Effect of Different Treatments on the Concentration of Chloride and Free Chlorine in Bottled Water and WASA Distributed Water in Chattogram.

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Roll No.: 0119/01

Registration No.: 651

Session: January-June, 2019

A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Science in Food Chemistry and Quality Assurance

Department of Applied Chemistry & Chemical Technology

Faculty of Food Science and Technology

Chattogram Veterinary and Animal Sciences University

Chattogram-4225, Bangladesh

June, 2022

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Md. Ashraful Islam

Assistant Professor

Dept. of Applied Chemistry and Chemical Technology

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The Author

June, 2022

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List of Abbreviation

Abbreviations	Elaboration
μL	Micro Litre
ppm	Parts per million
MLD	Million Liter per Day
TDS	Total Dissolved Solid
FAO	Food and Agricultural Organization
WHO	World Health Organization
WASA	Water Supply and Sewerage Authority

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Abstract

After several treatment process, Chattogram Water Supply and Sewerage Authority (CWASA) distributes the water from the Karnaphuli river into the Chattogram city. In this study the supplied water by CWASA and mineral water marketed around the country were analyzed. The CWASA supplied water samples were collected from three locations of Chattogram city and three samples of bottled mineral water of different brands were collected. Each sample was replicated three times and processed though filtration, sunlight treatment, boiling, combined treatment (boiling+filtration). The results were compared with the bottled mineral water samples. Recently a newspaper claimed that CWASA is applying extra chlorine to kill the coronavirus in the Covid-19 pandemic situation. That is why the Free Chlorine, Chloride Ion, pH and TDS of the supplied water are analyzed to determine if there is any health issue regarding this matter. In the raw supply water samples, maximum mean Chloride ion was observed in the sample WASA water 03 (391.07 ppm). The maximum mean free chlorine was observed in the raw WASA water 01 (0.5 mg/L) which lies within the standard limit. The highest pH in the raw water was observed in the WASA water 02 (8.2). In the raw water the maximum TDS was observed in WASA water 01 which is about 172. Among the bottled raw mineral water highest Chloride was observed in water bottle 03 (128.55 ppm), highest pH was observed in bottled water 01 (8.14), highest TDS was observed in the bottled water sample 03. Each result was varied after different treatments. But all of them were found within the standard limit. The free chlorine concentration claimed in the news was 0.5 to 1.0 mg/L. The standard limit is 0.2 to 0.5 mg/L. The news about increasing the chlorine in water can be true but this might be used for limited time only. After the study the results were within the standard limit.

Keywords: Supply Water, Chattogram, Free Chlorine, Chloride, TDS, pH, WASA

Chapter 01
Introduction

Chattogram is the second largest city in Bangladesh. The city is situated on the bank of the river Karnaphuli. The ground water is flown towards the Bay of Bengal, the southern part of the country, through the river Karnaphuli. As a result, the largest sea port of the country is situated on the bank of the river Karnaphuli. The river not only plays a vital role in the development of the city but also the whole country. It plays an important role in the industrial progress and economic growth of the country.

About 8.7 million people live in Chattogram City. To fulfil the demand of the pure drinking water Chattagram Water Supply and Sewerage Authority (CWASA) supplies ground water of the river Karnaphuli after several treatments. Salt processing industry, cement processing industry, fish processing industry, agro products processing industries, Sugar processing industries etc. are present on the bank of the river. Most of the time, the industrial waste is disposed in the river. Due to the growing industrialization the water gets polluted day by day. So, the supply of pure water to the citizens in Chattogram city is challenging.

Water is one of the major elements to sustain of all live creatures. It is really essential to supply pure water to the people. Polluted water contains different pollutants from the industries or different pathogenic disease-causing microbes like *Escherichia Coli*, Coliforms, and fecal Coliforms etc. which indicates the presence of pathogenic organisms resulting in different water borne diseases like diarrhea, cholera, typhoid, dysentery etc. These diseases may lead to the death of the patients (Mahbub *et al.,* 2011 and Mead *et al.*, 1999). Chattogram WASA treats the ground water using different treatment steps in different plants over the city and distributes among the people. Among the treatment the water is disinfected using chlorine. It has been reported that the Chattogram WASA is using extra chlorine to kill coronavirus which raises the health worries among the general mass (Sayem, 2020). It is really a concerning issue because excessing presence of free chlorine can cause different difficulties in human body. Again, high exposure to extreme pH and other parameter beyond standard may lead to eye irritation, skin rashes, and mucus.

The study is done to measure the presence of free chlorine, chloride ion and determine the quality of the supply water in Chattogram area.

1.1 Water Supply System in Chattogram Metropolitan Area

From the beginning, Chattogram WASA (CWASA) has the responsibility to distribute supply water into the Chattogram city area for about 3.16 million people. Each day CWASA distributes 450 million Liter water into 168.21 square Kilometer area. Among the distributed water 80% is ground water and 20% is under ground water. CWASA has three (03) ground water treatment plant (Mohora), One (01) underground water treatment plant and 49 underground deep tube well (Annual Report of CWASA, 2020-2021).

1.2 Mohora Water Treatment Plant:

Mohora water treatment plant consists of following components.

1. Intake and Raw Water Pump Station
2. Desilting Basin
3. Rapid Mixer
4. Clarifier
5. Filter
6. Chlorine Contact Chamber and Clear Well.
7. High Lift Pump Station
8. Chemical Facility
9. Sludge and Backwash facility
10. Power and Standby Generator
11. Laboratory
12. Plant Monitoring Arrangement

In the Clear well the chlorine comes in contact with the water to kill the microorganisms.

1.3 Treatment process description

According to the CWASA water treatment plant was established to bring the water quality within the maximum acceptable limit/standards set by the World Health Organization (WHO). The raw water for the CWASA Water Treatment Plant

(Mohora) is collected from the Halda River. The alkalinity of Halda river water varies from (10-75 mg/L) and turbidity varies from (15-350 NTU). Seasonal changes with the monsoon season result into variation in the higher turbidities, low alkalinities and high level of suspended solids. The structure with bar racks, the pump station, the raw water rising main, the desilting basins, the rapid mixtures, the clarifiers, the filters, the clear well, the high-lift pump station, the sludge, the backwash facilities, the standby power generator, the chemical storage area and facilities, and the administration building make up the entire water treatment process. The west bank of the Halda River is where the intake structure and pump station are situated. The input structure has five compartments, each with a 45 mL/d capacity (10 imp mgd). Each container has hand-raked bar screens to keep coarse dirt and floating stuff out. The intake structure is connected to the raw water pump station by a pipe in each compartment. Five raw water pumps are planned, but only two duty pumps and one standby pump are now available. The raw water is hoisted by raw water pumps from the intake structures to the desilting basins or directly to the rapid mix units. During the monsoon season, two desilting basins are provided to prevent large sediment loads to the clarifiers, although they can be bypassed during the dry season. If necessary, alum is added to the raw water at the meter vault to aid in the settling of suspended solids in the desilting basin.

