

Physicochemical and Microbial Groundwater Quality Assessment and Evaluation in Noakhali Region, Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author PS supervised, managed the analyses of the study, wrote the protocol and wrote the first draft of the manuscript. Authors SN and RB designed the study, investigated and managed the literature searches. Author SKSR performed the statistical analysis. Author MSR reviewed and revised the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Groundwater is an essential and valuable natural source of drinking water. But sometime ground water contains different types of chemical or biological substance which make water unsuitable for consumption. Quality of the ground water varies in different location. The recent study emphasized on monitoring the present condition of groundwater in the coastal region of Noakhali. The study area covered 24 different locations of two large Upazila Subarnachar and Kabirhat of Noakhali District. Groundwater quality was examined by analyzing various physicochemical parameters and microbial parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity, Total Hardness, Potassium, Sulphate, Chloride ions, Total Coliform, Fecal Coliform, and Total Bacterial Viable Count. These parameters were compared with the drinking water quality standards recommended by WHO and Bangladesh local standards. From the analysis, it was observed that pH, Sulphate, Potassium were within the acceptable limit according to WHO and Bangladesh standards. But maximum tube-wells water contains huge amount of TDS (6040 mg/l),

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EC (1786 μ s/cm), Salinity (6.8%) and hardness (1050 mg/l), which is not safe for human health. From the correlation studies of the water quality parameters, relatively high positive correlation between some chemical parameters was found. And it signifies a common origin or progressive enrichment of both parameters. The analysis of biological parameters showed the presence of bacteria in many of the water samples. Maximum value of Total coliform found from the groundwater was TNTC and fecal coliform was 3×10^1 CFU/ml. According to WHO and Bangladesh standard the groundwater of this region is not suitable for drinking. So, some simple primary treatment is needed prior to use this water for drinking purposes and necessary steps should be taken for alternative safe source of drinking water in this region.

Keywords: Physicochemical; microbial; groundwater; salinity; hardness; coliform.

1. INTRODUCTION

Groundwater is the most valuable renewable resource in the world [1]. But this resource is depleting day by day in Asia, South America, and North America [2]. People's livelihood and socio-economic activities of a country highly dependent on the availability and quality of groundwater as it satisfies the demand of agricultural, industrial and domestic sectors of the country [3].

The nature of the groundwater beneficiaries is impacted by contamination of soil what's more, air, mechanical and household squander transfer, natural parts, pathogenic microorganisms, use of composts and pesticides in farming, and so on [4]. So, it is very important to learn the quality of the water before its utilization for different purposes [5]. The quality of water is considered by different physical, chemical and biological conditions which are polluted by natural and anthropogenic sources. Water having high or low pH, high level of turbidity and so forth is offensive to utilize. An excessive amount of chloride substance and hardness makes the water unusable. The correspondingly higher substance of phosphate is undesirable. From microbiological perspective, drinking water ought to be free from any sorts of pathogens and in addition opportunistic microflora. Although there are various microorganisms present in water that may present wellbeing risk like *Salmonella spp.*, *Shigella spp.*, Coliforms, *Mycobacterium spp.* and so forth [6]. Coliforms are utilized to evaluate water quality. The microorganisms in water causes different sicknesses like typhoid, cholera, loose bowels, diarrhea, hepatitis and so on [4].

Natural water resources such as groundwater in coastal areas of Bangladesh are contaminated by salinity and other metal ions because of saline water intrusion, storm surges and excessive withdrawal of ground water for using various purposes [7]. Most of the people think

that ground water or water from tube-wells is free from contamination and tube-well water is used as primarily source of safe drinking water in Bangladesh [8]. Several water and hygiene-related issues, such as use of tube-well water and water safety practices, women in water hygiene [9] and knowledge gap on hygiene [10] and safe water [11] are very important factors. Some impeding factors towards access to safe drinking water are poverty, unhygienic sanitation practices, low groundwater levels, and impacts of natural hazards (e.g., arsenic, salinity, extreme weather events) [12]. Noakhali District is situated in the southern part of the Bangladesh, where ground water salinity is a major problem which causes serious health problem like (pre)eclampsia and gestational hypertension [13]. Ground water sources in this area contain highest level of EC and TDS which exceeded the standard level [2]. Not only that, many researchers found high amount of coliform in tube-well water that indicate improper sanitization of this area [14]. From literature it was also found that the level of arsenic, cadmium, lead and chromium was within acceptable limit recommended by WHO [15]. But this information is not enough to understand about the overall status of water quality of this area. For this reason, a regular monitoring of drinking water quality of groundwater in Noakhali region is important.

