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Physiochemical and Microbiological Analysis of Drinking Water in Chattogram City, Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Chattogram is the second most populated city in Bangladesh. This port city faces a serious threat mainly due to the lack of safe drinking water. This study was conducted for determining drinking water quality of groundwater sources in Chattogram city. The study was performed in the BCSIR laboratory, Chattogram. It was carried out for a period of six months from 1st July, 2018 to 31th December, 2018. Total six water samples were collected from three different locations (Baluchora, C&B colony and Khulshi area). Each sampling location consists of two separate sampling points. Physicochemical parameters of the collected samples like Temperature, pH, Electrical Conductivity (EC), Total dissolved solid (TDS), Hardness, Turbidity and concentration of Cl, As, Mn, Fe, Pb, Cr and Cd were examined. Microbial parameters like Total Coliform (TC) were also measured. All the analyzed parameters compared with BSTI and WHO drinking water quality standards to understand the overall ground water quality status of the study area. The results reveal that water samples in almost all locations were contaminated with microbial contamination and that the range of physico-chemical parameters was not adequate for consumption. Preliminary treatments like boiling, filtering etc are required before using groundwater for drinking and the necessary measures must be taken for a safe alternative source of drinking water.

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1. INTRODUCTION

Water is a vital element of every ecosystem and human being. After air; water is the most important need for life. Water performs a number of functions for the body. It serves as a body transport system; acts as a lubricant; regulates body temperature; etc. In fact; more than 2/3 of the human body is made of water. Safe access to safe drinking water for urban and rural populations in developing countries remains a challenge for sustainable development [1]. Drinking water quality is a vital concern for humanity, as it is directly related to public health. Drinking water quality has always been a serious problem in many countries, particularly in developing countries such as Bangladesh [2]. Water quality can be defined by the chemical, physical and biological content of water. The water quality of the surface water bodies of our country is decreasing both for conventional pollutants (heavy metals, pesticides), various organic or inorganic compounds and contaminants [3-4]. The environment, economic growth and developments in Bangladesh are strongly influenced by surface water due to their regional and seasonal availability [5]. Although drinking water is a key demand for people around the world, a large percentage of the world's population is deprived of pure drinking water, including Bangladesh [6]. Groundwater is being depleted prominently day after day in Asia, South America, North America and ecosystems are threatened [7].

Water pollution is now a global concern. Pathogenic bacteria and the presence of antibiotic-resistant bacteria in drinking water have become an emerging problem worldwide [8]. Bangladesh is a low-lying and deltaic country of three great rivers: the Ganges, the Brahmaputra and the Meghna. In the humid and tropical region of Bangladesh, this precious resource is increasingly threatened by the growth of the human population. Recent studies have shown that groundwater systems in Bangladesh are progressively vulnerable to microbiological and heavy metal contamination, particularly arsenic [9]. Chemical and physical contamination of water is no less serious, but potentially lethal contaminants in drinking water are of biological origin [10]. Contaminated drinking water is known to spread dangerous diseases such as hepatitis, cholera, dysentery, typhoid fever and diarrhea. Among these waterborne diseases, the most important is diarrhea. It is estimated that about 11% of all deaths in rural areas of Bangladesh are caused by diarrheal diseases [11]. It has been estimated that around 80% of all diseases and over a third of deaths in developing countries are caused by the consumption of contaminated water [12]. Among the diseases transmitted by water of bacterial origin, typhoid fever, bacillary dysentery and diarrhea are common in Bangladesh [13,14]. Despite the availability and promotion of the use of safe water sources, water-related diseases remain a major cause of mortality and morbidity in Bangladesh [15]. The availability of safe drinking water has increased in almost all parts of the world in recent decades, but around one billion people still do not have access to clean water [16].

Contaminated groundwater is used by the dwellers of Chattogram city for their drinking purposes. The situation is worse in low class residential areas i.e. slums [17]. For this reason, a detailed study of drinking water quality of Chattogram city is important. Although several reports on the assessment of drinking water quality based on physicochemical and microbiological parameters in different part of Bangladesh have been published by several researchers separately [6], [18-19], but limited research has done in Chattogram city. Considering the forgoing problem, the present section describes the overall status of drinking water quality of groundwater sources in Chattogram city.

