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Spatial Distribution of Groundwater Quality in Different Parts of Chittagong Region, Bangladesh using GIS

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Abstract

Chittagong is one of the major emergent cities in Bangladesh which its area is rapidly increasing as neighboring districts like Rangamati, Khagrachari, Bandarban and Cox's Bazar. Most of the people are using the groundwater as a prime source for their domestic needs. Assessing the quality of ground water is an essential concern in this new era. The work has been conceded by traveling to the sampling site, collection of required water samples, and estimation of water discharge and determination of basic parameters of the site. The water samples have been analyzed for physicochemical parameters as prescribed by APHA, using standard techniques and compared with WHO (2014-2015) drinking water quality standards. The ground water quality information maps of the entire study area were prepared by GIS Inverse Distance Weighting (IDW) technique for 26 parameters. GIS technology proved to be very useful for enhancing the accuracy. We obtained the location of the well by using the GPS and Arc GIS software. The IDW was applied to find out the spatial distribution of groundwater quality. In interpolation with the spatial analyst method of IDW, a weight is attributed to the point to be measured. The amount of this weight is dependent on the distance of the point to another unknown point. These weights are controlled on the bases of power of ten. With increase of power of ten, the effect of the points that are*

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farther diminishes. Lesser power distributes the weights more uniformly between neighboring points. In this method the distance between the points count, so the points of equal distance have equal weights. The advantage of IDW is that it is intuitive and efficient. This interpolation works best with evenly distributed points. Similar to the SPLINE functions, IDW is sensitive to outliers. Furthermore, unevenly distributed data clusters result in introduced errors. The results obtained in this study with the spatial database established in GIS was helpful for monitoring and managing groundwater quality and its pollution in the study area of greater Chittagong region and other neighboring districts.

Keywords: *Ground water, spatial distribution, physicochemical parameters, drinking water quality, GIS, inverse distance weighing technique*

INTRODUCTION

Natural resources are the important wealth of our country, water is one of them. Water is a wander of the nature. “No life without water ’’ is a common saying depending upon the fact that water is the one of the naturally occurring sectional requirement of all life supporting activities1. The quality of drinking water is closely associated with human health and providing safe drinking water is one of important public health priorities. Evaluation of water quality goes far beyond merely determining which constituents are present and at what concentrations. This is because identification of specific physical, chemical and biological characteristics has never been the primary goal in practical consideration of water quality. However, rapid industrial development, economic growth, and population growth have intensified the requirements for a vast number of materials and products, leading to an increase in the number of factories in various places across the World. However, recently, social concerns and the requirement for environmental conservation have increased across the world, with rising economic standards, which has led to the establishment of wastewater treatment facilities near the industrial complexes for the efficient control of wastewater2. The availability of water through surface and groundwater resources has become critical

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day to day. Estimated 80 percent of all diseases and over one third of deaths in developing countries are caused by the consumption of contaminated water, and on the average as much as one tenth of each person´s productive time is sacrificed to water- related diseases3. In Bangladesh, most of the population is dependent on groundwater as the only source of drinking water supply. The groundwater is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dump causes the groundwater to become polluted and created health problems4. The rapid growth of urban areas has further affected groundwater quality due to over exploitation of resources and improper waste disposal practices. Hence, there is always a need for and concern over the protection and management of groundwater quality4. Heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic and industrial application. The quality of drinking water in Bangladesh is also at high risk. Problems are acute, especially in urban areas. Chittagong is one of the major developing cities in Bangladesh; its area is rapidly increasing as neighboring districts like Rangamati, Khagrachhari, Bandharban and Cox´s Bazaar are demarcated as separate Municipal Corporation (MC). Majority of the people are using the groundwater as a prime source for their domestic needs, besides the MC is supplying them with an allocation of treated water. Only 1% part is available on land for drinking, agriculture, domestic power generation, industrial consummation, and transportation and waste disposal3,5. Greater Chittagong district, the important portion of Bangladesh, is one the densely populated urban and rural areas which have been suffering from inadequate supply of drinking water often associated with water quality problems too.

Deteriorating water treatment facilities and distribution systems can pose a significant public health threat as illustrated by a study in Pakistan6. Authors concluded with the epidemiological data that diahhoreal diseases could be attributed to cross-connection between the municipal water supply and sewer due to leaky joints. In the United State of America, 11-18% (1920-1990) and 22% (1991-1996) of reported outbreaks of water-borne diseases were attributable to contamination of the distribution system and storage facilities, respectively4; whereas in the United

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Kingdom, 36 % (1911-1995) reported water-bone disease outbreaks in public water supplies were related to the distribution system.

At present the underground water is not safe for drinking purpose because of arsenic contamination7. The groundwater quality information maps of the entire study area have been prepared by GIS, Inverse Distance Weighing (IDW) technique for all the above parameters. The result obtained in this study with the spatial database established in GIS has made helpful for monitoring and managing groundwater quality and its pollution in the study area of Chittagong region and other neighboring districts8, 9.

MATERIALS AND METHODS

Surface samples from different points of greater Chittagong district were collected for this study. Samples were collected in amber color polyethylene bottle cleaned by rinsing thoroughly with 8M HNO3, followed by repeated washing with distilled water. The samples were mixed well and a sample of 1.0-1.5 L was transferred for analysis in the laboratory. It was fixed to collect the sample from different places during winter season, especially December to January, which were first analyzed for Physicochemical analysis. There was followed the standard procedures prescribed by American Public Health Association (APHA) for Physicochemical Analysis, such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), pH, Bicarbonate, Acidity, Carbon dioxide, Alkalinity, Arsenic, Chloride, Chromium, Copper, Cobalt, Dissolved Oxygen (DO), Iron, Lead, Manganese, Nickel, Nitrate, Oxygen demand (Chemical) COD, Oxygen demand (Biochemical) BOD, Phosphate, Sulfate, Zinc etc10, 11. The results of drinking water quality were compared with standard values, which was suggested by World Health Organization WHO in 2006 and 2008.

GIS technology proved to be very useful for enhancing the accuracy. We obtained the location of the well by using the GPS and Arc GIS software. The IDW was applied to find out the spatial distribution of groundwater quality. In interpolation with the spatial analyst method of IDW, a weight is attributed to the point to be measured. The amount of this weight is dependent on the distance of the point to another unknown point6. These weights are controlled on the bases of power of ten. With increase of

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power of ten, the effect of the points that are farther diminishes. Lesser power distributes the weights more uniformly between neighboring points. In this method the distance between the points count, so the points of equal distance have equal weights12. The advantage of IDW is that it is intuitive and efficient. This interpolation works best with evenly distributed points. Similar to the SPLINE functions, IDW is sensitive to outliers. Furthermore, unevenly distributed data clusters result in introduced errors13.

Maps of well location and different water quality parameters e.g. pH, temperature, electrical conductivity, salinity, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), sulfate, nitrate, phosphate, chloride, total alkalinity, total hardness, arsenic, iron, manganese, chromium, nickel, cadmium, lead, copper, and zinc of 106 sampling locations were prepared with the help of spatial interpolation technique in Arc GIS Software. Three spatial interpolation techniques are used to estimate the missing gages values based on the remaining ones14. These techniques are available in Arc GIS Software are ranked based on the best minimum average to the worst maximum average and to other statistics.

RESULTS AND DISCUSSION

pH

Histogram of pH of Chittagong region groundwater samples shows (Fig. 1) that most of the samples have pH value in the acidic to alkaline (6.04-8.96) range. (Table 1-10) shows the lower values of pH, below the WHO limit (6.5-8.5), were found for the samples of Chittagong city (6.04) and Hathazari (6.20) upazila. Lower values of pH were found for the samples of Khagrachhari (7.20), Cox's Bazar (7.30), Rangamati (7.09) and Bandarban (7.35) districts. pH was found positively correlated with nitrate, total alkalinity, and arsenic, and negatively correlated with turbidity, phosphate and manganese. According to Halim et al.15 the groundwater samples had pH circum-neutral and values in the range between 6.9 and 7.3 with a mean value of 7.05 in Sherajdikhan, Bangladesh. According to Pandey et al.16 the value of pH 6.8 to 8.3 in groundwater samples of Ghaziabad city, India. Okoye et al.17 reported lower pH (5.7–7.8) in comparison to the WHO recommended range (6.5–8.5), in Gboko, Nigeria. Knowledge of pH in the raw water used for public water supplies is

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important because without adjustment to a suitable level, such waters may be corrosive and adversely affect treatment processes including coagulation and chlorination18. Spatial distributions of pH concentrations are shown in Figure 2.

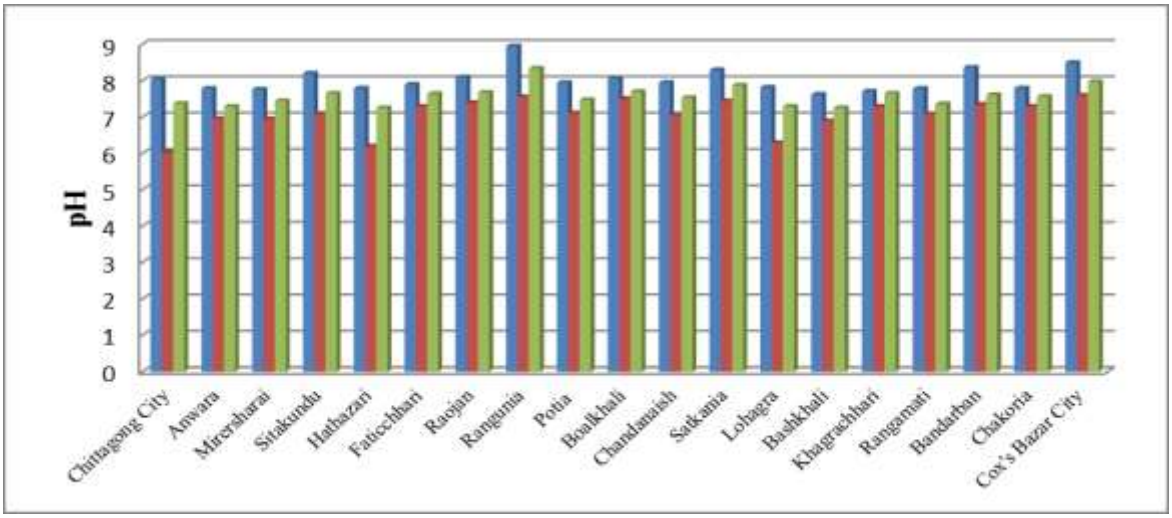


Figure 1 pH of greater Chittagong district groundwater samples.

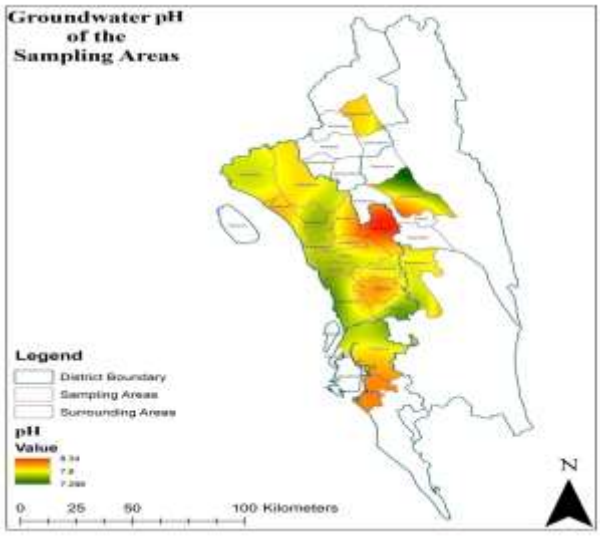


Figure 2 Spatial distributions of pH of groundwater samples.

Temperature

Histogram of temperature of Chittagong region groundwater samples shows (Fig. 3) that almost all of the samples temperature within the permissible limit. Figure 4 shows

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the spatial distribution of the temperature in the greater Chittagong district.

