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Research article

Drinking water quality of Chattogram city in Bangladesh: An analytical and residents' perception study

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ABSTRACT

Residents of Chattogram city areas in Bangladesh use drinking water from three sources, namely CWASA (Chattogram Water supply and Sewerage Authority), groundwater (tube-well), and commercial jar. In this study, we examined the quality of drinking water from these sources following an analytical and residents' perception. Water samples (both untreated and treated) from above three sources were collected from six locations across Chattogram city, and pH, total dissolved solids (TDS), total suspended solids (TSS), bicarbonate, electrical conductivity (EC), salinity, and microbial load were studied following the state-of-art testing methods. A total of 149 respondents were interviewed to understand their perception on the physical properties of water. The pH value of water from all sources and locations and irrespective of treatments, varied from 6.54 to 7.02. TDS of tube-well water in two locations exceeded the standard limit (1000 mg/l). In most locations, TSS varied from 40 to 1888 mg/l (treated and untreated) against the standard value of 10 mg/l, while bicarbonate of CWASA and tube-well water in most locations was also higher than the permissible amount (500 mg/l). Except for jar water, EC of CWASA and tube-well water (treated and untreated) in most locations were higher than the standard value (500 μS) and a similar situation was observed for salinity content. The microbial load was found beyond the permissible limit (0 CFU/ml) for all sources and locations. These parameters of water quality have also been reflected in residents' perceptions of drinking water. Respondents reported an unpleasant odour (56%), the presence of suspended particles (17%), and so CWASA water is not good for drinking (76%). Authorities (CWASA) need to take action toward a safe drinking water supply for residents.

1. Introduction

Bangladesh is one of the most densely populated countries in the world (Farid et al., 1970), with 163 million people (World Bank, 2019). The scarcity of resources is a common problem for this large population (Islam, 2016). The surface and groundwater resources are controlled by geological, climatic, and anthropogenic factors. The groundwater aquifer is contaminated by mixing higher amounts of arsenic and iron, bicarbonate content, saline water (to the coastal districts), and Total Dissolved Solids (TDS) (Rahman and Islam, 2018). Chattogram is the second-largest city in Bangladesh. National census 2011 and Bangladesh Statistics 2019 reported that about 4 million people live in this metropolitan city (BBS, 2011; BBS, 2019). The leading drinking water supplier in this city is CWASA (Chattogram Water Supply and Sewerage Authority) through its pipe network.

In contrast, a significant part depends on tube-well/groundwater or jar water supply. The population is increasing daily in Chattogram city due to industrialization, rapid urbanization, establishment of Export Processing Zone and migration of people etc. The city's excessive population growth has put extra pressure on the growing need for water supply, sewerage and storm water drainage services (Amin, 2015). Hasan and Uddin (2016) reported that CWASA could provide service to only 50% of the population. They also reported that only 30% of people drink shallow tube-well water, 23% of people drink deep tube-well water, 20% drink hand pump tube-well water, 13% drink water supplied by railway authority, and 14% of people drink WASA water. Due to over-extraction,

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the groundwater of the city experiences a gradual decline in its resource (Karmakar et al., 2006), which also creates additional pressure on the quality of water supply in the city. The city is experiencing a water shortage and a severe concern quality of water from its suppliers. The water resource in its surrounding regions also reported water quality due to increasing settlement and land use (Datta et al., 2022). However, a systematic study of this city's water supply is not reported in the literature to date.

CWASA of Bangladesh supplies water to the Chattogram city residents through its distribution network after treatment of water drawn from the two rivers, Karnafuli, Halda, and groundwater source. However, there is a growing concern about contamination in its extended distribution network due to a lack of regular monitoring (Nawas et al., 2012). The city drainage system is not sound and sometimes stagnates due to a significant amount of solid waste (Chowdhury and Akter, 2020). The existence of drainage congestion and water logging problem in many parts of Chattogram city also adds to unhygienic conditions like contamination of water bodies, the spread of diseases, breading of mosquitoes, etc. The leaching of drain water during water-logging can cause groundwater pollution, polluting the water of shallow tube-well (Amin, 2015). Jar water is consumed by the majority of the population in Chattogram city. Bangladesh Standards and Testing Institute (BSTI) provides guidelines and approval for producing commercially supplied drinking water (jar water) for handling, processing, and distribution from factory to consumer. However, many of the processors may not have been licensed for their operations, which could be the reason for more contamination of jar water (Mina et al., 2018).