2. MATERIALS AND METHODS

2.1 Study Area

In an order to assess the ground water quality three sample areas were chosen namely Baluchora, C&B colony and Khulshi area (Fig.1). Six drinking water samples were collected from three different locations (Table 1). The map of the study area is presented in Fig 1.

2.2 Water Sample Collection

Total six water samples were collected from six groundwater sources. Two water samples have been taken from each study area and got tested in BCSIR laboratory to find out the quality status of selected physicochemical parameters of the water. The samples were collected from electric pumps, the most common source of drinking water in Chattogram city. Before taking the water samples the sterile container were rinsed

three times with sample water for finding the accurate result. The samples were collected in two sets of containers with a sterile lid; one of which is intended for physico-chemical tests and another for microbiological analysis. The samples for microbiological analysis were stored at 4°C before the start of the analysis and the sample for physico-chemical tests was analyzed immediately. Hygiene and aseptic practices were performed during drinking water sampling. After it, the results of these parameters were compared and discussed with national and international standards [20-21].

Table 1. Labeling and sample ID

Sample no	Location	Sample ID
1	Baluchora	DWS-1
2	Baluchora	DWS-2
3	C&B colony	DWS-3
4	C&B colony	DWS-4
5	Khulshi	DWS-5
6	Khulshi	DWS-6

2.3 Physical Analysis

The quality of drinking water can be determined by its microbiological tests and by some important physico-chemical tests, such as pH, TDS and metal concentration. The detection of bacterial contamination and physico-chemical properties has attracted great attention worldwide due to the impacts on public health. So some physical characteristics of drinking water like Temperature; Turbidity; Total Dissolved Solids (TDS); Electrical Conductivity (EC) and pH were determined.

2.3.1 Temperature measurement

Temperature measurement was performed at the sample collection site using a mobile thermometer. This was done by immersing the thermometer in the sample and recording the stable reading [22].

2.3.2 Determination of pH

The pH of the water samples were determined using the Hanna microprocessor pH meter (model no 6011). It was standardized with a buffer solution of pH range between 4 and 9 [22].

2.3.3 Determination of turbidity

Turbidity was determined using the Lovibond Turbidirect turbidity meter. In this method; the water samples were taken in a vial and placed in the sample chamber after turning on the turbidity meter. Reading starts automatically after the countdown and has been recorded [23].

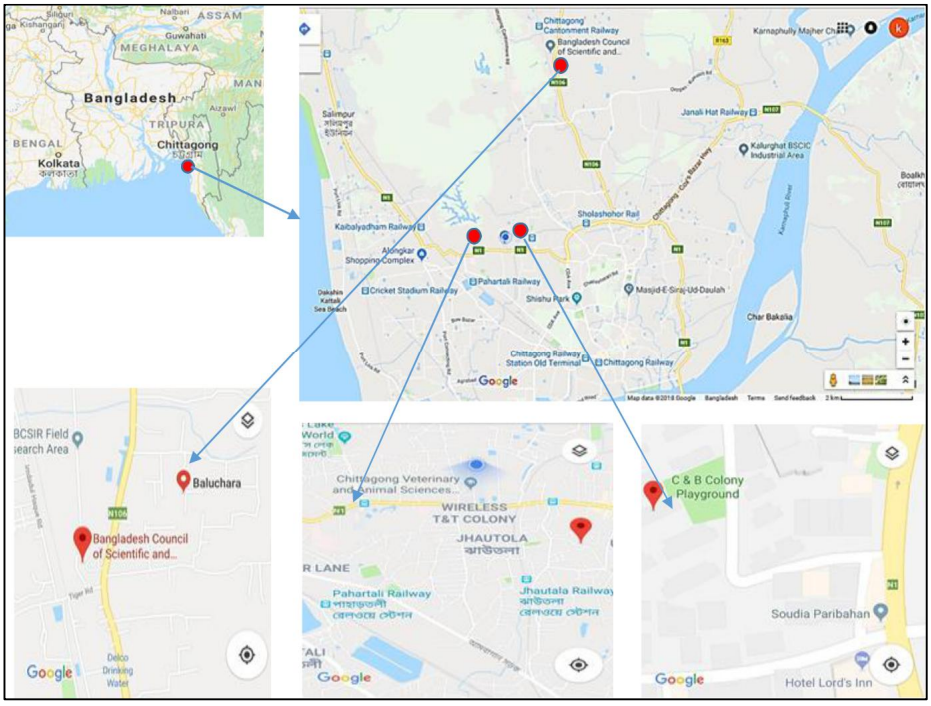

Fig. 1. Map of the study area

2.3.4 Determination of total dissolved solids (TDS)

TDS were measured by the TDS Meter (Hanna-HI8730N).