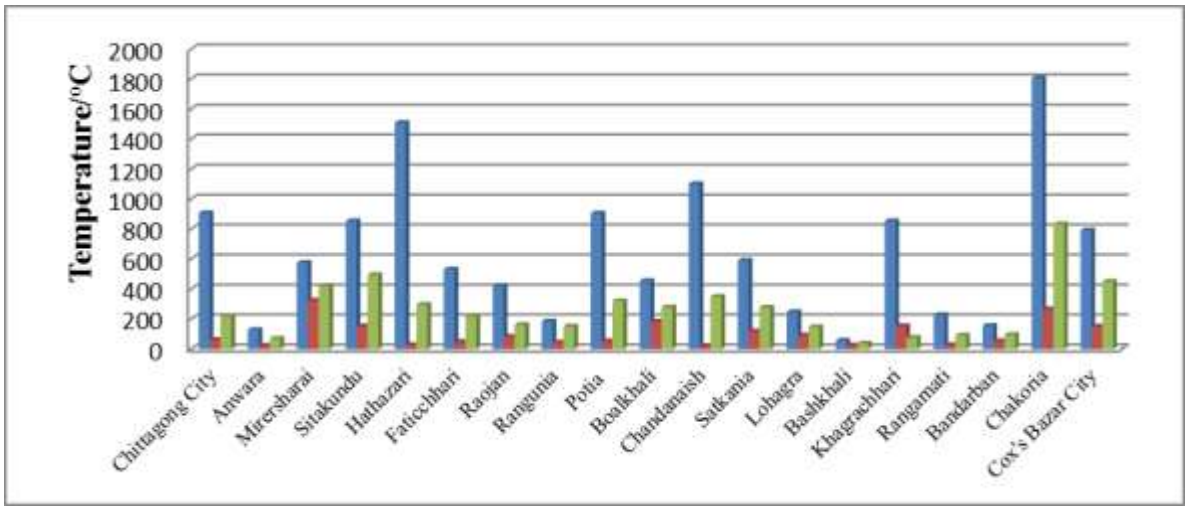


Figure 3 Temperature of greater Chittagong district groundwater samples

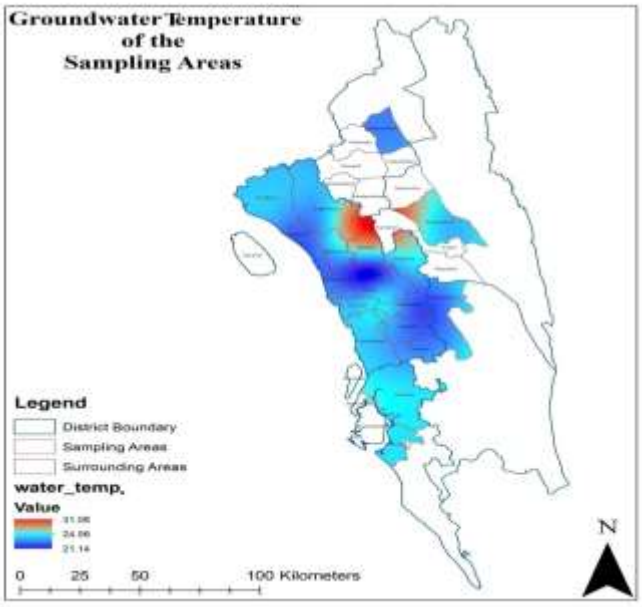


Figure 4 Spatial distributions of temperature of groundwater samples

Electrical conductivity (EC)

Histogram of EC of Chittagong region groundwater samples shows (Fig. 5) that most of the samples have EC values well below the WHO limit (500.00 mgL-1) for drinking water but (Table 1-10) shows the

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higher values of Chittagong (3020.00 mgL-1) and Cox's Bazar (3620.00 mgL-1) districts are far beyond the permissible limit. EC was found positively correlated with TDS, salinity, chloride, turbidity, phosphate, total hardness, total alkalinity and arsenic. Excess electrical conductivity is objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes and higher costs because of corrosion or the necessity for additional treatment.

Kouras et al.19 reported that in groundwater in the area of Chalkidiki, Northern Greece EC was relatively high, ranging from 828 to 1970 µscm-1 with mean value 1406 µS/cm-1. Figure 6 shows the spatial distribution of electrical conductivity in the study area.

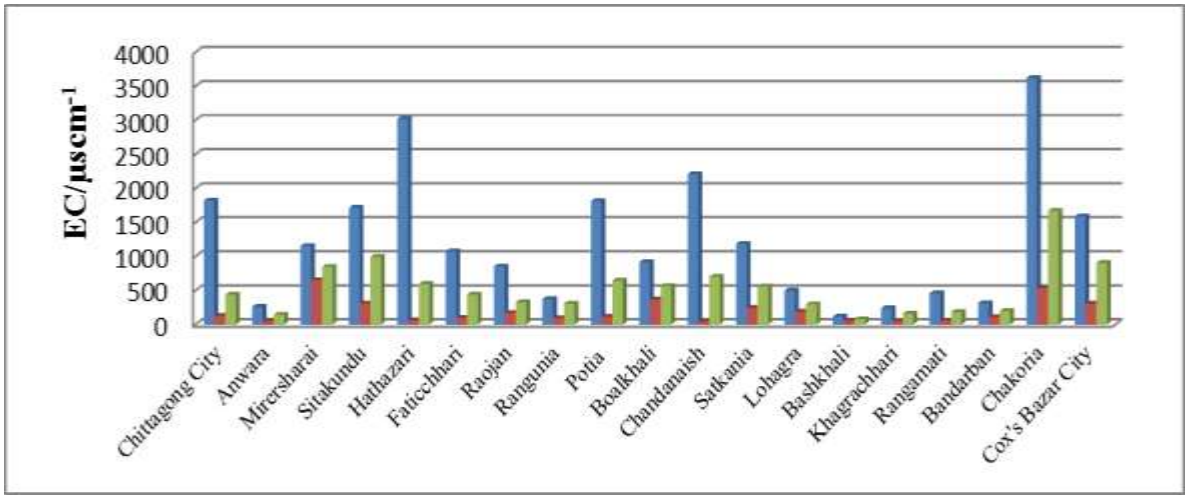


Figure 5: Electrical conductivity of greater Chittagong district groundwater samples

Maximum ***Minimum*** ***Mean***

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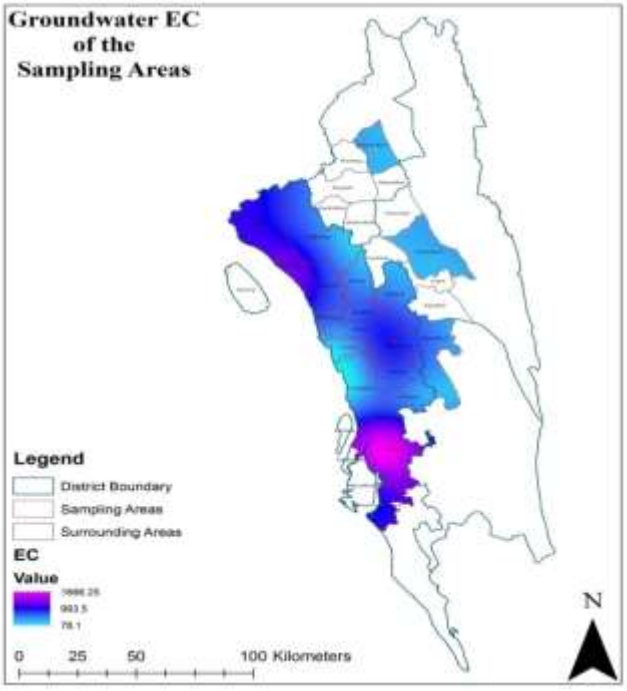


Figure 6 Spatial distributions of EC of groundwater samples

Total dissolved solids (TDS)

Total dissolved solids are terms generally associated with freshwater systems and consist of inorganic salts, small amounts of organic matter and dissolved materials. Salinity is an oceanographic term and although not precisely equivalent to the total dissolved salt content it is related to it. Histogram of TDS of Chittagong region groundwater samples shows (Fig.7) that most of the samples have TDS values well below the WHO limit (1000.00 mg L-1) for drinking water but shows the higher values of Chittagong (1563.00 mgL-1) and Cox's Bazar (1809.00 mgL-1) districts are far beyond the permissible limit. Water containing more than 500 mgL-1of TDS is not considered desirable for drinking water supplies, though more highly mineralised water may be used where better quality water is not available20. TDS was found positively correlated with EC, salinity, chloride, turbidity, phosphate, total hardness, total alkalinity and arsenic. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes and higher costs because of corrosion or the necessity for additional treatment. The physiological effects directly related to

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TDS include laxative effects principally from sodium sulfate and magnesium sulfate and the adverse effect of sodium on certain patients afflicted with cardiac disease and women with toxemia associated with pregnancy18. According to Mishra et al.21 in present investigation this limit is not crossed on either side by any of the samples under study. Figure 8 shows the spatial distribution of TDS in the study area.

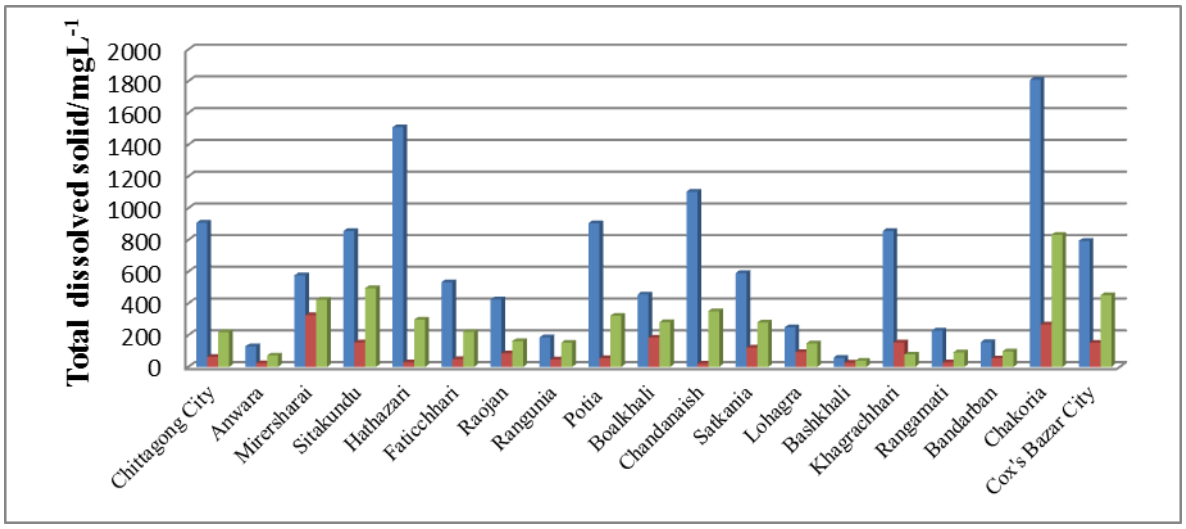


Figure 7 Total dissolved solid of greater Chittagong district groundwater samples

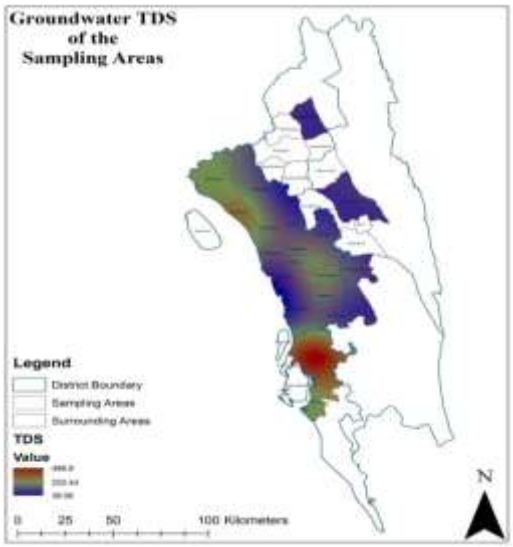


Figure 8 Spatial distributions of TDS of groundwater samples

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Salinity

Histogram of salinity of Chittagong region groundwater samples shows (Fig. 9) that almost all of the samples salinity within the permissible limit. Salinity was found positively correlated with chloride, EC, TDS, total alkalinity, total hardness, turbidity, phosphate, arsenic and nickel. Figure 10 shows the spatial distribution of salinity in the study area.

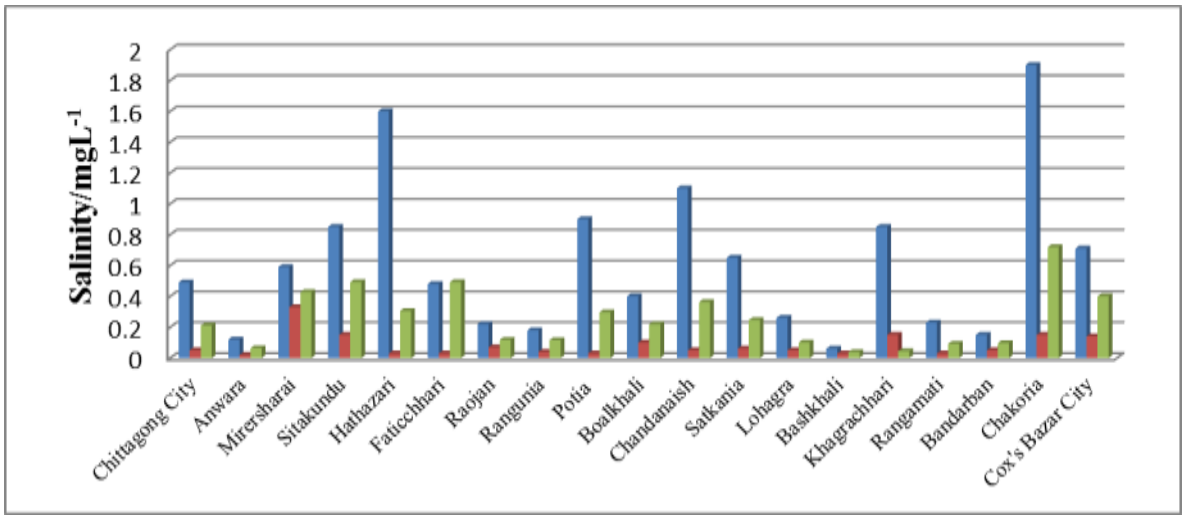


Figure 9 Salinity of greater Chittagong district groundwater samples

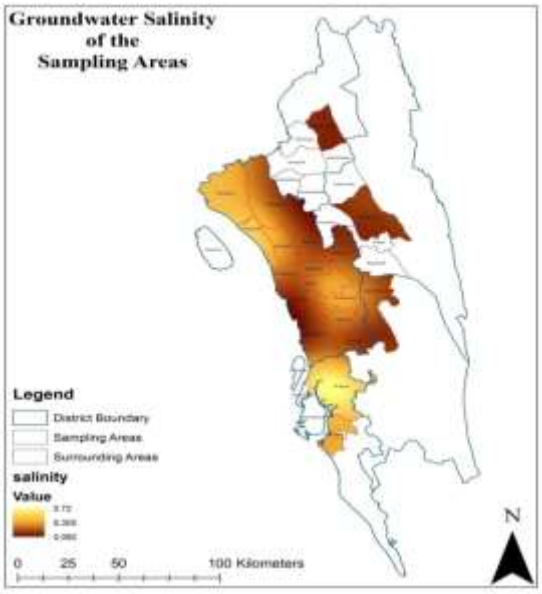


Figure 10 Spatial distributions of salinity of groundwater samples

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Chloride

Histogram of chloride content of Chittagong region groundwater samples shows (Fig. 11) that most of the samples have chloride below 200.0 mgL-1. (Table 1-10) shows the higher values for the samples of Chittagong (49.61 mgL-1) and Cox's Bazar (103.38 mgL-1) districts, which are also within the permissible limit (250.00 mgL-1) for drinking water. Chloride content of all the five districts is within the acceptable limit of BSTI standard (Max 600 mgL-1). Chloride was found positively correlated with salinity, TDS, acidity, total alkalinity, total hardness, phosphate and arsenic. Pandey et al.16 reported chloride content in groundwater samples in the range 78-106 mgL-1 of Ghaziabad city, India. According to Trivedy et al.22 over exploitation of groundwater in many parts of India has resulted into lowering of groundwater level and leading to ingress as sea water in coastal areas making the subsurface water saline. Chloride content of Noakhali and Lakshmipur exceeded the limit of BSTI standard (Max 600 mgL-1)23. Figure 12 shows the spatial distribution of chloride in the study area.

