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Q-GIS Mapping to Explore the Status of Quality of Drinking Water in Bangladesh

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Abstract: *To explore the status of trace element contents in drinking water in Bangladesh and to develop a drinking water quality map using Q-GIS software a study was carried out. The secondary data were collected and represented by graduated classification in maps. The average concentrations of As, B, Ba, Ca, Fe, Na, K, Mn, were 0.016, 0.237, 0.137, 201.94, 9.09, 21.54, 0.33 and182.82 mgl^{-1}, respectively and the results were comparable with drinking water quality standards of BWPCB and WHO. In some area of Bangladesh As was not detected in drinking water. Boron content in drinking water was ranged from 0.007 to 1.282 mgl^{-1}. The 95% recorded data of Ba concentration in drinking water remained below the average value of 0.137 mgl^{-1}. The recorded data of Ca content in drinking water was ranged from 3.08 to 169.85 mgl^{-1}. Fe was within the range of 0.24 to 6.20 mgl^{-1} where the mean value was noted 2.15 mgl^{-1}. The mean value of Na in drinking water was found 182.82 mgl^{-1} and ranged from 4.95 to 1035 mgl^{-1}. Potassium content in drinking water was ranged from 0.70 to 77.73 mgl^{-1}. From the Q-GIS mapping it is clear that the variation in drinking water quality mostly occurred in southern part in Bangladesh. According to the standard of different organizations the recorded value were below the danger level and suitable for drinking purposes but those were exceeded the standard value may not safe for human consumption because long term intake of contaminated water could cause acute and chronic toxicity, liver and kidney damage.*

Keywords: *Trace elements, Drinking water, Bangladesh, GIS mapping.*

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I. Introduction

Groundwater is an important element of earth, required for human health, socio-economic development and most importantly for ecosystem. In last few decades, there has been a tremendous increase in the demand for the drinking water due to rapid growth of population and their accelerated pace of industrialization (Amadi *et al*., 2010). The quality of drinking water is a powerful environmental determinant of the health of a community. The important of using safe water has become an international issue with the ever increasing of world population which eventually accelerates the water demand. This scares and fragile resource is under the risk of degradation in both quality and quantity in many parts of the world (Ambiga *et al*., 2013). Large quantities of human and industries waste disposals pose serious threat to this valuable resource. Excessive pumping and unscientific management of aquifers are also responsible for deterioration of water quality.

According to the report of WHO, 80% of all the diseases in human being are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source, therefore it becomes very important to regulate monitor the quality of groundwater and to device ways and means to protect it (Mufid, 2012). In Bangladesh, 90% of drinking water is supplied from groundwater source. Numerous water quality problems exist in groundwater and surface water system in Bangladesh (Adhikari *et al*., 2012). Due to the rapid growth of industries and urban areas many cities in Bangladesh are facing groundwater contamination. Although water is the most frequently occurring substance on earth, but lack of safe drinking water is more prominent in the developing countries.

Although drinking water quality is also influenced by the effects of human activities which cause pollution at the land surface because most drinking water originates by recharge of rainwater infiltrating from the surface. The rainwater itself may also have an increased acidity due to human activity. The unsaturated zone can help reduce the concentrations of some pollutants entering groundwater (especially micro-organisms), but it can also act as a store for significant quantities of pollutants, which may eventually be released. Some contaminants enter groundwater directly from abandoned wells, mines, quarries and buried sewerage pipes which by-pass the unsaturated zone and therefore, the possibility of some natural decontamination processes.

The south-west coastal regions of Bangladesh have been experiencing acute shortage of safe drinking water and increase in salinity intrusion and presence of high concentrations of Ba, Ca, Na, Mg, Fe, K, Sr and Si contents in surface and ground water over the past few years. Due to geographical disadvantage, this south-western region is commonly subjected to floods, river erosion and tidal surge but most importantly cyclones and storm surges (Dasgupta *et al*., 2011). Different types of water borne diseases are found around the whole year in the coastal people. Sometimes this disease turns into epidemic. This is only because of using the polluted water. So, groundwater is very much important for not only the people of Bangladesh but also for the people of whole world.

Though Bangladesh achieved success in providing safe drinking water to nearly 90% of its population through tube-well, the detection of high level of As in the groundwater from different parts of the country has raised a major public health concern. The first reported case of As contamination in groundwater from the Bengal Basin was recorded in 1978 West Bengal. Recently it has been estimated that 30% to 40% of Bangladesh may have As contaminated ground water and as many as 29 million people could be at serious risk from As poisoning (Ahmed, 2011). High Cl concentrations in drinking water sources present a potential risk to health particularly to infants less than six months of age (Huq and Naidu, 2002). On the other hand, higher concentrations of B in water systems are unusual and lead to environmental harm. B is a hazard to health in drinking water, so a provisional guideline value of 500 μgl^{-1} is quoted by the WHO (Saha, 2006).

Several analyses were done to determine the drinking water qualities in different parts in Bangladesh. Sarkar (2007), Islam (2006), Alam (2007), Mazumder (2006) and Saleha (2005) assessed groundwater quality used for irrigation, livestock and drinking purpose of various places of Bangladesh and in abroad, Ghule *et al*. (2007), Mondal *et al.* (2005), Sharma and Chandal (2004), Hosseinifard *et al.* (2006), Wang *et al.* (2003), Nakagiri *et al.* (2004) and Herrero *et al.* (2000) also assessed groundwater quality used for drinking purposes but the research work where all divisions in Bangladesh are considered have not yet done.

Though regular monitor of groundwater is very essential, the measurement of concentration from every possible location is not always feasible in view of the time and the cost involved in data collection. GIS is a potential technique in the field of groundwater modeling and mapping. GIS is a complete set of computer system for managing geographic data and recently GIS technology has accelerated by the growth of computer technology and become an effective tool for managing huge amount of geographical data to solve various spatial problems (Gorai *et al*., 2013). This study will be helpful to know about the present status of drinking water in Bangladesh and help general people to free from water borne disease. The Q-GIS maps of drinking water quality parameters will be beneficial to the city authority for effective management and monitoring of drinking water. Though people are more digitized now, so this GIS based study will help them to understand easily the status of drinking water quality of different areas in Bangladesh. Moreover, it will help researchers and policy planners for further investigation on drinking water status in Bangladesh.

