

Assessment of Microbial, Physicochemical Quality and Antibiotic Sensitivity Pattern of Bacteria of Drinking Water at Santosh, Tangail, Bangladesh

Tamalika Saha¹, Arifa Sultana¹, Md. Younus Mia^{1*}, Sourav Sarker², Shahin Mahmud²

¹Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh

²Department of Biotechnology and Genetic Engineering, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh
Email: *mdmia1998@gmail.com

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Abstract

Water is one of the most important elements for survival but unfortunately the pollution of these elements is an alarming problem. For leading a healthy life, water should be contamination free from any kinds of water-borne organisms. Water-borne pathogens are a leading cause of disease and death worldwide. The quality of drinking water plays an important role in human infection and disease. The present work was carried out with the assessment of physicochemical and bacteriological profile of several untreated drinking water sources to ensure its suitability for using drinking purposes. Total 12 samples were randomly selected and collected from Santosh, Tangail district of Bangladesh by following the standard procedure. Bacteriological analysis was carried out by following the standard bacteriological methods. Obtained results showed that water of the study area is slightly alkaline and no remarkable variation in the temperature of the water in different locations. In case of most of the water bodies, different physicochemical properties were below standard limit stipulated by WHO. In all water bodies, the Total Viable Count (TVC) ranged from 1.3×10^6 to 4.0×10^7 cfu/100 ml and Total Coliform Count (TCC) was 1.05×10^5 to 6.4×10^6 cfu/100 ml, where the Total *E. coli* Count (TEC) and Total *Shigella-Salmonella* Count (TSS) was ranged from 7.2×10^3 to 1.1×10^5 cfu/100 ml and 6.1×10^3 to 5.3×10^4 cfu/100 ml respectively. The total counts of these pathogenic bacteria exceeded the acceptable limit and that is dangerous for drinking. On the other hand, the isolated organisms also showed resistance against a broad range of commercially available antibiotics. Survey-based result revealed that, peoples of the study

area who were drinking these water, were suffering from various water-borne diseases and that was a major threat to public health. Considering the above issues public awareness, proper water treatment and necessary steps should be taken by the government and authority or necessary steps should be taken for alternative safe source of drinking water.

Keywords

Drinking Water, Physicochemical Parameters, Bacterial Load, Antibioqram, Public Health, Santosh

1. Introduction

Water is a crucial resource in the ecosystem since it can support lives to survive. Safe drinking water is essential to human and other life forms even though it provides no calories or organic nutrients. Availability of safe drinking water has increased over the last decades in almost every part of the world, but approximately one billion people still lack access to safe drinking water [1]. The quality of drinking water can be defined by the chemical, physical and biological contents of water. Safe water should be suitable not only for human consumption but also for washing/showering and domestic food preparation because chemical and other constituents of the water would give a rise to economic damage as well [2]. Access to safe drinking water is one of the basic human rights and is enormously crucial to good health. Diseases related to contamination of drinking-water constitute major causes on human health in Bangladesh [3]. About 1.1 billion people have no access to safe drinking water and diarrheal disease is highly endemic in these societies [4]. Every year more than 3.4 million people die as a result of water-related diseases, making it the leading cause of disease and death around the world [5]. Even in developed countries with improved water supplies, diarrhea is often endemic and it has been reported that environmental interventions have shown 15% to 17% median reduction in diarrhea from water quality interventions [6] [7] [8]. The provision of high-quality drinking water is one of the most important connotes for improving human health of a community by preventing the spread of water-borne diseases. For a nation to maintain optimal health and development there has to be a continual supply of safe drinking water to its population [9]. Inadequate sanitation and unhygienic practices account for the major source of microbial contamination of any potable drinking water. According to World Health Organization (WHO), physicochemical parameters of water are important to determine the quality of drinking water. The physical parameters that are likely to give rise to complaint from consumers are color, taste, odor and turbidity while low pH causes corrosion and high pH results in taste complaints [10]. The people lack in provision of safe drinking water that results in suffering of individual from various wa-

ter-borne diseases [11]. Microbiological water analysis is a method of analyzing water to estimate the numbers of microorganisms present and find out what sort of microbes. Frequent microbial analysis is inevitable for hygienic control. Microorganisms (Bacteria Protozoa and Viruses) are inclusive in aquatic environments. While most microorganisms are favorable and serve essential ecosystem function, some can be harmful to ecosystem and human health. In Bangladesh, we are troubled with water-borne diseases and dissemination of antibiotic resistance to coliform bacteria through drinking water just exacerbates the situation. Despite governmental plans and actions, non-governmental activities or personal awareness, the problem of safe water access as well as prevalence of water-borne diseases are still very common [12]. Microbial contaminated drinking water has long been implicated in human illness and historically, attention has focused on finished (end-product or tap) water quality [13]. Although a substantial amount of work has been carried out on common water-borne pathogens in Bangladesh, unfortunately a little information is available. As the tanks are not cleaned for a long time certain microorganisms are grown in the tanks and certain gastrointestinal disorders like diarrhea, cholera, dysentery, skin diseases etc. are occurred [14]. Nowadays, the demotion of water quality due to the multifarious pollution is an alarming problem. Both conventional pollutants such as heavy metals, nitrate, phosphate, pesticides and micro pollutants worsen the quality of the water bodies of the country [15]. Present study was commenced to determine physicochemical and microbiological load of the several drinking water sources at Santosh in Tangail districts, Bangladesh as well as antibiotic resistance pattern of the bacteria and to enhance the awareness and concern of the consumers of these drinking water.

