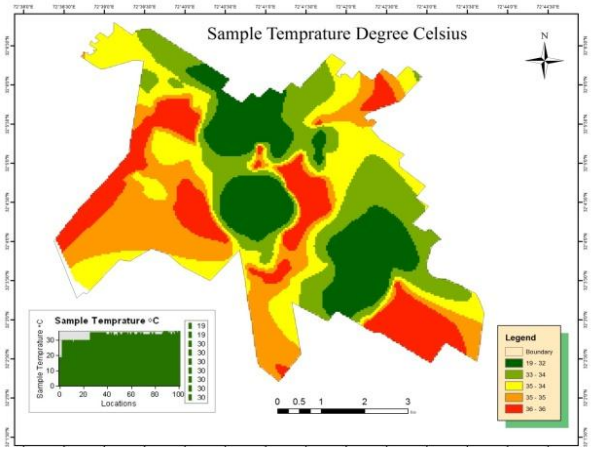

Fig. 3 Spatial pattern of temperature in water sources.

Electrical Conductivity

The electrical conductivity of groundwater determines the ionic measurement or its capacity to transmit electric current (Doherty and Hunt, 2010). The calculated electrical conductivity in the groundwater of Sargodha city showed fluctuation in all samples. The electrical conductivity in 101 samples ranges from 210 mg/l to 20,000 mg/l. and the values mostly exceed the permissible limit of WHO. Eight samples were found with very low electrical conductivity (Fig. 5). The borehole depths of these samples are 37, 32 and 46 meters respectively. The values are remarkably high all around the study area.

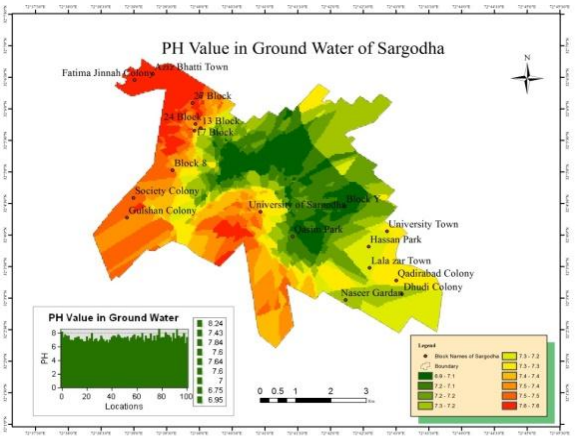

Fig. 4 Spatial pattern of pH value in sargodha groundwaters.

Turbidity

The turbidity is muddiness or haziness of water (Helmer et al., 1997). The calculated turbidity value in the groundwater of Sargodha city showed fluctuation in all samples. The turbidity values in 100 samples range from 0 to the highest value of 18.93 NTU, within

WHO permissible limit for drinking water. While only two samples are above the permissible range of the WHO standard for drinking water. The borehole depth of sample with turbidity value of 18.93 NTU was 70 feet and 8.05 NTU turbidity was found at 40 feet depth. High turbidity may be due to the adjacent pond which is only 10 to 30 meters away from the boreholes. The Figure 6 is showing the spatial pattern of the turbidity distribution in the study area. The northwestern portion of the study area is less constructed as compared to the surrounding area, which was highly turbid. The southwestern and some of areas the eastern portion of the study area have highly turbid groundwater. Ninety water samples were found within the highest desirable level of WHO standards. Only 2 samples were found above this limit which is 5 NTU (Fig. 6).