Chemical injection, flash mixing, and coagulation are the next processes after desilting. Vertical turbine mixtures are used to mix the solution in two upflow chambers in series. At this time, alum for coagulation, chlorine for controlling aquatic development, and, if necessary, lime for pH adjustment is all supplied. Water that has been chemically dosed travels from the mixing chambers to a set of 24 upflow, inverted pyramid-shaped clarity tanks with solid connections. As the water rises up the diverging tank and sludge blanket, the hydraulic energy released at the bottom by the entering coagulated water results in a decreasing mixing action. Each clarifier's sludge blanket is periodically removed by a draw off line for the sludge that settles to the bottom and consolidates when the tank is shut down for cleaning or continuously removed by fixed sludge conditioning.

As the water rises up the diverging tank and sludge blanket, the hydraulic energy released at the bottom by the entering coagulated water results in a decreasing mixing action. Sludge is sucked off the sludge blanket of each clarifier on a continuous basis by fixed sludge conditioning or on a periodic basis by a draw off line for the sludge that settles to the bottom and consolidates when the tank is taken out of operation for cleaning. Backwashing is achieved by manually stopping the incoming flow using a manual plug. The blocked filter receives filtered water from the running filters, which is used to clean the media. The waste water from the backwash passes via the central backwash water channel and is discharged into the waste.

Filtered water is gravity-fed into the clear well's chlorine contact zone, where chlorine is supplied for disinfection. Water pours over a weir from the contact zone into the clear well. After the addition of chlorine, the weir guarantees that filtered water has a 30-minute contact period and keeps a consistent head available for filter backwashing. To allow for alternate cleaning, the transparent well is divided into two halves.

The clear well is near to the high lift pump station. The treated water was transported to the Battali hill reservoir by five constant-speed, electric vertical centrifugal pumps (four on duty, one on standby).

Three processes produce sludge: filter backwashing, clarifiers, and desilting basins. Downstream of the plant's raw water intake, the sludge side streams will be discharged back into the Halda River. The river surface is often low enough to allow backwash water, silt, and sludge to flow naturally via a pipeline and discharge into the river. A check valve that directs backwash water and sludge into the wet well of the backwash water and sludge pumping plant will be shut off by backed-up water during periods of relatively high tides or river flooding. There, they will be raised high enough to allow gravity flow to the river. Three duty pump and one standby pump are provided at the sludge and backwash facility to handle the sludge and wash water from the clarifiers and the filters respectively. Silt and sludge are withdrawn from the desilting basins by gravity when the river stage is low enough (San, 2014).

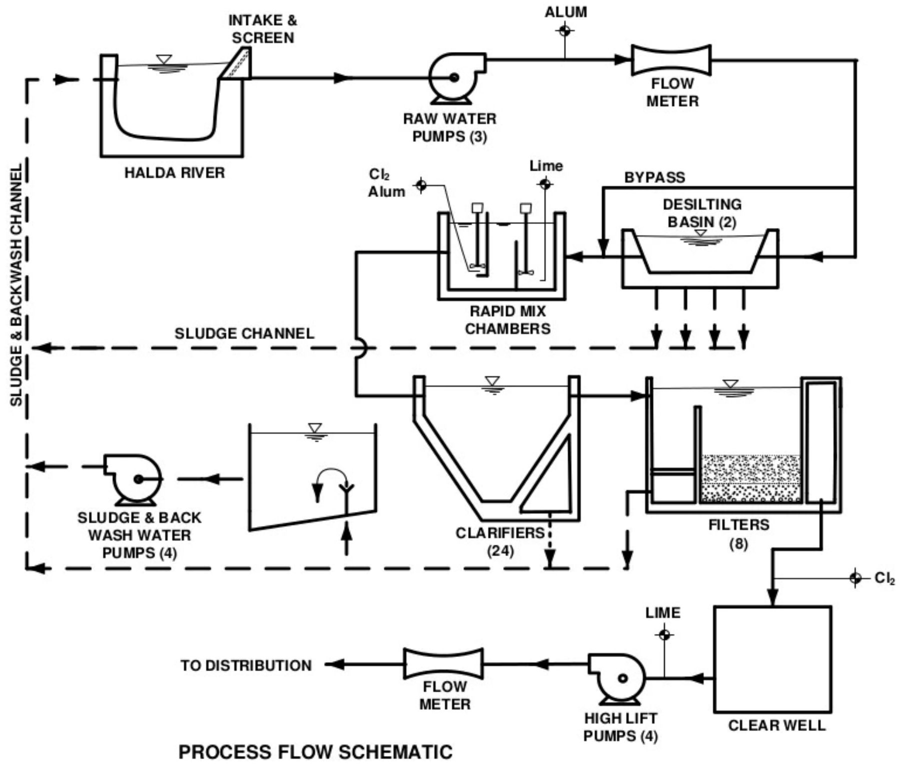

Figure 1: Process flow of Chattogram WASA Water Treatment Plant

1.4. Significance of the study

Treatment with chlorine is done to kill the pathogenic microorganisms in the supply water which is done in the step clean well before distribution. Long term consumption of water containing high amount of free chlorine leads to breathing problem, congenital disabilities, colon cancer, bladder cancer etc. So, it is important to know the current situation of the free chlorine and other quality parameters of the supply water of Chattogram WASA. With this study people can get a clear view about the current quality of the water and can take necessary steps to mitigate the probable difficulties coming in future.

1.5. Objectives:

The Overall objective of the study was to identify if there is any probable risk for drinking supply water by Chattogram WASA. The specific aim of the study was to determine the free chlorine concentration, chloride ion concentration, pH and TDS of the supply water in Chattogram area and compare the value with the bottled water marketed in Bangladesh.