2. Materials and Methods

2.1. Study Area Time and Sample Collection

Twelve water bodies (4 residential halls, 4 messes and 4 local restaurants drinking water samples including tube-well and tap) were randomly selected and collected from Santosh, Tangail district of Bangladesh (Figure 1). The study was carried out from January-May in 2018. Before sample collection all the plastic bottles were properly sterile by autoclave and cleaned by distilled water then approximately, 300 ml of water samples were collected in the bottles. The bottles were filled up and brought out of the water and properly closed. Then they were properly labeled with sample no, source, date, time etc. and samples were transported to the laboratory within one hour and immediately subjected to farther analysis.

2.2. Physiochemical Parameter Analysis

Water pH and temperature were determined by the digital pH meter (Model: pH Scan WP 1, 2; Malaysia) and the digital thermometer respectively. The Total

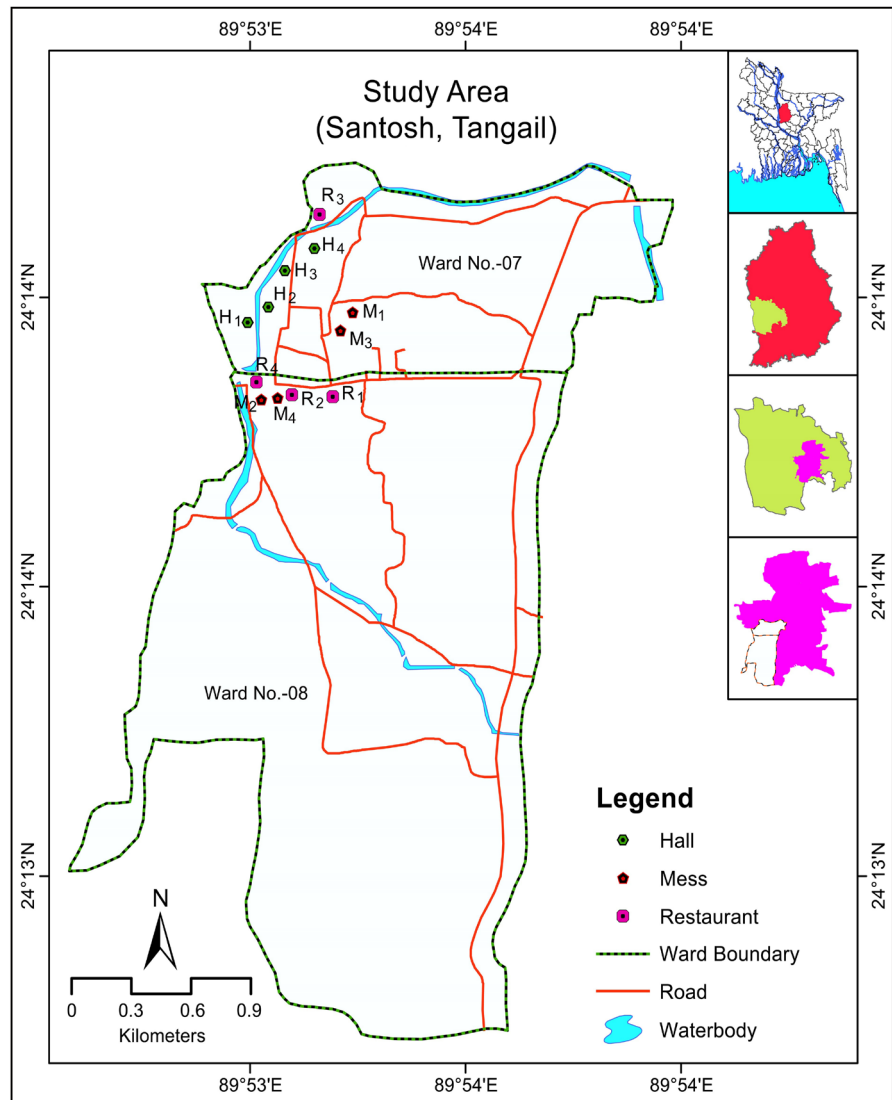


Figure 1. Map of the study area.

dissolved solids (TDS) of the samples were determined by electrometrically by the digital TDS meter (Model no: HM DIGITAL). The Electrical Conductivity (EC) of the samples were measured by electrometrically by the digital EC meter (Model no: HM DIGITAL). Total Hardness was estimated by EDTA (Ethylene diamine tetra-acetic acid) method. Chloride in water was determined by Mohr method. Nitrate ion (NO_3^-) Procedure described by Kitamura 1982 which was used to detect nitrate content in water.