2.3.5 Determination of conductivity

This was done using a conductivity meter (model no PCD-431). The probe was dipped into the container of the sample until a stable reading will be obtained and recorded [22].

2.3.6 Determination of hardness

The total hardness of the water samples was measured by a hardness test kit.

2.4 Chemical Analysis

Some chemical parameters like concentration of chloride, Iron, arsenic, lead, chromium, cadmium and manganese (Cl, Fe, As, Pb, Cr, Cd & Mn) were analyzed.

2.4.1 Determination of chloride (Cl)

Chloride; in the form of Cl- ion is in water. In the Mohr method; the chloride in neutral or weakly alkaline solution containing chromate ion is titrated with silver nitrate. Silver chloride precipitates and the end point forms the silver chromate. The color of silver chrome is red [24].

2.4.2 Determination of arsenic (As)

The arsenic test was performed using the Hach Arsenic Test kit. In this method; hydrogen sulfide is first oxidized to sulfate to avoid interference and the oxidizing environment is neutralized. Subsequently; sulfamic acid and zinc powder react to create strong reduction conditions in which inorganic arsenic is reduced to arsine gas. The arsine gas reacts with mercury bromide; impregnated in a test paper to form mixed arsenic / mercury halogenides (for example; AsH_2HgBr). Mixed halogenides discolor the test strip in proportion to the concentration of arsenic in the sample. The color change goes from white to yellow to tan to brown [25].

2.4.3 Other heavy metal determination

The heavy metal contents were determined by the AAS using a standard analytical procedure [26]. Sample collection is an important step in metal analysis. The samples were generally handled with care to avoid contamination. The glassware was cleaned properly and the reagents were of analytical quality. Distilled water was used during the study. Blank reagent determinations were used to correct instrument readings.

Calibration curves were found for concentration vs. absorbance. The data were statistically analyzed using straight line rectification using the least squares method. For greater precision; a blank reading was also taken and the necessary corrections were made during the calculation of the concentration of different elements.

2.5 Microbiological Analysis

2.5.1 Estimation of total coliform

Most Probable Number (MPN) test was used to identify and estimate the total coliforms in drinking water samples. This method is performed sequentially in three stages as presumptive; confirmed & completed test which are described below [27].

2.5.1.1 Stage 1: Presumptive test for coliform group of bacteria or determination of Most Probable Number (MPN)

This was done to determine the most probable number (MPN) of coliforms in a water sample in addition to its lactose fermentation and gas production properties. If gas was produced after inoculation and incubation of the lactose broth; it was assumed that coliforms were present in the sample.

2.5.1.2 Stage 2: Confirmed test for coliform bacteria

This test aims to differentiate coliforms from non-coliform bacteria; as well as gram-negative and gram-positive bacteria. In this test; the EMB agar inoculated from previous positive gas-producing tubes; showing small colonies with dark centers confirms the presence of Gram-negative; lactose-fermenting Coliform bacteria.

2.5.1.3 Stage 3: Completed test for coliform bacteria

This test is necessary for further confirmation.The final exam can help inoculate an inclination of nutritious agar and a Durham tube of lactose broth. This confirms the presence of coliforms.

2.6 Statistical Analysis

Data collected were presented as mean ± standard deviation using Microsoft Excel 2010.

3. RESULTS AND DISCUSSION

3.1 Physical Analysis

In the present study, the measured values of physical parameters of the selected water samples were represented at Table 2.

3.1.1 Temperature

The chemical, physical and biological characteristics of water is influenced by temperature. Table 2 shows that, the value of temperature in Baluchora were ranges from 28.4-28.6ºC. In C&B colony temperature ranges were 28.5-28.6ºC and in Khulshi, this value were ranges from 28.6-29ºC. Hence, the temperature was in acceptable limit for drinking water which is recommended with BSTI standard [20] and WHO standard (1996) [28].