II. Materials and Methods

The present study was to find out the previous recorded data of different elements of drinking water in Bangladesh, compare it with the standards of BWPCB (1976), WHO (2004, 2006) and DoE (1997) and find out the suitability of water for human and finally represented data in a map using Q-GIS. It took ten months (July, 2016 to May, 2017) to carry out the experiment, under the department of Environmental Science, Bangladesh Agricultural University, Mymensingh.

The study area: The study was conducted in all the divisions of Bangladesh based on the previous findings of research work about drinking water quality.

Collection of data: The data required for accomplishing the philosophy of this work had been drawn from-primary source (spatial and attribute data of the study area was obtained from upazila office to get a digital map of the study area) and secondary source (water quality parameters such as Arsenic (As), Boron (B), Barium (Ba), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Iron (Fe), Sodium (Na), Potassium (K), Manganese (Mn), Silicon (Si), Strontium (Sr) of the study area that were obtained from the records of Department of Public Health Engineering, publications and research papers.

Data analysis: Data were recorded on Microsoft Office Excel 2010 spreadsheets. Obtained data were compiled, then tabulated and analyzed for securing different objectives relevant to studied parameters.

Installation and setup of Q-GIS software and GIS application: The Q-GIS software was installed in a desktop computer then following procedures was maintained sequentially-

- Dhaka, Khulna, Barisal, Chittagong, Sylhet, Rajshahi and Rangpur division map was digitized using division shape files of Bangladesh.
- All the districts of Bangladesh were located in the division shape file.
- Selected drinking water parameters data were input in the shape file as attributes.
- The data were represented by different color shades in a map.

III. Results and Discussion

Arsenic (As) content in drinking water: As contents in drinking water in Bangladesh were represented in map using Q-GIS (Fig. 1). The average value of As in drinking water was found 0.016 mgl^{-1} and ranged from 0.001 to 0.35 mgl^{-1}. Among them 80% recorded data remained below the average value and 20% above the average value. The highest concentration (0.35 mgl^{-1}) was recorded in Chittagong division and the lowest concentration (0.001 mgl^{-1}) was recorded in Barisal, Bogra, Patuakhali, Cox's bazar, Khagrachari, Rangamati, Gazipur, Dinajpur and Natore district. As contamination in ground water cause due to natural processes, industrial activities, pesticides and industrial waste. Smelting of Cu, Pb, and Zn also take part in As contamination. Tannery and industrial areas discharge a large number of hazardous waste into surrounding environment, leaching of those metal causes groundwater contamination. As was not detected at different parts in Khulna division, *Char Badnaguchha Gram* at Barisal division and different parts in Dhaka division.

Most of the recent studies (Milton *et al*., 2006 and Islam *et al*., 2004) from the Bengal Basin show that high level of As is present in the shallow aquifer (<100m) and content of As in groundwater generally decreases with the increase in depth of wells. Presence of organic matter in the aquifer sediments of the Bengal Basin has been reported in several studies (Nickson *et al*., 2000 and Milton *et al*., 2006). Degradation of this organic matter could drive the sequence of redox reactions in the aquifer and may thereby enhance As mobilization in Bengal Basin. Maximum As content in groundwater found in Chittagong district and it was shown that the maximum north-east and north-west part in Bangladesh the concentration of As in drinking water was within the range of 0.001 to 0.05 mgl^{-1} but in the southern part of Bangladesh there were changes in concentration of As in drinking water (Fig. 1).

According to few organization's (BWPCB, 1976; WHO, 2004 & 2006) reports, the standards of As content in drinking water is 0.05 $mg^{/L}$. So the recorded value within the standards value were below the danger level and those recorded value exceeded the standards value may not safe for human consumption because long term intake of contaminated drinking water cause acute and chronic toxicity, liver and kidney damage.