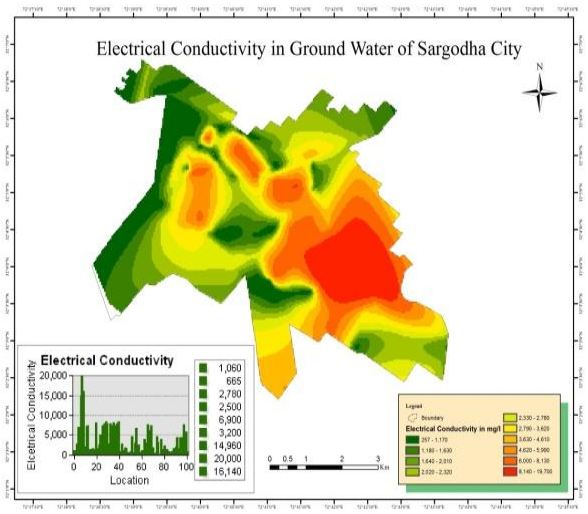

Fig. 5 Spatial pattern of electrical conductivity.

Total Alkalinity

The alkalinity determines the capacity of water to neutralize the acid (Khalid et al., 2011). Alkali means a chemical substance that reacts with acids to form a salt. The calculated alkalinity value in the groundwater of Sargodha city showed high fluctuation in all samples. The alkalinity in 100 samples ranges from 100 mg/l to 2150 mg/l. Only 24 values are under the permissible limit of the WHO, which is 50 to 500 mg/l (Fig. 7). The borehole depths of these samples were mostly 20 feet or less than 37 feet. The adjacent pond was only 10 m away from the borehole. While other 77 water samples were found to be highly alkaline and above the WHO limit. The highest value of alkalinity was found in Khayban e Siddique. The borehole depth of this sample was 40 feet and the adjacent pond was only 30 m away from the borehole. The values showed a high concentration of alkalinity and remarkable variations all around the study area. The southwestern area is less alkaline as compared to the northwestern, eastern and southern sides of the study area. While the central portion is average on alkalinity scale of WHO standards. The borehole depth in the highest concentration area was more than 30 feet and the adjacent pond is 10 to 30 m away from the borehole.

Total Dissolved Solids

Total dissolved salts determine the value of total salts dissolved in groundwater. Mostly dissolved salts are carbonates bicarbonates, chloride, sulfate, phosphate, nitrate, calcium, sodium, iron, potassium and manganese. The values of total dissolved solids of 100 samples range from 150 mg/l to 29600 mg/l. The values are not under the permissible limit of WHO standards for drinking water. Permissible limit is 500 mg/l. Only two samples are found phenomenally very low at total dissolved solids scale of WHO. The low concentration may be due to the adjacent pound, which is only 10 to 30 m away from the borehole. The values showed remarkable variations all around the study area. The northwestern area showed lower values in the map and on moving towards the central part of the study area which is highly built up, the concentration of TDS is high While in the southern part the concentration is low as compared to central and western parts, but it is still high on TDS scale of the WHO. The permissible limit of WHO is 500 mg/l and the admissible limit is 1000 mg/l (Fig. 8).

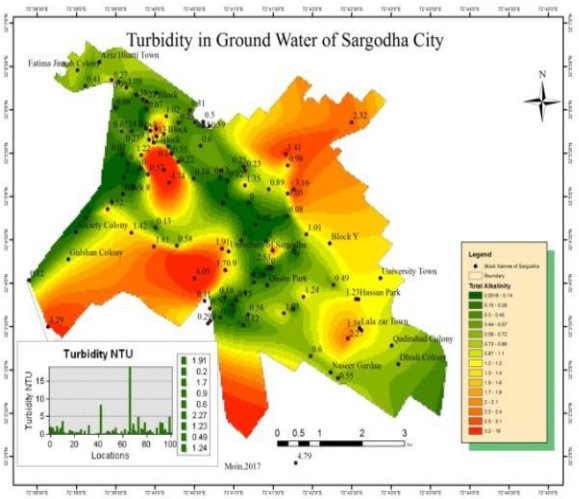

Fig. 6 Spatial distribution of turbidity.

