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Assessment of Physicochemical and Bacteriological Quality of Different Surface Water Samples of Tangail District, Bangladesh

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Abstract

Surface water, a vital element of ecosystem must be hygienic, but unfortunately the pollution of this water is now an alarming problem. The present work deals with the assessment of physicochemical and bacteriological profile of several untreated surface water sources to ensure its suitability for using domestic purposes and drinking along with the impact of bacterial contaminated water on public health and antibiotic resistance pattern of these bacteria. The samples were collected from twenty sampling point (13 ponds, 4 lakes, 2 rivers and one canal) of Tangail District from January 2017 to June 2017. To understand the seasonal variation, water samples were measured in two month; February (dry season) and June (wet season). Most of the water sampling points were polluted by dumping of waste, cattle wash and were not suitable for the drinking or other domestic purposes. Obtained results showed that water of the study area is slightly alkaline, no remarkable variation in the temperature of the water in both seasons and DO of all the sampling station were lower than standard limit during February. The mean concentration (M.C.) of total Coliform were 4×10^{22} cfu/100ml and 4.5×10^{18} cfu/100ml at February and June respectively and all the sampling point were contaminated with fecal coliform. Other pathogenic bacteria, *E. coli* (M.C: 1.1×10^{11} cfu/100ml at February and M.C: 2.2×10^{7} cfu/100ml at June), *Salmonella spp.* (M.C: 1.1×10^{5} cfu/100ml at February and M.C: 3.4×10^{5} cfu/100ml at June), *Shigella spp.* (M.C: 8×10^{4} cfu/100ml at February and M.C: 3.4×10^{7} cfu/100ml at June), *Vibrio spp.* (M.C: 8.6×10^{5} cfu/100ml at February and M.C: 1.1×10^{8}

cfu/100ml at June) were isolated from several of the investigated water sources. The total counts of these pathogenic bacteria exceeded the acceptable limit during both season and also showed resistance against a broad range of commercially available antibiotics. People who were using these water frequently suffering from various water borne diseases. These untreated water sources pose a major threat to the public health and therefore need for exigent intervention by government.

Keywords

pH, Dissolved Oxygen, Coliform, *E. coli*, *Shigella spp.*, *Salmonella spp.*, *Vibrio spp.*, Antibiotic, Tangail

1. Introduction

Water is not only essential for the survival of any form of life, but also vital for the recreational aspects of life [1]. Although water envelope 80% of the earth surface, but only 3% are available for drinking, agriculture, domestic and industrial consumption [2]. This surface water from rivers, lakes, canals and ponds are vital resources of water that are necessary to the subsistence of all living organisms [3].

Low lying flat country, Bangladesh is fulfilled high number of upland water bodies including rivers, lakes, haors, baors, beels, ponds, cultivated fields with water inundated and estuarine systems with extensive mangrove swamps [4]. Most of the poverty stricken village people depend on these surface water for their daily purposes activities as they have no any potable water sources in Bangladesh [5]. But nowadays this valuable water resources are ominous, as directly exposure to people's domestic purposes, pollution from untreated industrial effluents, municipal wastewater, runoff from chemical industry and agricultural fields and oil and lube spillage from different operation, fecal contamination and aquatic pathogenic microorganisms [6]. Physical, chemical and biological properties of water known as water quality which have a direct influence on the types and distribution of aquatic biota [7]. 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 water quality of the surface water bodies of the country [8].

Pathogenic microorganisms contaminate the water, is now a major global problem. The main causes of bacteria in the aquatic environment are the disposal of human waste and municipal waste water through sewage and drainage ditches systems. Human pathogenic bacteria, particularly members of the coliform can inhabit on fishes and aquatic environment [9]. Feces of warm-blooded animals can harbor fecal coliforms and they are the most commonly used indicators of fecal pollution in water and food. Increased levels of fecal coliforms provide a warning of failure of the water distribution system and possible contamination with other pathogens such as *E. coli*, *shigella spp.*, *salmonella Spp.*, *Cholera* etc. [10]. Water become unsafe for human consumption or usage when it contains pathogenic or diseases causing microorganisms. The consumption of unhygienic drinking water and uses of unsafe water for daily purposes lead to the prevalence of diseases like diarrhea, typhoid, cholera and bacillary dysentery among the population [11].

Besides, contaminated surface water with pathogenic bacteria, the presence of antibiotic resistant bacteria in these water bodies has become an emerging problem throughout the world [12]. This antibiotic resistance exacerbates the prevalence of waterborne diseases among the people of surrounding of these wetlands [13]. Therefore, the maintenance of good water quality is essential for healthy survival of aquatic organisms and people's good health those who are exposed to this water. However, there are only a few published data on the microbiological quality of wetland water and antibiotic resistance pattern of these microorganisms in few areas around the country. Our study was commenced to evaluate physicochemical and bacteriological profile of the several water bodies of Tangail districts as well as antibiotic resistance pattern of the bacteria associated with these water bodies.

2. Materials and Methods

2.1. Study Area, Time and Sample Collection

Our study was conducted at twenty selected water bodies including 13 ponds, 4 lakes, 1 canal and 2 rivers which are situated in Tangail sadar upazila, Bangladesh (**Figure 1**).

The study was carried out from January to July 2017. Approximately, 300 ml of water samples were collected in 500 ml of plastic bottles and before sample collection, all the plastic bottles were properly cleaned by distilled water. Bottles were immersed below the water surface, filled, brought out of the water and properly closed. Then they were properly labeled (sample no, source, date, time etc.) and samples were carried to the laboratory within the six hours of collection.

2.2. Primary Data Collection

Some primary data related to water contamination (such as-cattle wash, dumping of waste, opening of drains and latrines in water sources, color, odor, appearance of water bodies etc.) were collected with a semi-structured based questionnaire [14].

2.3. Physiochemical Parameters Analysis

pH was determined by the digital pH meter (Model: pH Scan WP 1, 2; Malaysia). The Dissolved Oxygen (DO) was determined by digital DO meter (Model: D.46974; Taiwan). Temperature was measured by the digital thermometer