In Chattogram, about 62.01% (3090.63 km^2) area is under the severe saline zone. Hence, salinity is a common problem here (Sarker and Ahmed, 2015). Groundwater in Chattogram city contains a high iron concentration (2–8 mg/l), as Amin (2006) reported. Besides, human induced factors also deteriorate the water quality. Direct disposal of industrial organic pollutants (Nazir et al., 2020b) and sewage into rivers by municipalities causes water pollution, which deteriorates water quality. For example, methyl orange, which is widely used in various industries, can cause several health issues including jaundice, tissue necrosis, vomiting, etc. (Nazir et al., 2021). As CWASA cannot meet the demand for water in the city, many households and industries have installed deep tube-wells. As a result, many people become dependent on tube-well water for drinking purposes. Residents in city areas use some sorts of water treatments (boiling and filtration) to confirm quality of the water before household uses. In this study, we investigated the drinking water quality from different sources (CWASA, tube-well and commercial jar) across six different locations in Chattogran city areas. We also assessed residents' perceptions on the physical properties of drinking water.

2. Materials and method

This study followed standard ethics guidelines and confirmed that it meets the guidelines of "Elsevier's Publishing Ethics policies".

2.1. Residents' survey and water sampling

This study was conducted in six locations (e. g. Kotwali, Halishahar, Bayzid, Chandgaon, Bandar, and Soraipara) of Chattogram City Corporation (CCC) area (Figure 1). We conducted a quick questionnaire survey on residents' perception on physical quality of drinking water sources and prevalence of water borne diseases. We interviewed 149 residents

