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Assessment of Drinking Water Quality Served in Different Restaurants at Islam Nagor Road Adjacent to Khulna University Campus, Bangladesh

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Abstract

Potable water is a growing requirement for sound health as contaminated water and water-borne pathogens pose serious health risks to human beings. Considering this issue, the current study aimed to assess the drinking water quality served in different restaurants close to the Khulna University campus in Bangladesh. A total number of ten drinking water samples were collected from different restaurants. Afterward, the collected water samples were analyzed to examine the physico-chemical properties and microbiological contamination of the water samples. Besides, microbial properties such as Total Coliform (TC), Fecal Coliform (FC), and *E. coli* were analyzed by the Membrane Filtration (MF) technique. The findings suggest that all the physico-chemical attributes were within the permissible limits regarding recommended Bangladesh standards and WHO guidelines. But in case of EC, 40% of the samples exceeded the WHO permissible limits and for sodium, 10% of samples exceeded both the BD and WHO standards. In addition, the results disclosed that the drinking water served in different restaurants was contaminated by TC, FC, and *E. coli*. It is observed that 100% of the samples were contaminated by TC and FC whereas 70% of the samples were contaminated by *E. coli*. Consequently, it is clearly evident that the water is considered suitable with respect to physico-chemical analysis but this drinking water is unfit for consumption while taking into account its microbiological quality. The total coliform, fecal coliform, and *E. coli* count attests to the fact that anyone can become harmed at any moment by ingesting water from roadside restaurants. Finally, due to bacterial contamination, the served drinking water in these places doesn't meet safe and suitable water excellence, therefore, consumption of this water is deleterious to public health.

Keywords

Physico-Chemical Attributes, Microbial Contamination, Coliform, Restaurants, Acceptable Limits, Bangladesh

1. Introduction

Water is one of the prime natural resources and vital for human life comprising its physical, chemical, and biological attributes that help to sustain life on Earth (Kumar & Puri, 2012; Cosgrove & Loucks, 2015; Adimalla & Taloor, 2020). Although there is an availability of water around us, scarcity of fresh drinking water is also prevailing (Gude, 2017). It is estimated that only 3 percent of the freshwater in the oceans, of which 2.97 percent is made up of glaciers and ice caps and the remaining tiny part of 0.3 percent is available as surface and groundwater for human use, is appropriate for drinking (Miller Jr., 1997; Mohsin et al., 2013). Worldwide safe drinking water is a major burning issue and a vast portion of the world is deprived of fresh drinking water (Chowdhury et al., 2014; Islam et al., 2016). It is manifested that the demand for fresh drinking water is increasing day by day and this demand for water will be exceeded by 50% in the developing part of the world by 2030 (Prosun et al., 2018; Islam & Karim, 2019). The main reasons behind this increase in demand for water are overpopulation or increasing population at an alarming rate, urbanization, industrialization, and overall due to global climate change (Jackson et al., 2001; Mou et al., 2023).

The quality and quantity of drinking water are inextricably linked with human well-being and health (Swarnokar et al., 2019). If polluted or contaminated water is consumed by people, many waterborne diseases lead to many deaths worldwide. The ingesting of contaminated water is accountable for 80 percent of all diseases in developing countries and hence, causes one-third of losses of life (UNCED, 1992; Scheumann & Klaphake, 2001). In accordance with WHO, universally about 2.2 million individuals annually, of the 1.9 million children are killed by various foodborne and waterborne diarrheal diseases (WHO, 2015; Ahmed et al., 2020). Like other countries, Bangladesh is not excluded in this issue and the urban area of this country is at high risk as compared to rural areas. Moreover, the main cause of waterborne diseases or illnesses is the consumption of unsafe or contaminated water in Bangladesh (Sobsey et al., 2003).

Since the population of Bangladesh is increasing day by day, as a result, their dependency on restaurants for food and water is also increasing in recent times. In most cases, a large number of people spend time outside of the home for their work, so they have to take food and consume water from local restaurants. These local restaurants are an undisputed part of cities with varied populations, different food cultures, and huge populations involved in untrained and low-salaried jobs (Pal et al., 2018; Hasan et al., 2019). Nowadays, due to several unknown diseases, public health is typically troubled, most of which are connected to food and drinking water (Boxall, 2004; Schwab et al., 2005). Different unknown food-borne diseases are introduced as a result of foods that are manufactured in road-side restaurants and the water served for drinking in the roadside restaurants is also a main source of anonymous waterborne diseases (Baldursson & Karanis, 2011).