2.3. Microbial Analysis

Standard plate count (SPC) techniques were used for microbial load from the drinking water samples [16]. Firstly, ten-fold serial dilution was carried out of every raw water samples. 0.1 ml of each sample is transferred by a micro pipette and spread on agar plates with a sterile bent glass rod. All the plates were inoculated at 37°C for 18 hours. Total count is expressed as colony forming unit per

100 ml (cfu/ml). Nutrient Agar media was used as culture media for enumeration of total viable bacteria in sample. For enumeration of different bacteria, different selective media such as MacConkey agar for total coliform bacteria, Eosin methylene blue Agar (EMB) agar for *Escherichia coli* and *Shigella-Salmonella* Agar (SS) agar was used for the isolation of *Salmonella spp.* and *Shigella spp.* and spread plate technique was performed as described previously.

2.4. Antibiotic Susceptibility Test

Antibiotic susceptibility test was performed by disk diffusion method (Kirby-Baur method) using the commercially available antibiotic disk on Mueller-Hinton agar to assess the susceptibility and resistance pattern of the isolates [17]. Eight different types of common antibiotic disks (Himedia, India and Oxoid Ltd. England) were used in this study.

2.5. Evaluation of Public Health Impact

A field investigation and semi-structured questionnaire-based survey were conducted among randomly selected 400 respondents (10 from each sampling sight, 50% male and 50% female) of the study area to determine the health status of people who were the consumers of these water.

2.6. Statistical Analysis

MS Excel 2010 and SPSS 20 software were used for calculating average and presentation of graphs. The relation among these parameters was determined by the Karl Pearson's co-relation. The one-way analysis of variance (ANOVA) was used to determine whether there are any statistically significant differences among parameters.

3. Result and Discussion

3.1. Physiochemical Parameter

3.1.1. Temperature

The variation of water temperature generally depends on season, geographic location and sampling time. The temperature of twelve water bodies were founded ranging from 28°C to 30°C, and the mean was 28.7°C (**Table 1**). In another similar study conducted in Santosh, Tangail recorded the temperature of drinking water bodies range from 20°C to 28°C [18]. According to the study, it was noticeable that temperature values of all the tested water samples were suitable for drinking and other household purposes (According to Bangladesh standard 20°C - 30°C in drinking water).

3.1.2. Water pH

pH is one of the most vital factors of water which ensures the optimum quality for drinking. According to the study, average pH values of the most of samples were more than 7 which is slightly alkaline. This might be due to different kinds of inorganic sediments and salts. The pH values were range form 7.05 - 7.64 in

Table 1. Physico-chemical parameters of drinking water.

Locations	Sampling stations	Temperature (°C)	pH	EC (µS/cm)	TDS (PPM)	Total Hardness (mg/l)	Chloride ion (PPM)	Nitrate ion (PPM)
Hall	H1	28.2 ± 0.3	7.25 ± 0.04	718 ± 21	224 ± 15	250 ± 4	220 ± 8	0.37 ± 0.004
	H2	28.6 ± 0.2	7.12 ± 0.03	714 ± 12	326 ± 20	390 ± 7	383 ± 12	0.62 ± 0.005
	H3	28 ± 0.3	7.27 ± 0.02	753 ± 16	289 ± 10	228 ± 5	270 ± 9	0.52 ± 0.007
	H4	29 ± 0.2	7.33 ± 0.03	780 ± 17	377 ± 15	222 ± 4	349 ± 5	0.35 ± 0.004
Mess	M1	30 ± 0.2	7.16 ± 0.02	730 ± 20	463 ± 25	284 ± 6	425 ± 10	0.87 ± 0.006
	M2	30 ± 0.3	7.05 ± 0.02	725 ± 13	458 ± 13	252 ± 9	420 ± 8	0.51 ± 0.008
	M3	29 ± 0.1	7.3 ± 0.02	718 ± 8	455 ± 18	320 ± 7	333 ± 7	0.54 ± 0.007
	M4	28 ± 0.3	7.13 ± 0.03	720 ± 12	452 ± 12	246 ± 6	350 ± 8	0.56 ± 0.008
Restaurant	R1	28 ± 0.1	7.26 ± 0.03	713 ± 14	279 ± 14	316 ± 8	303 ± 9	0.39 ± 0.006
	R2	29 ± 0.2	7.45 ± 0.02	777 ± 15	203 ± 22	398 ± 7	340 ± 6	0.481 ± 0.006
	R3	29 ± 0.3	7.64 ± 0.02	785 ± 22	155 ± 16	272 ± 5	326 ± 11	0.33 ± 0.005
	R4	28 ± 0.3	7.35 ± 0.02	700 ± 10	274 ± 10	352 ± 6	369 ± 9	0.158 ± 0.007

different selected drinking water samples. The highest value of pH was recorded as 7.64 (Restaurant-R3) and the lowest value was 7.05 (Mess-M2) (**Table 1**). Some previous studies reported the similar result regarding as pH for drinking water [14] [3]. According to WHO's standard, an appropriate range of pH for drinking water is 6.5 - 8.5 [19]. The average pH drinking water of the study area was within the standard limit.