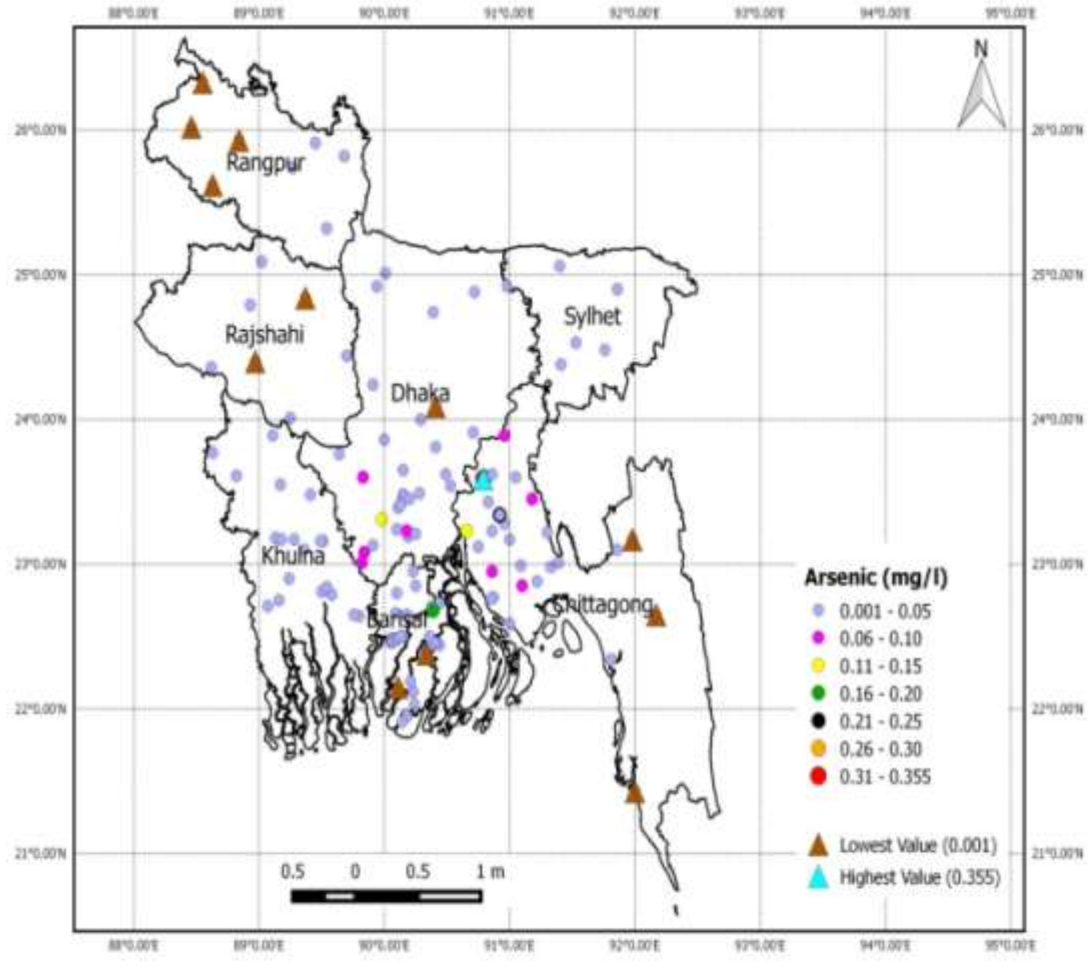

Figure 1: Showing As contents in drinking water of different regions in Bangladesh using Q-GIS.

Boron (B) content in drinking water: The recorded data of B in drinking water was within the range of 0.007 to 1.282 mgl^{-1}. The mean value of B was found 0.237 mgl^{-1}. B status of 90% recorded data was lower than the mean value and 10% were in higher level. The maximum B content (1.282 mgl^{-1}) was detected in *Banaripara union*, Barisal district and minimum B content (0.007 mgl^{-1}) was detected in *Lalmonirhat*, Rangpur district and it was found that the different area of northern parts in Bangladesh the B concentration in drinking water within the range of 0.007 to 0.189 mgl^{-1} and maximum variation of B concentration in drinking water occurred in Barisal division (Fig. 2). B exhibits hydro-geochemical retardation in groundwater environments containing a high clay fraction. The hydraulic conductivity, salinity, type of clayey sediments, pH and temperature are the crucial factors that determine B mobility in the groundwater system (Alam, 1990). Previous hydrochemical studies in Bangladesh indicate that B in groundwater is principally geogenic and appears to drive mainly from residual sea water or mineral sorption sites (Ravenscroft *et al*., 2005).

Islam (2014) recorded B status of the 15 ground water samples ranged from 0.12 mgl^{-1} to 0.52 mgl^{-1} with the mean value of 0.29 mgl^{-1} in Bogra district. The concentration of B in all groundwater samples collected from *sadar upazila* under Faridpur district area ranged from 0.01 to 0.75 mgl^{-1} with the mean value of 0.48 mgl^{-1} (Shaik, 2010). The recommended maximum concentration of B for drinking water is 1 is 0.05 mgl^{-1} (WHO, 2004 & 2006).

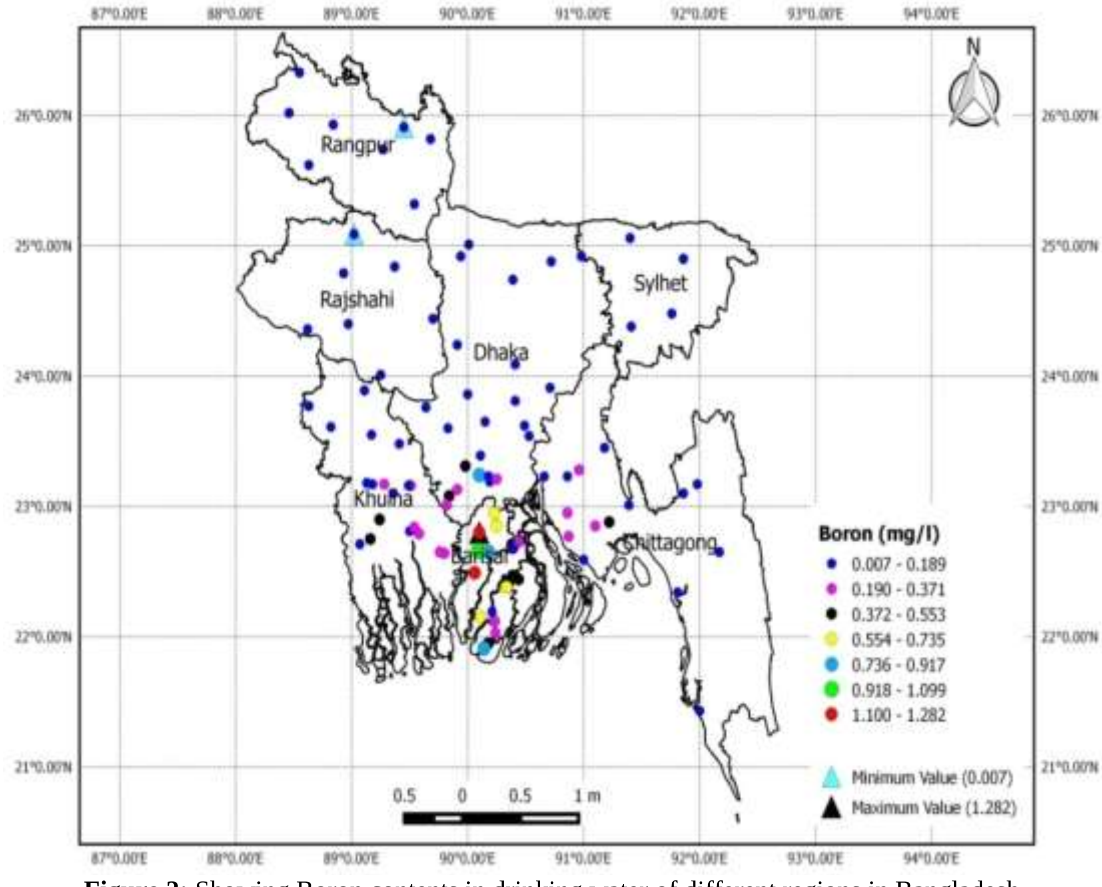

Figure 2: Showing Boron contents in drinking water of different regions in Bangladesh.