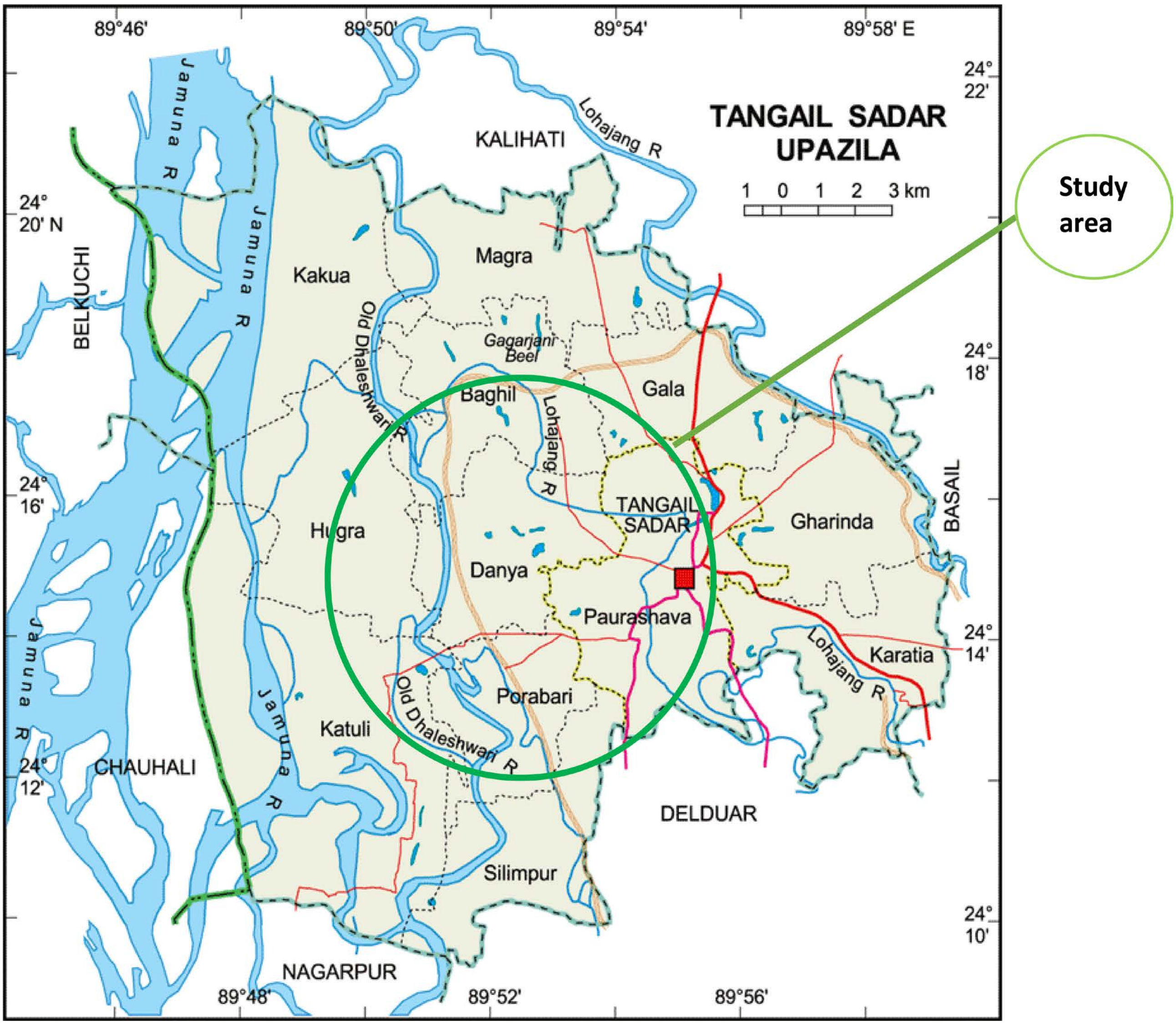

Figure 1. Map of the study area.

(GF-MT502, China).

2.4. Microbial analysis

2.4.1. Total Coliform Count

Most probable number (MPN) test was used to detect the presence of coliforms in sample water [15]. In presumptive MPN procedure, 15 lactose broth tubes were inoculated with the water samples. Five tubes received 10 ml of water, 5 tubes received 1 ml of water and 5 tubes received 0.1 ml of water. The number of tubes showing gas production and color change was compared to a standard table developed by American Public Health Association. The number of coliform was the MPN of coliforms per 100 ml of the water sample [16].

2.4.2. Detection of Fecal Coliforms

The positive presumptive cultures were transferred to lactose broth, which is specific for fecal coliform bacteria. Any presumptive tube which showed gas production after 24 (±2) hours incubation at 44.5˚C (±0.2˚C), confirmed the presence of fecal coliform bacteria in that tube and was recorded as positive [17].

2.4.3. Isolation of Pathogenic Bacteria

To isolate specific pathogenic bacteria, the samples were enriched separately with alkaline peptone water (APW) for plating in thiosulfate citrate bile salts sucrose agar (TCBS) media, with GN (Gram-Negative) Broth for plating in *Salmonella Shigella* Agar (SS) agar, with *Enterobacteria* Enrichment Broth-Mossel for plating in MacConkey media. 1 ml of water from each sample was added with 3 ml of respective enrichment media. All the samples were then incubated at 37˚C for 24 hours. After overnight enrichment, the samples were plated in MacConkey, TCBS and SS agar plate separately. All the plates were incubated at 37˚C for 24 hours. After overnight incubation, the plates were observed for selective pathogens. For the confirmation of *Escherichia coli*, red/pink colonies form MacConkey agar plates were plated in eosin methylene blue agar (EMB) plates and for the confirmation of *Vibrio cholerae and Vibrio parahaemolyticus*, standard biochemical tests were performed from the yellow and green colonies in TCBS media respectively. Lactose fermenting (LF) and Non-LF bacteria were determined by differential media (MacConkey medium) to differentiate lactose fermenters (pink/yellow) colonies & non lactose fermenter colonies (colorless). Lastly, conformation of *Shigella spp.*, *Salmonella spp.* and their serotype was determined with the antisera (polyvalent) developed by Denka Seiken, Japan [18] [19].

2.4.4. Antibiotic Sensitivity Test

Antibiotic susceptibility test was performed by disk diffusion method using the commercially available antibiotic disk on Mullar-Hinton agar to assess the susceptibility and resistance pattern of the isolates [20]. For this purpose, 12 different antibiotic discs were obtained from commercial sources (Himedia, India and Oxoid Ltd. England).

2.5. Evaluation of Environmental Human Health Impact

A field investigation and random questionnaire based survey of 400 respondents (20 person from each sampling site) of the study area was conducted to determine the health status of people who used these water for bathing, Oju and other daily purposes.

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 coefficient and coefficient of co-relation (r). 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 Parameters Analysis

3.1.1. Cattle Washing in the Sample Water Sources

Cattle washing on public wetlands degrades water quality and sanctions concern microbial contaminants include fecal coliform and *E. coli* which are threatening to human and ecological health [21]. In our study, it was found that most of the water sample sources are not usually used for washing of cattle. Among twenty sample sources, one pond, two lakes and both rivers under study area were used for cattle washing activity by the people around it (Table 1).

Table 1. Sources of the collected water samples with location.