3.1.3. Electrical Conductivity (EC)

Electrical conductivity (EC) is a quantification of the capability of a liquid to conduct an electric current. EC values of different water samples varied from 713 - 785 µS/cm where the maximum value was found as 785 µS/cm (Restaurant-R3) and minimum value was 700 µS/cm (Restaurant-R4). The maximum permissible limit of EC is 250 µS/cm for safe drinking water. According to the current study, EC value crossed the maximum acceptable limit of all kinds of drinking water samples. From the conductivity investigation it was observed that the water almost of all the sources has several dissolved minerals content. It is said that drinking water of higher conductivity is not always safe as regular drinking it may be the cause of hyper tension, kidney failure, stone deposition in various in intestine. The concentration of EC may be fluctuating due to seasonal change and contamination of groundwater [20].

3.1.4. TDS

The current work recorded the highest value of TDS was 463 mg/l (Mess-M1) and the lowest was 203 mg/l (Restaurant-R2). A study reported that, in Tangail Municipality area, the average TDS in drinking water at academic institutions was 194 mg/l [3]. But according to WHO's guidelines, TDS for drinking water is

1000 mg/l [19]. Here, the TDS values were lower than the acceptable limit (Table 1), that indicates, this water was safe for drinking purpose.

3.1.5. Total Hardness

Present study revealed that the total hardness of drinking water bodies range from 222 mg/l to 398 mg/l and the average was 294.17 mg/l. A previous similar study at Sakhipur pourasava in Tangail district reported that, total hardness in the drinking water sample area ranged from 80 mg/l to 200 mg/l [21]. According to WHO's guideline the average hardness of water bodies in study area was above the satisfactory level.

3.1.6. Chloride Ion

The highest value of chloride ion was recorded as 425 mg/l (Mess-M1) and lowest was 220 mg/l (Hall-H1). The standard of chloride ion concentration ranges from 150 mg/l to 600 mg/l in drinking water quality of Bangladesh [22]. According to WHO's standard, chlorides ion concentrations are less than 250 mg/l [23] and all of the water bodies in the study area were exceed the permissible limit of this ion concentration. Due to the high concentration of chloride ion may damage metallic pipes and structures as well as growing plants also.

3.1.7. Nitrate Ion

Nitrate ion concentration ranged from 0.158 to 0.87 mg/l whereas the highest value was recorded at Mess-M1 and the lowest value was at Restaurant-R4. In a previous study, reported that the concentration of nitrate ion ranging from 7.18 - 7.43 mg/l around the Dingaputha Haor, Netrokona District, Bangladesh [24]. But the standard level of nitrate ion for drinking water was 10 mg/l [19]. In comparison with standard level, the concentration of nitrate ion of the present study is below to the standard limit.

3.2. Microbial Analysis

3.2.1. Total Viable Count (TVC)

Total viable count (TVC) indicates a quantitative estimate of the concentration of microorganisms in a sample. Among twelve drinking water samples, the highest TVC count was $4.0 \times 10^7 \pm 0.6$ cfu/100 ml (Restaurant 2), lowest count was $1.3 \times 10^6 \pm 0.5$ cfu/100 ml (Hall 3) and the TVC was ranged from 1.3×10^6 cfu/100 ml to 4.0×10^7 cfu/100 ml (Figure 2). A study conducted at Matlab in Bangladesh reported that, the total viable count of bacteria in tube-well water ranged from 3.0×10^3 to 8.5×10^5 cfu/100 ml [12]. Due to the contamination of microorganisms, personal unhygienic condition, cross-contamination or pre-existing microbial contaminants may exceed the standard limit of TVC in the study area that is recommended by WHO [19].

3.2.2. Total Coliform Count (TCC)

Total coliform count used as an indicator to determine the microbial quality of untreated water and it's suitability for human consumption or not. In all col-

lected samples, the range of total count of coliform bacteria were varied from 1.1×10^5 cfu/100 ml to 7.6×10^6 cfu/100 ml, where the mean value was 1.6×10^6 cfu/100 ml (Figure 3). Another study conducted in Dingaputha Haor area of Netrokona district, Bangladesh reported that, the total Coliform Count (TCC) of tube-well water ranged from 30 to 39 cfu/100 ml where the mean was 34.4 ± 3.44 cfu/100 ml [24]. An another study conducted at Jahangirnagar University Campus, found high concentration (1.52×10^2 cfu/100 ml) of coliform bacterial load in supplied water [25]. The value of Total coliform Count was found in all drinking water samples were comparatively high because of poor protection and unhygienic condition, cross-contamination or pre-existing microbial contaminants present in handle or upper surface of tube-well or the tap.