Barium (Ba) content in drinking water: The average value of Ba content in drinking water was found 0.137 mgl^{-1} and ranged from 0.0062 to 0.7831 mgl^{-1}. Among them 95% recorded data remained below the average value and 5% above the average value. The highest concentration (0.7831 mgl^{-1}) was recorded in Jessore district and the lowest concentration (0.0062 mgl^{-1}) was recorded in *Amtali upazila*, Barisal division and the concentration of Ba in drinking water in the northern part in Bangladesh was within the range of 0.0062 to 0.1172 mgl^{-1} and there were no fluctuations in data but in the southern part of Bangladesh (Barisal division) there were changes in concentration of Ba in drinking water because of being a coastal area (Fig. 3). According to World Health Organization (WHO, 2004; 2006), the standard of barium content in drinking water is 0.7 mgl^{-1}. So the recorded value is lower than the standard one that's why examined water is below the danger level and suitable for drinking purposes.

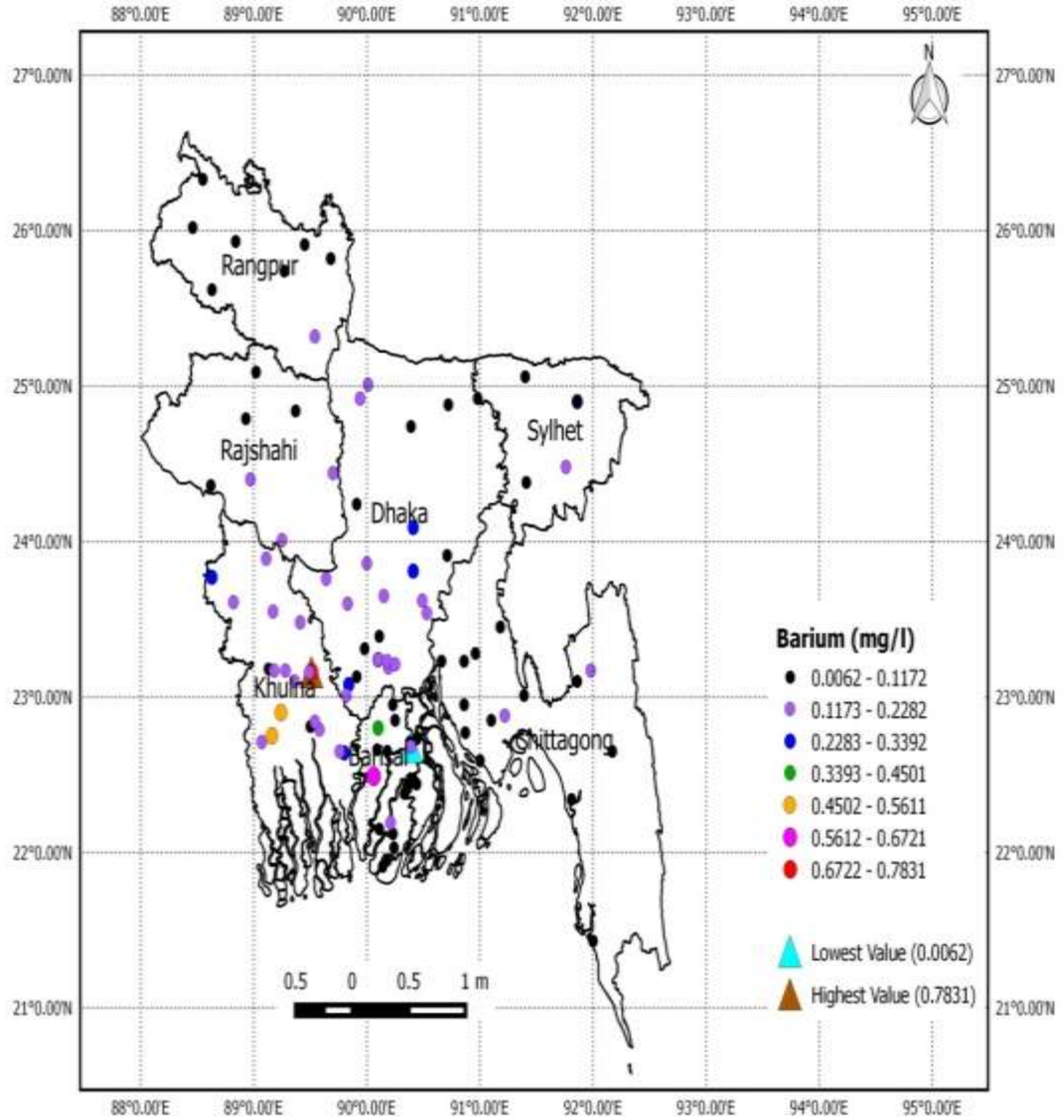

Figure 3: Showing Q-GIS based digital map of Ba status of drinking water in Bangladesh.

Calcium (Ca) content in drinking water: The average value of Ca in drinking water was recorded 45.15 mgl^{-1} and ranged from 3.08 to 169.85 mgl^{-1}. The highest concentration (169.85 mgl^{-1}) was recorded in *Dighalia, Khulna* district and the lowest concentration (3.08 mgl^{-1}) was recorded in *Kachua upazila*, Chittagong division (Fig. 4). It was found that the groundwater contained relatively more Ca than surface water. The range of Ca concentration in groundwater may largely dependent on the solubility of $CaCO_3$, $CaSO_4$ and rarely on $CaCl_2$. The Ca contents in groundwater are controlled by the availability of the elements in the soil and rock through which the water has flowed, by geochemical constraints such as solubility and adsorption, by the rates of geochemical processes, and by the sequence in which the water has come into contact with the various minerals occurring in the geologic materials along the flow paths (Freeze and Cherry, 1979).