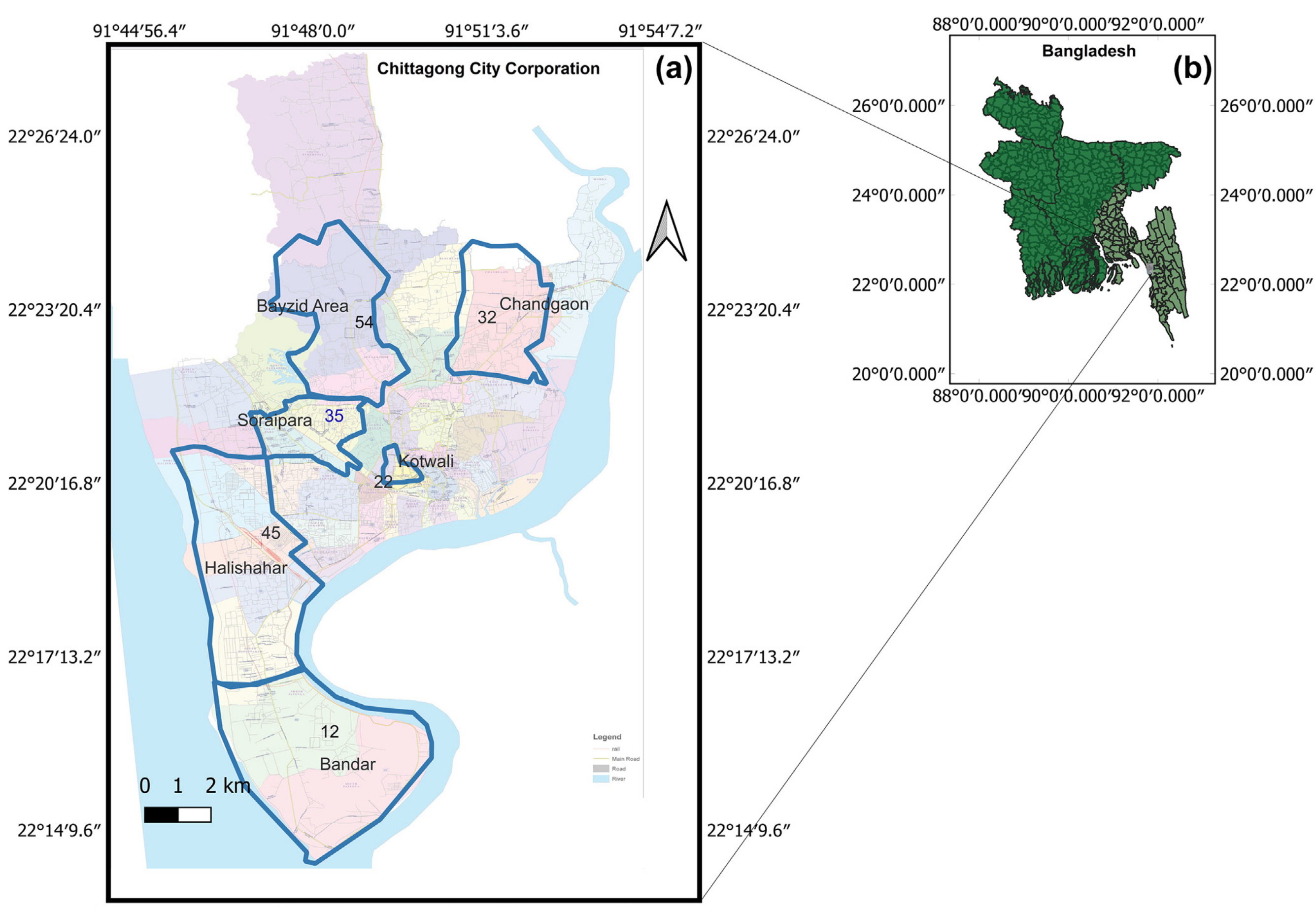

Figure 1. (a) Map of Chattogram City Corporation (left) showing the study area and the number of water samples and respondents, the post and (b) map of Bangladesh. We prepared this map using QGIS 3.24 (www.qgis.org).

following a convenience sampling. Water samples were collected from interviewees houses. We found that residents drink water from three sources, namely CWASA, tube-well and commercial jar. They usually treat CWASA and tube-well water before drinking. The treatment process includes boiling (20–30 min) followed by filtration using available commercial filtration modules. For jar water, they only use filtration process. We collected two water samples (treated and untreated) from each source in each study site. However, there was no CWASA water supply in Bayzid during this study time (2019–20) and so could not collect CWASA water samples. For each water sample, we collected 200 ml water in plastic bottle, which was later kept in airtight condition and labeled with source and location before chemical analysis.

2.2. Analytical method

pH, TDS, and EC of water samples were measured by a HANNA multiparameter meter (Model-HI98129). TSS was determined by filtration method (Baxter, 2017). while carbonate and bicarbonate were determined by titration method (Thomas and Lynch, 1960) For microbial load determination, total number of colonies was determined by nutrient agar method (Mamun et al., 2016). Salinity was determined from the value of TDS, as described by the Government of South Australia (2020). These parameters of water samples indicate pollution or contamination that will affect drinking water use (Omer, 2020).

2.3. Calculation method

2.3.1. TSS

First, 50 ml of sample water was poured into a beaker from which 10 ml was taken in a measuring cylinder. Took a filter paper and weighted, and then used it to filter 10 ml sample water. The wetted filter paper was then dried entirely in the woven at 103 °C for 24 h. Finally, the weight of the dried filter paper was taken. The differences between these two weights represent the value of TSS of the water (Rajvaidya and Markandey, 1998). Following formula was used to calculate TSS:

$$\text{TSS (mg / l)} = \frac{(\text{A} - \text{B}) \times 1000}{\text{Volume of the sample water}}$$

where.