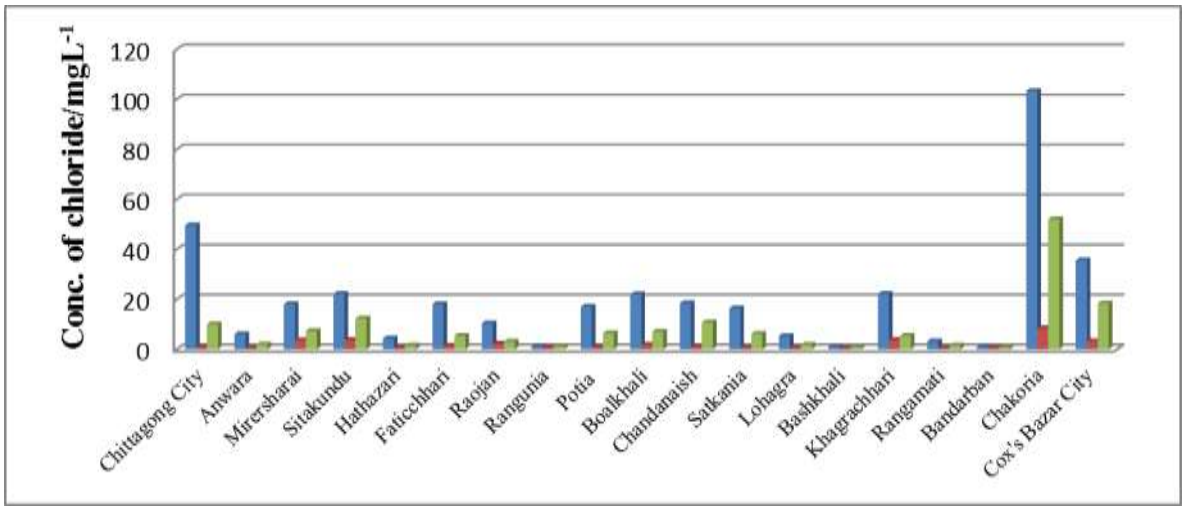


Figure 11 Concentration of chloride of greater Chittagong district groundwater samples.

Maximum ***Minimum*** ***Mean***

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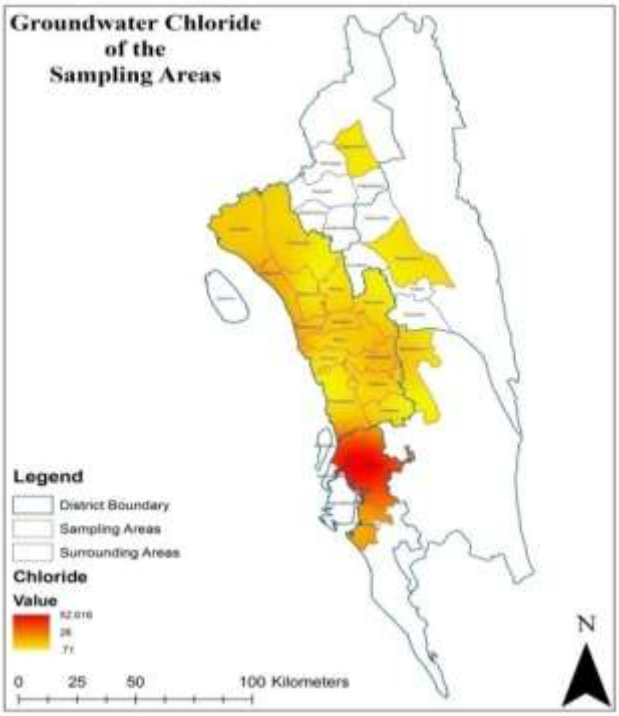


Figure 12 Spatial distributions of chloride of groundwater samples

Dissolved Oxygen (DO)

Dissolved oxygen is an important parameter in water quality assessment and biological processes prevailing in the water. The DO values indicate the degree of pollution in the water bodies. The presence of dissolved oxygen (DO) enhances the quality of water and also acceptability24. An ideal DO value of 5.0 mgL-1 is the standard for drinking water.

Dissolved oxygen (DO) of bore well water under the area determined in the present investigation ranged between from 3.4– 8.5 mgL-1. Histogram of DO of Chittagong region groundwater samples shows (Fig.13) that most of the samples have DO within the standard for drinking water. Kerketta et al.24 found the value of DO (3.95+0.05 to 8.95+0.15 mgL-1) around Ranchi, Jharkhand, India. DO was found positively correlated with BOD and nickel and negatively correlated with temperature and copper.

Figure 14 shows the spatial distribution of DO in the study area.

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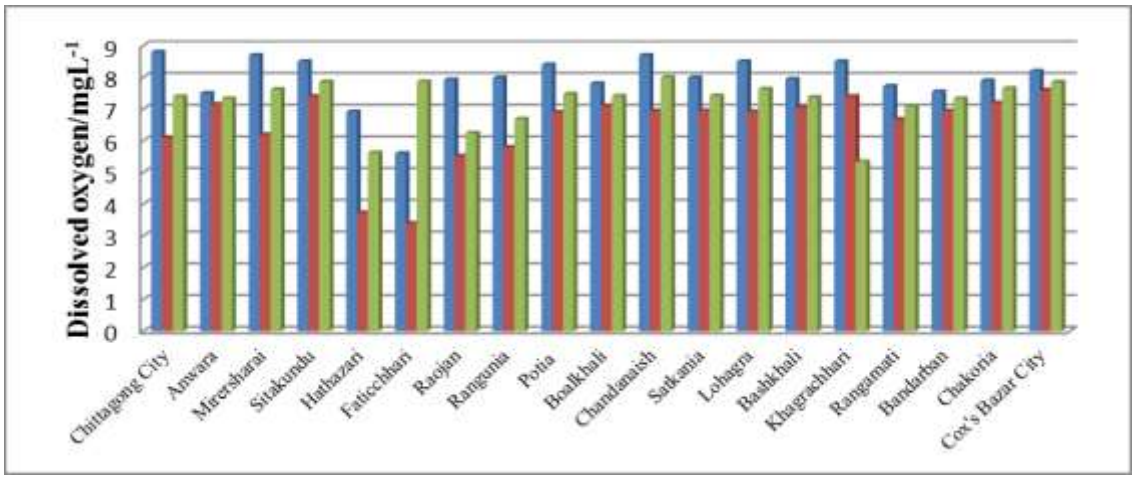


Figure 13 Dissolved oxygen of greater Chittagong district groundwater samples

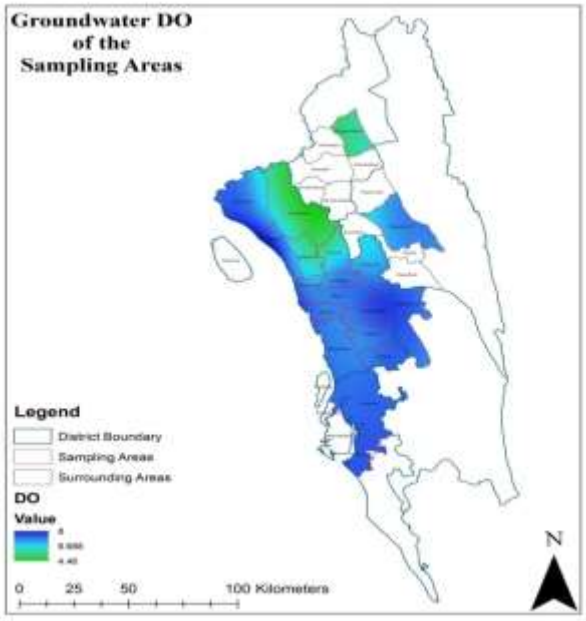


Figure 14 Spatial distributions of DO of groundwater samples.

Turbidity

Histogram of turbidity of Chittagong region groundwater samples shows (Fig. 15) that most of the samples turbidity exceeds the permissible limit. (Table 1-10) shows the minimum and maximum value of turbidity is 0 to 203 NTU. Turbidity was found positively correlated with EC, TDS, salinity and manganese and negatively correlated with pH. Figure 16 shows the spatial distribution of turbidity in the study area.

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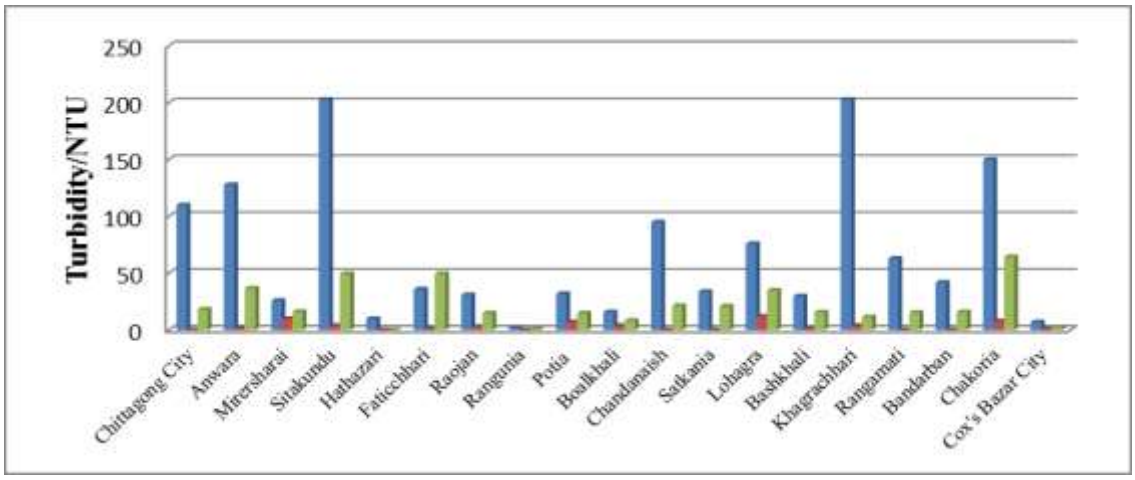


Figure 15 Turbidity of greater Chittagong district groundwater samples

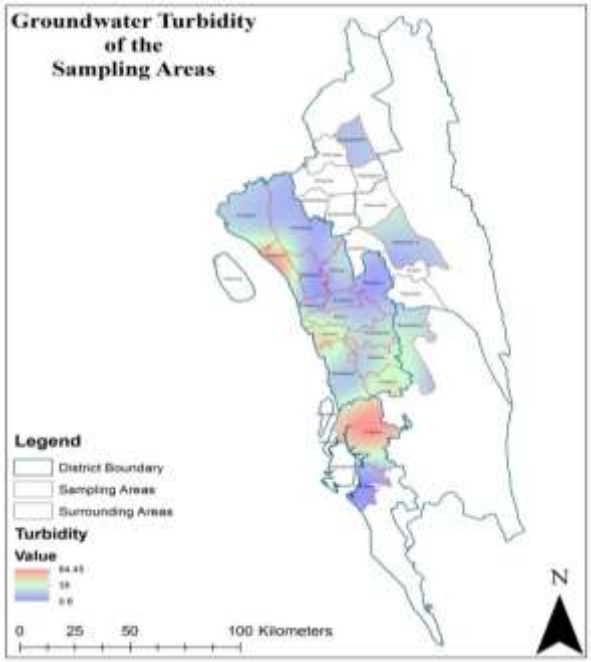


Figure 16 Spatial distributions of turbidity of groundwater samples

Phosphate

Histogram of phosphate of Chittagong region groundwater samples shows (Fig. 17) that most of the samples have o-phosphate-P value below 5.00 mgL-1. Table 1-10 shows the higher values for the sample of Chittagong (9.3 mgL-1) and Cox's Bazar (8.7 mgL-1) districts are beyond the BSTI limit for drinking water. Phosphate was found positively correlated with chloride.