According to WHO (2004 & 2006) reported the standards of Ca concentration in drinking water is 200 mgl^{-1}. So the recorded value remained within the standard value is suitable for drinking purposes.

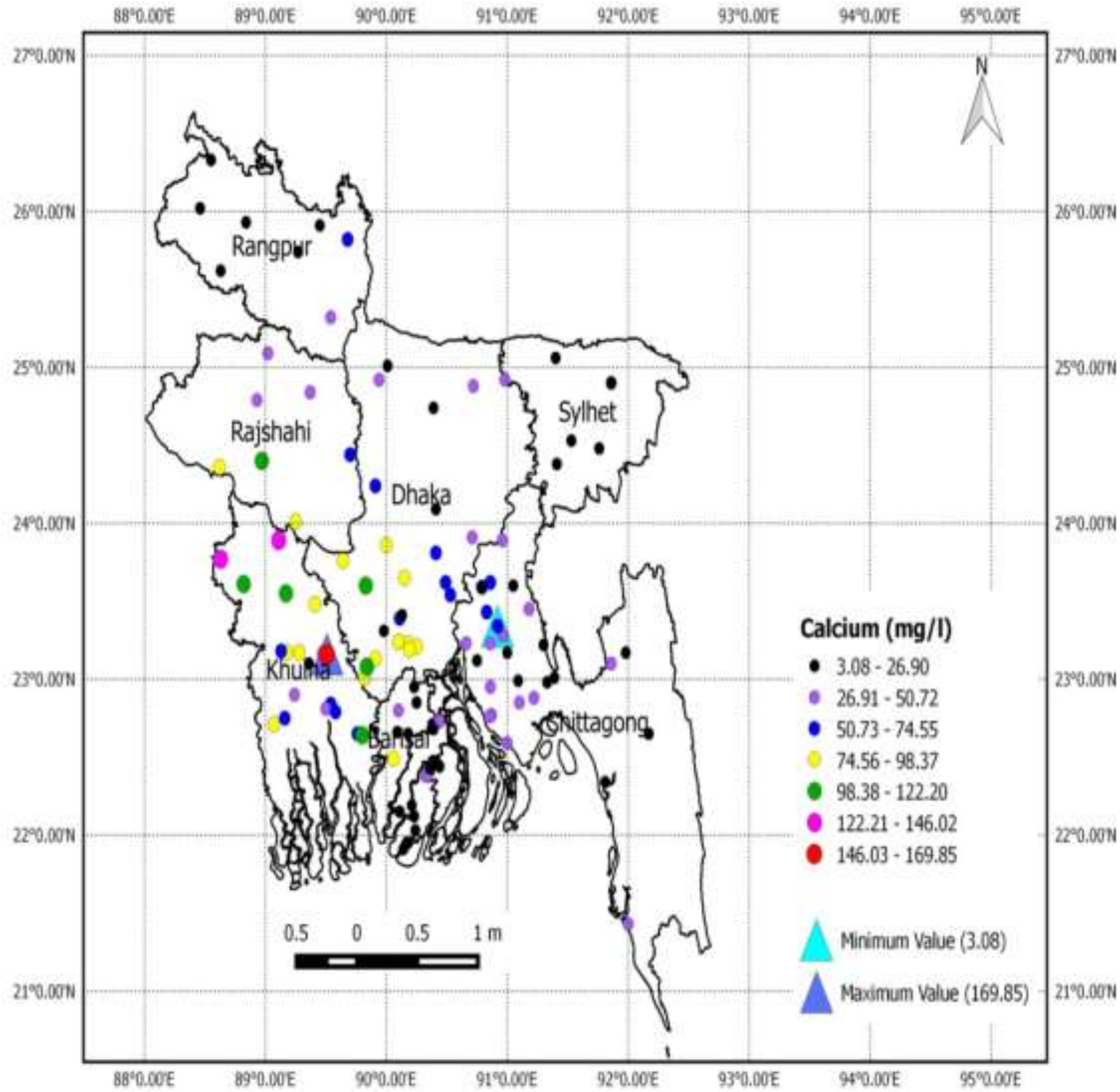

Figure 4: Showing Ca concentrations in drinking water in Bangladesh using Q-GIS.

Iron (Fe) content in drinking water: Fe contents in drinking water were digitized in Bangladesh map using Q-GIS software which is shown in Fig. 5. The recorded data of Fe was within the range of 0.24 to 6.2 mg/L. The mean value of Fe was found 2.15 mg/L. Fe status of 30% recorded data was lower than the mean value and 70% were in higher level. The lowest Fe content (0.24 mg/L) was detected in Patuakhali district and highest Fe content (6.2 mgl^{-1}) was detected in Gaibandha district, Rangpur division and the lowest value of Fe contents in drinking water was located in southern portion of Bangladesh and highest value of Fe contents in drinking water was located in northern portion of Bangladesh. Adhikary *et al*. (2012) recorded Fe contents in groundwater in Khulna district, 0.07-2.30 mgl^{-1} with the mean value 1.21 mg/L. The standard of Fe concentration in drinking water is ranged from 0.3-5 mg/L based on different reports. Fe defects lead to anemia, causing tiredness, headaches and loss of concentration so that that area contains high amount of Fe in drinking water are not suitable for drinking purposes.