The environmental conditions of these roadside restaurants are not so good as well as the water storage containers are also low quality (Shaibur et al., 2021). In addition, the water serving system of these restaurants is not well facilitated, and they serve water in different types of plastic bottles that are of very poor quality. So, in recent times, the chance of being affected by waterborne diseases has increased among people (Miah et al., 2015).

Khulna is one of the most significant economic zones concerning Bangladesh's economic condition and the people of this city are also affected by water-borne diseases (Rana, 2009; Kabir et al., 2016). There are plenty of unhygienic or unsanitary roadside restaurants existing around Khulna City as well as many roadside restaurants are also found adjunct to the Khulna University campus, which is the source of food and water-related diseases. Most of the students of Khulna University and local inhabitants depend on this roadside restaurant for their food and water daily. Hence, their health condition is closely associated with the food and water that is served in these restaurants. The objective of the study is to assess the quality of drinking water served in roadside restaurants at Islam Nagar Road adjacent to Khulna University. Several studies have been conducted on drinking and microbial quality of food and water in Bangladesh (Shaibur et al., 2021; Alam et al., 2006; Bodrud-Doza et al., 2020; Mostafa et al., 2017; Khan & Farha, 2022). Studies have also been done in Khulna City (Pranta et al., 2019), regarding this issue but there is no specific study done on the water quality of local restaurants around Islam Nagor Road adjacent to Khulna University Khulna. That's why this study is very unique and helpful to aware the students and local people about the condition of water served in these restaurants.

2. Materials and Methods

2.1. Study Area

This study was carried out around Islam Nagor Road which is located near to Khulna University campus in Bangladesh. From this road, 10 different roadside restaurants/restoras have been selected for this study purpose. A large number of students of this university have their meals from these restaurants. So, the health of the student directly or indirectly depends on the food and water that is served in these restaurants. The detailed information on the sampling location is summarized in **Table 1** with GPS coordination (GPS map 62 s, Garmin). The site map of the study area shows 10 different sampling points (**Figure 1**).

Table 1. Sampling location of the different restaurants in and around Islam Nagor Road.

SL. No.	Restaurant Name	Sample ID	GPS Reading	
			Latitude (N)	Longitude (E)
1	Vai Vai Restora	VVR	22˚48.179'	89˚32.292'
2	Vai Vai Restora (New)	VVR (N)	22˚48.081'	89˚32.187'
3	Khan Jahan Ali Restora	KJAR	22˚48.249'	89˚32.277'
4	Vai Bon Restora	VBR	22˚48.258'	89˚32.275'
5	Jalil Hotel and Restaurant	JHAR	22˚48.258'	89˚32.271'
6	Amader Take Hotel	ATH	22˚48.080'	89˚32.184'
7	Pankowri Rannaghor	PR	22˚48.418'	89˚32.218'
8	Cocktail Restaurant	CTR	22˚48.430'	89˚32.213'
9	Mayar Doa Hotel	MDH	22˚48.503'	89˚32.195'
10	Macca Madina Hotel	MMH	22˚48.720'	89˚32.136'