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Phosphate was found positively correlated with EC, TDS, salinity, total alkalinity, arsenic, nickel, lead and zinc and negatively correlated with pH. According to Jafari et al.25 in groundwater samples of Kohdasht region of the Lorestan, Iran, phosphate (PO43-) ranged from 0.11-0.31 mgL-1. According to Rahman et al.20 groundwater samples of cox's Bazar district contained mean concentration of o-phosphate-P 12.7 mgL-1. Figure 18 shows the spatial distribution of phosphate in the study area.

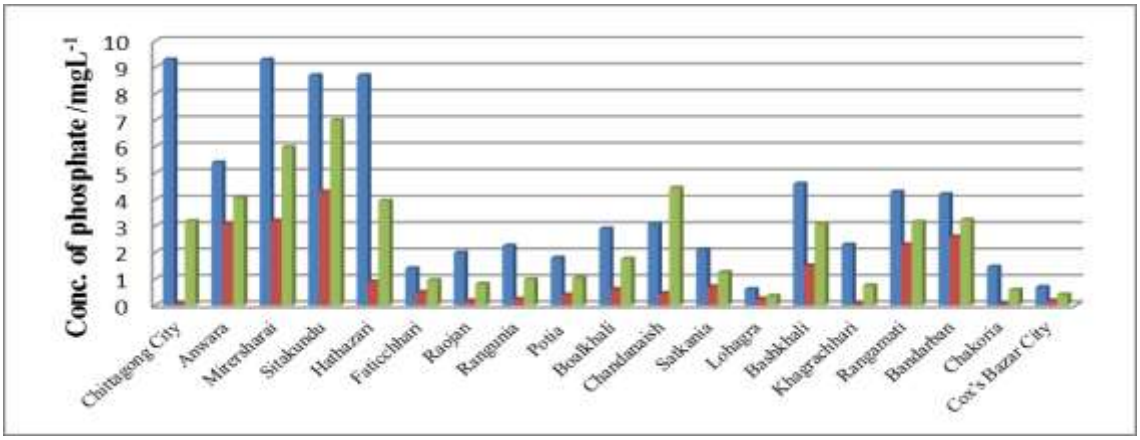


Figure 17 Concentration of phosphate of greater Chittagong district groundwater samples.

Maximum ***Minimum*** ***Mean***

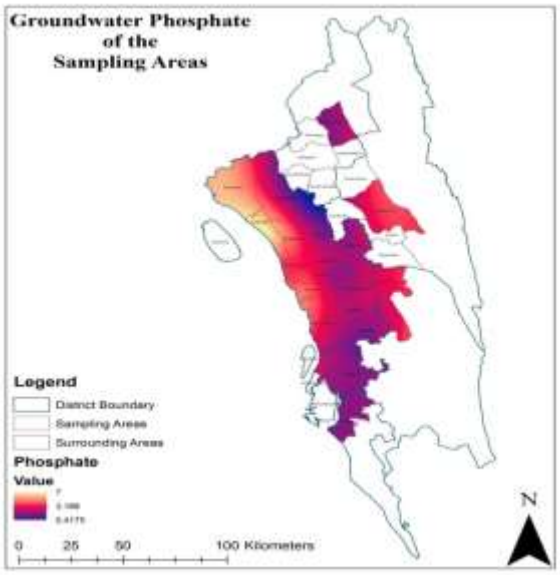


Figure 18 Spatial distributions of phosphate of groundwater samples.

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Sulphate

Histogram of sulfate-S of Chittagong region groundwater samples shows **(Fig. 19)** that most of the samples have sulfate value below 300.00 mgL^{-1}, well below the WHO limit (Max. 400.00 mgL^{-1}). Highest value (75 mgL^{-1}) was found for the sample of Cox's Bazar district, which is also within the WHO limit for drinking water.

Sulfate content of this region is within the acceptable limit of BSTI standard (Max 400 mgL^{-1}) [23]. Sulfate was found positively correlated with total hardness and nickel. Consumption of water with higher amount of sulfate may impart laxative effects. **Figure 20** shows the spatial distribution of sulphate in the study area.

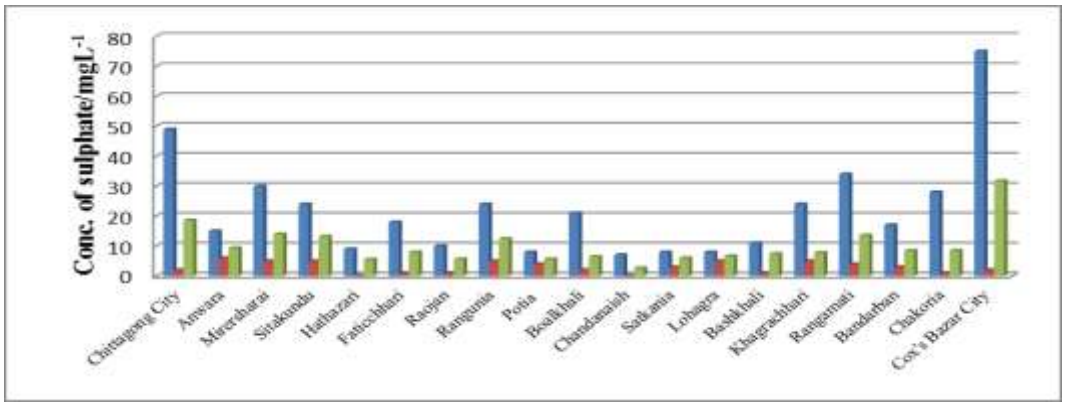


Figure 19 Concentration of sulphate of greater Chittagong district groundwater samples

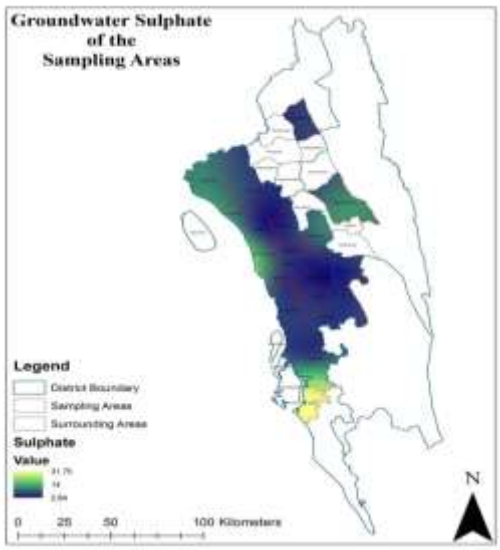


Figure 20 Spatial distributions of sulphate of groundwater samples

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Nitrate

Histogram of nitrate content of Chittagong region groundwater samples shows (**Fig. 21)** that most of the samples have nitrate value below 2.00 mgL^{-1}, well below the WHO (10.00 mg L^{-1}) limit for drinking water. Highest value (3.20 mgL^{-1}) was found for the sample of Chittagong district, which was also within the WHO limit. Nitrate of the groundwater samples were found for the Chittagong region (0-3.2 mgL^{-1}).

Bashar *et al*.[26] reported that nitrate-N is the most prevalent form of nitrogen compound in groundwater and (1.1-1.8 mgL^{-1}) in Maddhayapara Granite mine area of Dinajpur district. Nitrate was found positively correlated with pH and nickel. In a study by Katsoyiannis *et al*.[27] in Thessaloniki, Northern Greece nitrate was detected only in 3 out of 11 ground waters exhibiting a maximum concentration of 0.11 mgL^{-1} being a lot lower than the MCL of nitrate in ground waters of 50 mgL^{-1} **Figure 22** shows the spatial distribution of nitrate in the study area.

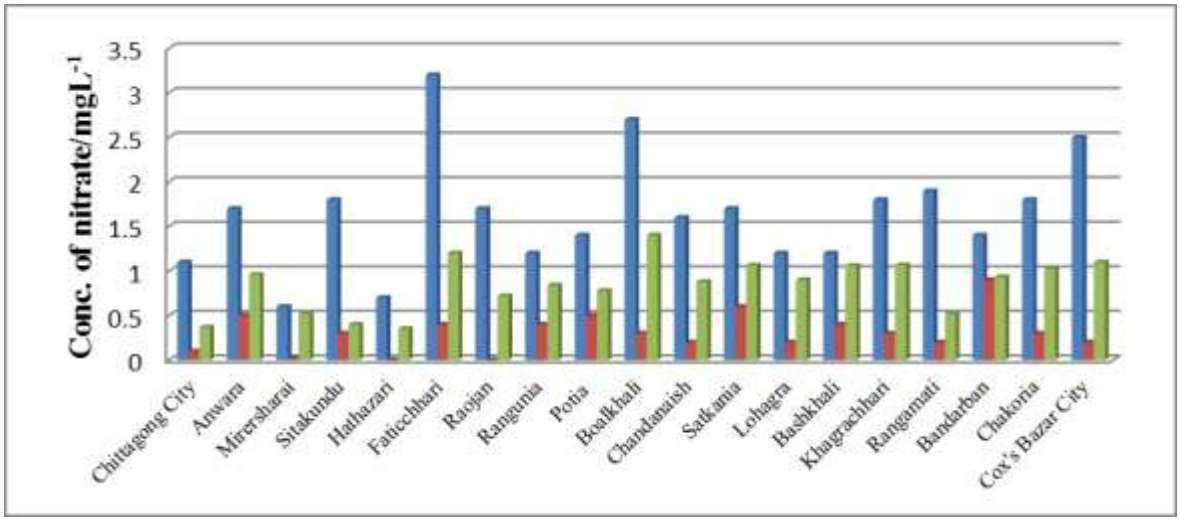


Figure 21 Concentration of nitrate of greater Chittagong district groundwater samples.

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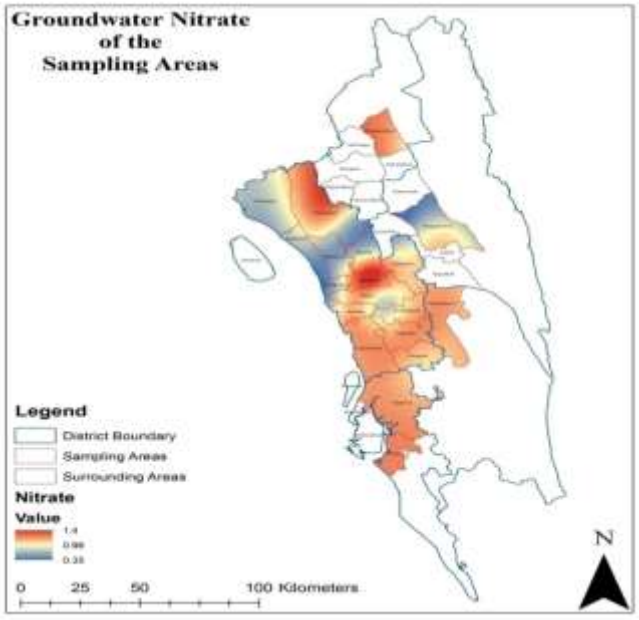


Figure 22 ***Spatial distributions of nitrate of groundwater samples***.

Total hardness

Histogram of total hardness of Chittagong region groundwater samples shows **(Fig. 23)** that most of the samples have total hardness below 300.0 mgL^{-1}. **Table 1-10** shows the highest value (820.00 mgL^{-1}) for the sample of Cox's Bazar district. Total hardness was found positively correlated with EC, TDS, salinity, chloride and sulphate.

Katsoyiannis *et al.*[27] reported as calcium and bicarbonate were also recorded as dominant ions in the majority of groundwater samples in the area of Thessaloniki, Northern Greece.

Ray *et al.*[28] distributed data for the total hardness showed that 81.3% of the observations fall within the allowable standards of 500 mgL^{-1}, the highest being 1610 mgL^{-1}. **Figure 24** shows the spatial distribution of total hardness in the study area.