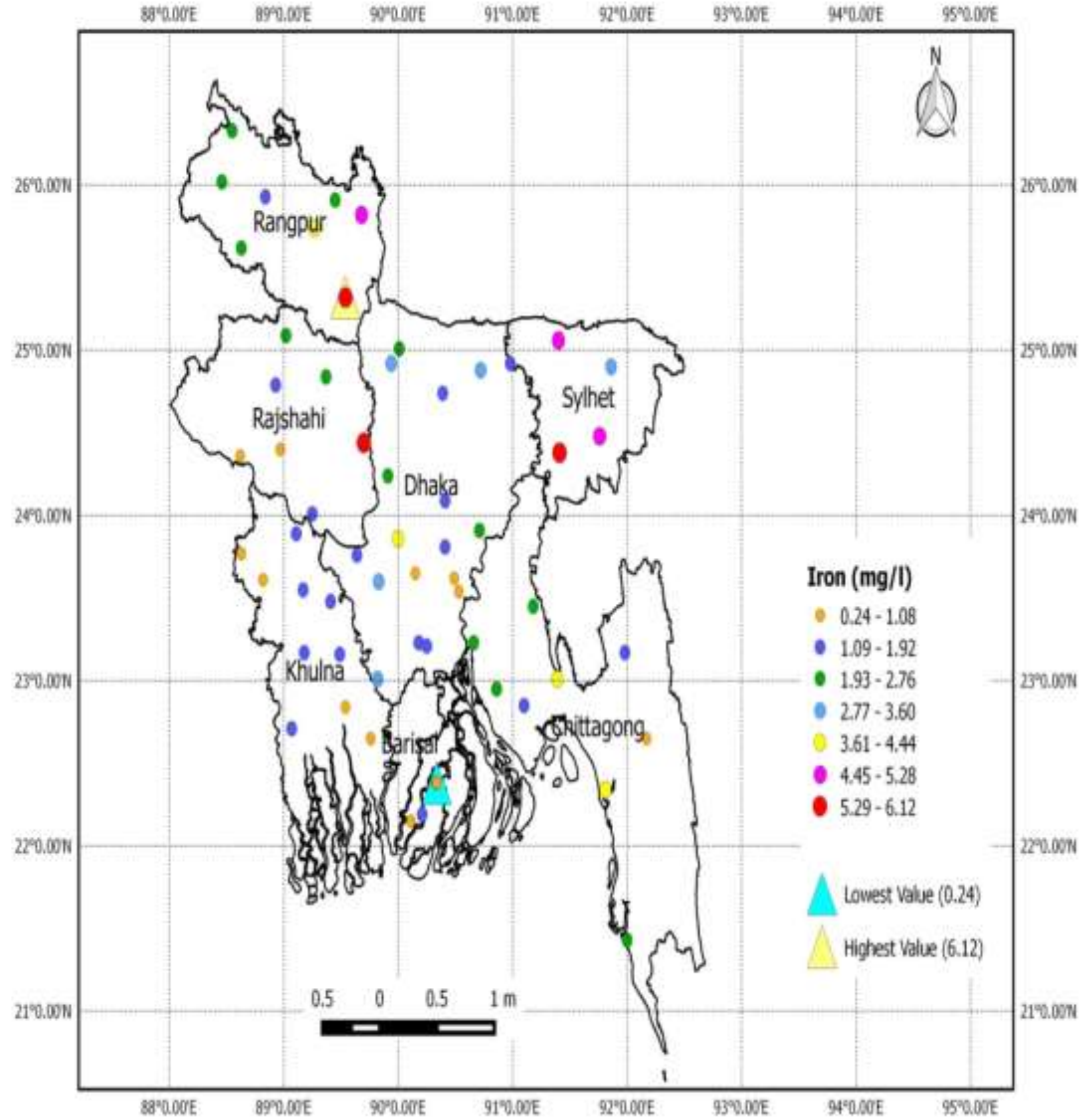

Figure 5: Showing Q-GIS based digital map of Fe content of different drinking water in Bangladesh.

Potassium (K) content in drinking water: The K contents in drinking water in Bangladesh were digitized by using available reports where the mean value of K in drinking water was found 9.09 mg/L and ranged from 0.70 to 77.73 mgl^{-1}. The highest concentration (77.73 mg/L) was recorded in *Banaripara union*, Barisal district and the lowest concentration (0.70 mg/L) was recorded at *Shibchar union* in Dhaka division and the variation of K concentrations in drinking water occurred in Barisal division (Fig. 6). Hasan (2013) recorded K status of the 50 groundwater in Barisal District ranged from 2.15 to 7.17 mg/L with the mean value of 4.26 mg/L and in another study, Quddus and Zaman (1996) stated K in Meherpur, varied from 0.13 to 0.76 mg/L. So the recorded value matched within the standards value that's why the sample water is below the danger level.