A = Final weight of filter paper
B=Initial weight of filter paper

2.3.2. Alkalinity (carbonate, bicarbonate)

For the measurement of bicarbonate, 50 ml of water (10 ml sample water and 40 ml distilled water) was taken in a 250 ml conical flask where 2–3 drops of phenolphthalein were then added. The appearance of pink color indicated the presence of carbonate. The content so prepared was titrated against 0.02 N H_2SO_4 until the color disappeared because of alkali carbonate being converted to bicarbonate. Then, 2–3 drops of methyl red indicator solution were added to the colorless solution to give yellow color, which was again titrated against 0.02 N H_2SO_4 until rosy red color developed. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) were calculated using following equations (Thomas and Lynch, 1960).

$$CO_3^{2-}\ (\text{mg / l}) = \frac{\text{Volume of } H_2SO_4(2x) \times N \times 30 \times 1000}{\text{Volume of water sample taken}}$$

$$HCO_3^{-}\ (\text{mg / l}) = \frac{\text{Volume of } H_2SO_4 \times N \times 61 \times 1000}{\text{Volume of water sample taken}}$$

where,

N is the normality of H_2SO_4,
X is the volume of H_2SO_4 required for phenolphthalein at end point,
Therefore, total alkalinity = CO_3^{2-}(mg/l) + HCO_3^-(mg/l).

2.3.3. Salinity

Salinity was measured from the value of TDS by using following the formula:

$$\text{Salinity} \approx \frac{TDS(\text{mg/l})}{0.55}$$

The conversion factor 0.55 was used for determining the salinity of the water. This value ranges from 0.5 to 0.7 depending on the water source. For drinking water, 0.55 was used for determining salinity (Government of South Australia, 2020).

2.4. Data analysis

Residents' responses were analysed in percentages. A one-way analysis of variance (ANOVA) was used to find the significant differences of water quality values between two treatments, among three sources and six locations.

3. Results and discussion

3.1. Physical and chemical assessment

3.1.1. pH

The pH value of water from all sources and locations and irrespective of treatments were varied from 6.54 to 7.02 (Figure 2). The pH value of CWASA water (untreated) was lowest (6.54) in Bandar are highest (6.81) in Halishahar areas. The pH values of tube-well water (untreated) varied from 6.58 (Soraipara) to 6.92 (Bayzid and Halishahae). On the other hand, pH of jar water (untreated) ranged from 6.67 (Soraipara) to 7.02 (Bayzid). In case of treated water samples, the range of pH values were almost similar to untreated water samples and statistically there was no significant difference between treated and untreated water samples across all sources. However, significant differences ($p < 0.05$) were observed across locations except jar water. The standard level of pH for drinking water is 6.5–8.5 (Nur-E-Alam et al., 2016). Similar results were found in Pakistan where the pH level of bottled water ranges from 7.35 to 7.95 (Nazir et al., 2020a). As such, it can be said that the pH of studied water samples in different locations of CCC was within the permissible limit.

3.1.2. Total dissolved solids

The minimum and maximum value of TDS for untreated CWASA, tube-well and jar water was 74–539 mg/l, 191–1314 mg/l, and 150–321 mg/l, respectively, across study locations (Figure 2). After treatment, there were remarkable changes of TDS value in some locations. For examples, TDS value of CWASA water at Bandar location increased to 717 mg/l from 146 mg/l (untreated). In case of tube-well water, it was reduced to 82 mg/l from 1314 mg/l (untreated) at the same location, and at Halishahar this was lightly increased to 1051 mg/l. Across different locations, there was a significant ($p < 0.05$) difference of TDS values between treated and untreated water. According to ECR 1997, the standard level of TDS is 1000 mg/l (Nur-E-Alam et al., 2016). Hence, tube-well water at Bandar and Halishahar locations exceeded the permissible drinking water limit.