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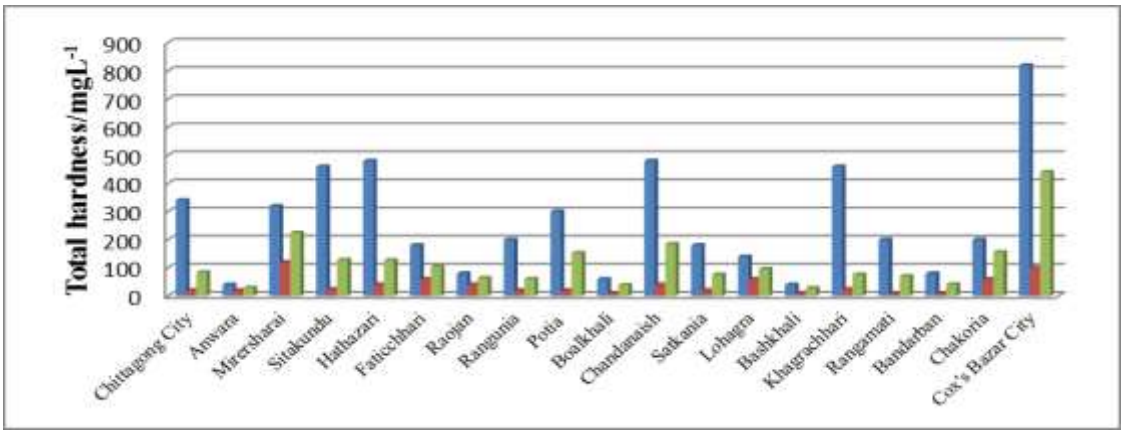


Figure: 23 Total hardness of greater Chittagong district groundwater samples

Maximum ***Minimum*** ***Mean***

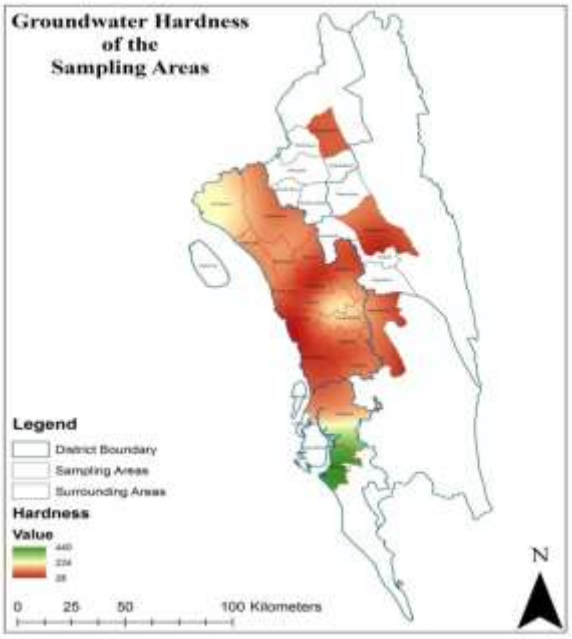


Figure 24 Spatial distributions of total hardness of groundwater samples

Total alkalinity

Histogram of alkalinity of Chittagong region groundwater samples shows **(Fig. 25)** that most of the samples have alkalinity below 500.0mgL^{-1}. **Table 1-10** shows the highest values for the samples of Chittagong (1097.77 mgL^{-1}) and Cox's Bazar (500.115 mgL^{-1}) districts. According to Gupta *et al.*[29]

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in the city of Taz, India, total alkalinity of groundwater samples ranged from 200-600 mgL^{-1}. Total alkalinity was found positively correlated with pH, EC, TDS, salinity, chloride and phosphate. **Figure 26** shows the spatial distribution of total alkalinity in the study area.

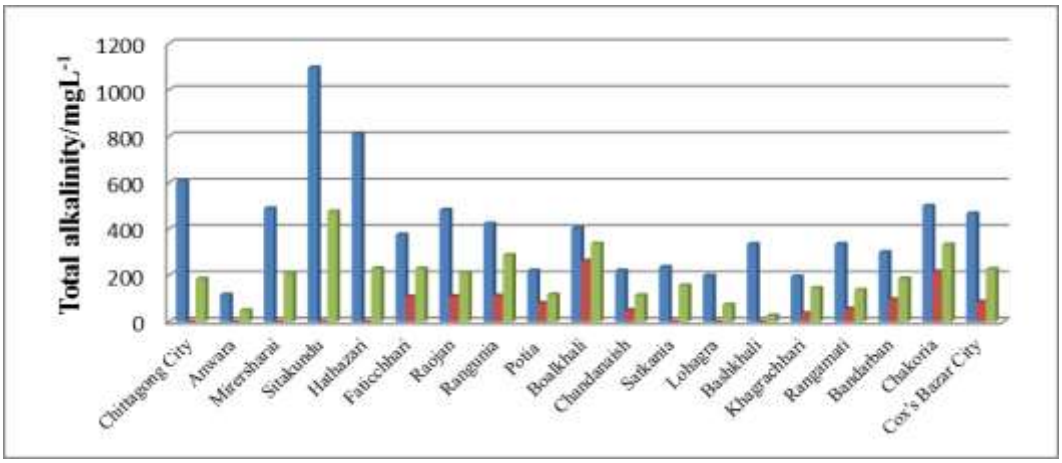


Figure 25 Total alkalinity of greater Chittagong district groundwater samples

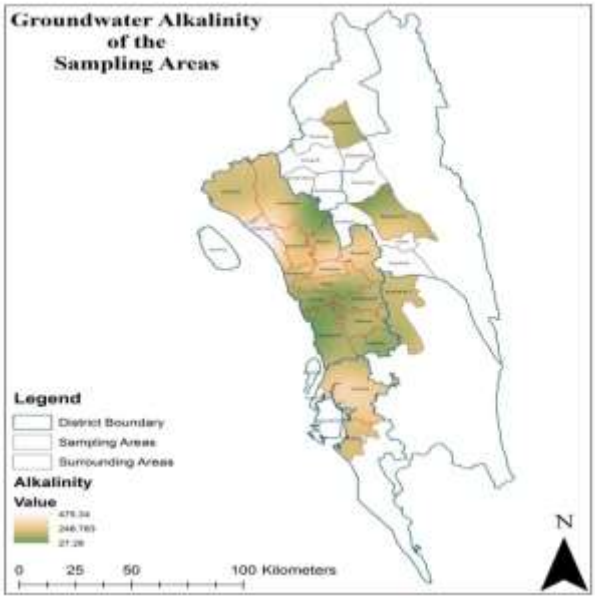


Figure 26 Spatial distributions of total alkalinity of groundwater samples.

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Biological oxygen demand (BOD)

Biochemical oxygen demand (BOD) is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. It is not a precise quantitative test, although it is widely used as an indication of the organic quality of water. According to WHO (1993), the permissible limit of BOD in water is 5 mgL-1. However, in all the stations samples showed the permissible limits. Onwughara et al.30 reported that the BOD values range is 5.35-15.9 mgL-1 of selected boreholes in Umuahia North Local Government Area, in Abia State, Nigeria. **Figure 28** shows the spatial distribution of biological oxygen demand in the study area.

Chemical oxygen demand (COD)

Chemical Oxygen Demand (COD) is a measure of pollution in aquatic system. High COD may cause oxygen depletion on account of decomposition by microbes to a level detrimental to aquatic life. In the present study COD values are found to be 2.8 to 156.8mgL-1. Jain et al.31 found that most of the samples COD values exceed the permissible limits. **Figure 30** shows the spatial distribution of chemical oxygen demand in the study area.

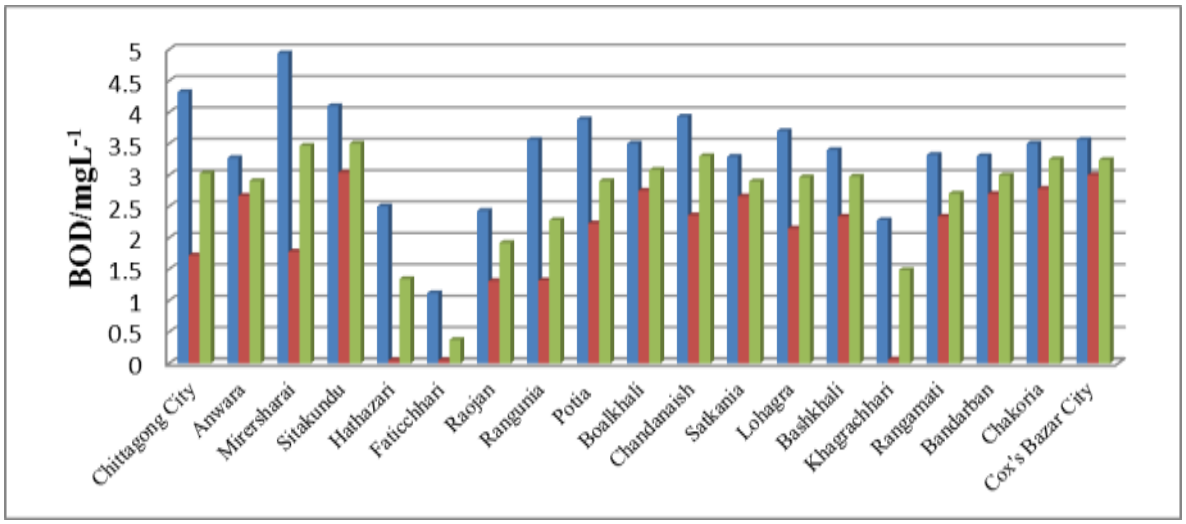


Figure 27 BOD of greater Chittagong district groundwater samples

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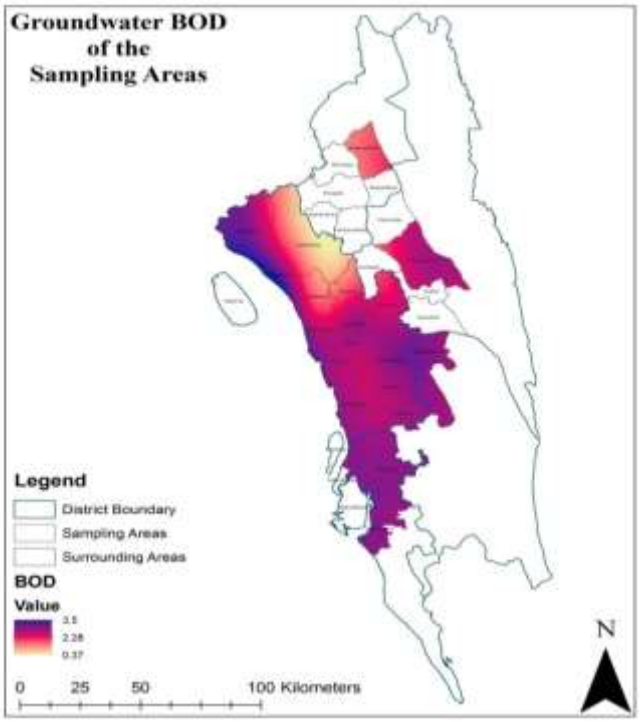


Figure 28 Spatial distributions of BOD of groundwater samples

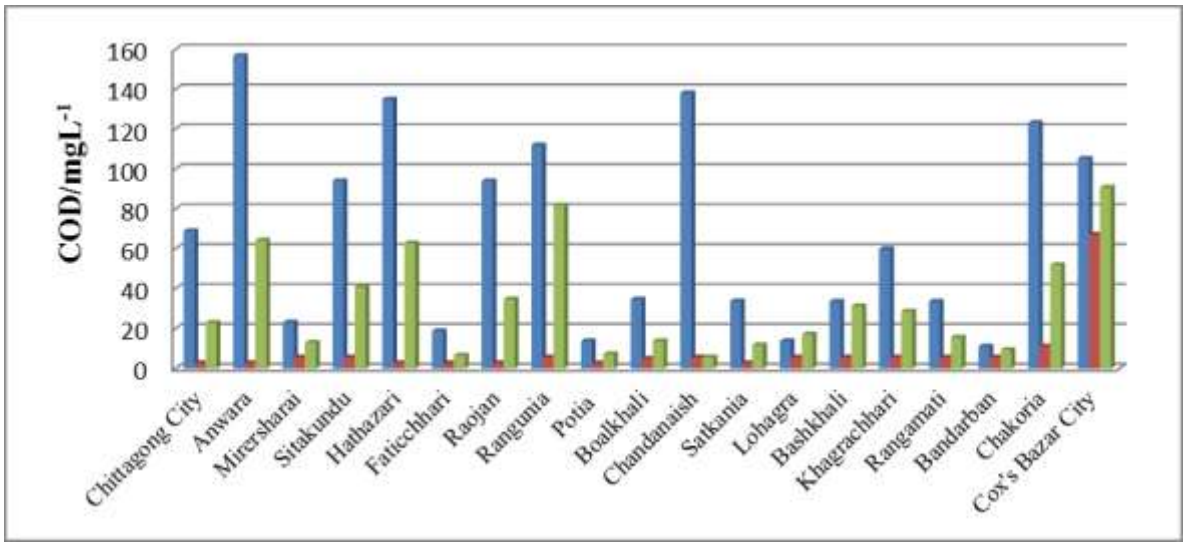


Figure 29 COD of greater Chittagong district groundwater samples.
Maximum ***Minimum.*** ***Mean***

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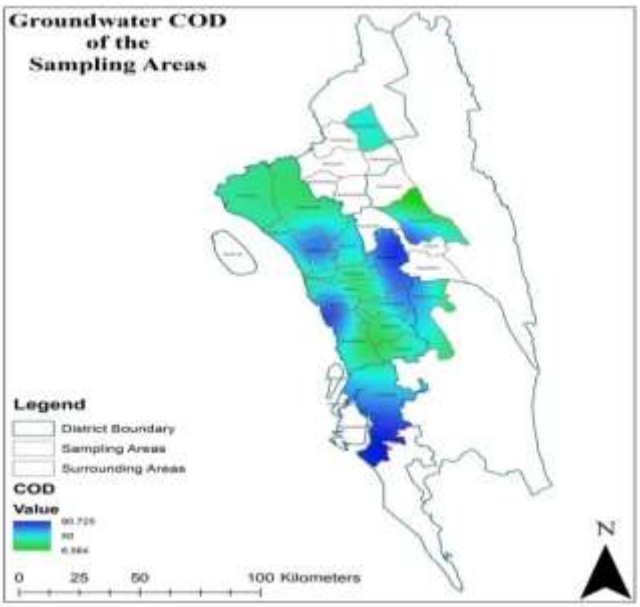


Figure 30 Spatial distributions of COD of groundwater samples

Acidity

Figure 31 shows the spatial distribution of acidity in the study area.