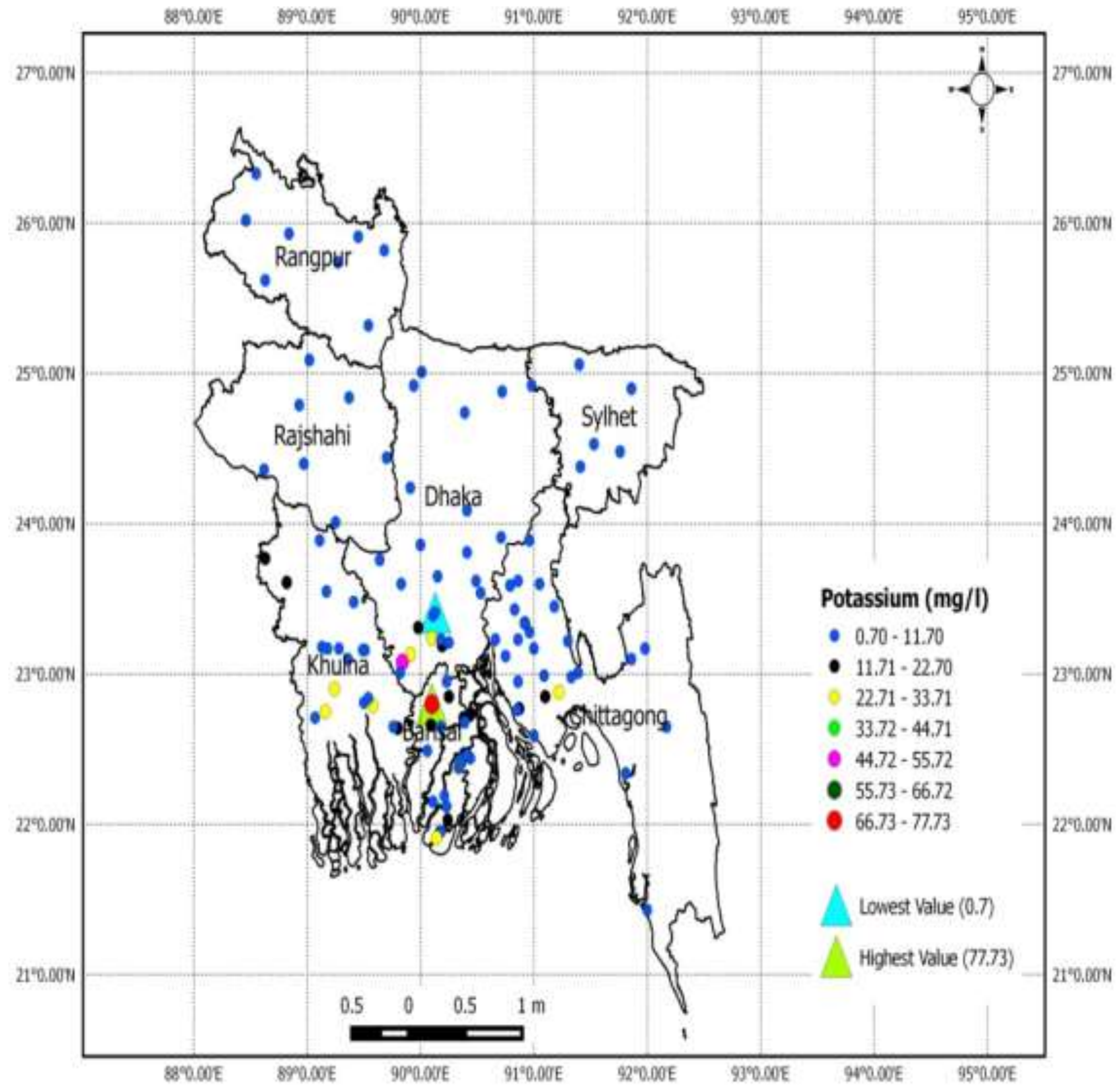

Figure 6: Showing K concentrations in drinking water at different parts in Bangladesh using Q-GIS.

Manganese (Mn) content in drinking water: The recorded data of Mn in drinking water was within the range of 0.0019 to 4.40 mgl^{-1}. The mean value of Mn in drinking water was found 0.33 mgl^{-1}. Mn status of 40% recorded data was lower than the mean value and 60% were in higher level. The highest Mn content (4.40 mgl^{-1}) was detected in Kalakandi, Chittagong division and lowest Mn content (0.0019 mgl^{-1}) was detected in Chauddagram upazila, Chittagong division (Fig. 7). In Madaripur sadar upazila, Dhaka, Amtali upazila, Barisal and Shibchar upazila, Dhaka Mn content in drinking water was not detected. The maximum number of data of Mn in drinking water in Bangladesh was recorded within the range of 0.0019 to 0.6286 mgl^{-1} and the minimum value was found at lower southern part in Bangladesh. According to World Health Organization (WHO, 2004 & 2006), the standard value of Mn concentration in drinking water is 0.5 mgl^{-1}.