Water sample	Source name and Location	Cattle wash	Dumping of waste	Water type	Color of water	Used for			
						Drinking after normal filtration	Cooking	Bath	Oju
Pond-01	Pir Shahjaman Dhighi, MBSTU campus	No	No	Normal	Deep Green	No	No	Yes	Yes
Pond-02	Rani Dinomoni dhighi, MBSTU campus	No	No	Normal	Light Green	No	No	Yes	Yes
Pond-03	Academic building pond, MBSTU campus	No	No	Normal	Light Green	No	No	Yes	Yes
Pond-04	Govt. girls high school pond, MBSTU campus	No	No	Normal	Light Green	No	No	Yes	Yes
Pond-05	Trustee Board pond, MBSTU campus	No	No	Normal	Light Green	No	No	Yes	Yes
Pond-06	Rani pond, MBSTU campus	No	No	Normal	Deep Green	No	No	Yes	Yes
Pond-07	Bokkhobadhi pond, Santosh, Tangail	No	Yes	Polluted	Gray	No	No	Yes	No
Pond-08	Santosh bazaar pond, Santosh, Tangail	No	Yes	Polluted	Turbid	No	No	No	No
Pond-09	Poraton para pond, Santosh, Tangail	Yes	Yes	Polluted	Brown	No	No	Yes	No
Pond-10	Zhannobi school pond, Santosh, Tangail	No	No	Normal	Light Green	No	No	Yes	Yes
Pond-11	Thanapara pond, Thanapara, Tangail	No	Yes	Polluted	Turbid	No	No	Yes	No
Pond-12	Sadar hospital pond, Tangail	No	Yes	Polluted	Turbid	No	No	No	No
Pond-13	Polytechnics pond, Tangail polytechnic Ins.	No	No	Normal	Brown	No	No	Yes	Yes
Lake-14	District Lake (north), District area, Tangail	No	Yes	Normal	Deep Green	No	No	Yes	Yes
Lake-15	District Lake (south), District area, Tangail	No	Yes	Polluted	Gray	No	No	Yes	No
Lake-16	Lake infront of Tangail polytechnical Inst.	Yes	Yes	Polluted	Turbid	No	No	No	No
Lake-17	DC lake, New bus stand, Tangail	No	No	Normal	Light Green	No	No	Yes	No
Canal-18	Gazibari canal, Santosh, Tangail	Yes	Yes	Polluted	Light Green	No	No	No	No
River-19	Dholesshori river, Charabari, Tangail	Yes	Yes	Polluted	Gray	No	No	Yes	Yes
River-20	Lowhojong river, babystand, Tangail	Yes	Yes	Polluted	Turbid	No	No	Yes	No

3.1.2. Dumping of Waste into the Sample Water Sources

At present, the majority number of water reservoirs in Bangladesh are unsafe for human due to dumping of domestic, untreated industrial and municipal wastes [22]. Most of our study areas were being used as a dumping point of waste. In this study, 55% (11 out of 20) of the sampling point was polluted by directly dumping of waste (**Table 1**).

3.1.3. Color of Water

The color of water is the important premier indicators of water quality which indicates its suitability for human, fishes or others inhabitants of water. Water should be clear and colorless for acceptance to the general public. Discoloration in water can be attributed to the presence of iron or magnesium or to the presence of humus, peat molecules, plankton and the pH level of the water. The WHO has established the color levels below 15 true color unit (TCU) are acceptable for most consumers and the color above 15 TCU are detected by naked eye [23]. The color of the investigated water sources was observed visually. Out of twenty sampling stations, three sampling point were deep green in color, seven points were light green in color, three point were gray in color, four point were turbid and other three water bodies were brown in color (**Table 1**). Water rich in phytoplankton and other algae usually appears green, soil runoff produces gray colors, dissolved organic matter, such as humus, peat or decaying plant matter can produce brown color and presence of much clay and unnecessary inorganic substances in water causes turbid color [24].

3.1.4. Usage of Sample Water Sources

The most people of rural village of Bangladesh use wetland water for their daily purposes (washing, cooking, bathing etc.) due to unavailable of safe water sources [4]. In our study, sample water of study area neither used for the drinking nor cooking purposes due to presence of available safe water sources. Most cases, these waters were used to take bath and Oju (for holiness of prayer) by the people living around it. But water of pond-8, pond-12, Lake-16 and Canal-18 even were not suitable for bathing and Oju too (**Table 1**).

3.1.5. Odor of the Water Samples

Pure water (distilled) is odorless. The odor of the water indirectly indicates the severity of the pollution of water and the presence of toxic substances in it. The odor of the investigated sampling water was smelt by nose. About 85% of the sampling water had normal odor and 15% had bad odor during the June while 50% of the study point had bad odor during the February (**Figure 2**). Bad odor also results from discharging of domestic and industrial waste from the surrounding area and bacterial growth on water [25].

3.1.6. pH of the Water

pH is the vital factor of water which ensures the optimum environment for aquatic inhabitants. In our study, average pH values of the most of samples were more

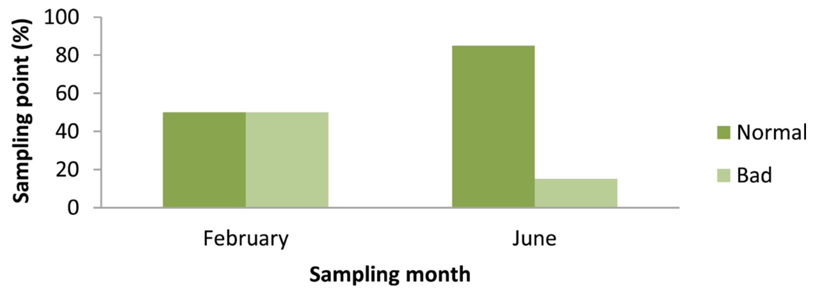

Figure 2. Odor of water at different sampling stations.

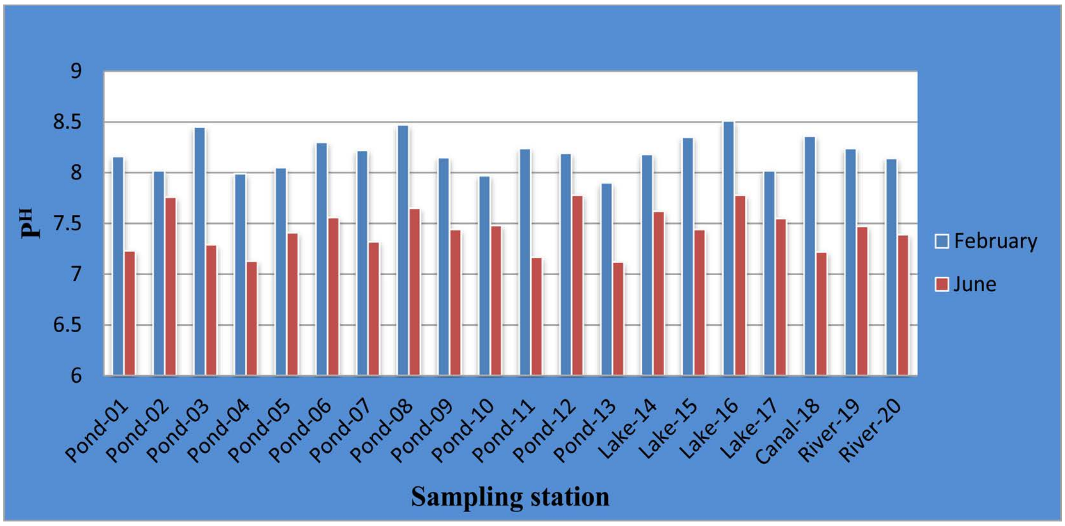

Figure 3. pH values of water at different sampling stations.

than 7 which is slightly alkaline. This might be due to inorganic sediments or domestic and agricultural wastes disposed in it. The pH values of samples ranged from 7.12 - 8.51 (**Figure 3**). pH range (7.5 - 8.4) is good for the growth of algae and range (6.0 - 7.2) is optimum for laying fish [26]. As per STOAS, pH values 4 or less and 12 or high cause death to most of the fish species, 6 to 8 is the range for good growth and reproduction, and pH as low as 5 or as high as 9 to 11 do not allow fishes to reproduce as well as cause slow growth [27]. The observed values reflect its suitability for aquatic life.