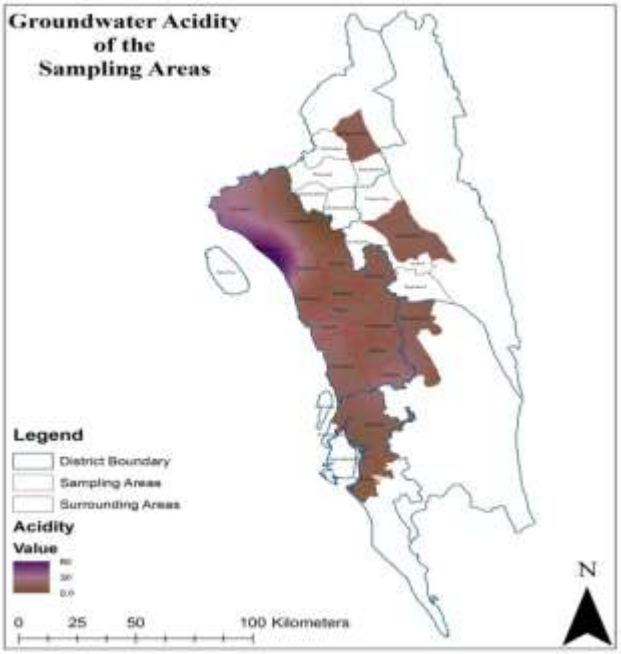


Figure 31 Spatial distributions of acidity of groundwater samples

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Carbon dioxide (CO2)

Figure 32 shows the spatial distribution of CO2 in the study area.

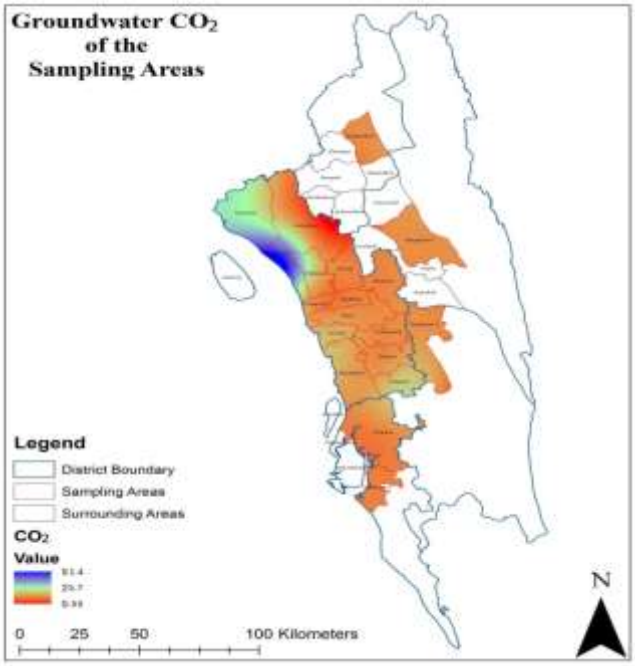


Figure 32 Spatial distributions of CO2 of groundwater samples

Arsenic (As)

Arsenic is a toxic element and classified as a human carcinogen32. According to WHO (1981), 1.0 µg of inorganic As per day may give rise to skin lesions within a few years33. According to Islam et al.34 underground water is not safe for drinking purpose because of arsenic contamination. The total Arsenic (As) content in polluted environmental samples (soil, sediment) is poor indicator of its bioavailability, mobility or toxicity35. Histogram of arsenic content of Chittagong region groundwater samples shows (Fig. 33) that most of the samples did not contain arsenic. Figure 33 shows that about 1% of the samples examined contained arsenic ≥0.5 mgL-1 and 17% of the samples contained arsenic ≥0.1 mgL-1. Highest value (0.5 mgL-1) was found for the sample of Chittagong district, which is far above the WHO limit (0.01 mgL-1) for drinking water. Arsenic contamination of groundwater is a huge health problem and the largest environmental catastrophe now taking place in Bangladesh. Millions of people have been suffering from chronic

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arsenic poisoning not only in Bangladesh but also in many countries of the world. Miah et al.36 reported that irrigation with high arsenic water (>100µgL-1) is positively related to the high arsenic content in wetland rice. Proper investigation is urgently required to address the issue of food and medicine contamination with arsenic. Rahman et al.37 also reported that >94% shallow tube wells of Mirersharai and 82.7% of Sitakunda upazilas contained arsenic above the permissible limit. Groundwater contamination by arsenic is a big threat to the lives of thousands of people in Bangladesh38. Positively correlation was found for arsenic with pH, TDS, salinity, EC, PO43-, total alkalinity, and nickel. According to Halim et al.15 groundwater samples had dissolved arsenic ranged from 0.006 to 0.461 mgL-1, with 69% groundwater samples exceeded the Bangladesh limit for safe drinking water (0.05 mgL-1)18. According to Baig et al.39 As pollution in surface and groundwater resources of Jamshoro, Sindh, Pakistan exceeded the WHO provisional guideline value of 10 (µgL−1). According to Hossain et al.40 an estimated 50 million people are at risk from drinking arsenic contaminated water in Bangladesh and West Bengal, India. Although Arsenic (As) was found in many samples of this region, in comparison with other regions of this division, such as Comilla and Noakhali, this region is less prone to arsenic. Figure 34 shows the spatial distribution of arsenic in the study area.

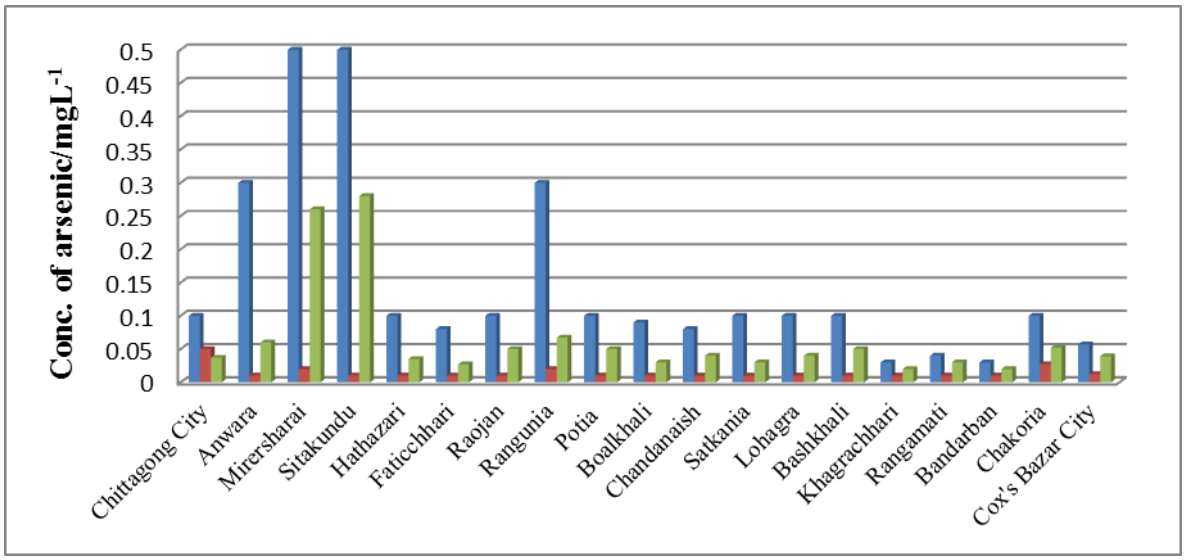


Figure 33 Concentration of arsenic of greater Chittagong district groundwater samples.

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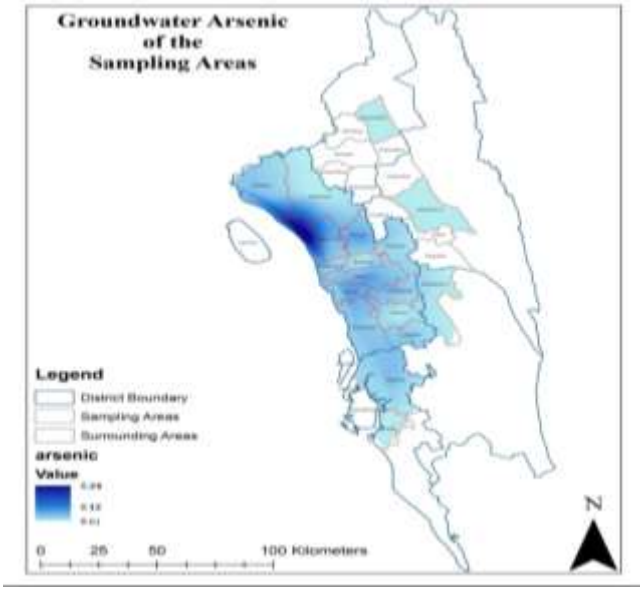


Figure 34 Spatial distributions of arsenic of groundwater samples

Cadmium (Cd)

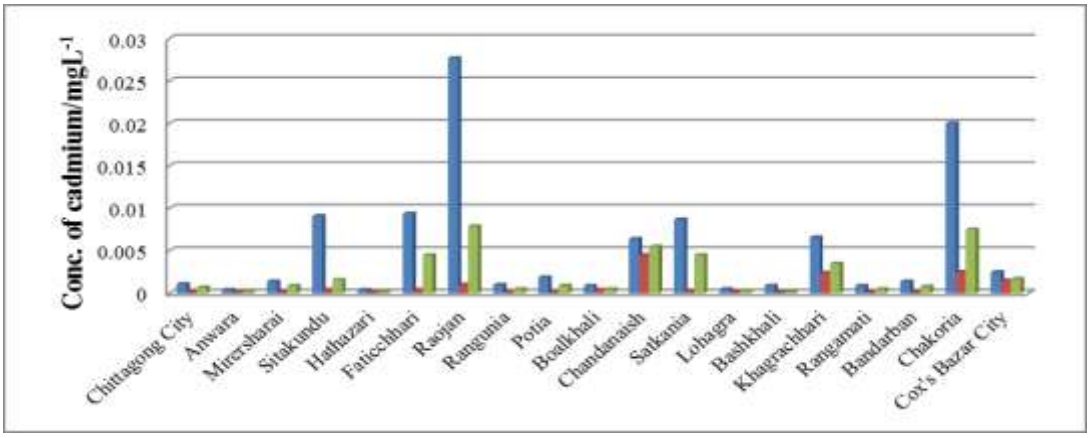


Figure 35 Concentration of cadmium of greater Chittagong district groundwater samples.

Cadmium content of Chittagong region groundwater samples shows that the cadmium of all the stations ranged from BDL to 0.0094 mgL-1. All the values were within the permissible limits. Important source of cadmium is the use of mineral phosphate fertilizer, which typically contains high cadmium concentrations in addition to other elements. Kerketta et al.24 found the range for cadmium is (0.04±0.01 to 0.11±0.03 mgL-1) around Ranchi, Jharkhand, India. Figure 36 shows the spatial distribution of cadmium in the study area.

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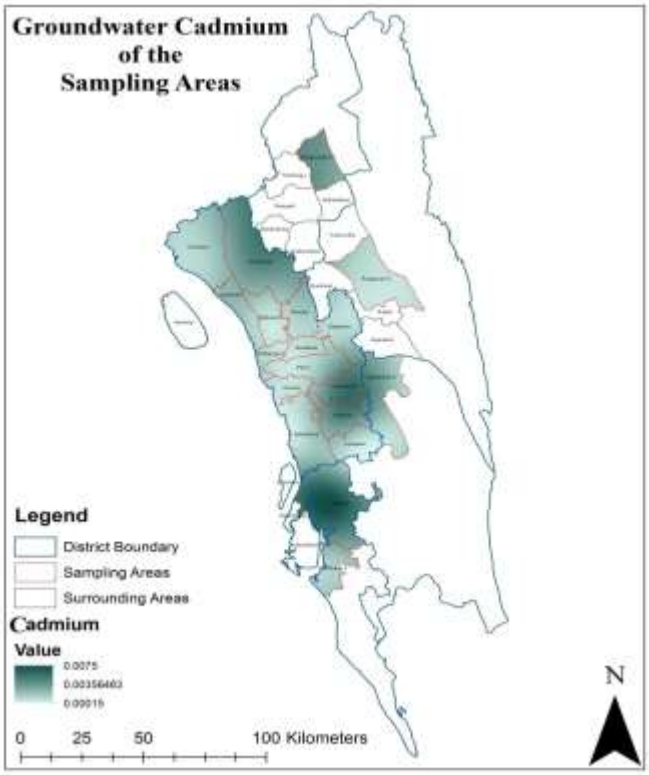


Figure 36 Spatial distributions of cadmium of groundwater samples

Cobalt (Co)

Histogram of cobalt content of Chittagong region groundwater samples shows that almost all of the concentrations of cobalt (Co) were in general very low and less than the permissible limits. Oladipo et al.41 found the cobalt which was above the limit set by FEPA 1998 and WHO 2011 in Lapai Metropolis.

Chromium (Cr)

Histogram of chromium content of Chittagong region groundwater samples shows (Fig. 37) that the concentrations of chromium in the present study ranged between BDL-0.193 mgL-1. Most of the concentrations of chromium (Cr) were in general very low and less than the permissible limits.

According to Ngele et al.42 found the range for chromium is 0.048-0.059 mgL-1 in Amike-Aba, Abkaliki Ebonyi State, Nigeria. Figure 38 shows the spatial distribution of chromium in the study area.