Chapter 02
Review and Literature

2.1. Drinking Water

Water is the primary component of the Earth's surface and the fluids of all known living things. It is an inorganic chemical with the chemical formula H_2O and is transparent, tasteless, odorless, and almost colorless (in which it acts as a solvent) (Water Science School, 2019). Despite not providing food, energy, or organic micronutrients, it is essential for all known forms of life. Each of its molecules has one oxygen and two hydrogen atoms, which are joined by covalent bonds, according to the chemical formula H_2O. An angle of 104.45° separates the hydrogen atoms from the oxygen atom. H_2O in its liquid form at room temperature and pressure is referred to as "water."

About 50 % of people in developing countries are afflicted by one or more of the six major diseases linked to water supply and sanitation (Diarrhea, which is carried on by a variety of microbial and viral pathogens in food and water; Ascaris, Dracunculiasis, Hookworm, and Schistosomiasis, which are all brought on by infestation with different worms and cause morbidity, disability, and occasionally death; and Trachoma, which is brought In impoverished countries, watery diarrheal illnesses claim the lives of 400 children under the age of five every hour (Gadgil *et al.*, 1998).

2.2 pH of Potable Water

The pH is the measurement of negative logarithm of Hydrogen ion. The pH is an important parameter for the potable water. It represents the acidity and alkalinity of water. According to WHO and Department of Public Health Engineering, Bangladesh, the pH should be 6.5 to 8.5.

In the previous studies it has been found that the mean pH of the supply water in Chattogram metropolitan area was within the standard limit. In the study the highest pH observed was 11.80 and the lowest was 5.50 (Molla et al., 2014).

pH can be affected by different chemicals in water due to water pollution or other ways. It denotes that water is changed chemically. A high pH of water is known to be base and low pH of water is known to be acid. The pH of water determines the solubility, biological availability like nutrients for aquatic life, heavy metals toxicity. The water containing metals become more toxic at lower pH as metal solubility increases at low pH (Islam *et al.*, 2017).

2.3 Effect of altered pH on Human Health and other factors:

pH levels that are either too high or too low can have an impact on how much water is consumed. High pH results in a bitter taste, deposits in water pipelines and water-using devices, and reduced chlorine disinfection effectiveness, necessitating the use of additional chlorine. In low pH water, metals and other objects will corrode or dissolve. In previous studies it has been seen that lower pH water does not pose health risk as our stomach pH level is naturally low at pH 2 but it can cause aesthetic problems (Islam *et al.*, 2017; USGS, 2016). According to Dirisu *et al.*, 2016, Low pH supply water can cause irritating of skin when used for bathing. The study also reports that low pH water can also cause sickness. Other than these effects low pH water can make the soil acidic, leads death of fishes, can cause the death of soil organisms and reduces crop yields. Spoils roof sheets etc. pH indicates the hardness and softness of water. The corrosiveness and toxicity of water are also indicated by pH. Different environmental factors can alter the pH in water which results in changing the states of some pollutants like copper ammonia. This can affect the aquatic lives. The altered pH also affects the human body. Hard water results in aesthetic issues such giving the water an alkali taste, forming scale on laundry and cooking appliances, reducing the efficacy of soaps and detergents, and leaving insoluble precipitates on garments. Reduced reproduction, a decline in biodiversity, slowed growth, and harm to organs like the eyes and olfactory system are all effects of high-water pH. Additionally, hazardous chemicals like ammonia and hydrogen sulfide become more toxic at high pH levels (Dirisu *et al.*, 2016; WRN, 2016; Svobodova *et al.*, 1993). The Low pH in water causes due to the decomposition of organic materials in water, formation of carbonic acid, presence of metals like aluminum, copper, zinc, calcium oxide, sodium carbonates etc. The low pH water may include heavy metals, which can lead to toxicity, metal poisoning, and other health problems, as well as symptoms like chills, weakness, shortness of breath, weakness of the immune system, organ damage, and so forth (Anyanwu *et al.*, 2018; Jan *et al.*, 2015).

2.4 Total Dissolved Solid (TDS) in Water

Total dissolved solids, or TDS, are the inorganic salts and minute amounts of organic compounds in solution in water. The most common cations include calcium, magnesium, sodium, and potassium; anions include carbonate, hydrogen carbonate, chloride, sulfate, and nitrate (Islam *et al.,* 2017; WHO, 2017).

According to Gray (2008), another way to evaluate hardness is total dissolved solids (TDS), which is a measurement of the total concentration of ions in water. TDS in groundwater is usually several orders of magnitude higher than TDS in surface water. Because less fresh recharge water dilutes the existing groundwater and ions take longer to dissolve, TDS rises with depth in aquifers. As groundwater gets older and deeper, its mineral content increases, making it saltier. High salt concentrations in groundwater are a result of over-abstraction, dry conditions, and the upward replacement of old saline groundwater into boreholes or saline incursion into the aquifer from the sea.

2.5 Chloride ion in water

Chlorides are inorganic substances created when chlorine gas reacts with a metal. Two typical chlorides are sodium chloride (NaCl) and magnesium chloride ($MgCl_2$). Chlorine (Cl_2) is a very poisonous gas that is frequently employed as a disinfectant. It becomes needed for life when combined with a metal like salt. In plant and animal life, small levels of chlorides are essential for appropriate cell activities. Chloride ions (Cl^-) in the form of calcium, magnesium, and sodium salts are present in almost all water sources. Despite the fact that different sources have different amounts of Cl^-. Seawater contains up to 19,000 mg/L of chlorine. Once more, common surface water and groundwater can have less than 50 mg/L. The tolerance of terrestrial animals and plants to Cl^- is in a particular range, despite the fact that marine life has a relatively high tolerance for it. Natural strata, some salt deposits, and sediments that contain Cl^- are the sources of chlorine in natural water. The amount of chlorine ions in the environment has increased year over year due to industrialization in recent years (Kumar and Puri, 2012).

2.6 Adverse effect of Chloride Ion in water:

Chlorides normally have a positive impact on human health, however the sodium in table salt has been linked to kidney and heart disease. Sodium chloride can start to taste salty at 250 mg/l, however calcium or magnesium chloride often don't taste salty until

1000 mg/l. Public drinking water cannot include more chloride than 250 mg/l. Chlorides in surface water may come from a variety of sources, including chloride-containing rocks, agricultural runoff, industrial waste, oil well waste, and effluent waste water from waste water treatment facilities. Chlorides have the potential to corrode metals and alter food flavor. Chlorides have the potential to contaminate freshwater lakes and streams. High levels of pollution make it impossible for fish and aquatic ecosystems to exist (Kumar and Puri, 2012).