3.1.3. Total suspended solids (TSS)

TSS are not desirable in drinking water. According to ECR 1997, the standard value of TSS for drinking water is 10 mg/l (Nur-E-Alam et al., 2016). In three locations, CWASA water (treated and untreated) had TSS (40–521 mg/l untreated and 85–854 mg/l treated water) exceeding the standard limit (Figure 2). Similar findings were found for tube-well in four locations where the range was 240–768 mg/l

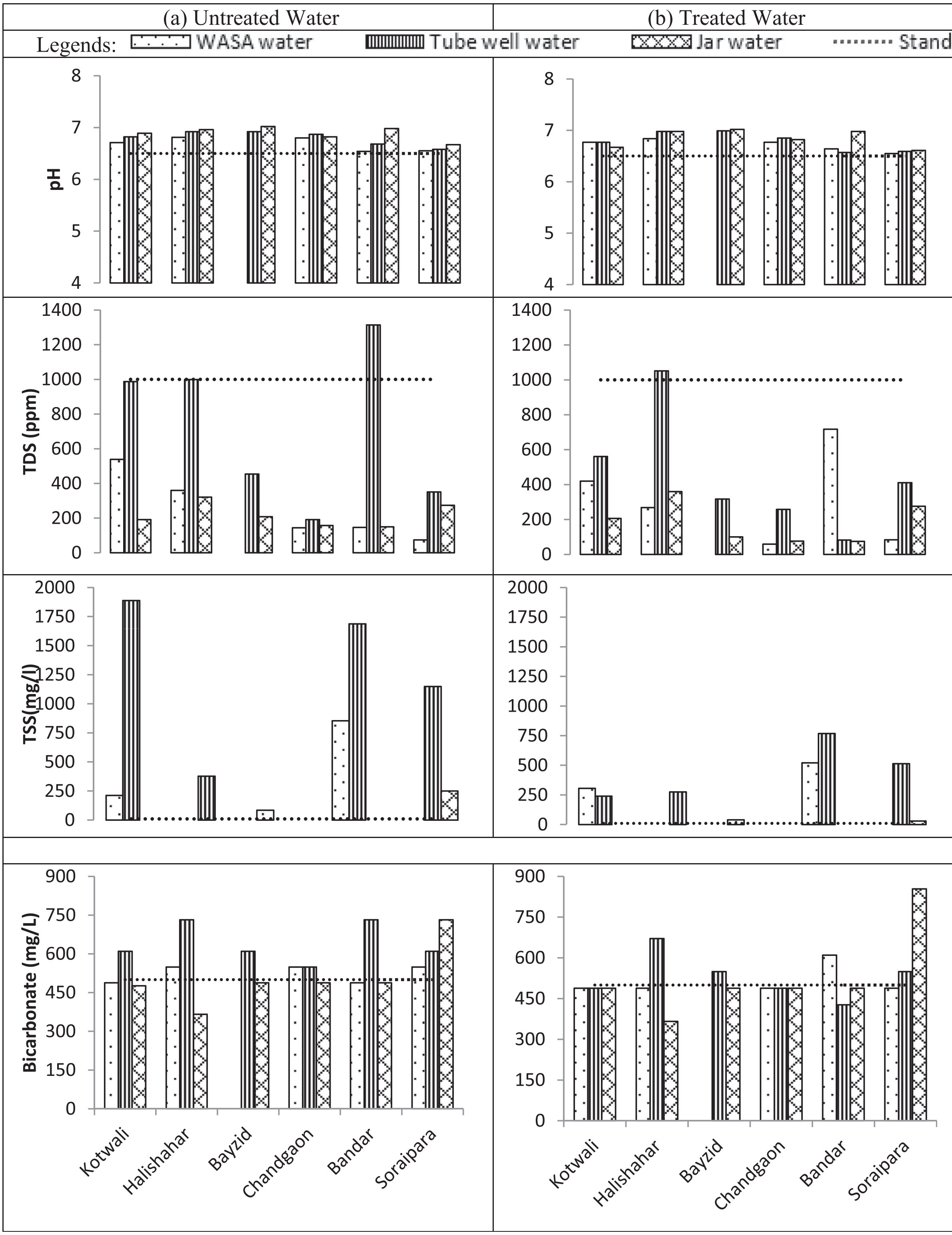

Figure 2. pH, TDS (mg/L), TSS (mg/L) and bicarbonate (mg/L) in 2(a) untreated and 2(b) treated water from various sources in different location in CCC, Bangladesh.