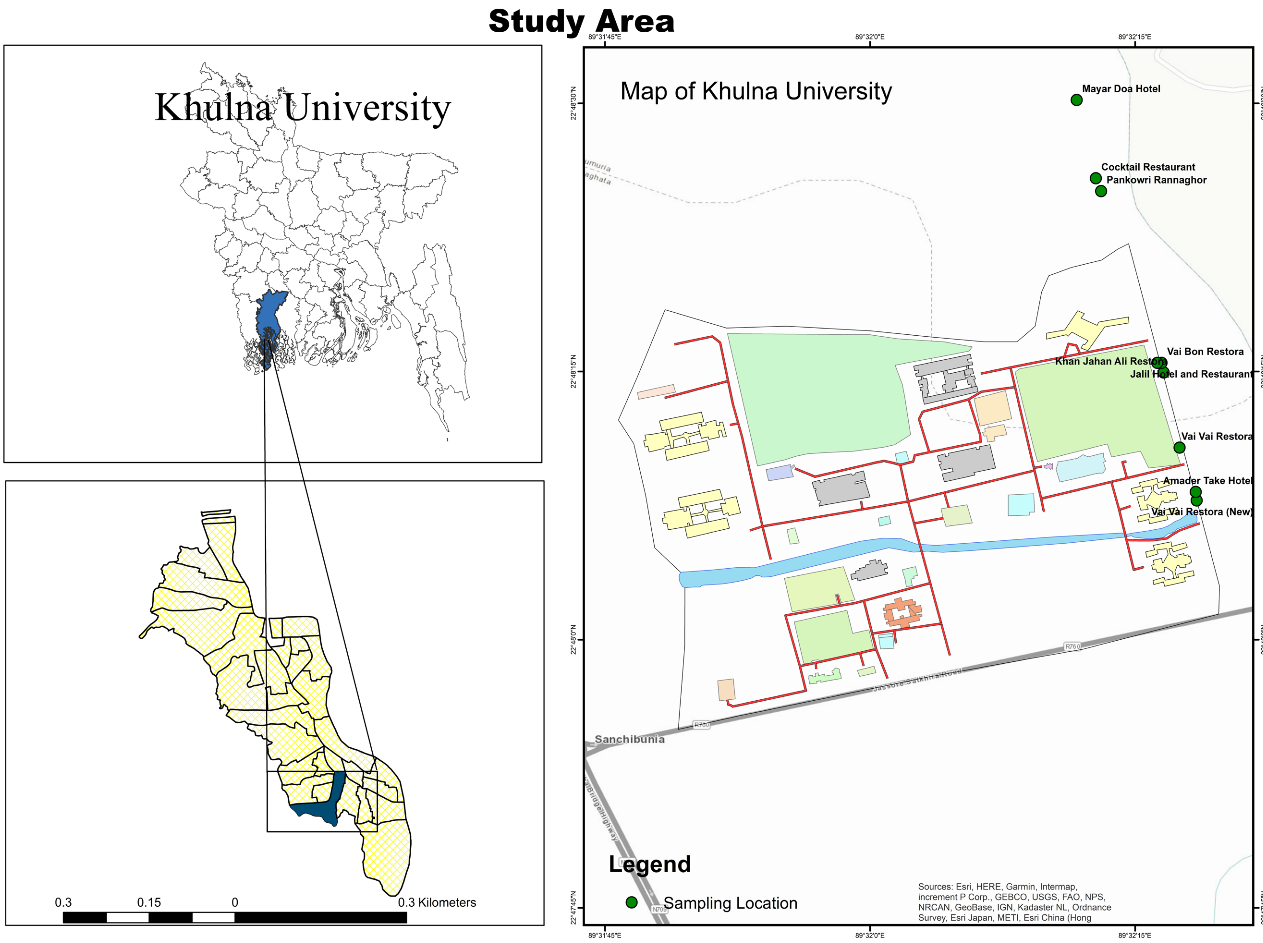

Figure 1. Location of different restaurants in and around Islam Nagor Road, Khulna, Bangladesh.

2.2. Sample Collection and Preservation

Islam Nagor Road in Khulna is a popular place for university students and local people for their food consumption. In this study place, most of the students along with common people have taken their daily meals and varieties of fast-food items from these restaurants. Considering the issues, 10 samples were collected through a purposive sampling technique from 10 different roadside restaurants to evaluate the water quality by examining the physico-chemical and bacterial contamination. Sample collection was conducted by using 1 L of the plastic bottle to perform the physico-chemical analysis, 300 ml of autoclavable Polypropylene (PP) bottle was used for microbial analysis of water that was previously autoclaved under ambient conditions in the microbiology laboratory. The bottles were washed with a cleaning solution before the collection of samples. Before taking the samples, the plastic bottles were rinsed at least three times by filling them to one-fourth of their capacity with water to be sampled properly shaken and then emptied. The bottles were air-tightened and wrapped with tape to constrain contact of air with water samples as well as properly labeled. All possible efforts were made to reduce the time lag between collection and analysis to avoid significant changes in water quality. An isolated box was used to transfer the samples to the laboratory in order to maintain temperatures. After that at 4˚C temperature, collected samples were kept in the laboratory (APHA, 2012; Ramesh & Anbu, 1996).