2.7 Free Chlorine:

The most often used disinfectant in the world is chlorine, which is used in many different forms. Calculating the dosage of chlorine involves multiplying the concentration by the contact time. Water and chlorine interact to produce HOCl, H^+, and CI^-. The hypochlorite ion, which is produced when HOCl, or hypochlorous acid, breaks into H^+ and OCl^-, is known as the hypochlorite ion. Lower water pH and warmer water temperature both lessen hypochlorous acid dissociation, which lowers the ratio $[OCl^-]/[HOCl]$. In addition, as the substance in the suspended particles interacts and bonds with the chlorine in the water, it is removed from the process and converted to hypochlorous acid. A stronger antibacterial disinfectant than hypochlorite is hypochlorous acid. When a result, the amount of chlorine required for disinfection increases noticeably as turbidity, pH, water temperature, and the contents of ammonia, hydrogen sulfide, iron, and manganese all climb (Gadgil *et al*, 1998). Chlorination works to eliminate or inactivate pathogen-causing bacteria in drinking water sources and swimming pools. It can react with ammonia, iron, sulfide, and some organic compounds to improve the quality of water. However, a high chlorine content in water can have negative effects, such as the production of carcinogenic chloroform or other pollutants. It is crucial to regularly monitor the chlorine levels in order to decrease the purpose for chlorination and minimize any negative consequences.

2.8 Adverse effects of free chlorine on human health:

Chlorine is used to sterilize the water but excessive presence of chlorine in drinking water creates adverse effects on health. When Chlorine is introduced in drinking water it reacts with the organic matters found in the water and creates hydrocarbons like chloroform, benzene, bromoform, dibromo-chloromethane, bromo-dichloro methane etc. These compounds are mostly present in the excessive chlorinated supply water and responsible for the main reason behind liver, kidney and colon cancer (Mohsen *et al.*, 2019). According to Michaud *et al.,* (2007), the increase in temperature of water increases the free chlorine in water. If the free chlorine is 0.2mg at 30ºC, it will rise up to 7mg when the temperature is increased to 40ºC. Asthma, allergies and sinuses can be occurred due to inhalation of the free chlorine. Eyes, chest, nose pain, cough and sputum are caused due to short term exposure to this condition. Excessive exposure to chlorinated water can be absorbed through bathing or regular use in our body which is 100 time higher than the drinking water. It causes several health issues in our body. Chlorine in high concentrations can irritate and inflame the membranes in your nose, throat, and respiratory system. It can also lead to pneumonia, bronchitis, fluid buildup of the lungs, dyspnea, and even death from suffocation. Low levels of chlorinated water can cause symptoms of bronchitis, asthma etc. when they are continuously used. This exposure increases the risk of tuberculosis. Lotus-borne illnesses are brought on by chlorine-based water sterilizers. Chloramines, hypochlorous acid, and epithelial tissue junction disruption all contribute to muscle oxidation and increased lung epithelium permeability (Bernard *et al.*, 2006; Mohsen *et al.*, 2019; Nemery *et al.*, 2002). The exposure to continuous chlorinated water can cause respiratory issues to the kids, tank attendants, lifesavers, best bathers etc. (Lourencetti *et al.*, 2008). The Chlorine reacts with the mucus membrane of the cornea. The reaction is acidic. The proteins of the tears help to reduce the damage caused by these acids. The burns caused by the acids in the cornea can lead to ulcer and leave scars (Mohsen *et al.*, 2019; Bernard, 2007). Due to bathing with excessive chlorinated water can result into scalp, skin redness to those who are allergic to chlorinated water. The chlorinated water can destroy the hair protein, causes dryness of the hair, makes it fragile, reduces the hair color and increases the dandruff problem. Swimming in the chlorinated swimming pool can make skin dry and itchy and can make worsen the skin condition like dermatitis. Chlorinated water increases the free radicals in the body and causes aging of human being (Cmest, 2000).

Chapter 03

Materials and Methods

3.1. Site of the Study

The study was conducted in the Department of Applied Chemistry and Chemical Technology, Department of Physiology, Biochemistry and Pharmacology of Chattogram Veterinary and Animal Sciences University.

3.2. Collection of Samples

The study was done based on the Chattogram city and all the samples were collected from the city. To assess the supply water quality three sample areas were collected from Chandgaon, Khulshi area and Port Colony area. Total nine water samples were collected from three six supplied groundwater sources. The samples were collected from supply water distributed by Chattogram WASA in Chattogram city. And three samples (three replications each) of commercially bottled mineral water were collected from three different brands from different area of Chattogram metropolitan area. The water samples have been taken from each study area and got tested in Quality Control and Analytical Lab (Dept. of Applied Chemistry and Chemical Technology) & Post Harvest Research Laboratory (Department of physiology, Biochemistry and pharmacology) to find out the quality status of selected physicochemical parameters of the water which are free chlorine concentration, chloride ion, pH and TDS. Before taking the water samples the sterile container were rinsed. The map of the study area is presented in Fig 1.