3.1.7. Dissolved Oxygen (DO)

Dissolved oxygen is essential for aquatic creature for respiration. Insufficient and imbalance DO may lead to cause of sudden death of these creature. In this study, values of DO at different sampling points were ranged from 2.8 to 6.1 mg/l. The highest DO value 6.1 mg/l was observed at two stations (pond-13 and lake-14) during June and the lowest DO 2.8 mg/l was also observed at pond-12 during February, which is not suitable for aquatic organisms (**Figure 4**). DO content should be above 6.0 mg/l for drinking water and more than 5.0 mg/l is suggested for fisheries, recreation and irrigation [28]. Except lake-14, all the sampling station had DO lower than 5 mg/l. during the February. Study showed that DO of the sampling station was not suitable for fish production during the

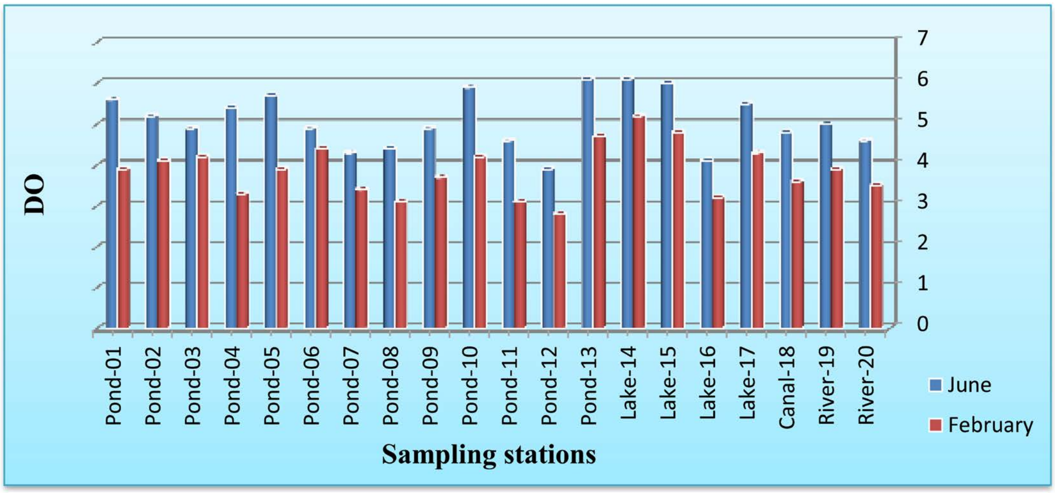

Figure 4. Values of DO at different sampling stations.

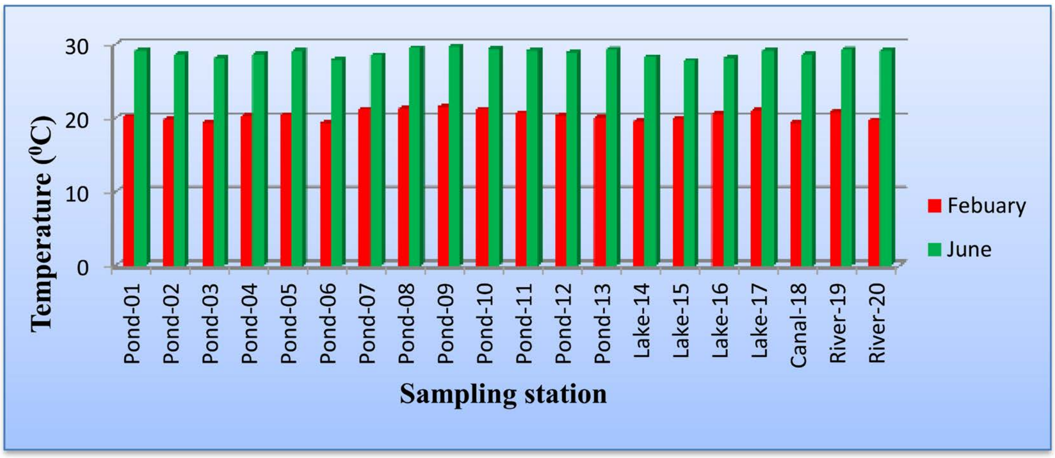

Figure 5. Temperature at different sampling stations.

month of February.

3.1.8. Temperature

According to the DoE standard, the ideal temperature of water for aquatic life is 20˚C to 30˚C [29]. The study showed that the range of temperature of all collected samples were (19.4˚C - 21.5˚C) during February and (27.7˚C - 29.8˚C) during June (Figure 5). The temperature range of June month fall within the DoE standard, but the temperature range of February month beneath the DoE standard. This is might be happened due to turbidity that prevent sunlight penetration, photo period which is directly related to the temperature, seasonality and flow rate.

3.2. Opening of the Drain into the Water Bodies

Most of the water bodies of the study area were polluted by effusion of drainage pollutants which carried different types of untreated wastes [30]. Drains were opened into 65% (13 out of 20) of the water body. Only 35% of the water bodies were not polluted by drainage waste (**Figure 6**).

3.3. Direct Fecal Contamination through Open Latrine System

Fecal contamination of surface water is a common phenomenon in Bangladesh. It occurs due to unsanitary or open latrine systems on the side of wetlands and that causes high rate of chronic, food and water borne diseases [31]. In our study, about 45% of the water bodies were fecal contaminated and 55% of water bodies were not contaminated with faeces (**Figure 7**). All the lakes, canals and rivers of the study area were fecal contaminated. All the ponds except pond-8, 9 were free from fecal contamination.

3.4. Bacteriological Analysis

3.4.1. Total Coliform Count

Present study showed that all of the water samples contained a variety of bacteria. Total coliforms which are used to evaluate the general quality of water, exceeded the WHO recommended acceptable limit in all of our study sample [32]. The range of total coliforms in all of collected samples was varied from 1.9×10^{5} cfu/100ml to 6.3×10^{23} cfu/100ml. The recorded mean concentration of total coliform was 4.5×10^{18} cfu/100ml during June and mean concentration was 4×10^{22} cfu/100ml during February (**Figure 8**). The coliform counts at several points of the Buriganga river water was varied from 1.1×10^{3} to 2.4×10^{3} cfu/100ml [33]. The maximum mean concentration of total coliform was 13.81

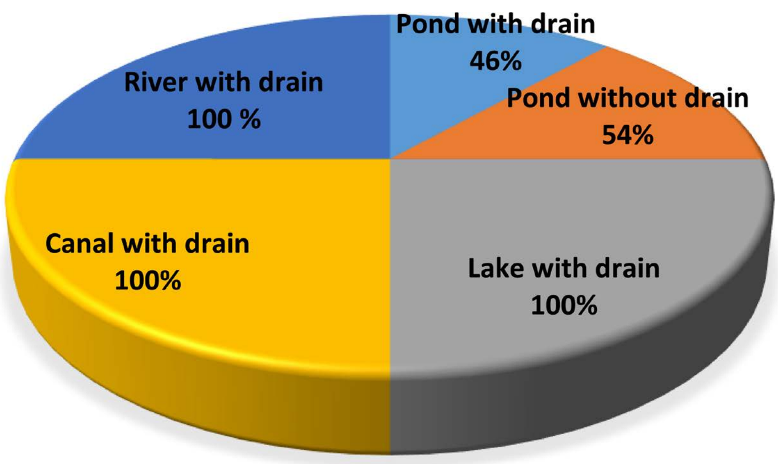

Figure 6. Opening of the drain into the water bodies.