3.2.3. Total *E. coli* Count

Presence of *E. coli* in water is a common phenomenon but a high count of *E. coli* indicates that the water is unfit for drinking and any kinds of household works. High number of *E. coli* also indicates probable recent fecal contamination and there is a greater risk that pathogenic *E. coli* may present. According to the study, total *E. coli* count was ranged from 7.2×10^3 cfu/100 ml to 1.1×10^5 cfu/100 ml,

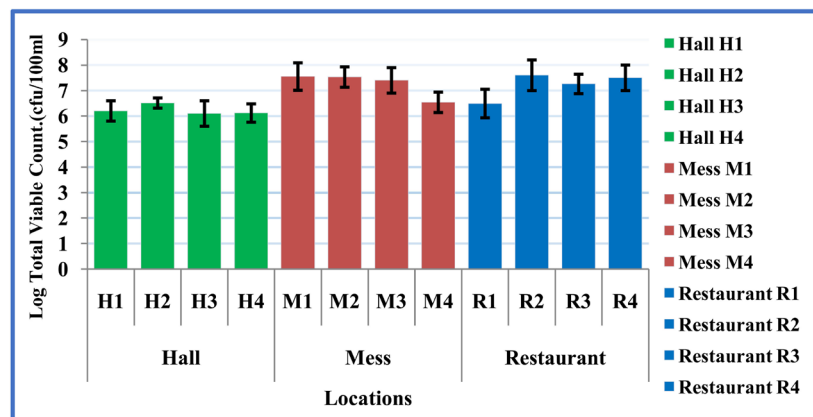


Figure 2. Total viable count in different selected drinking water samples.

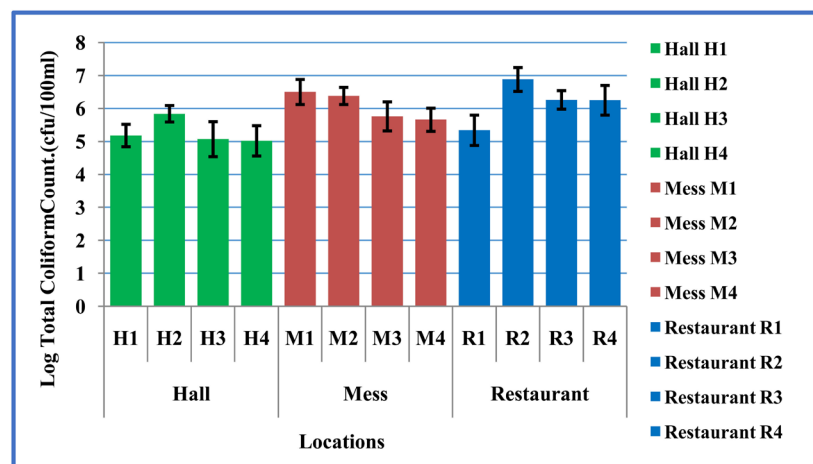


Figure 3. Total coliform count in different selected drinking water samples.

where the average count was 3.7×10^4 cfu/100 ml (Figure 4). According to the World Health Organization and Environmental Quality Standard for Bangladesh, the standard value of total load of *Escherichia coli* for drinking water is nil/ml of water [26].

A study reported that the average concentration of *E. coli* at household water of Dhaka city was 1.40×10^2 cfu/100 ml [27]. Another study found that *Escherichia coli* in drinking water ranging from 3×10^2 to 2.40×10^4 cfu/ml that was lower than our study [24]. In our study area, all of the water samples were contaminated with *E. coli* and it exceeded the recommended limit also. The high number of *E. coli* count obtained that, the samples may be fecally contaminated or another direct source of microorganisms.

3.2.4. Total *Shigella-Salmonella* Count

Among twelve water bodies, the maximum and minimum count of *Shigella* and *Salmonella* spp. was $5.2 \times 10^4 \pm 0.36$ cfu/100 ml (Restaurant 2) and $6 \times 10^3 \pm 0.5$ cfu/100 ml (Hall 4) respectively where the average count was 2.5×10^4 cfu/100 ml (Figure 5). A previous study found that maximum *Shigella-Salmonella* count