Calcium Concentration

Calcium is an alkaline chemical element of the earth. The calculated calcium in the groundwater of Sargodha city showed changes in all samples. The calcium values in 100 samples of Sargodha city range from 12 to 6448 mg/l, which is not the permissible limit of WHO standards. Only 11 samples were found below the calcium scale. The lowest value detected in the water sample of the Department of Earth Sciences at the University of Sargodha. The value is 12 mg/l and the borehole depth is more than 30m. While the other low concentration samples were also found in the surrounding area of this location, which included MEO Colony, Revenue officers Colony, Islam Pura, Muhammadi Colony, Block A, Block Z, and Bhalwal

Road. The borehole depth of these samples ranges from 25 to 49 feet. Figure 9 shows the spatial pattern of calcium value distribution in the study area. The calcium concentration is different all around the study area. The northwestern portion is found with low concentration of calcium and the western portion is under the permissible limit of the WHO. While on moving towards the central, eastern and southern parts of the study area, the concentration of calcium is very high and highest concentration is found in Naseer Colony near a graveyard. The value of this location is 6448 mg/l, which is very alarming according to the WHO permissible limit of 200 mg/l (Fig. 9).

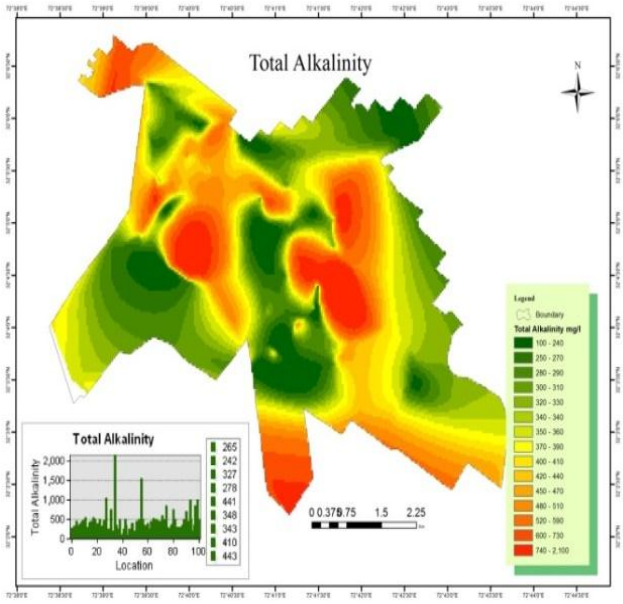

Fig.7 Spatial distribution of alkalinity.

Hardness

The groundwater hardness determines high mineral contents or high values of calcium, magnesium, and metal in water (Qureshi et al., 2003). The calculated groundwater hardness value in the groundwater of Sargodha city showed fluctuation in all samples. The hardness value in 101 samples ranges from 86.66 mg/l to 5515mg/l. The values are not under the permissible range of WHO standards. Only two samples are found low on the hardness scale. The borehole depth of both samples is 37 feet. The low hardness may be due to the adjacent pond which is only 10m away from the borehole. The hardness values showed remarkable variation all around the study area (Fig. 10). The northern part named Aziz Bhati town, Fatima Jinnah Colony, 8, 13, 17, 27 blocks and a central part with the southern extent of the city were also found with high groundwater hardness. The southern part of the city, named Society colony and Gulshan colony were found within the limit of the WHO (Fig. 10).

Magnesium

The magnesium value of groundwater determines a chemical element, which is light silver-white metal along with eight abundant metallic elements in the earth surface. The calculated magnesium in groundwater of Sargodha city showed fluctuation in all samples. The magnesium value in 101 samples ranges from 8.8mg/l to 4635mg/l. which is above the WHO standard. Only 14 samples were found phenomenally low and within the permissible limit of the WHO (Fig. 11). The sample low concentration of magnesium may be attributed to an adjacent pond, which is only 10m away from the borehole at 27m depth. The value showed variations all around Sargodha city. The northwestern part was found under the permissible limit, while the central and southern parts are found with high magnesium concentration in groundwater. and the surrounding areas are average in the permissible limit of WHO. The western portion is below the permissible limit of WHO (150mg/l). The borehole depths of samples with high magnesium contents were 25, 32, and 40 feet respectively. While, 52 samples were found within the limit of magnesium and 33 samples exceeded the WHO of 150 mg/l (Fig. 11).