2.3. Laboratory Analysis

After the collection of water samples, some laboratory analysis of parameters like pH, Electric Conductivity (EC), Total Dissolved Solid (TDS), turbidity, chloride, carbonate, bicarbonate, sodium, potassium, calcium, magnesium, nitrate, sulfate, phosphate were undergone. Biological parameters like Total Coliform (TC), Fecal Coliform (FC), as well as *E. coli*, were tested for water samples. Physico-chemical parameters were analyzed at the Soil, Water, and Air Research Laboratory of Environmental Science Discipline at Khulna University during the year 2022 by following standard techniques set by American Public Health Association (APHA, 2012). The physico-chemical parameters of water quality were carried out by different methods shown in **Table 2**.

In addition, in the case of microbiological analysis, samples were transferred to the Environmental Microbiological Laboratory of Environmental Science Discipline at Khulna University within 2 hours and performed the analyzing procedure. Total Coliform (TC), Fecal Coliform (FC), and *E. coli* were analyzed by the Membrane Filtration (MF) technique using an Incubator; IB-05G and Incubator named Incucell (MMM Group) (APHA, 2012; Shaibur et al., 2012, 2019). **Table 3** represents the method, agar media including the incubation period and temperature required for the analysis of microbiological parameters of water samples from the roadside restaurants of the study area.

Table 2. Methods/instruments used for the analysis of physico-chemical parameters of water.

Parameters*	Methods/Instruments	Reference
pH	pH meter (M106MAX, milwaukee)	Ramesh and Anbu (1996); APHA (2012)
EC	EC meter (AD 332, Adwa)	
Turbidity	Turbidity meter (MI415PRO, milwaukee)	
TDS	TDS meter (AD 332, Adwa)	
Na^+, K^+	Flame photometric method (PEP 7 Flam photometer)	
Ca^{2+}, Mg^{2+}, CO_3^-, HCO_3^-, Cl^-	Titrimetric method	
CO_3^{2-}	Turbidimetric method (Thermo Spectronic, UV-visible Spectrophotometers)	
NO_3^-	Spectrophotometric method (UV-1900i, SHIMADZU, UV-VIS Spectrophotometer)	
PO_4^{3-}	Scorbic acid method (Thermo Spectronic, UV-visible Spectrophotometers)	

Note: *All units are in mg/l excluded pH, EC (μS/cm), and Turbidity (NTU).

Table 3. Methodological steps followed for analysis of microbiological parameters.

Microbial Parameters	Unit	Used Agar	Incubation Period and Temperature	Methods
FC	CFU/100ml	MFC	24 hours and 44.5˚C water bath	Membrane Filtration (MF) technique
TC		M Endo	24 hours and 37˚C	
E. coli		M TEC	35˚C for two hours after two hours 44.5˚C for 24 hours water bath	

Note: CFU = Colony Forming Unit; FC = Fecal Coliform; TC = Total Coliform.

2.4. Statistical Analysis

Statistical analysis of the data was carried out by using Microsoft Excel, Minitab, and SPSS (28.0 version) software.

3. Results and Discussion

3.1. Physico-Chemical Properties of Water

pH: The pH value ranged from 7.87 to 8.34 in the water samples with a mean value of 8.12. Among the 10 different restaurants, the maximum value (8.34) of pH was observed in JHAR and the minimum value (7.87) was recorded in CTR. According to Bangladesh and WHO standards, for drinking water the standard pH value is 6.50 to 8.50 (BBS, 2009; WHO, 1984). From the study, it is said that the pH value did not exceed the permissible limit of BD and WHO Standards. The fact is that 100% of the collected samples were within the desired limits. Besides, the collected water samples are alkaline in nature. The pH of the water of restaurants mainly relies on the pH of the source water (Shaibur et al., 2021). Figure 2(a) illustrates the pH values of different restaurants along with standards.

Figure 2. Physico-chemical variation and comparative assessment of water quality parameters, where X-axis represents the sample ID (restaurants name) and Y-axis denotes the concentration of respective parameters in mg/l except pH, EC (μS/cm) and Turbidity (NTU). (St. = Standard; BD = Bangladesh, WHO = World Health Organization). (a) pH, (b) EC, (c) TDS, (d) Turbidity, (e) Sodium, (f) Potassium, (g) Calcium, (h) Magnesium, (i) Chloride, (j) Sulphate, (k) Nitrate, (l) Phosphate.