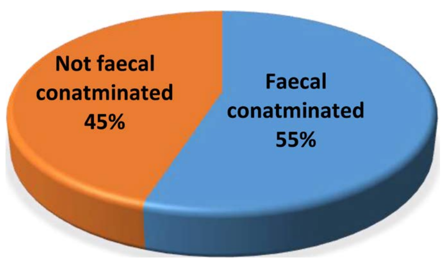

Figure 7. Contamination of water through open latrine system.

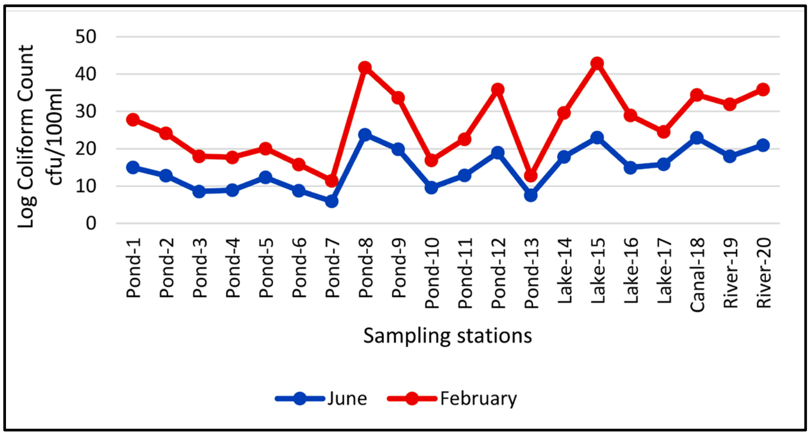

Figure 8. Total coliform bacterial count at different sampling stations.

$\times 10^{23}$cfu/100ml during May and minimum mean concentration of total coliform was 12.7×10^{8}cfu/100ml during April in Dhaleshwari River, Tangail [19]. The underlying causes of maximum load of bacteria in February were unhygienic conditions besides the water bodies, less amount of water present and the less rainfall. On the other hand there were sufficient amount of water present due to heavy rainfall, increase the amount of water that reduce the concentration of bacteria during the June.

3.4.2. Fecal Coliform

In our study, all of our samples were fecal coliform positive. Total coliform is a large collection of bacteria. Fecal coliform are types of total coliforms that exist in faeces. Fecal coliform bacteria are unlikely to cause illness, however their presence in drinking water may indicate the presence of disease-causing organisms [34].

3.4.3. *Escherichia coli* Count

The count of *E. coli* in our collected samples exceeded the EPA's recommended limit of *E. coli* [34]. *E. coli* is a subgroup of fecal coliform. The presence of *E. coli* in a drinking water sample usually indicates recent fecal contamination and means there is a greater risk that pathogens are present [35]. The range of *E. coli* in all of our collected samples was from 1.2×10^{3} cfu/100ml to 2.1×10^{12} cfu/100ml. The recorded mean concentration of *E. coli* was 2.2×10^{7} cfu/100ml during February and mean concentration was 1.05×10^{11} cfu/100ml during June (**Figure 9**). During June, monsoon rainwater runoff contaminated wetlands which causes the higher *E. coli* load in water.

3.4.4. *Salmonella spp.* Count

Typhoid fever is a severe systemic infection which is triggered by the ingestion of the bacteria *Salmonella typhi* and *Salmonella paratyphi*. Transmission of this disease is linked to contaminated food and water or via contact with fecal matter from acute or chronically infected individuals [36]. Among 20 water bodies, only 5 were contaminated with *Salmonella spp.* in February (mean concentration

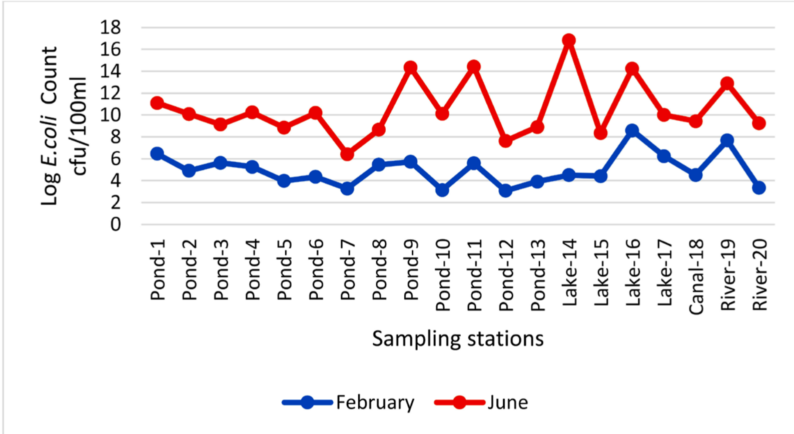

Figure 9. Total *E. coli* count at different sampling stations.

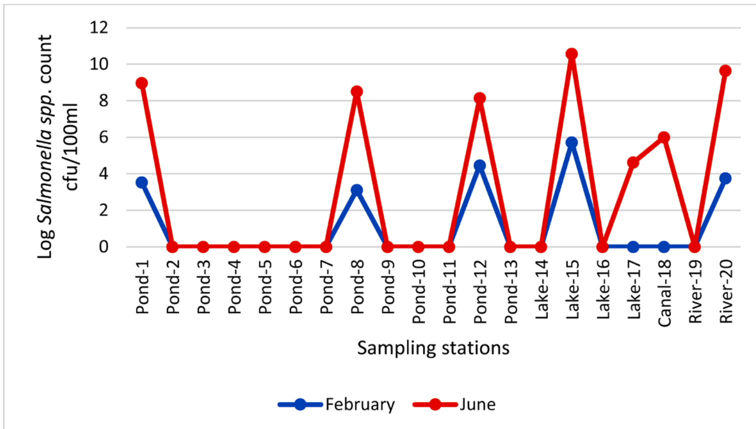

Figure 10. *Salmonella spp.* count at different sampling stations.

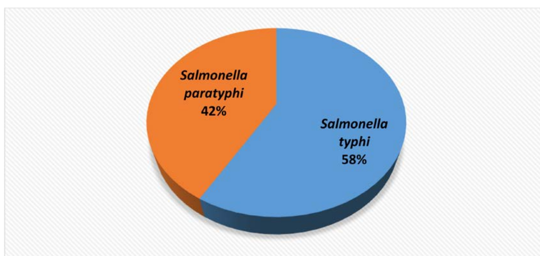

Figure 11. Distribution of *Salmonella spp.* at contaminated water samples.