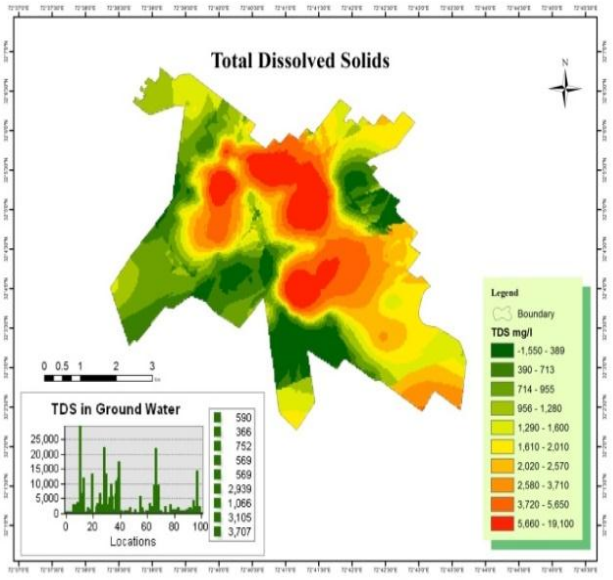

Fig. 8 Spatial Pattern of TDS source.

Chloride

Chloride is basically a determined salt of hydrochloric acid in water. The calculation of chloride value in the groundwater of Sargodha city showed variation in all samples. The chloride values in 101 samples range from 10mg/l to 25000. The northwestern part was found with a low concentration of chloride. While the central part shows the highest concentration of chloride and southwestern part is also found with a high concentration of chloride. While, on moving towards the built-up and central part of the city, the concentration of chloride is high. The southern and less built-up areas were found with average chloride concentration and 34 samples were found within the WHO limit of 25 ml/g (Fig. 12).

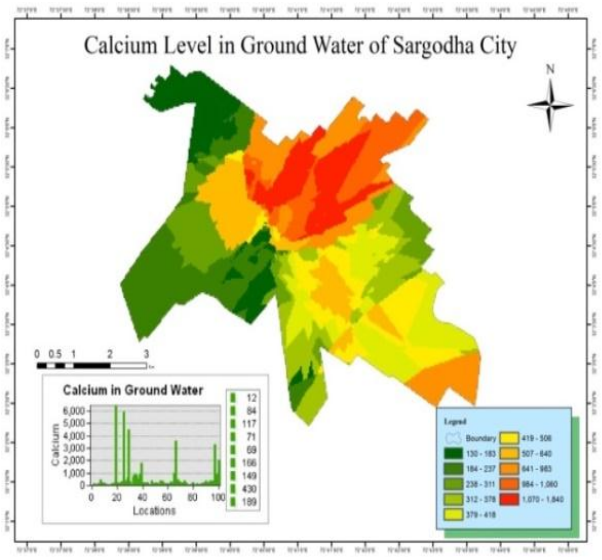

Fig. 9 Spatial pattern of calcium.

Sulfate

The sulfates are salts of sulfuric acid. It is a polyatomic anion. The calculated sulfate in the groundwater of Sargodha city showed fluctuation all around the study area. The sulfate in 101 samples showed variations from 57145.07 mg/l to 44.21 mg/l. Only 39 samples were found within the permissible limit of WHO which is 250 mg/l (Fig. 13). The northwestern part of the study area showed a low concentration of sulfate while southern western and southern parts of the map showed values within the WHO standard. These parts of the study area are less built up while the center has a highly built-up and urbanized area of the city containing high concentration samples of sulfate. Sixty-two samples were found above the permissible limit of WHO standards of sulfate. The borehole depths of high sulphate enriched samples are 25,35 and 40 feet respectively.