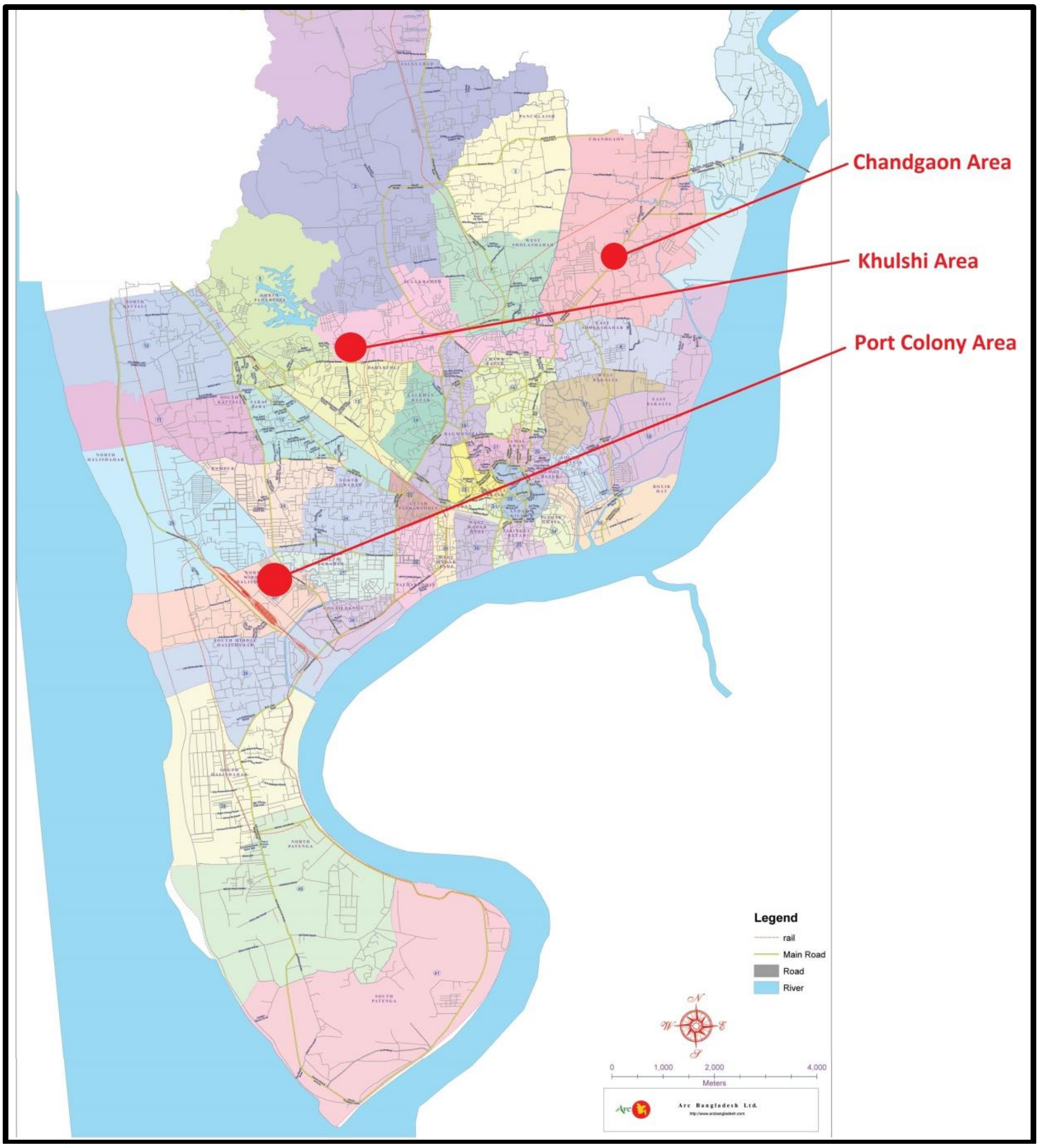

Fig 2: Study area for analysis of supply water in Chattogram city area.

3.3 Treatments applied in the collected samples

Five treatments were done for each sample of CWASA Water and Bottled Mineral Water. Details of the treatment processes are described below.

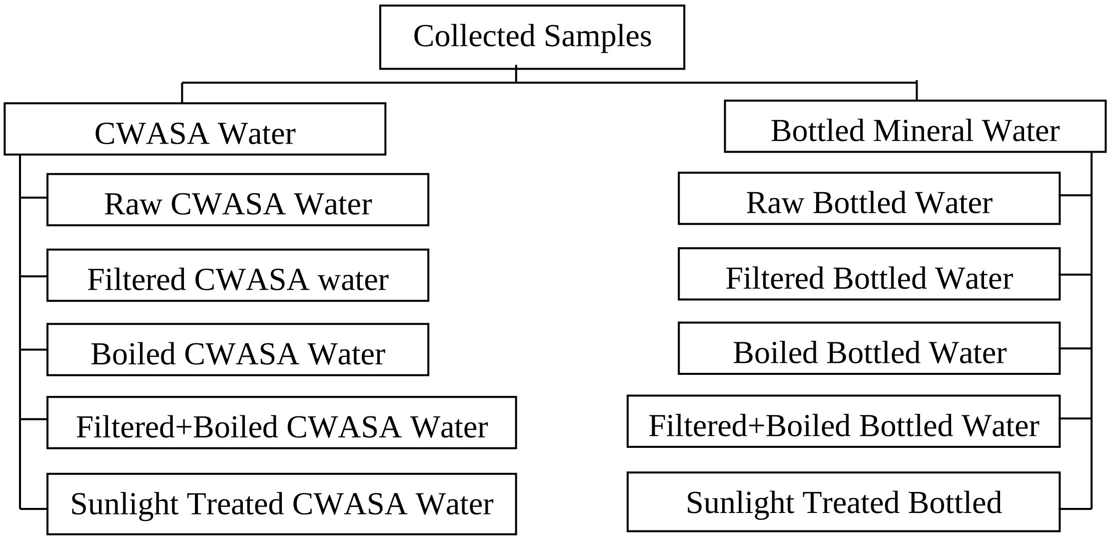

Figure 3: Different Treatments of CWASA supply water samples and bottled mineral water

3.3.1 Filtration of the Different Sample Water

At first 500 mL of the raw CWASA supplied water and Bottled water are placed into a normal regular domestic filter bought from local market. This was done to obtain the actual result for the different water parameters. Three replicates of each sample were taken for the treatment.

3.3.2 Boiling of the Different Sample Water

In a Beaker about 500 mL of raw CWASA water and bottled water are taken and boiled at 100ºC for about 4 to 10 minutes. Three replicates of each sample were taken for the treatment.

3.3.3 Combined Treatment of Filtration and Boiling

After filtration of the water samples about 250 mL of the filtered water was separated and boiled following the previous procedure.

3.3.4 Sunlight Treatment of the Samples

The samples were taken into transparent bottle and treated under sunlight for about 4-6 hours.

3.4. Determination of Chloride Ion in the collected samples

Principle: Theoretically, mercuric thiocyanate can be broken down into thiocyanate by combining with free mercuric ions. A reddish-brown ferric thiocyanate complex is created when the released thiocyanate mixes with the ferric ions. The amount of chloride contained in the sample directly correlates with how intense the color is.