(untreated water) and 377–1888 mg/l (treated water). Surprisingly, commercial jar water also had TSS in Soraipara. The quantity of TSS was increased after treatment except CWASA water sampled from Kotwali. The TSS values of CWASA water across different locations were significantly ($p < 0.05$) different, which was probably due to higher TSS in Bandar area.

3.1.4. Bicarbonate

Considering the ECR, 1997 standard (500 mg/l) for alkalinity, untreated tube-well water in all studied locations of CCC is not suitable for drinking because bicarbonate values across all locations varied from 549 mg/l (Chandgaon) to 732 mg/l (Bandar and Halishahar) (Figure 2). Even after treatment, these values in some locations were higher than the

Table 1. Comparison of EC (μS) between untreated and treated water of different sources and locations in CCC, Bangladesh.

Location	CWASA		Tube-well		Jar	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Kotwali	1076	862	2027	1246	364	433
Halishahar	706	576	1883	2040	650	720
Bayzid			739	640	413	200
Chandgaon	291	153	385	495	322	152
Bandar	304	1432	2630	163	300	150
Soraipara	147	184	701	822	547	570

Table 2. Comparison of salinity (ppt) between untreated and treated water from different sources and locations in CCC, Bangladesh.

Location	WASA		Tube-well		Jar	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Kotwali	0.98	0.76	1.8	1.02	0.35	0.37
Halishahar	0.65	0.49	1.82	1.91	0.58	0.65
Bayzid	-	-	0.82	0.58	0.38	0.18
Chandgaon	0.26	0.12	0.35	0.5	0.26	0.14
Bandar	0.27	1.3	2.39	0.15	0.27	0.14
Soraipara	0.13	0.15	0.64	0.75	0.5	0.5

standard. In case of CWASA, bicarbonate in untreated water varied from 488 mg/l to 549 mg/l. Surprisingly, bicarbonate of CWASA water increased to 610 mg/l from 488 mg/l after treatment. Jar water (both treated and untreated) had bicarbonate below the standard except in Soraipara location and this was significantly ($p < 0.05$) different to other locations.

3.1.5. Electrical conductivity (EC)

With respect to sources, the EC of tube-well water has higher EC ranging from 385 to 2630 μS (untreated) and 163 to 2040 μS (treated) across different locations (Table 1). EC measures the concentration of ions and dissolved solids in water which help to transmit current. Higher EC means the higher presence of salts as well as dissolved solids (Meride and Ayenew, 2016). Saline water is not good for drinking because, it causes dysentery, diarrhea and abdominal pain etc. (Chakraborty et al., 2019). Across different locations, the EC values of jar water were comparatively lower (300–650 μS, untreated). Except Kotwali and Halishahar locations, the EC of CWASA water was lower than 300 μS. In Bangladesh, permissible EC for drinking water is 500 μS (Nur-E-Alam et al., 2016). As such, in many locations, the EC of studied water samples from different sources across various locations is higher than the prescribed limit.

3.1.6. Salinity

The salinity standard for drinking water in Bangladesh is 0.6 ppt (Chakraborty et al., 2019). In untreated tube-well water of Kotwali, Halishahar, Bayzid, and Bandar area, and treated tube-well water of Kotwali, Halishahar area, salinity levels were higher than 0.6 ppt (Table 2). Salinity levels of jar water irrespective of treatment and across locations, showed within the standard limit. In case of CWASA water, salinity (for both treated and untreated water) was higher than the standard at Kotwali location.

3.2. Microbial load analysis

According to ECR (1997), the standard number of colony-forming units is 0 CFU/ml and 50 CFU/ml for drinking water and supply water (CWASA). In jar water, the microbial load was found to be less than the microbial load of other sources (Table 3). According to the survey, the improper management of WASA, the leakage in pipelines, etc., were the reasons for the contamination of WASA water as all the values of the colony-forming units were beyond the standard level, so the water of all sources was not safe for drinking. A statistical analysis of ANOVA (related to untreated to treated conditions for all sources) microbial colony counts from all sources showed no significant variation between untreated and treated conditions. This signifies that household treatment units are ineffective in decontaminating the water for safe drinking. From the ANOVA test (related to untreated and treated water of different sources according to areas), a significant difference was observed in microbial load for jar water than other sources with location (P-value <0.05).