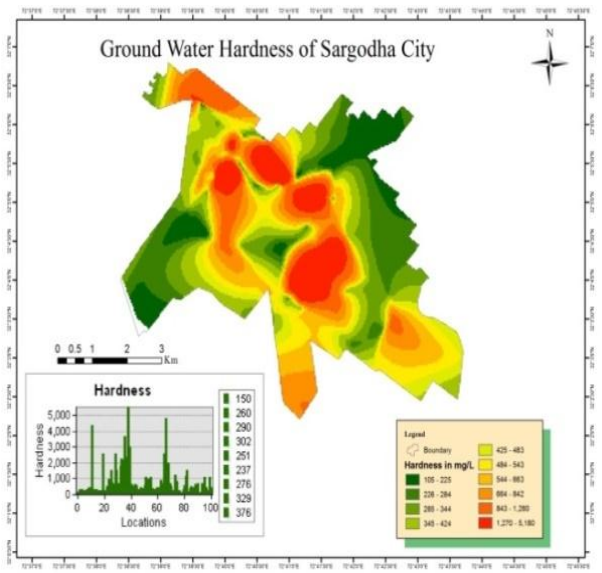

Fig. 10 Spatial distribution of ground water hardness.

Nitrate

The nitrate value of groundwater determines the occurrence of nitrogen in the groundwater. Higher concentration of nitrate in water is health hazardous for humans. The calculated value of nitrates in the groundwater of Sargodha city is found fit in all 100 samples. The nitrate value in 100 samples ranges from 0 mg/l to 0.113 mg/l. The values are under the permissible limit of WHO standards for nitrate. The maximum values showed in Islam Pura and Aziz Bhatti towns while the northwestern and southwestern parts of the map show very minor concentration (Fig. 14).

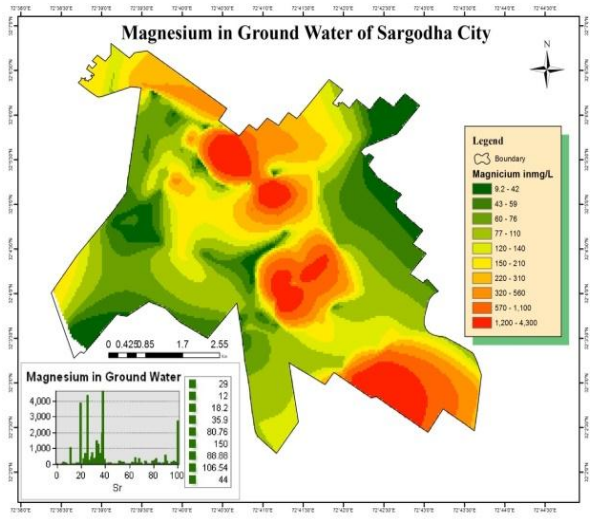

Fig. 11 Spatial distribution of magnesium.

Iron

The iron value in water determines the presence of iron in the water. No sample was found to be above this limit of WHO. The map is showing variations within the permissible limit of iron. While, the southern part is higher and the central part, the values are higher. These values are under the permissible limit (0.3 mg/l) of WHO (Fig. 15).

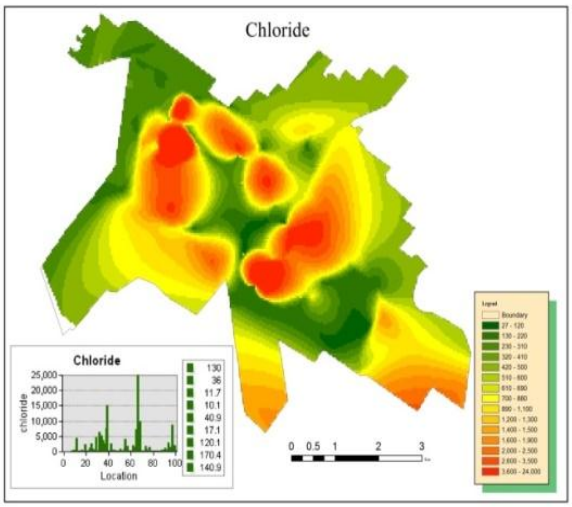

Fig. 12 Spatial distributer of chloride sources.