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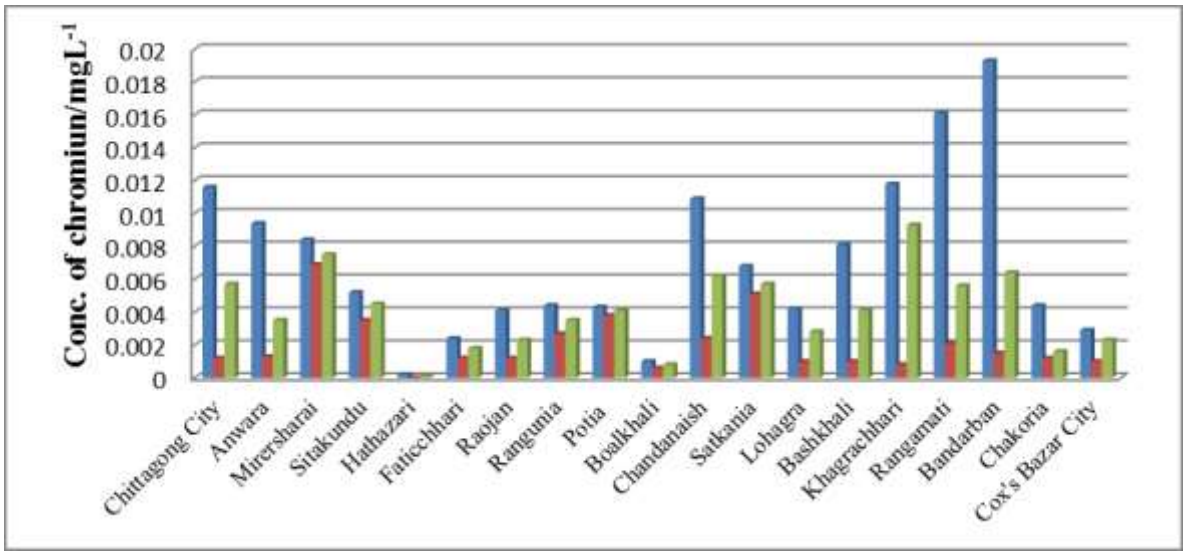


Figure 37 Concentration of Chromium of greater Chittagong district groundwater samples.

Maximum ***Minimum*** ***Mean***

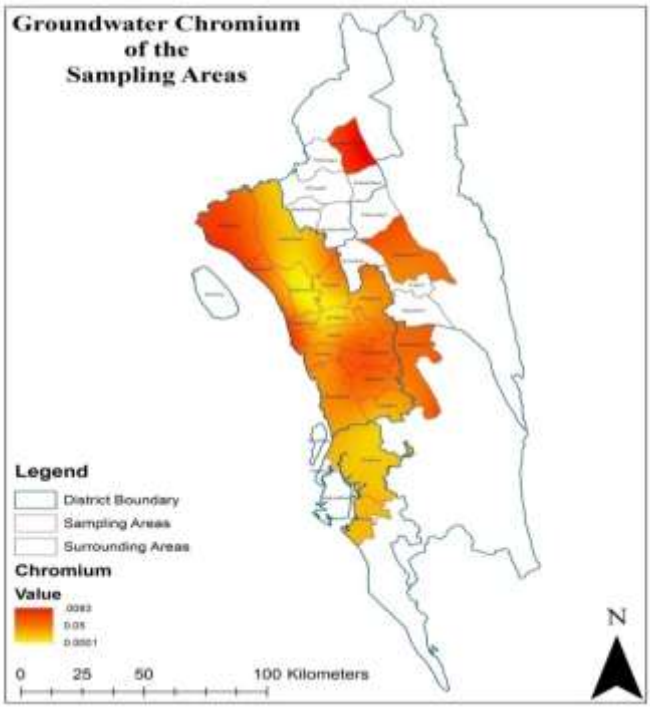


Figure 38 Spatial distributions of chromium of groundwater samples

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Copper (Cu)

Histogram of copper content of Chittagong region groundwater samples shows (Fig. 39) that the concentrations of Copper (Cu) were below the desirable limits. All the stations showed the concentrations between BDL to 0.18 mgL-1. The low concentrations of copper might be due to non-utilization of copper compounds either as raw material or intermediates in the nearby industrial areas and agricultural practices. According to Ngele et al.42 found the range for copper is 0.032-0.040 mgL-1 in Amike-Aba, Abkaliki Ebonyi State, Nigeria. Figure 40 shows the spatial distribution of copper in the study area.

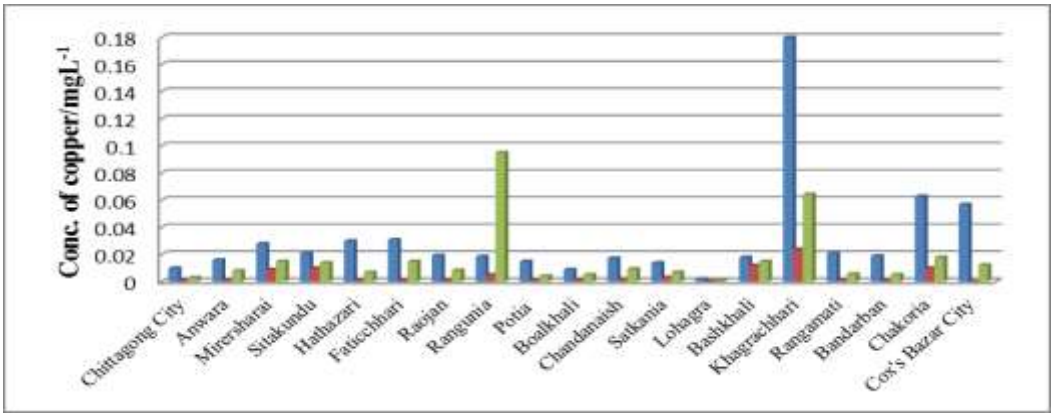


Figure 39 Concentration of copper of greater Chittagong district groundwater samples.

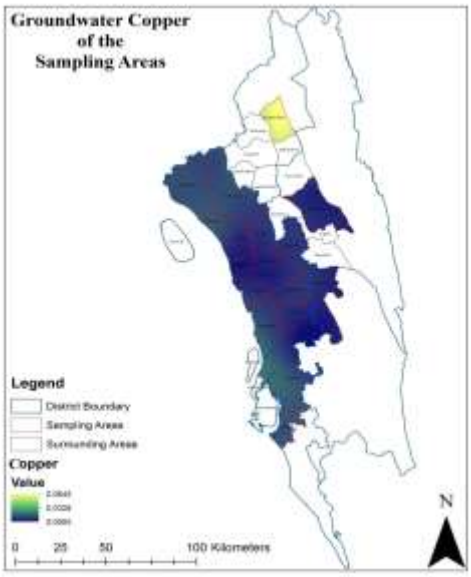


Figure 40 Spatial distributions of copper of groundwater samples.

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Iron (Fe)

Iron is an essential trace element required by both plants and animals. In some waters it may be a limiting factor for the growth of algae and other plants. Iron content of Chittagong region groundwater samples shows (Fig. 41) that most of the samples contained iron above the WHO permissible limit of 1.00 mgL-1. Figure 41 shows that the highest values for Chittagong (11.20 mgL-1), Rangamati (0.985 mgL-1), Cox's Bazar (3.460 mgL-1), Bandarban (1.205 mgL-1) and Khagrachhari (0.86 mgL-1) were far above the permissible limit for drinking water. Iron was found positively correlated with manganese and negatively correlated with pH. According to Rahman et al.20 the mean iron concentration in the groundwater samples from Cox's Bazar district was 6.7 mgL-1, which is above the standard (1.0 mgL-1) set by WHO for iron content in potable water. According to Ray et al.28 the distributed data for iron shows that 62.9% of the observations are equal to or less than the allowable limit of 0.3 mgL-1, the maximum concentration being 60.8 mg L-1 in Rohtas district of Bihar. Higher values of iron content of all the districts is higher than the permissible limit of 0.3 mgL-1 for domestic water supplies18. Iron has positive correlation with arsenic. According to EPA, 1986 the presence of low concentrations of iron may intensify the adverse effects of manganese18. Elevated amount of iron found in groundwater may be due to the geology of this region and other chemical components of the waterway. Figure 42 shows the spatial distribution of iron in the study area.

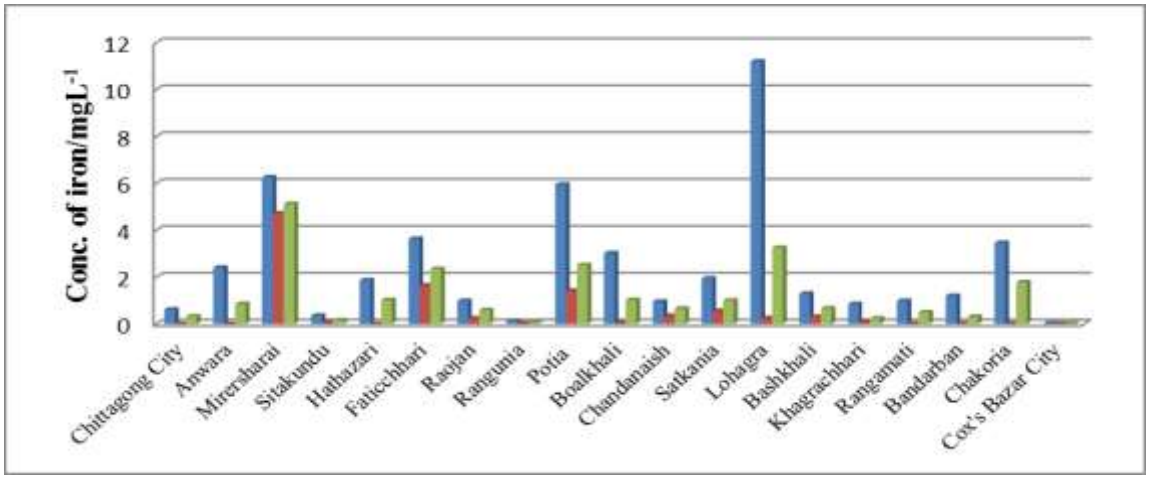


Figure 41 Concentration of iron of greater Chittagong district groundwater samples

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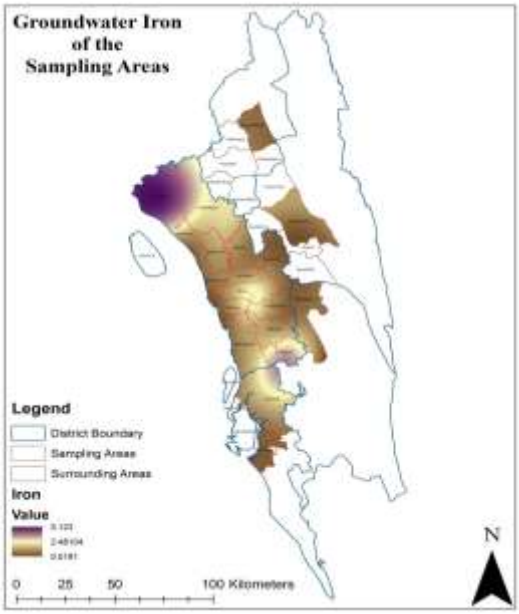


Figure 42 Spatial distributions of iron of groundwater samples.

Lead (Pb)

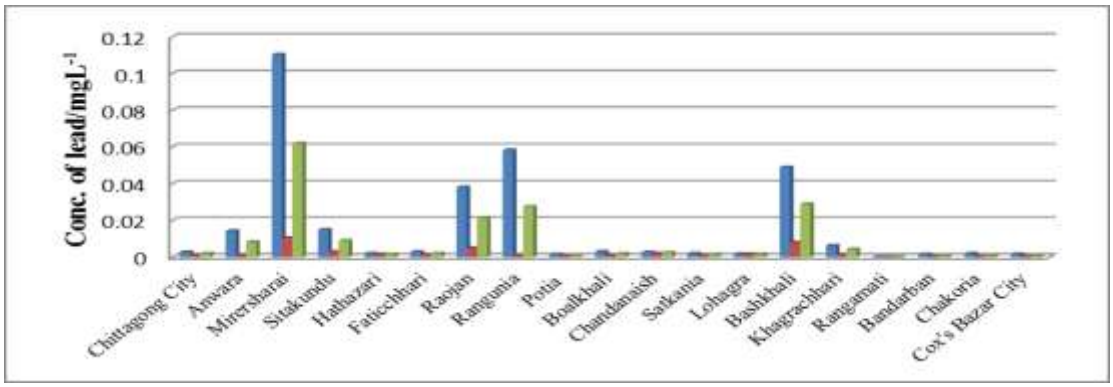


Figure 43 Concentration of lead of greater Chittagong district groundwater samples.

Maximum Minimum. Mean

Lead content of Chittagong region groundwater samples shows (Table 1-10) that the concentrations of Lead in the present study ranged between BDL-0.1105 mgL-1. Histogram of lead shows (Fig. 43) that the most of the concentrations of lead (Pb) were in general very low and less than the permissible limits. Rasheed et al.43 2013 reported the lead metal ranged from 0.01 to 0.140 mgL-1 in Uppal Industrial Area, Hyderabad, India. Figure 44 shows the spatial distribution of lead in the study area.