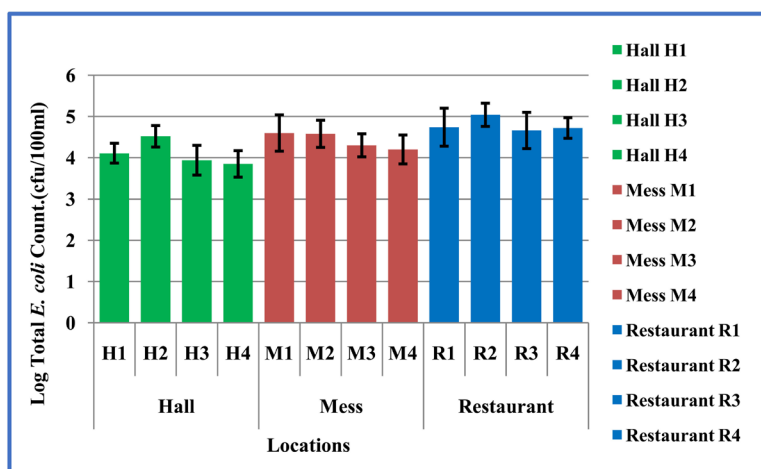


Figure 4. Total *E. coli* count in different selected drinking water samples.

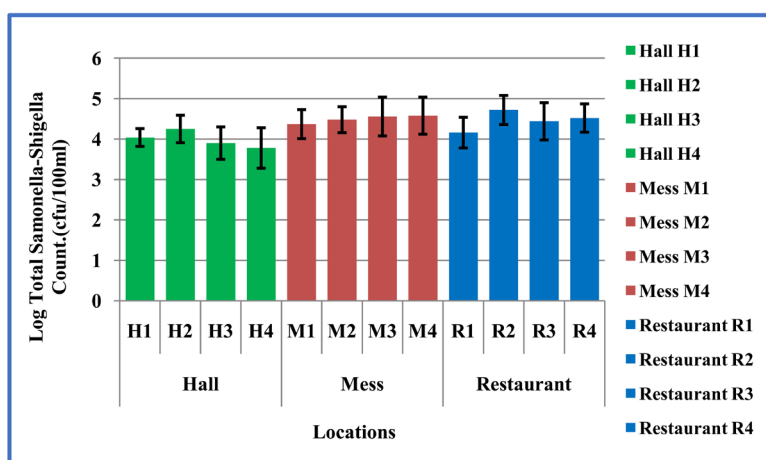


Figure 5. Total *Shigella-Salmonella* count in different selected drinking water samples.

was 7.8×10^4 cfu/ml and minimum was 1×10^3 cfu/ml which was lower than present study [24]. High concentration of *Shigella-Salmonella* count indicates that the water bodies are totally unfit for drinking and somehow the water bodies of the study area are directly contaminated with animal and human faces thus may be prolonged outbreak serious infectious diseases, which are now becoming matter of concern and damning news for public health.

3.3. Antibiotic Resistance Pattern of Waterborne Pathogen

A great deal of health threat may arise through the spreading of the antibiotic resistance to normal flora or creating the environment that would be favorable for opportunistic pathogens. In antibiogram study, most of the available waterborne pathogens were found to be antibiotic resistance. Almost all waterborne bacteria in this study, were mostly resistance to Ampicillin and Amoxicillin; as well as Tetracycline and Nalidixic acid, where highly sensitive to Ciprofloxacin and Azithromycin (Figure 6).

Most of the isolates of Dhaka WASA drinking water were found resistant to Ampicillin, Amoxicillin, kanamycin, Penicillin, Sulphomethoxazole antibiotics. Nearly all of them were found sensitive to Gentamycin and Nalidixic acid [28]. Some previous studies reported that different bacteria that were isolated from the drinking water were also resistant to some common commercially available antibiotics [29] [30]. This multidrug resistance might have arisen due to misuse of antibiotics or prolonged use of single antibiotic. The result suggested that immediate precautions should be taken by the government to stop the selling of antibiotics without prescription, increase the public health concern and ensure the proper use of antibiotics by doctors and patient, respectively.

3.4. Correlation Matrix among Different Bacteriological, Physiochemical and Anion Concentration of Drinking Water

Correlation matrix among the parameters were given in the following table (Table 2). Present study showed that TCC had significant positive correlation with chloride ion ($r = 0.631$; $p < 0.05$). TVC showed significant positive relation

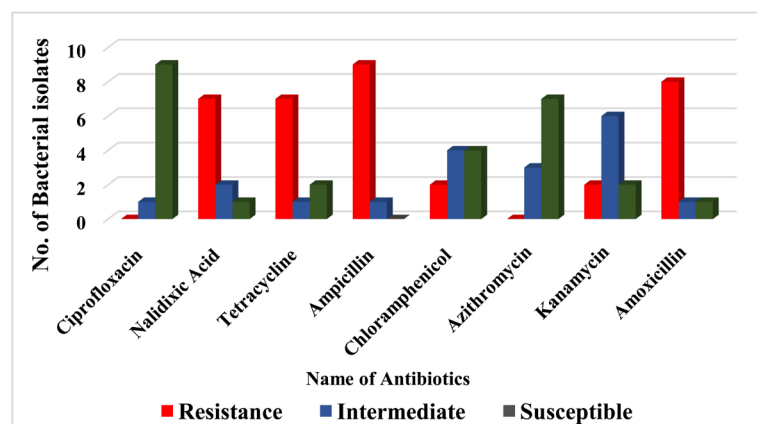


Figure 6. Antibiotic sensitivity pattern on isolates.