3.3. Residents' perception on water quality, physical properties, and associated diseases

Respondents had no complaints about the quality and physical properties of commercial jar water; hence their responses are not presented in Table 4. Only 5% of the respondents reported that untreated CWASA water is good for drinking (Table 4). In case of tube-well water, this response rate was 72%. Regarding physical properties of untreated CWASA water, the main complaints were unpleasant odour (56%) and presence of suspended particles (17%). On the other hand, 58% of

Table 3. Microbial load in different water sources and locations in CCC, Bangladesh.

Water source	Location	Microbial load in CFU/ml	
WASA water	Kotwali	Untreated	Treated
		1.0×10^4	8×10^3
	Halishahar	9.25×10^3	8×10^3
	Chandgaon	1.4×10^4	3.4×10^3
	Bandar	1.14×10^4	6.75×10^3
	Soraipara	1.15×10^4	1.03×10^4
Tube-well water	Kotwali	8.9×10^3	2.7×10^3
	Halishahar	1.55×10^3	6.8×10^2
	Bayzid	1.05×10^4	1.0×10^4
	Chandgaon	6.8×10^2	6.0×10^3
	Bandar	1.35×10^4	1.0×10^4
	Soraipara	6.2×10^3	5.1×10^3
Jar water	Kotwali	1.0×10^3	6.5×10^2
	Halishahar	1.5×10^2	1.0×10^2
	Chandgaon	3.0×10^2	2.0×10^2

Table 4. Residents' responses on water quality, physical properties, and drinking water related disease prevalence in the study areas in CCC, Bangladesh.

Name of disease	Consumers of CWASA water (%)	Consumers of tube-well water (%)
Water quality (untreated)		
Good for drinking	5	72
Not good for drinking	76	14
No comment	19	14
Physical properties of untreated water		
Colour	-	58
Odour	56	5
Unusual taste	3	-
Suspended particles	17	-
No comment	24	37
Diseases related to drinking water (treated)		
No disease	82	84
Diarrhea	11	9
Jaundice	7	7
Household members having above diseases		
Adult	-	29
Children	70	71
Both	30	-

respondents commented on the presence of brownish colour in tube-well water.

Even though residents commented that CWASA water (untreated) was not good for drinking, however, with treated CWASA water, they (82%) reported having no water related diseases. Similar observation can also be seen in case of tube-well water (Table 4). In both sources (CWASA and tube-well), children are mostly affected by water related diseases.

We found that respondents boil and filter water for purifying before drinking. To reduce turbidity, alum mixing can be used. Filters made of quartz, charcoal, or activated carbon can filter water at home (Hussain et al., 2020). In some cases, pressure driven or electrical filters can purify drinking water which follows an additional membrane or ion exchange or reverse-osmosis process (Sharma and Bhattacharya, 2017). Some of the easiest purification methods are sedimentation or settling, boiling distillation, chemical treatment (precipitation/coagulation/adsorbents), disinfection, and filtration (Sharma and Bhattacharya, 2017).

4. Conclusion

We have found that the quality of supply water by CWASA may be at risk of contamination in the distribution system. Many respondents reported unpleasant odour, abnormal taste, suspended particles in untreated CWASA and tube-well water. Some respondents also reported experiencing waterborne diseases. Residents practice boiling and filtering processes to purify water, which imposes cost and consumption of gas energy. Authorities (CWASA) need to take appropriate actions toward supplying safe water for residents.

Declarations

Author contribution statement

Prety Debnath: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

M. M. Abdullah Al Mamun: Conceived and designed the experiments, Analyzed and interpreted the data contributed reagents, materials, analysis tools or data.

Shyamal Karmakar: Conceived and designed the experiments, Analyzed and interpreted the data, Wrote the paper.

Mohammed Salim Uddin: Performed the experiments, Contributed reagents, materials, analysis tools or data.

Tapan Kumar Nath: Analyzed and interpreted the data, Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

Additional information

No additional information is available for this paper.

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