The current study was aimed to examine the present status of the physicochemical and microbial quality of groundwater in different locations of Subarnachar and Kabirhat upazila of Noakhali district of Bangladesh.

2. MATERIALS AND METHODS

2.1 Study Area

Noakhali is a district in South-eastern Bangladesh. Noakhali district is located in the Chittagong Division and bounded by the Comilla district in the north, the Meghna estuary and the

Bay of Bengal in the south, Feni and Chittagong districts in the east, Lakshmipur and the Bhola districts in the west. Geographically it stands on 22.70°N 91.10°E coordinates. The district has an area of 4,202 km². The district represents an extensive flat, coastal and delta land, located on the tidal floodplain of the Meghna river delta, characterized by flat land and low relief. The district of Noakhali has actually gained more than 28 square miles (73 km²) of land in the past fifty years and so on [16].

The present study was conducted to determine the drinking water quality of groundwater from 24 different locations of Subarnachar Upazila and Kabirhat Upazila in Noakhali district (Fig. 1).

Sampling locations in Kabirhat Upazila are Transmeter, Tetultola bazaar, Kabirhat bazaar, Ghoshabagh School, Upazila Porisod, Health complex, Kabirhat College, North ghoshabagh, Doctor Hath, Chowrasta Bazar, Ballokotta Oshudia, and Mosjid zero point.

Sampling locations in Subarnachar Upazila are Noakhali Science and Technology University, Banglabazar Madrasa, Dharmapur, Subarnachar upazila road, Darogabari, Cowmohuni Bazar vatirtak, Siraj bari, Terijpul, Badamtoli, Al-amin bazar, Char wapda shubarna char, and Char jubli.

2.2 Sampling

Three samples of groundwater were collected from each location. In these studies, physical and chemical tests were replicated at least three times. Analyzed values of these parameters were compared to WHO and Bangladesh drinking water quality standards. The bottles were filled up with the sample leaving only a small air gap at the top of the stoppard and sealed bottles. Then the samples were preserved in 4°C in the icebox. All the experiment was carried out at Department of Environmental Science and disaster management laboratory, Department of Applied Chemistry and Chemical Engineering (ACCE) Laboratory, Department of Microbiology of Noakhali Science and Technology University (NSTU), Soil Research and Development Institute, Noakhali.

2.3 Analysis of Physicochemical Parameters

Different physicochemical parameters of collected water samples were measured by

using different techniques. DO, pH, TDS, Salinity and EC were measured by using digital multimeter (Multi-3510 ids set 3). Turbidity was measured by using a digital turbidity meter (2020we Turbidity meter). Analyzing techniques of other parameters were described in below.

2.3.1 Total hardness

Hardness is caused by the calcium and magnesium ions present in water. Total hardness was determined by EDTA method. This was done by titrating 100 mL of sample in a conical flask and adding 1 mL of buffer solution with Erichrome Black-T indicator against standard EDTA (Ethylene diamine tetra acetic acid). The solution was changed from wine blue at the end point. Total hardness might be caused by the sum of all metallic cations other than alkali metals expressed as equivalent calcium carbonate concentration. Total hardness (as CaCO₃), (mg/L) = mL of EDTA used × 100 mL of sample [17].

2.3.2 Sulphate

Sulphate was determined by using Turbidimetric Method. Sulphate ion is precipitated in an acidic medium with barium chloride to form a barium sulphate crystal with uniform size. The absorbance of the BaSO₄ suspension is measured by a photometer at 420 nm and the sulphate concentration is determined by comparison of the reading with a standard curve. 100 ml sample was measured and diluted to 100 ml into a 250 ml Erlenmeyer flask. Exactly 5 ml conditioning reagent was added and mixed by stirring. A spoonful of barium chloride crystals was added while still stirring and commenced timing for 60 seconds at a constant speed. After stirring, the absorbance was measured at 420 nm on the spectrophotometer-Ultra spec model II within 5 minutes. The result was read directly from the calibration curve, and expressed in mg/l, to three significant figures [17].