Table 2. Correlation matrix among the bacterial load, physicochemical parameters and the anion concentration of drinking water.

Parameters	Temp.	pH	Hardness	Chloride ion	Nitrate ion	TVC	TCC	TEC	TSS
Temp.	1								
pH	-0.127	1							
Hardness	-0.042	0.140	1						
Chloride ion	0.666*	-0.336	0.248	1					
Nitrate ion	0.506	-0.528	0.003	0.415	1				
TVC	0.591*	0.176	0.458	0.609*	0.128	1			
TCC	0.561	0.162	0.555	0.631*	0.212	0.917**	1		
TEC	0.237	0.236	0.745**	0.392	-0.009	0.741**	0.828**	1	
TSS	0.241	0.093	0.540	0.442	0.115	0.824**	0.826**	0.714**	1

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

with temperature ($r = 0.591$; $p < 0.05$) and chloride ion ($r = 0.609$; $p < 0.05$). Again pH showed significant strong negative relation with nitrate ion ($r = -0.528$; $p < 0.05$). There seen significant strong positive relation between temperature and chloride ion ($r = 0.666$, $p < 0.01$) and significant negative relation between chloride ion ($r = -0.336$; $p < 0.01$; $p < 0.05$). There found decrease trend ($r = -0.336$; $p < 0.05$) in total chloride ion with the increase of pH and increase trend with the increase of hardness ($r = 0.248$; $p < 0.05$). TVC also showed significant strong positive relation with TCC ($r = 0.917$; $p < 0.01$). Environmental parameters such as temperature, salinity, pH and dissolved oxygen play a foremost part in the distribution of bacteria in aquatic environment [31].

3.5. Result on Survey Analysis

Water-borne diseases are the major burden in the study area. Most of these waterborne diseases are attributed to the contaminated water that contains various infectious pathogens. Further, few people have been found in the study area who use proper water purification systems are free from these waterborne diseases. To investigate the impact of contaminated water on public health, 3 persons were taken from each sampling site during the study period of samples collection and total respondents were 400 (50% were male and 50% female). Among the respondents, 30.5% suffered from diarrhea, 23.5% skin disease, 8.0% typhoid, 11.5 % dysentery, 2.0% vomiting, others 11.5% (Figure 7). Most of the people had clear concept about these waterborne diseases. Very little number of people were suffering from those diseases from long time. Some people were affected with these waterborne diseases within last three months and took antibiotic dosage for treatment. But the efficiency of these antibiotics was not satisfactory and which also indicates the occurrence of antibiotic resistance.

In our survey analysis, it was seen that there are many reasons for drinking water contamination. As a result, water-related diseases are increasing in alarm-

ing rate. Present study revealed that unclean tank and unhygienic practice is highly responsible for waterborne diseases (Figure 8). Highest reason of drinking water contamination occurs in unclean tank 46.0%.

The contamination of the water sources is probably due to poor protections and poor hygienic condition. The behavioral and hygienic practices of the community might also be contributing to this high load of waterborne disease. During the survey it was observed that people in the study area carry unhygienic condition. So there task for safe drinking water quality percentage is given in graph (Figure 9). For safety in drinking water quality and reduce in water-related disease must be the follow some responsibility for our proper health condition such as: Regular clean of storage tank, boiling and filtering and avoid long

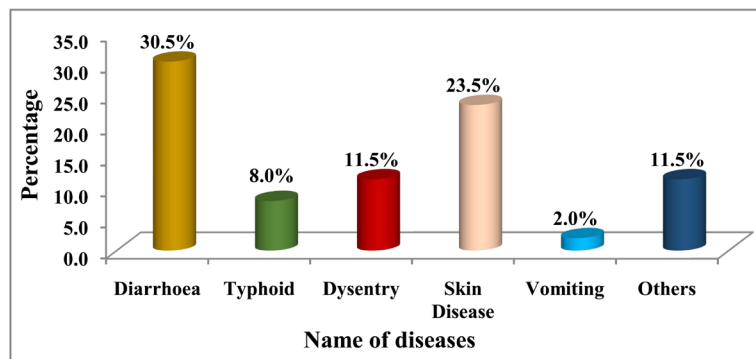


Figure 7. Suffering from waterborne disease percentage.