1.1×10^5cfu/100ml) and 7 water bodies were contaminated in June (mean concentration 3.4×10^5 cfu/100ml) (Figure 10). Among that contaminated water bodies, about 58% were contaminated with *Salmonella typhi* and 42% were contaminated with *Salmonella paratyphi* (Figure 11). *Salmonella* count in water showed peak during June and the prevalence of *Salmonella typhi* is higher than *Salmonella paratyphi* in Bangladesh [37].

3.4.5. *Vibrio spp.* Count

Vibrio cholerae caused cholera which is a major public health problem in developing countries like Bangladesh. *Vibrio cholera* is a waterborne pathogen and transmission of this bacteria is occurred through mainly contaminated aquatic sources or the faeces of an infected person [38]. Among 20 water bodies, only 8 were contaminated by *Vibrio spp.* in February (mean concentration 8.6 × 10^5cfu/100ml) and 11 water bodies were contaminated in June (mean concentration 1.1 × 10^8 cfu/100ml) (**Figure 12**). The ingestion of approximately 10^4 - 10^6 *Vibrio cholerae* organisms is likely to produce clinical cholera [39]. The load of *Vibrio cholerae* in our sample during both February and June are able to cause cholera outbreak. Among that contaminated water bodies, about 87% were contaminated by *Vibrio cholerae* and 13% were contaminated by *Vibrio parahaemolytics* (**Figure 13**). In Bangladesh, the outbreaks of cholera is mainly caused by *Vibrio cholerae O*139 *and Vibrio cholerae o*1 replaces the other with time in an endemic area or during a prolonged outbreak [40].

3.4.6. *Shigella spp.* Count

Shigella spp. causes bacillary dysentery that can be transmitted by contaminated food and water. Research has shown a number of large waterborne outbreaks of shigellosis over the past years [41]. Among 20 water bodies, only 6 were contaminated with *Shigella spp.* in February (mean concentration 8 × 10^4cfu/100ml) and 9 water bodies were contaminated in June (mean concentration 3.7 × 10^7 cfu/100ml) (**Figure 14**). The load of *Shigella spp.* in study samples are enough to

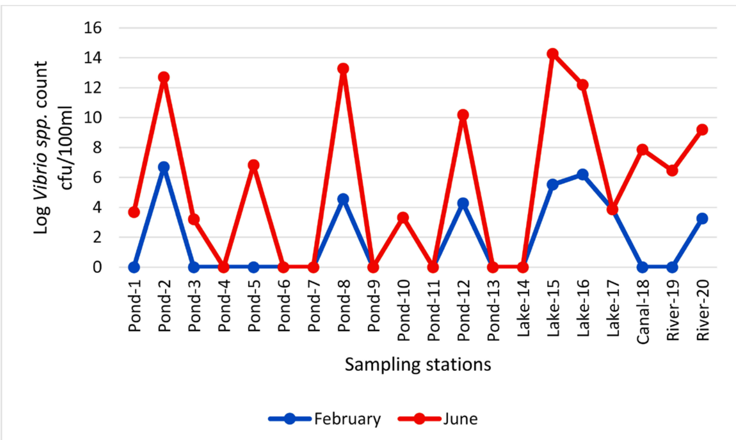

Figure 12. *Vibrio spp.* load at different sampling stations.

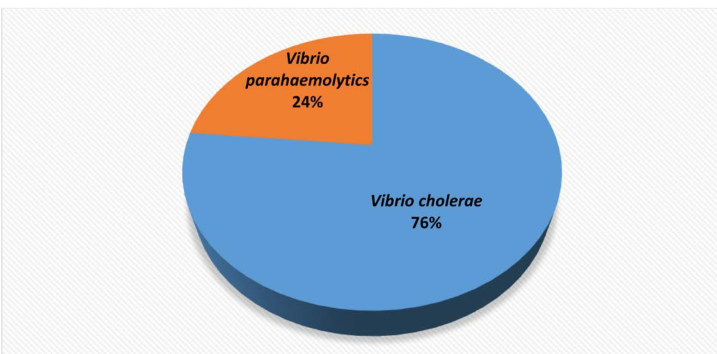

Figure 13. Distributions of *Vibrio spp.* at different sampling stations.

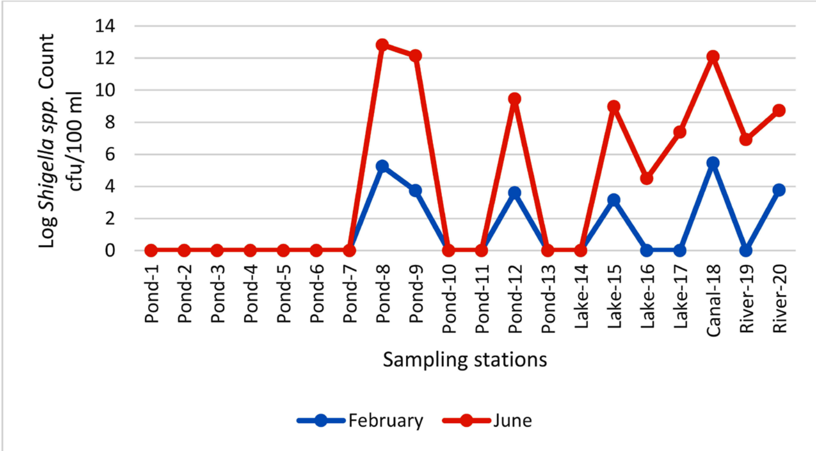

Figure 14. *Shigella spp.* load at different sampling stations.

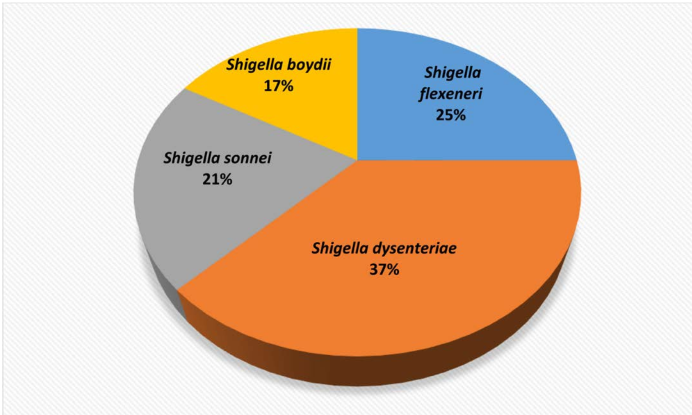

Figure 15. Distributions of *Shigella spp.* at different sampling stations.

cause shigellosis [42]. Among different serotypes of *Shigella spp.*, *Shigella dysenteriae* were the dominating one. Among that contaminated water bodies, about 37% were contaminated by *Shigella dysenteriae*, 25% were contaminated by *Shigella flexneri*, 21% by *Shigella sonnei* and 17% by *Shigella boydii* (Figure 15). In Bangladesh two predominant *Shigella spp.*, *Shigella flexneri* was isolated most frequently during August - January and *Shigella dysenteriae* during June to July [43].