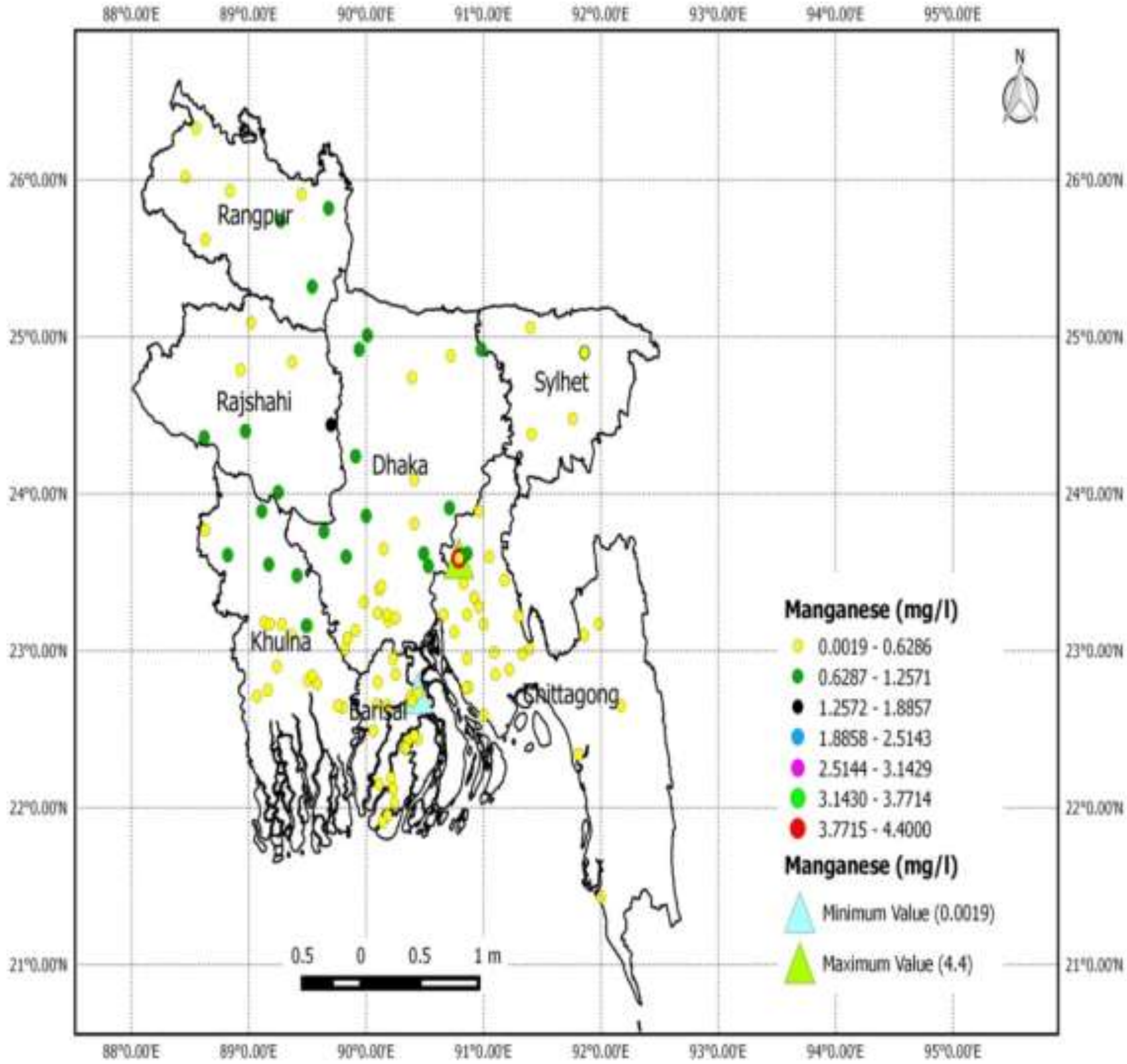

Figure 7: Showing Mn contents in drinking water in Bangladesh using Q-GIS.

Sodium (Na) content in drinking water: Na contents in drinking water in Bangladesh were digitized using Q-GIS software. The mean value of Na in drinking water was found 182.82 mgl^{-1} and ranged from 4.95 to 1035 mgl^{-1} (Fig. 8). Among them 70% recorded data remained below the mean value and 30% above the mean value. The highest concentration (1035 mgl^{-1}) was recorded in Banaripara union, Barisal district and the lowest concentration (4.95 mgl^{-1}) was recorded at Abhaynagar upazila in Jessore district and the lowest value of Na content in drinking water was recorded at south-west part and highest value was recorded at southern part in Bangladesh. Hasan (2013) recorded Na content of 50 groundwater samples in Barisal district ranged from 10.60 to 21.95 mgl^{-1} with the average value of 17.03 mgl^{-1}. The recorded values almost noted within the standards value given by different reports, so the available drinking water samples are free from danger and useable as drinking water.

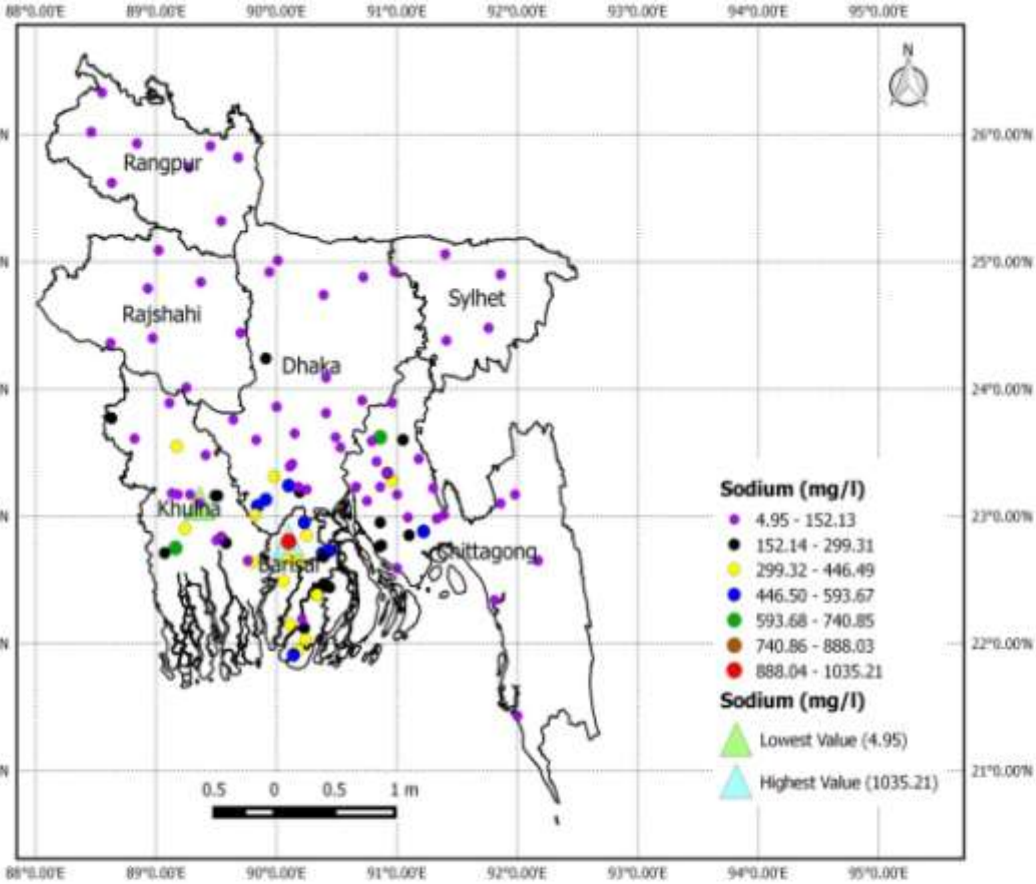

Figure 8: Showing Na contents in drinking water in Bangladesh using Q-GIS.

IV. Conclusion

Water is essential for the survival of any form of life. On an average, a human being consumes about 2 liters of water every day. About 80% of the earth surface is covered by water. The study was conducted to explore the status of drinking water at different parts in Bangladesh and check the water suitability for drinking purposes. From the Q-GIS maps of As, B, Ba, Ca, Fe, Mn, K, and Na contents, the status of drinking water in Bangladesh can be understand easily and the different color shades in map indicates the variation of concentrations of these parameters at different parts in Bangladesh. Q-GIS is an useful tool for not only drinking water purposes but also agricultural practices so that Government and different NGOs should take necessary steps to enhance the practices of this technology. Finally, the exploration of major trace elements content in drinking water of different regions of Bangladesh stated at a glance which will helpful for further research works in future.

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