3.1.2 pH

According to Sasikaran, et al. (2012) [29] pH is an important parameter in the evaluation of the acid-base balance of water. The pH of pure water refers to the measurement of hydrogen ion concentration in water. It is an important parameter that determines the suitability of water for various purposes. It is also the indicator of the acid or alkaline condition of the water state. In general, water with a pH of 7 is considered neutral, while a lower acid refers to an acid and a pH greater than 7 is known as a base. Normally, the pH of the water varies from 6 to 8.5. It is noted that low pH water tends to be toxic and with a high pH value it becomes a bitter taste. According to WHO standards pH of water should be 6.5 to 8.5. In Baluchora, it was ranges from 5.4-6.3; in C&B colony pH was 6.7-6.5 and in Khulshi pH values observed at 6.9. The pH value of C& B colony and in Khulshi were within the recommended limit. The identified pH value of Baluchora was below the pH range of the WHO standards for drinking water. The low pH indicates the acidity of the water and has a metallic or acid taste. Water with acidic pH levels can corrode the pipes and release the metal.

3.1.3 Turbidity

The Turbidity value was found 0.47-0.52 NTU in study area which is within the acceptable limit for drinking water.

3.1.4 Total Dissolve Solid (TDS)

A wide range of inorganic minerals and some organic ones, such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates, etc. are dissolved in water. These minerals are responsible for producing an unwanted taste and a color diluted in the appearance of the water. Total dissolved solids (TDS) in drinking water come in many ways from wastewater to urban industrial wastewater, etc. Therefore, the TDS test is considered a signal to determine the overall water quality and also an important chemical parameter of water [29]. Table 2 clears that, in Baluchora TDS values were ranges from 82-87 mg/l. In C&B colony TDS ranges were 41-62 mg/l and in Khulshi these values were from 116-158 mg/l. Hence, the values were found in acceptable limit. Water with a high TDS value indicates that the water is highly mineralized. High levels of TDS in groundwater are generally not harmful to humans; but a high concentration of these can affect people suffering from kidney and heart disease. Water that contains high solids content can cause laxative effects or constipation.

3.1.5 Electrical Conductivity (EC)

The electrical conductivity (EC) is a parameter which is used to indicate the total concentration of ionic species loaded in water. The standard limit of EC for drinking water is 1000 µs / cm [28]. The EC value was found 140-281 µs/cm in study area. The EC value found in the samples are lower than the value recommended by the WHO. A lower EC value clearly indicates that drinking water in the study area has not ionized considerably and has the lowest level of ion concentration activity due to small dissolution solids.

3.2 Chemical Analysis

The chemical constituents of collected drinking water samples from Baluchora, C&B colony and Khulshi area was represented in Table 3. In Baluchora, C&B colony and Khulshi area; the chloride (Cl) and manganese (Mn) value were ranges from 0–31 mg/l, 0.01-0.45 mg/l and iron content also found in acceptable limit. In this study, arsenic (As); lead (Pb); chromium (Cr); cadmium (Cd) were also measured where no arsenic was detected in the in water samples. Concentration of chromium (Cr) was within the limits of BSTI standards and WHO standards.

Only DWS-1 sample from Baluchora area was found higher concentration (0.03 mg/l) of lead (Pb) in it. Higher cadmium (Cd) concentration was found in Khulshi and Baluchora area. Drinking water that contains high levels of metals such as cobalt; copper; iron; manganese; molybdenum; selenium and zinc or toxic metals such as aluminum; arsenic; barium; cadmium; chromium; lead; mercury and silver may be hazardous to health.

3.3 Microbial Analysis

The highest value of total coliforrm was found in Baluchora (4×10^2 cfu/ml) and lowest value was found in Khulshi (0 cfu/ml) (Table 4). This result revealed that the values were excessively higher than the WHO guideline. Therefore, the total coliforms of the water samples exceed the permitted limit. So pretreatment like boiling, filtering etc. is needed before drinking this water. This contamination can occur due to the lack of sanitation and leakage around the pipe walls where contaminants can enter through the leak and can be mixed with the water lifting path [30]. Enteropathogenic *E. coli* causes diarrhea; food-borne disease and vomiting [31]. Moreover; *E. coli* is also responsible for urinary tract infection. Other coliforms such as *Enterobacter aerogenes* creates food spoilage and *Klebsiella pneumonia* causes urinary tract infection and pneumonia. The organism may be harmful to newborns and elderly patients because it can multiply and reach to harmful number very quickly [32].