3.5. Correlation Matrix among Bacteriological and Physiochemical Parameters of Different Sampling Stations

Karl Pearson's correlation coefficient along with their significant test was used to correlate among parameters to build up a matrix. This study showed that cattle wash and dumping of waste directly pollute the water and change the color and odor of the water. Opening of the drain into water sources and direct fecal contamination through opening of latrine indirectly polluted the water (Table 2). Total coliform count was positively correlated with pH (r = 0.385; $p < 0.01$) and temperature (r = 0.259; $p < 0.05$) and negatively correlated with DO. Otherwise, total *E. coli.* count was positively correlated with DO (r = 0.441; $p < 0.01$). *Salmonella*

Table 2. Correlation Analysis (Physical conditions of the ponds and waters).

Parameters	Odor of water	Cattle wash	Dumping of waste	Water type	Color of water	Opening of the drain into the pond	Direct fecal contamination through opening of latrine
Odor of water	1						
Cattle wash	0.437	1					
Dumping of waste	0.810**	0.522*	1				
Water type	0.895**	0.577**	0.905**	1			
Color of water	0.639**	0.37	0.499*	0.641**	1		
Opening of the drain into the pond	−0.512*	−0.424	−0.601**	−0.524*	−0.134	1	
Direct fecal contamination	−0.436	−0.638**	−0.616**	−0.503*	−0.225	0.664**	1

Table 3. Correlation Analysis (Internal conditions).

Parameters	pH	DO	Temperature	Total coliform count	Total *E. coli* count	*Salmonella spp.*	*Vibrio spp.*	*Shigella spp.*
pH	1							
DO	−0.375*	1						
Temperature	−0.200**	−0.249	1					
Total coliform count	0.385**	−0.234	0.259*	1				
Total *E. coli* count	0.127*	0.441**	−0.262	−0.068	1			
Salmonella spp.	0.319	−0.171*	−0.427	−0.190	−0.045	1		
Vibrio spp.	−0.099	0.038**	0.413*	−0.143	0.451**	−0.325	1	
Shigella spp.	0.263**	0.290	−0.292*	−0.107	−0.182	−0.068	−0.272	1

spp. showed negative correlation with DO and temperature; and positive correlation with pH. *Vibrio spp.* was significantly correlated with DO (r = 0.038; $p < 0.01$) and *E. coli* count (r = 0.451; $p < 0.01$). *Shigella spp.* showed positive correlation with DO and pH; and negative correlation with temperature. Environmental parameters such as temperature, pH and dissolved oxygen play a vital role in various bacterial count in water (**Table 3**) [44]. The decrease trend (r = −0.707; $p < 0.05$) in total coliform bacteria with the increase of DO and increase trend with the increase of temperature (r = 0.755; $p < 0.05$) [19] which is similar to our study result. One-way ANOVA study was conducted to know the mean differences of the quantity of parameters among different times of sampling (**Table 4**). The result revealed that the p-value is 0.00 (<0.05) for the parameters of pH, DO and Temperature, which implies that the quantity of these parameters significantly differ at different times of taking the samples. The result also represented that the p-values are greater than 0.05 for the parameters of total coliform count, total *E. coli* count, *Salmonella spp.*, *Vibrio spp.* and *Shigella spp.*, which implies that the quantity of these parameters remain the same for all the time of taking the samples.

3.6. Prevalence of Waterborne Diseases at the Study Area

Waterborne diseases are the major burden in the study area. Most of these water

Table 4. Multiple comparison among parameters.

Parameters	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*
p^H	*Between Groups*	5.70025	2	2.850125	87.35851	**0.00**
	Within Groups	1.85966	57	0.032626		
DO	*Between Groups*	15.129	2	7.5645	18.23773	**0.00**
	Within Groups	23.642	57	0.414772		
Temperature	*Between Groups*	721.6503	2	360.8251	970.4234	**0.00**
	Within Groups	21.19388	57	0.371822		
Total Coliform count	*Between Groups*	1.64E+46	2	8.22E+45	0.985578	**0.38**
	Within Groups	4.75E+47	57	8.34E+45		
Total *E. coli* count	*Between Groups*	1.1E+23	2	5.52E+22	0.6004	**0.55**
	Within Groups	5.24E+24	57	9.19E+22		
Salmonella spp.	*Between Groups*	1.59E+11	2	7.97E+10	0.736115	**0.49**
	Within Groups	1.73E+12	16	1.08E+11		
Vibrio spp.	*Between Groups*	5.37E+16	2	2.68E+16	1.30015	**0.29**
	Within Groups	5.99E+17	29	2.06E+16		
Shigella spp.	*Between Groups*	5E+15	2	2.5E+15	0.736673	**0.49**
	Within Groups	7.13E+16	21	3.39E+15		

Table 5. Impact of waterborne diseases on public health.

Diseases	Clear concept about reasons and treatment	Suffering from a long time	Number of respondents frequently	Affected within last 3 months	Took antibiotic dosages	Efficiency of antibiotic dosage (%)
Diarrhea	290	11	14	15	13	30.8
Dysentery	211	8	6	20	19	26.3
Cholera	76	-	2	7	5	40
Typhoid	145	-	-	17	15	47.2
Hepatitis	232	-	-	6	3	66.6
Botulism	37	-	5	-		
Scabies	145	3	12	2	1	100
Skin diseases	229	27	19	9	8	50
Skin cancer	172	-	-	-	-	
Dad	257	2	-	2	1	100
Itching	315	13	26	15	10	35

borne 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 source on surroundings public health, we took 20 persons from each sampling site and total respondents were 400 people (Table 5). 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 were not satisfactory and which also indicates the occurrence of antibiotic resistance.

3.7. Antibiotic Resistance Pattern of Waterborne Pathogen

In antibiogram study, most of the available waterborne pathogens in Bangladesh were found to be antibiotic resistance. Almost all waterborne bacteria in our study, were mostly resistance to Penicillin. *Shigella spp.* was highly resistance to Ampicillin (86%) and highly sensitive to Ciprofloxacin (66%) (**Figure 16**). *Salmonella spp.* was highly resistance to Amoxicillin (66%) and highly sensitive to Gentamicin (53%) (**Figure 17**). *Vibrio spp.* was highly resistance to Ampicillin (93%) and highly sensitive to Gentamicin (40%) (**Figure 18**). *E. coli* was highly resistance to Erythromycin (53%), Ampicillin (53%) and highly sensitive to Gentamicin (80%), Ciprofloxacin (80%) (**Figure 19**). In Bangladesh, problem with waterborne diseases and dissemination of antibiotic resistance bacteria through surface water exacerbates the situation [45].