EC: The prescribed value of EC in the drinking water sample is 300 - 1500 µS/cm and 750 µS/cm according to Bangladesh and WHO standards, respectively. In this study, the EC value varied from 638 to 867 µS/cm with an average value of 740 µS/cm. In VVR, the maximal value of 867 µS/cm of EC was found whereas the minimal value of 638 µS/cm was recorded in MMH. Considering the BD standard values all the samples were in desired range but according to WHO guidelines for drinking water 40% of samples exceeded the permissible limits and the rest of the samples were within the limits (**Figure 2(b)**). In addition to this, it is stated that if the EC outstrips the value of 300 µS/cm have to be careful because it provides an indirect measure of the total salt content or TDS. The higher EC of the samples may reflect the higher mineralization in the study area (Shaibur et al., 2021).

TDS: The mean value of TDS of the collected samples from different restaurants was recorded as 370.1 mg/l and the TDS value ranged between 319 to 434 mg/l. The highest concentration of TDS was detected in VVR with a value of 434 mg/l on the contrary the lowest concentration was noticed in MMH with a value of 319 mg/l. In the case of drinking water, the TDS may originate from different sources like industrial wastewater discharge, sewage systems, etc., and TDS is regarded as a sign to measure the water quality (Mohsin et al., 2013). The permissible limit of TDS is 1000 mg/l in water both for BD and WHO standards. In this study, all the samples (100%) remained within permissible limits (**Figure 2(c)**). Water can be categorized as excellent (<300 mg/l), good (300 - 600 mg/l), fair (601 - 900 mg/l), poor (900 - 1200 mg/l), and unacceptable (>1200 mg/l) based on TDS level (Rahman et al., 2015; Khan & Farha, 2022). In this study, all the samples were in the range of 300 - 600 mg/l means that based on the TDS level the quality of water is in good condition.

Turbidity: The turbidity of the water samples varied from 0.12 to 1.58 NTU with an average value of 0.42 NTU. In CTR the turbidity was highest (1.58 NTU) whereas in PR lowest value (0.12 NTU) was observed (**Figure 2(d)**). The BD and WHO standards for turbidity are 10 NTU and 5 NTU, respectively. It is said that no water samples exceeded the desired limits. Due to the existence of suspended materials, water becomes turbid and in addition, particulate matter is mainly responsible for the high turbidity of water (WHO, 2004).

Calcium and Magnesium: In the study area, the concentration of calcium measured between 10.02 to 38.07 mg/l with a mean value of 19.04 mg/l. The results revealed that the maximal concentration of calcium was recorded in MDH on the other hand minimal concentration was found in two samples, namely JHAR and MMH (**Table 4**). The permissible limits for calcium are 75 mg/l (BBS, 2009) and 100 mg/l (WHO, 2017). From the study, it is concluded that 100% of the samples fell within the desired limits of both standards (**Figure 2(g)**).

The value of magnesium ranged from 4.86 to 34.03 mg/l with an average of 17.01 mg/l. The highest value was found in CTR whereas in VVR lowest value was noticed (**Table 4**). The standard value for magnesium is 30 - 35 mg/l in the case of BD standard and for WHO guidelines it is 150 mg/l. Regarding these

Table 4. Physico-chemical properties of drinking water served at different restaurants in and around Islam Nagor Road.

Sample ID	pH	EC	TDS	Turbidity	Ca^{2+}	Mg^{2+}	Cl^-	Na^+	K^+	SO_4^{2-}	NO_3^-	PO_4^{3-}	CO_3^{2-}	HCO_3^-
VVR	8.29	867	434	0.4	22.04	4.86	60.26	184.13	3.57	2.09	0.94	0.36	30	414.8
ATR	8.21	829	414	0.53	16.03	13.37	81.53	173.86	5.68	2.09	0.45	0.37	12	353.8
VVR (N)	7.95	735	367	0.17	16.03	9.72	63.81	177.28	3.57	1.07	0.51	0.59	12	341.6
KJAR	8.05	679	342	0.21	14.03	17.01	85.08	167.02	3.77	0.79	0.54	0.37	18	183.0
VBR	8.16	808	404	0.15	20.04	10.94	92.17	173.86	3.87	1.53	0.52	0.37	18	384.3
JHAR	8.34	811	405	0.24	10.02	23.09	42.54	231.38	1.66	4.05	1.83	1.31	24	475.8
PR	8.01	699	350	0.12	26.05	32.81	60.26	122.53	5.68	0.32	1.16	0.33	12	390.4
CTR	7.87	678	338	1.58	18.03	34.03	77.99	122.53	4.57	1.81	0.49	0.52	12	305.0
MDH	8.07	656	328	0.13	38.07	17.01	35.45	132.79	4.88	0.23	0.49	0.46	30	402.6
MMH	8.24	638	319	0.69	10.02	7.29	70.9	160.17	2.36	2.65	0.67	0.92	18	433.1
Average	8.12	740	370.1	0.42	19.04	17.01	66.99	164.56	3.96	1.66	0.76	0.56	18.6	368.44
Maximum	8.34	867	434	1.58	38.07	34.03	92.17	231.38	5.68	4.05	1.83	1.31	30	475.8
Minimum	7.87	638	319	0.12	10.02	4.86	35.45	122.53	1.66	0.23	0.45	0.33	12	183
St. Dev.	0.153	81.95	40.82	0.45	8.35	10.12	18.26	32.91	1.30	1.16	0.44	0.31	7.18	81.04