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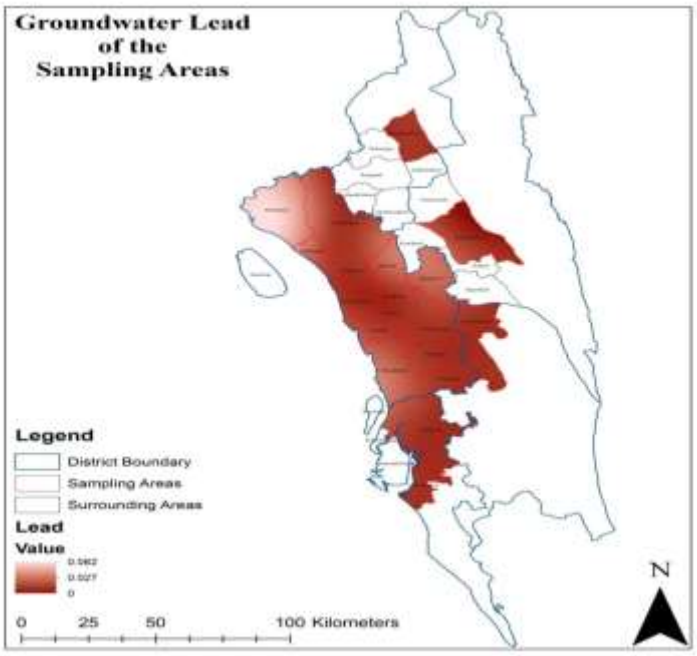


Figure 44 Spatial distributions of lead of groundwater samples

Manganese (Mn)

Manganese content of Chittagong region groundwater samples shows (Table 1-10) that most of the samples contained manganese above the WHO permissible limit of 0.1mgL-1. Histogram of manganese shows (Fig. 45) that the highest values for Chittagong (1.146 mgL-1), Rangamati (0.5229 mgL-1), Cox's Bazar (0.441 mgL-1), Bandarban (2.1297 mgL-1) and Khagrachhari (0.2769 mgL-1) were far above the permissible limit for drinking water. Higher values of manganese of all districts exceeded the permissible limit for drinking water (Max. 0.1 mgL-1)32. Manganese was found positively correlated with iron only. **Figure 46** shows the spatial distribution of manganese in the study area.

Nickel (Ni)

Nickel content of Chittagong region groundwater samples shows (Table 1-10) that nickel are found to be BDL to 0.035 mgL-1. Histogram shows (**Fig. 47**) that the minimum and maximum concentrations of nickel were found Bandarban and Chittagong district respectively. Rasheed et al.43 reported the nickel metal ranged from 0.05 to 0.420 mgL-1 in Uppal Industrial Area, Hyderabad, India. **Figure 48** shows the spatial distribution of nickel in the study area.

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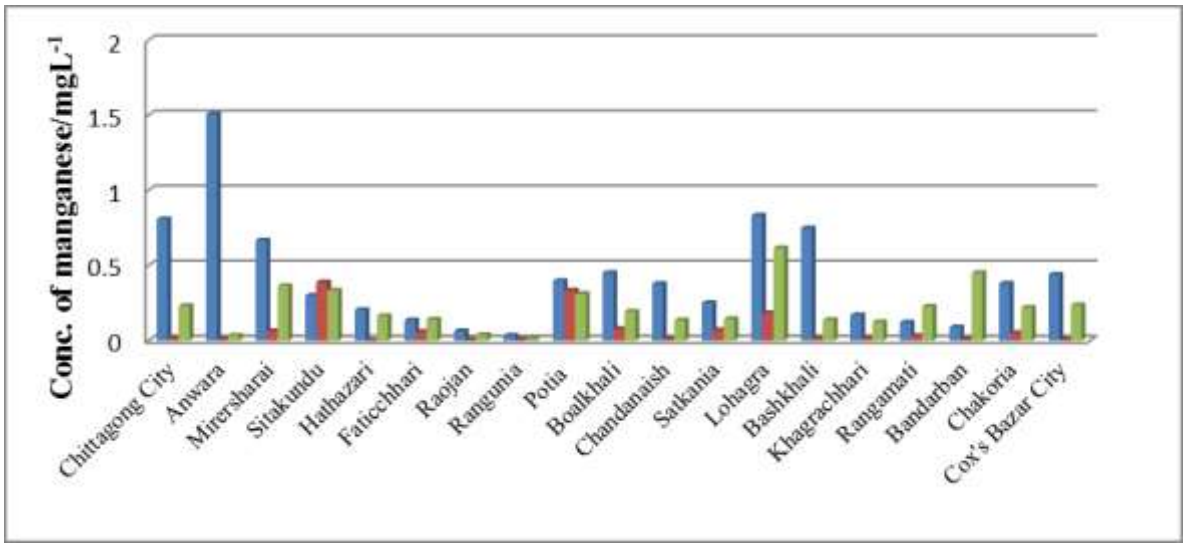


Figure 45 Concentration of manganese of greater Chittagong district groundwater samples

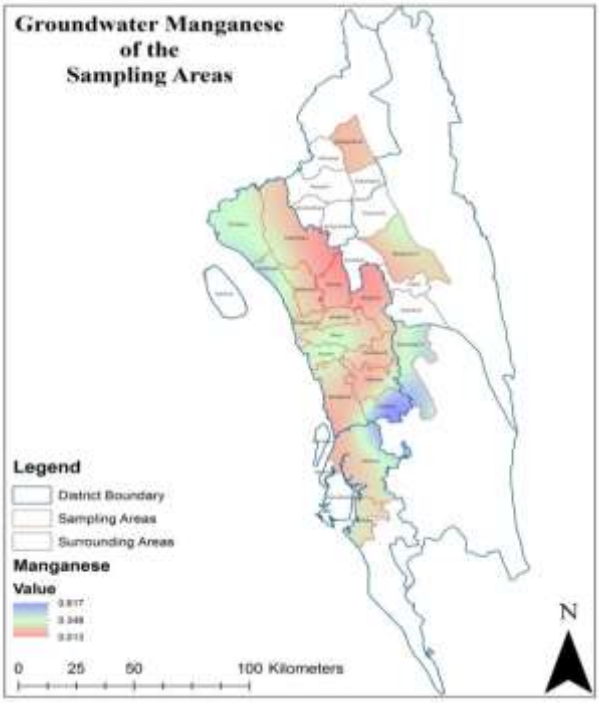


***Figure 46 Spatial distributions of manganese of groundwater samples*.**

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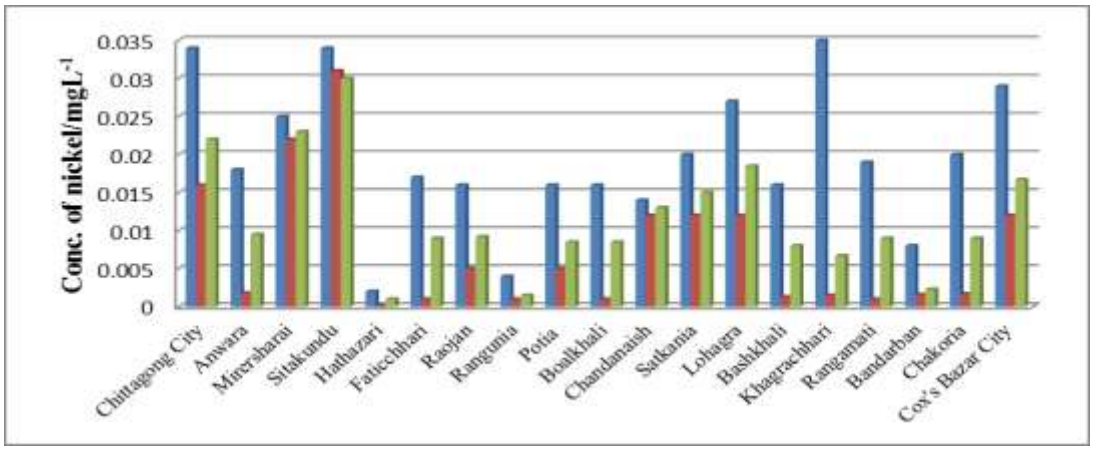


Figure 47 Concentration of nickel of greater Chittagong district groundwater samples

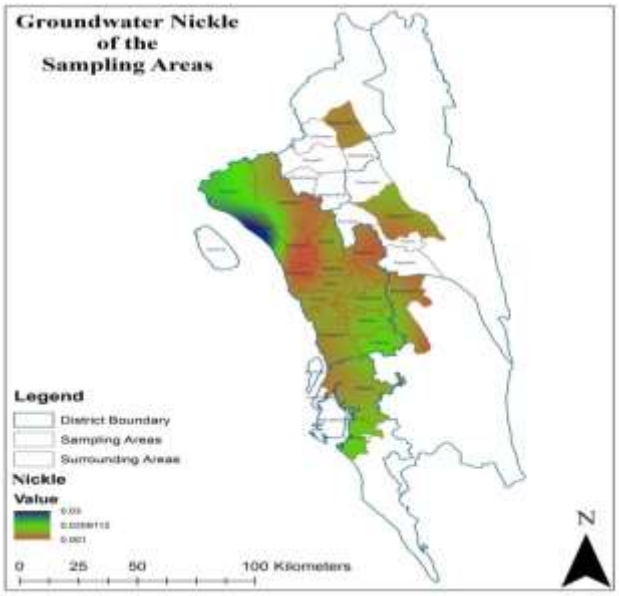


Figure 48 Spatial distributions of nickel of groundwater samples

Zinc (Zn)

Histogram of zinc content of Chittagong region groundwater samples shows (Fig. 49) that the concentrations of Zinc (Zn) were below the desirable limit. In the present study all the stations showed values between BDL to 0.8052 mgL-1. Zinc is a nutritionally essential element. It is necessary for growth and is involved in several physiological functions. Oladipo et al.41 found the cobalt which was above the limit set by FEPA 1998 and WHO 2011 in Lapai Metropolis. Figure 50 shows the spatial distribution of zinc in the study area.

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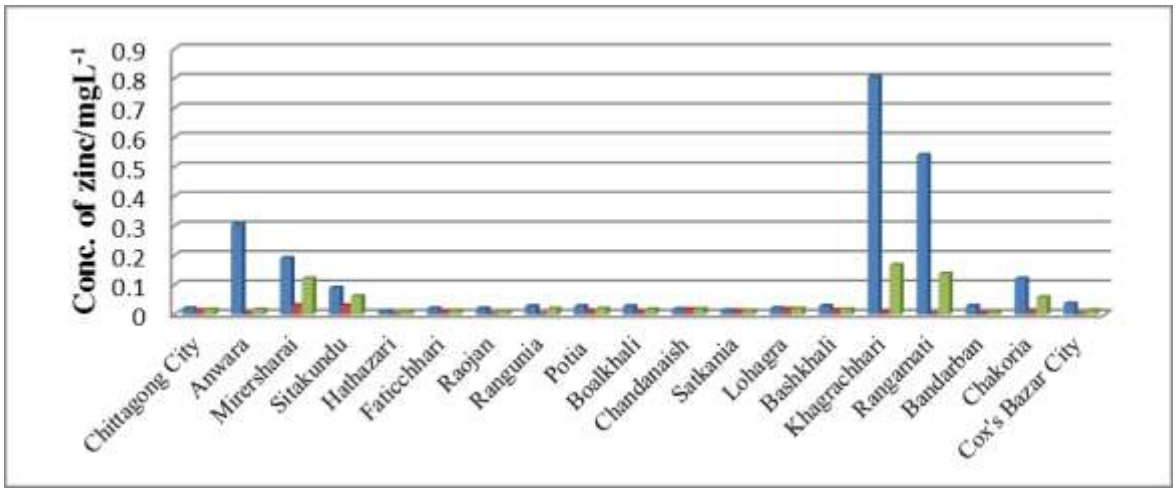


Fig.49 Concentration of zinc of greater Chittagong district groundwater samples.

Maximum ***Minimum.*** ***Mean***

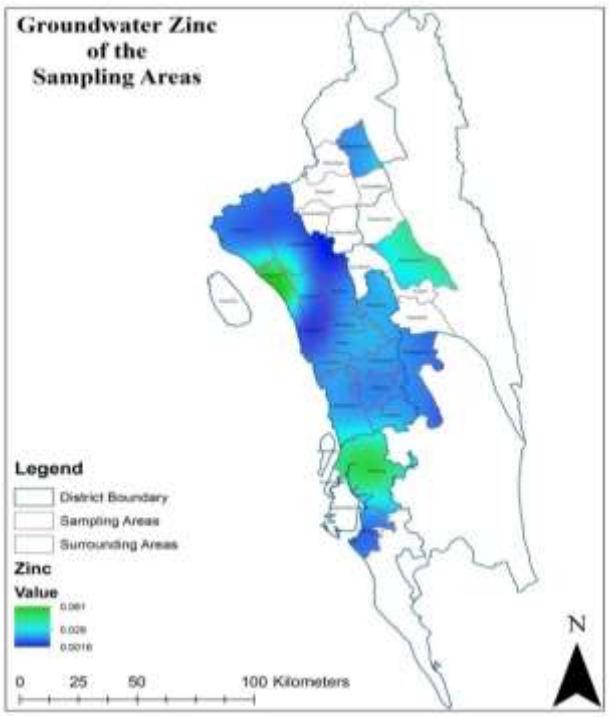


Figure 50. Spatial distribution of zinc in the study area

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CONCLUSIONS

In the present investigation, spatial distributions of groundwater quality assessment parameters were carried out through geographic information system, GIS. In this study, the obtained results and the spatial database established in GIS has been showed the same approach which can be used for determining, monitoring and managing ground water quality and its pollution for wide areas. This designed database will provide useful information for water quality assessment which can be used for future research and reference.

ACKNOWLEDGEMENTS

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