$2Cl^- + Hg(SCN)_2 \rightarrow HgCl_2 + 2(SCN)$

$3(SCN) + Fe^{3+} \rightarrow Fe(SCN)_3$

Reagent Composition:

1. **Chloride Reagent (L1):** Mercuric Thiocyanate, Ferric Nitatre, Nitric Acid, Non Reactivr stabilizers and preservatives.
2. **Chloride Standard**

Procedure:

For each sample, three dry, spot-free PCR tubes (small plastic tubes) were used and labeled as Blank (B), Standard (S), and Test (T). After that the pipetting was done by using micro pipette. Into the tube Blank (B), 1.0mL of Chloride reagent (L1) and 0.01 deionized water were taken. In the tube Standard (S), 1.0 mL of Chloride reagent (L1) and 0.01 Chloride standard were taken. Into the tube Test (T), 1.0 mL of Chloride Reagent (L1) and 0.01 of samples were taken. Following pipetting, they were well combined and incubated for two minutes at room temperature. Finally, within 60 minutes, the absorbance of the Standard and Test samples compared to the blank sample was evaluated. This was done by using spectrophotometer at a wavelength of 505 nm (Hg 546)/Green.

Calculations:

Chloride in mmol/L= $\frac{Absorbance\ of\ Test\ Sample}{Absorbance\ of\ Standard} \times 100$

3.5 Determination of free Chlorine:

The free chlorine content of supply water sample and bottled mineral waters were determined by following kit method. Free Chlorine test kit (Model: HI3831F. Manufacturer: HANNA instruments) was used to measure the free Chlorine.

Principle:

Acids such as hypochlorous and hydrochloric are created when chlorine is added to water. The disinfection and bleaching agent is hypochlorous acid. These are measured using a colorimetric technique and are referred to as free chlorine. At a buffered pH of about 6.3, DPD (N.N-diethyl-p-phenylenediamine) is rapidly oxidized by chlorine, giving the reaction a crimson hue. The concentration of free chlorine is determined by the color intensity of the solution.

Apparatus and chemicals:

1. 1 color Comparator cube
2. Reagent 1 (20 mL);
3. Reagent 2 (1 mL)

Procedure:

At first the chemical test kit were removed and examined carefully so that there is no damage present in the kit. The comparator cube were taken from the packaging. To the color comparator cube, add 3 drops of Reagent 2 and 5 drops of Reagent 1 next. The color comparator cube was then filled to the 5 mL mark with a water sample. The comparator cap was then gently placed on the cube, and it was delicately swirled and repeatedly inverted. At last the best match of color band were determined with the reference color attached beside the vessel and the free chlorine concentration mg/L (ppm) free chlorine were recorded.

3.6 Determination of pH:

Utilizing the Hanna microprocessor pH meter, the pH of the water samples was determined (Model No: HI98107 pHep). It was calibrated using a buffer solution with a pH range of 4 to 9.

3.7 Determination of total dissolved solids (TDS):

TDS were assessed using the TDS Meter (HI 98301). The water samples were initially collected into 50mL beakers. The TDS meter was then fully submerged in the water samples to measure TDS levels. To get rid of any air bubbles, it is lightly swirled or tapped. Since the device's ability to read data can be hampered by air pockets between the electrodes.

3.8. Statistical Analysis

Statistical software called SPSS was used for all statistical data analysis (Version 26). The mean and standard deviation were calculated using a one-way ANOVA test, and the values were compared using the Duncan multiple comparison post hoc test, $p<0.05$. Three replications were used in the three testing procedures.

Chapter 04
Results

4.1. Result of Chloride ion

Table-1: Chloride Concentration of Different treatments of Selected Samples (CWASA Supply Water and Bottled Mineral Water)

Treatment Name	Mineral Water Bottle 1 (ppm)	Mineral Water Bottle 2 (ppm)	Mineral Water Bottle 3 (ppm)	WASA Water 1 (ppm)	WASA Water 2 (ppm)	WASA Water 3 (ppm)
Raw	98.65 ± 0.12^{e}	113.45 ± 0.33^{d}	128.55 ± 0.14^{cd}	127.08 ± 0.04^{cd}	259.04 ± 0.25^{b}	391.07 ± 0.44^{a}
Filtered	89.37 ± 0.45^{e}	113.45 ± 0.25^{d}	137.53 ± 0.35^{c}	67.82 ± 0.62^{f}	198.26 ± 0.35^{b}	208.72 ± 0.66^{a}
Sunlight	104.37 ± 0.64^{f}	205.63 ± 0.18^{d}	306.93 ± 0.51^{b}	125.19 ± 0.15^{e}	257.82 ± 0.14^{c}	388.44 ± 0.95^{a}
Boiling	103.89 ± 0.72^{f}	150.45 ± 0.79^{d}	123.01 ± 0.95^{e}	172.15 ± 0.52^{c}	354.53 ± 0.36^{b}	533.54 ± 0.75^{a}
Boiled + Filtered	85.35 ± 0.93^{e}	130.93 ± 0.74^{c}	113.45 ± 0.45^{d}	84.35 ± 0.85^{f}	173.719 ± 0.61^{b}	261.43 ± 0.49^{a}

Results are presented as means and standard deviations of three replicates on a ppm basis. One-way ANOVA followed by Duncan multiple comparison post hoc test, $p<0.05$, indicates that different superscript letters in the same row within each fraction indicate a significant difference between mean values.

4.2. Result for free Chlorine Concentration

Table 2: Free chlorine concentration in in CWASA supply water samples and bottled mineral water with different treatment

Treatment Name	Mineral Water Bottle 1 (ppm)	Mineral Water Bottle 2 (ppm)	Mineral Water Bottle 3 (ppm)	WASA Water 1 (ppm)	WASA Water 2 (ppm)	WASA Water 3 (ppm)
Raw	< 0.5	< 0.5	< 0.5	0.5	< 0.5	< 0.5
Filtered	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Sunlight	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Boiling	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Boiled + Filtered	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

4.3. Result for pH

Table 3: pH of CWASA supply water samples and bottled mineral water with different treatment.