4. Conclusion

Surface water is vital for the daily activities of life which is polluted by household, municipal, industrial and agricultural wastes. The quality of surface water may impact on the incidence of various water-borne 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, domestic purposes and fish culture due to fecal pollution. Low dissolved oxygen and higher pH values indicate that organic and chemical wastes polluted surface water bodies. Microbial colonization was low in February and increased in June due to rainfall. The antibiotic resistant bacteria in surface water resources poses

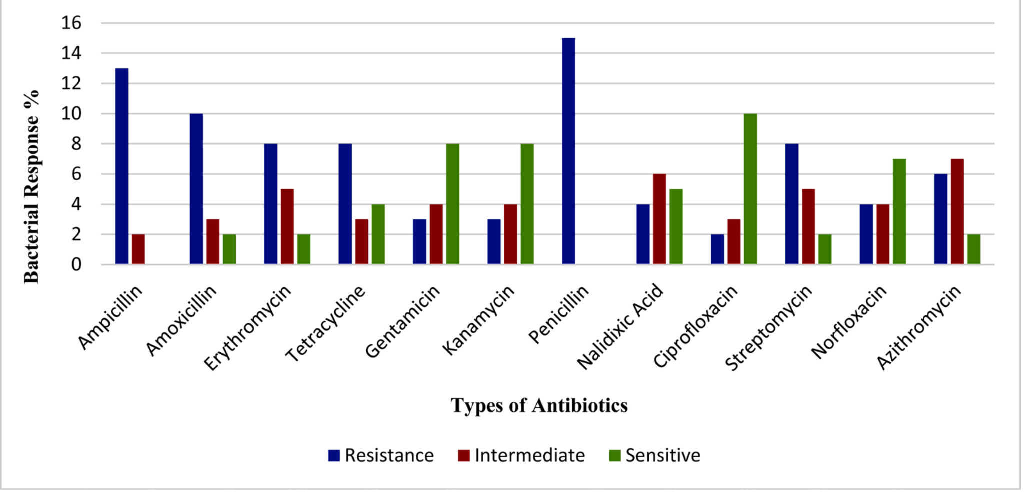

Figure 16. Antibiotic resistance pattern of *Shigella spp.*

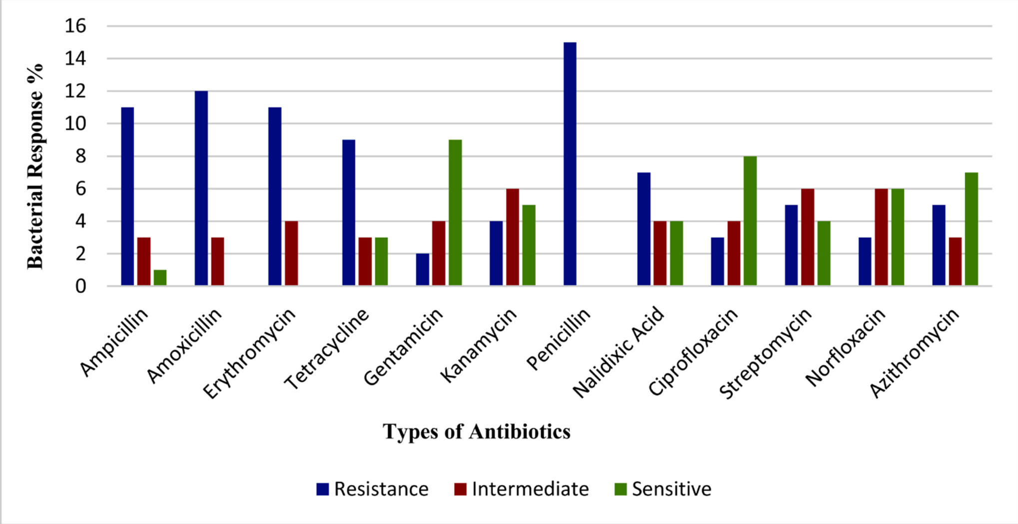

Figure 17. Antibiotic resistance pattern of *Salmonella spp.*

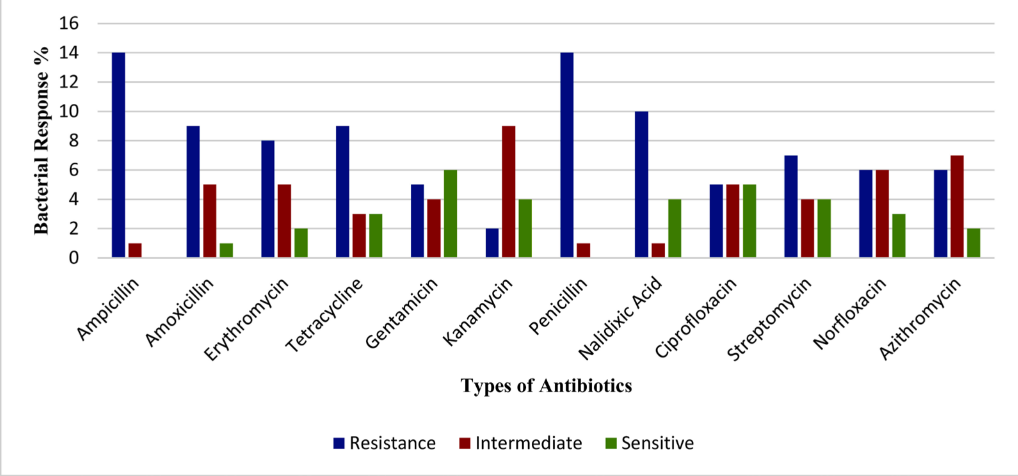

Figure 18. Antibiotic resistance pattern of *Vibrio spp.*

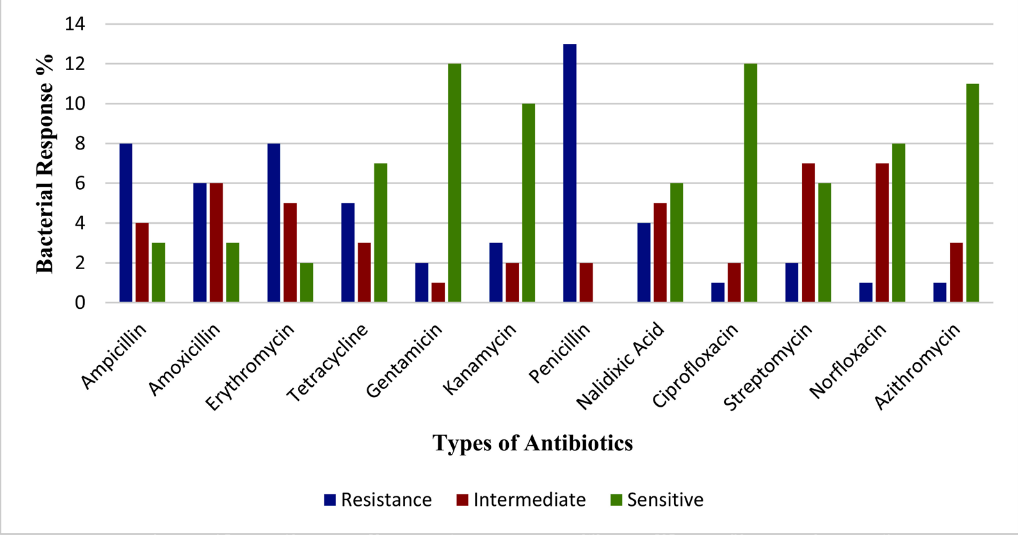

Figure 19. Antibiotic resistance pattern of *E. coli.*

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.

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