Note: EC = Electrical Conductivity, TDS = Total Dissolved Solid (TDS), St. Dev. = Standard Deviation.

standards, all the samples (100%) were within the recommended values (Figure 2(h)). Therefore, it is stated that the obtained values for both calcium and magnesium are found to be satisfactory and considered safe for drinking.

Chloride: The value of chloride was enlarged from 35.45 - 92.17 mg/l along a mean concentration of 66.99 mg/l. In addition to this water served in VBR had a high value of chloride was reported as paralleled to other restaurant's water (Table 4) The allowable limit for chloride is 150 - 200 mg/l (BBS, 2009) and 250 mg/l (WHO, 2017). From Figure 2(i), it is easily recognized that 100% of the water served in different restaurants has a lower chloride value than both standards.

Sodium and Potassium: Figure 2(e) depicts the concentration of sodium with BD and WHO standards. In both cases, the prescribed value of sodium is 200 mg/l. In the study area, the concentration of sodium fluctuated from 122.53 to 231.38 mg/l. Moreover, the average is 164.46 mg/l. It is said that the water served in JHAR had a high concentration of sodium compared to other restaurants in the study area (Table 4). Allowing the recommended value of sodium all the samples were within the prescribed range excluding JHAR (Figure 2(e)). Although the water served in different restaurants has a sodium content measurably high and a few were borderline but water may be considered safe for drinking except JHAR.

The value of Potassium in the water samples served in restaurants arrayed from 1.66 to 5.68 mg/l and the mean concentration was 3.96 mg/l. Table 4 indicates that the highest value was noticed in two water samples collected from ATR and PR on the contrary and lowest value was in JHAR. Besides a similar concentration (3.57 mg/l) of potassium was reported in VVR and VVR (N). The standard value of potassium is 12 mg/l for BD and 30 mg/l in the case of the WHO standard. From **Figure 2(f)**, it is clearly understood that 100% of water samples fall between the recommended standard values.

***Nitrate, Phosphate, and Sulfate*:** The nitrate concentration in the water samples varied from 0.45 to 1.83 mg/l and 0.76 mg/l was its mean concentration. The highest concentration was reported in JHAR whereas the lowest value was observed in ATR. A similar value was recorded in water samples supplied in CTR and MDH (**Table 4**). The allowable limits of nitrate in drinking water are 10 mg/l in case of BD standards and 50 mg/l prescribed by WHO. In this study, it is manifested that all the samples have lower concentrations of nitrate than the guidelines of BD and WHO (**Figure 2(k)**). Regarding both the limits water samples were safe for drinking.

The recommended standard for phosphate is 6 mg/l (BBS, 2009) although there is no specific standard for phosphate by WHO. This study found a range of 0.33 to 1.31 mg/l of phosphate which is lower than the standard limits (**Table 4**). The mean concentration of phosphate was 0.56 mg/l and the highest and lowest values were noticed in JHAR and PR, respectively.

Further, the value of sulfate varied from 0.23 to 4.05 mg/l among the collected water samples from the restaurants and the mean value of sulfate was 1.66 mg/l. In JHAR, the maximum concentration of sulfate was found compared to other water samples collected from the restaurants in the study area. The prescribed value for sulfate is 400 mg/l (BBS, 2009) and 250 mg/l (WHO, 2017). The study revealed that all the samples were within the limits and it is considerably lower than standards (**Figure 2(j)**).