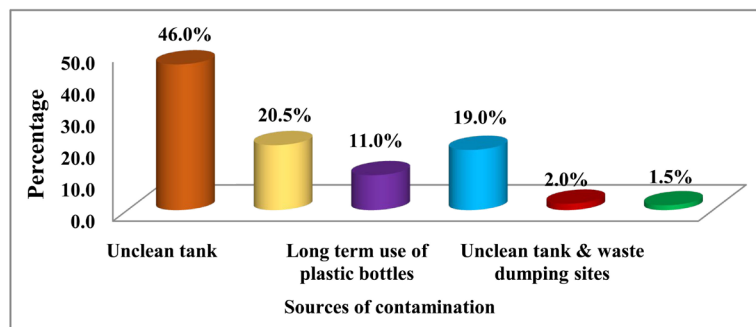


Figure 8. Reason of drinking water contamination.

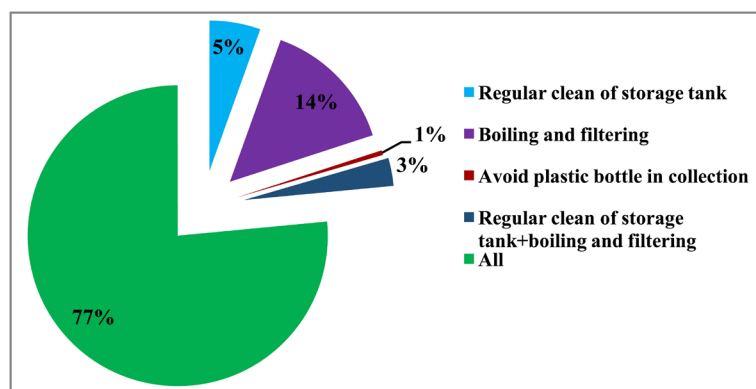


Figure 9. Task for safe drinking water quality.

term use plastic bottle. In graph maximum respondents says that all of technique should be follow for safe and potable drinking water and better benefit for their life.

Based on survey, the consumers faced many problem in drinking water such as, Iron, odor, and others problems. Iron problem in maximum drinking 60%, and others problem are less 4% (Figure 10). The contamination of the water sources is probably due to poor protections and exposure to contamination by human and domestic wastes. The behavioral and hygienic practices of the community might also be contributing to this high load of indicator organisms. During the survey it was observed that communities in the study area people unhygienic carry.

From the survey analysis it was revealed that, water related disease sometimes varies on seasons. Rainy season is highly responsible for waterborne disease. The highest disease percentage 62.5% occurs in rainy season, and the lowest disease occur in winter season 11.0% (Figure 11).

4. Conclusion

Water is vital for the daily activities of life and drinking which is continuously polluted by municipal wastes and contaminated with different pathogenic bacteria. The quality of drinking water may impact on the incidence of various water-borne

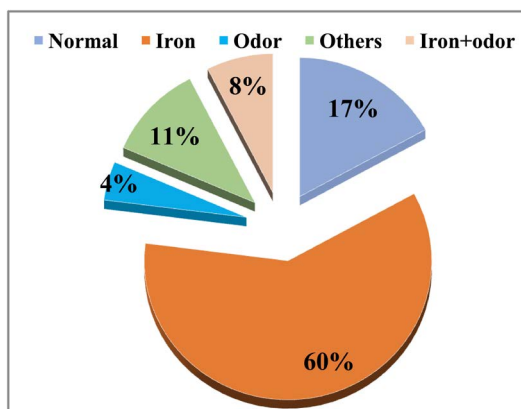


Figure 10. Problem in drinking water.

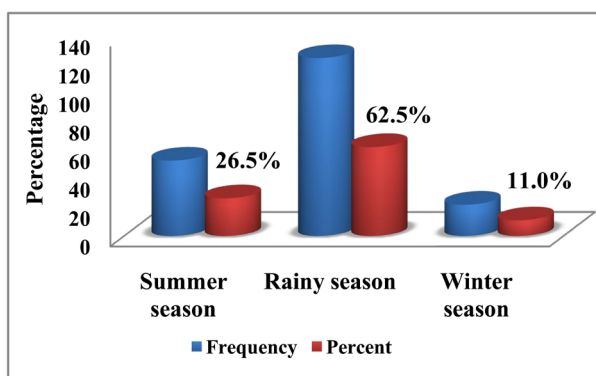


Figure 11. Seasons in waterborne diseases.

infectious diseases. The present study revealed that the physiochemical and bacterial quality of the water sources were out of the acceptable limit of WHO and hazardous for drinking and other domestic purposes. Low dissolved oxygen and higher TDS values are the key indicators of unsafe drinking water bodies polluted by organic or chemical wastes. The antibiotic resistant bacteria in drinking water resources pose a serious public health treat and the source of resistant bacteria and responsible genes for resistance should be explored. From this study, it can be recommended that the government authorities should establish protocols to monitor water quality in the Tangail district communities and develop awareness programs to inform the communities about status of the water quality to protect people from water-borne infection diseases.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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