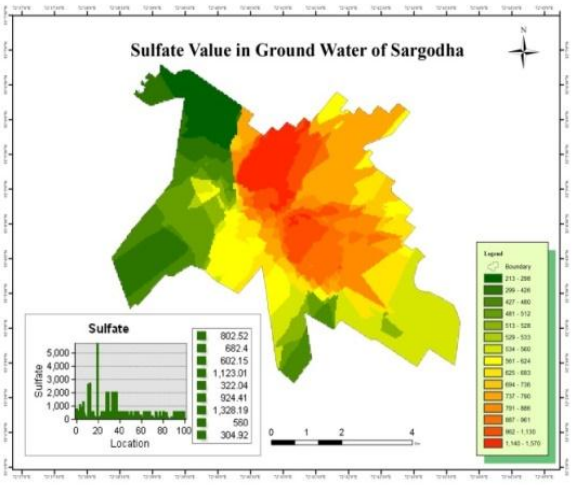

Fig. 13 Spatial distributer of sulfate sources.

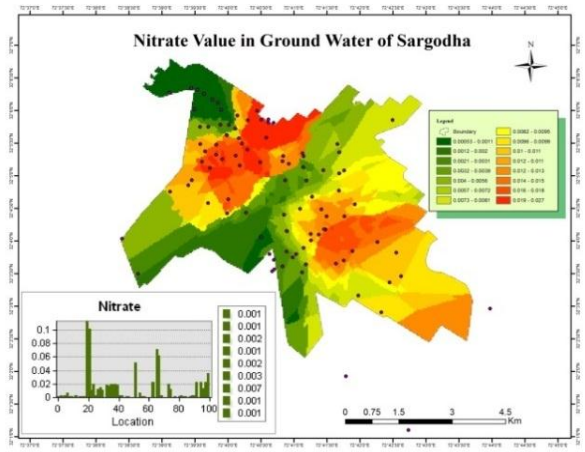

Fig.14 Spatial pattern of nitrate sources.

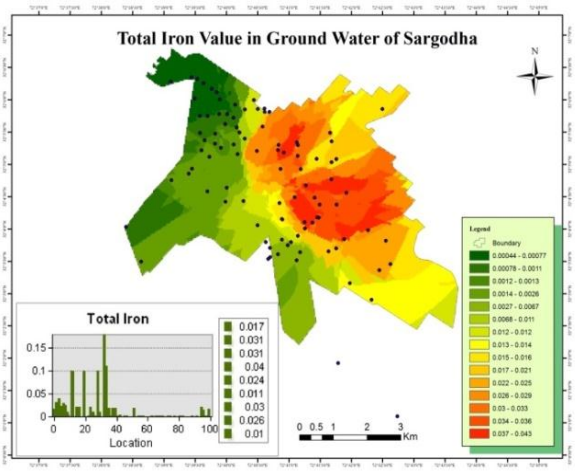

Fig.15 Spatial pattern of iron sources.

Conclusion

The geospatial trends of groundwater quality analysis showed high variations. The results of each parameter fluctuate in various parts of Sargodha. The water quality is worse in the central parts of Sargodha where the area is highly built up, whereas, the quality of water is relatively better in the surroundings of the city, with is less developed area.

The groundwater analysis determines the water quality of Sargodha. The pH values of groundwater were within the limit of WHO standards, but the condition is different in case of alkalinity. The results show very small number of samples are within permissible scale of WHO while larger number of samples are unfit for drinking purpose. Turbidity was found fit in groundwater of Sargodha. Electrical conductivity of groundwater was found very high and alarming. The hardness analysis shows the large number of samples exceeded moreover, the permissible limit of WHO. On magnesium, chloride and sulphate concentrations in groundwater of Sargodha were found very high, while nitrate and iron were found at trace levels.

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