***Carbonate and Bicarbonate*:** Carbonate concentration differed from 12 - 30 mg/l among the served water samples along with a mean value of 18.6 mg/l. In addition, an analogous value (12 mg/l) existed in four restaurants as well as utmost value (30 mg/l) was found in two restaurants' water samples. In water, the concentration of Bicarbonates depends on the pH and in groundwater this value is generally < 500 mg/l. Groundwater and surface bodies contain bicarbonate that shakes the hardness and alkalinity of water. For the addition of bicarbonate in water bodies' rock weathering is mainly responsible (Mohsin et al., 2013). The concentration of bicarbonate in this study was found in the range of 183 - 475.8 mg/l with an average value of 368.44 mg/l. This study manifested that the maximum value of bicarbonate was noticed in JHAR in contrast to KJAR water samples (**Table 4**). Though there is no recommended value for bicarbonate by WHO as well as BD standards however this value is not exceeded 500 mg/l. This study revealed that the served water samples were within the expected values.

3.2. Correlation Matrix

Table 5 represents the relationship between the physico-chemical properties of

Table 5. Correlation analysis among the physico-chemical properties of water.

Parameters	pH	EC	TDS	Turbidity	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	CO_3^{2-}	HCO_3^{-}	NO_3^{-}	SO_4^{2-}	PO_4^{3-}
pH	1													
EC	0.574	1												
TDS	0.577	1.00**	1											
Turbidity	−0.317	−0.219	−0.230	1										
Ca^{2+}	−0.294	−0.169	−0.169	−0.250	1									
Mg^{2+}	−0.516	−0.338	−0.343	0.356	0.153	1								
Na^{+}	0.727*	0.656*	0.658*	−0.344	−0.578	−0.451	1							
K^{+}	−0.511	−0.078	−0.078	0.052	0.609	0.345	−0.703*	1						
Cl^{-}	−0.194	0.087	0.092	0.289	−0.432	−0.124	−0.108	0.184	1					
CO_3^{2-}	0.544	0.199	0.204	−0.314	0.389	−0.368	0.295	−0.350	−0.593	1				
HCO_3^{-}	0.606	0.306	0.294	−0.162	0.086	−0.152	0.319	−0.335	−0.577	0.402	1			
NO_3^{-}	0.512	0.312	0.311	−0.247	−0.232	0.281	0.534	−0.480	−0.536	0.280	0.568	1		
SO_4^{2-}	0.684*	0.439	0.432	0.264	−0.704*	−0.146	0.736*	−0.707*	−0.065	0.139	0.500	0.563	1	
PO_4^{3-}	0.454	−0.030	−0.038	0.064	−0.545	0.023	0.594	−0.815**	−0.424	0.169	0.525	0.649*	0.788**	1

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

water collected from the study area. In this study, to set up the relationships between the physico-chemical characteristics of water samples, the Pearson correlation was accomplished which exhibits the degree of positive and negative correlation among parameters. The coefficient of correlation ranges from −1 to 1 (Hamzaoui-Azaza et al., 2011). Correlation coefficient 1 or near 1 defines very good and strong correlation and if the value is 0 then there is no correlation between parameters. It also said that parameters showing r > 0.7 are considered strongly correlated whereas r between 0.5 and 0.7 displays moderate correlation (Chidambaram et al., 2009). From **Table 5**, it is manifested that there is a strong positive correlation between EC and TDS (0.999), pH and Na^+ (0.727), SO_4^{2-} and PO_4^{3-} (0.787), SO_4^{2-} and Na^+ (0.735). On the contrary, there is a strong negative correlation between parameters like K^+ and PO_4^{3-} (−0.815), SO_4^{2-} and Ca^{2+} (−0.704) as well as SO_4^{2-} and K^+ (−0.707). Besides, parameters like EC - pH, TDS - pH, EC - Na^+, TDS - Na^+, Ca^{2+} - K^+, SO_4^{2-} - pH, NO_3^- - pH, NO_3^- - Na^+, NO_3^- - PO_4^{3-}, PO_4^{3-} - Na^+, CO_3^{2-} - pH, HCO_3^- - pH and HCO_3^- - NO_3^- exhibit the moderately positive correlation. In addition, Mg^{2+} - pH, Ca^{2+} - Na^+, pH - K^+, Cl^- - NO_3^-, Ca^{2+} - PO_4^{3-} and Cl^- - HCO_3^-) have shown moderately negative correlation.