Table 2. Physical parameters of collected drinking water samples from Baluchora, C&B colony and Khulshi area

Sample no	Sample ID	Temperature (°C)	pH	Turbidity (NTU)	TDS (mg/l)	EC (µS/cm)	Hardness as $CaCo_3$
1	DWS-1	28.6±0.01	6.3± 0.46	0.47±0.29	87.5±0.15	140±0.71	12.46±0.28
2	DWS-2	28.4±0.28	5.4±0.23	0.55±0.08	82.0±0.28	176±0.01	12.87±0.33
3	DWS-3	28.5±0.29	6.7± 0.19	0.56±0.23	62.6± 0.19	281±0.01	68.98±0.04
4	DWS-4	28.6±0.28	6.5±0.02	0.69±0.01	41.8±0.11	267±0.08	87.67±0.11
5	DWS-5	28.6±0.14	6.9±0.01	0.51±0.15	158.1±0.70	253±0.28	75.65±0.03
6	DWS-6	29±0.01	6.9±0.03	0.52± 0.19	116.8±0.31	187±0.02	55.18±0.08
Bangladesh standards (BDS 1240:2001)		20-30	6.5-8.5	5	250	600-1000	200-500
WHO Standards		30	6.5-8.5	Not exceeding 1.5 NTU	500	1000	500

DWS= Drinking Water Sample

Table 3. Chemical constituents of collected drinking water samples from Baluchora, C&B colony and Khulshi area

Sample no	Sample ID	Cl^- (mg/l)	Mn (mg/l)	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)	Fe (mg/l)	As (mg/l)
1	DWS-1	9.79±0.01	0.06±0.28	0.03±0.16	0.003±0.38	0.004±0.05	0.08±0.28	ND
2	DWS-2	-	ND	ND	0.008±0.15	0.007±0.01	ND	ND
3	DWS-3	-	ND	ND	0.002±0.01	0.011±0.28	ND	ND
4	DWS-4	5±0.01	0.01±0.28	ND	0.003±0.15	0.01±0.38	ND	ND
5	DWS-5	31±0.47	0.45±0.13	0.01±0.29	0.006±0.34	0.004±0.22	0.08±0.02	ND
6	DWS-6	14±0.28	0.12±0.28	ND	0.004±0.19	0.009±0.13	ND	ND
Bangladesh Standards (BDS 1240:2001)		Max 250	Max 0.05	Max 0.01	0.003	0.05	Max 0.30	Max 0.01
WHO Standards		No guideline	No guideline	0.01	0.003	0.05	No guideline	Max 0.01

DWS= Drinking Water Sample

Table 4. Microbiological parameters of collected drinking water samples from Baluchora, C&B colony and Khulshi area

Sample no	Sample ID	TC(CFU/ml)
1	DWS-1	3×10^3
2	DWS-2	4×10^2
3	DWS-3	1.03×10^4
4	DWS-4	1.08×10^3
5	DWS-5	0
6	DWS-6	1.03×10^4
Bangladesh Standards		0
WHO Standards		0

DWS= Drinking Water Sample

4. CONCLUSION

The overall study indicates that almost all the physicochemical parameter of sample water were not within recommended level, and also the microbial parameter were not match with acceptable limit. The study result indicated that almost all the samples from different locations were not suitable for drinking purposes or consumption without any primary treatment. So consumers of this drinking water are under the threat of water related disease & health risk. Therefore; those drinking water samples must be treated before drinking especially in terms of hygiene and to ensure strict compliance with guidelines as set by BDS standards. Awareness raising on chemical contents in drinking water at household level of this area is required to improve public health. Therefore; this study on drinking water will play a great significance in addressing the public health concerns in developing countries; especially Bangladesh. Moreover; this study will shed light on the necessary steps to ensure safe and quality drinking water supply in city areas.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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