Treatment Name	Bottled Mineral Water 1	Bottled Mineral Water 2	Bottled Mineral Water 3	WASA Water 1	WASA Water 2	WASA Water 3
Raw	8.14 ±0.01^{a}	7.17 ± 0.03^{c}	7.5 ± 0.01^{b}	7.5 ± 0.03^{b}	8.2 ± 0.03^{a}	7.5 ± 0.01^{b}
Filtered	7.73 ±0.02^{bc}	8.35 ± 0.01^{a}	7.4 ± 0.03^{c}	7.9 ± 0.02^{b}	8.6 ± 0.06^{a}	7.9 ± 0.03^{b}
Sunlight	7.54 ±0.01^{bc}	8.04 ± 0.02^{a}	7.5 ± 0.02^{bc}	7.9 ± 0.01^{a}	8.0 ± 0.04^{a}	7.7 ± 0.04^{b}
Boiling	6.55 ±0.02^{d}	7.63 ± 0.02^{b}	7.1 ± 0.01^{c}	7.6 ± 0.02^{b}	7.5 ± 0.03^{b}	8.3 ± 0.02^{a}
Boiled + Filtered	7.46 ±0.03^{c}	7.57 ± 0.04^{b}	7.4 ± 0.01^{c}	8.0 ± 0.03^{a}	8.2 ± 0.01^{a}	8.2 ± 0.02^{a}

Results are presented as means and standard deviations of three replicates. One-way ANOVA followed by Duncan multiple comparison post hoc test, $p<0.05$, indicates that different superscript letters in the same row within each fraction indicate a significant difference between mean values.

4.4 Result for TDS:

Table 4: TDS of CWASA supply water samples and bottled mineral water with different treatment.

Treatment Name	Bottled Mineral Water 1	Bottled Mineral Water 2	Bottled Mineral Water 3	WASA Water 1	WASA Water 2	WASA Water 3
Raw	94 ± 2^{b}	90 ± 2^{b}	95 ± 1^{b}	172 ± 3^{a}	52 ± 1^{d}	87 ± 2^{c}
Filtered	92 ± 1^{a}	58 ± 1^{c}	40 ± 1^{d}	88 ± 1^{a}	83 ± 1^{b}	91 ± 1^{a}
Sunlight	90 ± 1^{b}	88 ± 1^{b}	45 ± 2^{c}	198 ± 2^{a}	88 ± 1^{b}	92 ± 1^{b}
Boiling	25 ± 3^{d}	90 ± 1^{c}	16 ± 1^{e}	222 ± 2^{a}	103 ± 1^{c}	117 ± 1^{b}
Boiled + Filtered	46 ± 2^{c}	45 ± 1^{c}	45 ± 1^{c}	192 ± 1^{b}	242 ± 2^{a}	242 ± 2^{a}

Results are presented as means and standard deviations of three replicates. One-way ANOVA followed by Duncan multiple comparison post hoc test, $p<0.05$, indicates that different superscript letters in the same row within each fraction indicate a significant difference between mean values.

Chapter 05

Discussion

5.1. Chloride ion

After analyzing the data, we can see that among the WASA water samples raw water contained the highest amount of chloride ion. The raw WASA water sample 3 is highest in the chloride concentration. It has been seen that found that the Chlorine concentration was quite high in the boiled water in both cases. The lowest Chloride concentration was observed in filtered water.

According to the packaging labels of the Bottled Mineral water the chloride is present below 250 ppm. In our study we can see that the Chloride ion in the bottled was below 250 ppm. Maximum chloride ion was observed in the Mineral Water Bottle 02 which was after sunlight treatment. The chloride contents after other treatments were obtained between 85 to 150 ppm.

According to Rahman *et al.* (2017), the chloride content of bottled drinking water of different brand was also observed below 250 ppm. But the range of Chloride present on those samples were between 1.6 ppm to 57 ppm which is quite lower than our observed values.

In the Chattogram WASA supply water it has been found that the maximum Chloride ion was 533.54 ppm which is higher than 250 ppm. The lowest Chloride ion was observed in the CWASA supply water is 67.82 ppm after filtration treatment. After boiling maximum chloride ion is observed. Boiling reduces the water content and can increase the chloride concentration. The river Karnaphuli is connected with the Bay of Bengal. The salinity and chloride ion content of the Karnaphuli River vary along with different seasons. This could be a reason behind the increase in the chloride ion content.

According to Molla *et al.* (2014), the maximum chloride was observed 909.90 ppm which is higher than our determined values. The mean chloride content was 195.977 mg/L and 270.410 mg/L in two different study area. Zannat *et al.* (2020), the mean chloride was found 43.75 ppm in Mohora-Batali hill area. In Hathajari Road the value was found 40.75 ppm and in Nasirabad road the mean chloride value was obtained

43.75 ppm. In our raw WASA supply water we found 127.08 mg/L, 259.04 mg/L and 391.07 mg/L in three different areas which is higher than the previous study.

5.2. Free Chlorine

The WHO Guideline (2011) states that, despite the possibility of chlorine residuals exceeding the advised range of 0.2-0.5 mg/L for water that is centrally treated at the point of delivery, the free chlorine doses are suitable for household water treatment to maintain a free chlorine residual of 0.2 mg/L in stored household water treated by chlorination. Chowdhury *et al* (2011) found that the mean free chlorine concentration in the CWASA supply water of two different zone of Chattogram city are 1.78 mg/L and 2.4393 mg/L respectively. The Maximum value was obtained 40.56 mg/L. In 2011 the value was definitely higher than the standard free chlorine concentration of water. In our study it has been found that all of the samples (both mineral water bottle and the CWASA supply water) are equal or below 0.5 mg/L. This result can be an indicator of the continuous development in the water supply system of Chattogram WASA.

According to the news before the Covid-19 situation CWASA previously chlorinated containing from 0.2 to 0.8 milligrams of free chlorine. During the Covid-19 situation the news about adding extra chlorine to kill the coronavirus is very concerning. Because excessive chlorine in water can result in excessive levels of chlorine, over time, could cause things like breathing issues, congenital defects, colon cancer, bladder cancer, etc. In order to eradicate the coronavirus, the news reports that CWASA is adding 0.5–1.0 milligrams of chlorine per litre of water. Continuous intake of water containing free Chlorine Higher than 0.5 mg/L can affect the public. But our study shows that the free chlorine of the CWASA water was within the limit according to the standard.

5.3. pH

If we observe the WASA supply water samples we can see that the WASA water sample 2 has the highest pH among all. In the WASA Water sample 2 the pH varies from 7.5 to 8.6. In WASA water sample 1 the pH in after different treatment varies from 7.5 to 8.0. In WASA water sample 3 the pH varied from 7.5 to 8.3. The difference of pH between these three samples were very little. The pH of Bottled water was observed a little lower than the WASA water samples.