3.3. Microbiological Load and Contamination Status

The pollution level of water can be determined by the status of Fecal Coliform (FC), Total Coliform (TC), and *E. coli*. **Table 6** represents the sample-wise values

Table 6. Microbial status of water served in different restaurants in the study area.

Restaurant Name	Sample ID	TC	FC	*E. coli*	BD & WHO Standard
Vai Vai Restora	VVR	5600	624	10	0 CFU/100ml
Amader Take Hotel	ATR	4200	392	38	
Vai Vai Restora (New)	VVR (N)	3000	86	4	
Khan Jahan Ali Restora	KJAR	1774	552	0	
Vai Bon Restora	VBR	608	66	0	
Jalil Hotel and Restaurant	JHAR	648	252	6	
Pankowri Rannaghor	PR	7400	432	192	
Cocktail Restaurant	CTR	328	24	6	
Mayar Doa Hotel	MDH	864	704	0	
Macca Madina Hotel	MMH	456	50	2	

Note: CFU = Colony Forming Unit, FC = Fecal Coliform, TC = Total Coliform.

of total coliform, fecal coliform, and *E. coli*, compared with their recommended standards limit considering both Bangladesh and the World Health Organization. The recommended values for TC, FC, and *E. coli* are 0 CFU/100 ml water sample. In this study, the highest number of colonies of TC and *E. coli* were found in PR which indicates the worst water quality than the other water samples served in different restaurants. In addition, the highest contamination of FC was 707 CFU/100 mL in MDH (Table 6). Besides this, 100% of the samples were contaminated by TC, and FC as well as 70% of the samples were contaminated by *E. coli*. Among the 10 water samples, only three samples i.e. 30% of the samples were free from *E. coli* (Table 6). According to BD and WHO guidelines, drinking water must be free from microbial contamination but in this study, all samples exceed the prescribed limits which may create major problems among the consumers who drink water from here on a daily basis.

One of the major causes of this contamination may be the environmental conditions and the water storage facilities of these roadside restaurants. Another reason behind this microbial contamination is their water serving bottles, in most cases, they serve water in used plastic bottles like 7-Up, Coca-Cola, Spirits, and so on. Moreover, the unhealthy condition of restaurants as well as the unhygienic practices of water distribution by the serving boy (wetter) may lead to this type of bacteriological contamination. It is concluded that the provided drinking water in those restaurants was highly contaminated with TC, FC, and *E. coli*. Furthermore, this might be accountable for many problems like dysentery, diarrhea, or gastric problems of the people as well as different levels of health risks to local people and students who are used to consuming food items from these restaurants (Shaibur et al., 2021). Therefore, the major finding of this research is that the water used in different restaurants was unsuitable for drinking purposes as it contains a huge number of bacteriological loads. Generally, the groundwater (i.e. deep tube wells) is free from pathogens that are normally present in good numbers in surface water (Shaibur et al., 2012). The possible sources of microbial contamination may be due to poor water storage facilities and the unhygienic water serving system of those restaurants.

4. Conclusion

This study revealed that in most cases, the physico-chemical properties of water were within the recommended value while some exceeded the allowable limits. Considering the Bangladesh standard, the EC of all the samples was within the desired range but in accordance with WHO guidelines for drinking water, 40% of samples exceeded the permissible limits. Allowing the recommended value of sodium, all the samples were within the prescribed range except Jalil Hotel and Restaurant (JHAR). In addition, for TDS, all the samples were in the range of 300 - 600 mg/l means that the water quality is not harmful to drinking and domestic uses. However, microbial analysis revealed that 100% of samples were contaminated by TC and FC, and 70% of water samples were contaminated by *E. coli*—an insight into microbial contamination of water that was really unsatisfactory and might have been responsible for major health problems of the consumer. This study might help to raise awareness among the students and local people who consume food and drink water on a daily basis from here. Besides, the awareness of water hygiene behaviors could help to uphold cleanliness and safety measures among consumers. Further, the findings of the study will help the owner of the restaurant to take compulsory steps and hygienic practices for the maintenance of microbial contamination to prevent waterborne infectious diseases. Based on the study, it is also suggested that the collection and storage system should be improved first. Then should focus on the source of water from where water is collected to ensure proper inspection under a regular monitoring system. Further, it is intensely recommended that the storage reservoirs or containers need to be cleaned up regular basis with disinfectants. Overall, the ambient environment of the restaurant should be hygienically developed to prevent microbial infection and pathogens outbreaks.

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Conflicts of Interest

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

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