The pH of the water samples was determined using a digital pH meter. The pH levels of every water sample from the various CWASA areas fell within the permissible limit. The range is 6.5-8.5, according to the World Health Organization (Kumar and Puri, 2012). Values that have been defined as standards by the World Health Organization (WHO). Bangladesh's Environment Conservation Rules were promulgated in 1997 (BECR'97). The maximum pH of the six samples is observed in WASA supply water sample 02 after filtration. In water samples, the minimum pH was found to be 6.5 which is in Bottled Mineral water sample 01 after boiling.

There is no significant difference observed in the pH value which was observed by previous study. Zuthi *et al.* (2009) stated that the CWASA supply water had a mean pH value from7.08 to 7.43. In our study the CWASA supply water mean pH was from 7.5 to 8.6. However, the Bottled water pH mean values are also within the acceptable limit.

5.4. TDS

The maximum TDS was found in the WASA supply water sample 02 and sample 03 when they were boiled and filtered. This might be happened due to reduction of some water during boiling causing it increasing the TDS concentration. The maximum value in the WASA supply water after treatment is 242 mg/L. Whether the raw water contained within the standard level. According to Akter *et al.* (2012), The TDS were from 66 to 330 mg/L.

According to the Islam *et al.* (2017), the maximum TDS 317.29 mg/L and minimum 12.28 mg/L was observed

In 2014, Molla *et al.* studied two areas in Chattogram Metropolitan Area regarding the CWASA supply water. It was observed that the mean TDS in those two areas were 394.814 mg/L and 500.982 mg/L. In that study the maximum TDS was found 1450.30 mg/L which was quite shocking. This result was beyond the standard level. So in our case we found the results within the international standard. This might be caused due to continuous improvement in the water supply system in the Chattogram WASA within these 8 years.

Chapter 06

Conclusion

The Chloride Ion, Free Chlorine, pH and TDS of different samples of CWASA water and bottled mineral water were determined in this study. It has been seen that the free chlorine in CWASA supplied water was below or equal <0.5 ppm. In some news there was a claim that CWASA was using extra chlorine where the free chlorine is 0.5 ppm to 1 ppm. But the free chlorine we observed was within the standard limit. In the raw CWASA supply water sample 03 the highest chloride ion was observed. After filtration the amount of chloride ion was reduce a little. Among the bottled mineral water, the mineral water bottle water was higher in chloride ion. But the Chloride ion was within the limit. These chloride ion concentrations vary with the season as the river Karnafully directly connects with the Bay of Bengal. The pH and TDS were also observed. The pH of raw CWASA water was within 7.2 to 8.5. And in the bottled mineral water was in the range of 7.14 to 8.5. All of them were within the standard limit. Treatment like boiling increases the TDS and Chloride contents. From the overall result we can say that in the Covid-19 situation water supplied by the CWASA and bottled mineral water distributed in the market were found to be within the maximum acceptable limit.

Chapter 07

Recommendation and Future perspectives

The Chloride Concentration, Free Chlorine, pH and TDS of CWASA supply water were analyzed in this thesis and has provided some finding against the present situation and discussion regarding recent issues. Some suggestions for continued work in this issue are the following:

1. The further analysis of the microbiological quality will show how effective the chlorination of the CWASA supply water is.
2. The further study of public health in different area of Chattogram regarding the diseases caused by excessive chlorination in water can facilitate the results of these findings.
3. Heavy metals, Hardness, Turbidity, BOD, DO etc. tests can be done to get more information about the present supplied water quality in Chattogram city.
4. As the water supplied by the CWASA is coming from the Karnafully River, better drainage system and waste disposal system should be introduced and implemented soon. If we can reduce the water pollution in the Karnafully river. The supply water quality will also be increased. These steps can minimize the cost of processing and treatment of ground water and will lead to a healthy society.

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APPENDICES

Appendix A: Sample Preparation

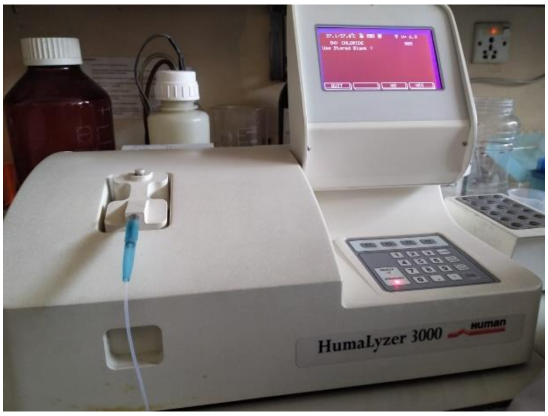
Boiling of Water Samples

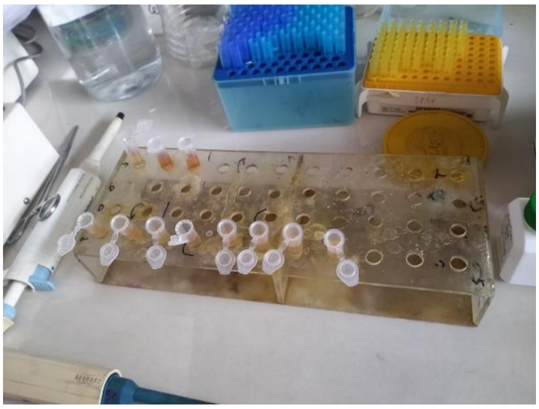
Sunlight Treatment of the samples

Lab Work

Water Samples from different sources

Appendix B: Determination of Chloride Ion using spectrophotometer





Samples taken for chloride ion test using the spectrophotometer

Appendix C: Determination of Free Chlorine

Reagent Kit and Testing tube for color comparison used in free Chlorine determination

Color comparing to measure the Free Chlorine in ppm.

Appendix C: Determination of pH and TDS

TDS and pH determination using TDS meter and pH meter

Brief Biography

Sharmin Akter has successfully finished the B.Sc. in Food Science and Technology program at Chattogram Veterinary and Animal Sciences University's Faculty of Food Science and Technology. She passed the Higher Secondary Certificate Exam in 2012 after passing the Secondary School Certificate Exam in 2010. She is currently a candidate for the Master of Food Chemistry and Quality Assurance degree through the Faculty of Food Science and Technology at Chattogram Veterinary and Animal Sciences University's Department of Applied Chemistry and Chemical Technology. Her research interests include the creation of new products, food processing, preservation, toxicology, management of food safety and safety, public health, and innovation in the food industry.