2.3.3 Phosphate

Phosphate content in the given water sample was determined as inorganic phosphate by calorimetric method. In this method, 50 mL of the filtrate clear sample was taken in a conical flask. 20 mL of ammonium molybdate was added to it. 5 drops of SnCl₂ solution was added to it. The solution becomes blue and the reading was taken at 690 nm on the spectrometer within 10-12 minutes. Same procedure was repeated for the standard solution of different concentration

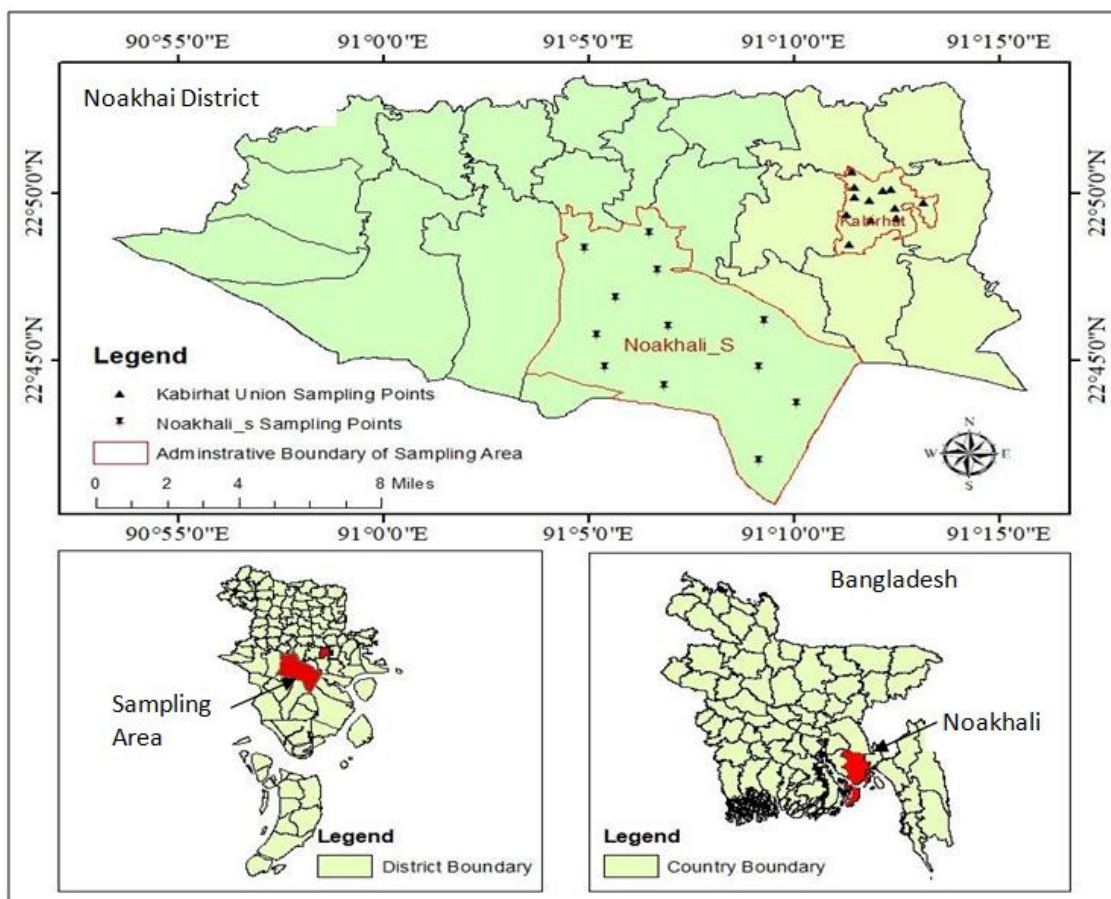


Fig. 1. Sampling area (Subarnachar and Kabirhat Upazila), Noakhali district, Bangladesh

for distilled water. The concentration was determined with the help of standard curve obtained by plotting standard values against absorbance [17].

2.3.4 Potassium

Potassium ranks seventh among the elements in order of abundance, behaves like sodium and remains low. Though found in small quantities (<20 mg/L) it plays a vital role in the metabolism. Trace amount of potassium can be determined by direct reading of flame photometer at a specific wavelength of 766.5 nm by spraying the sample into the flame. The desired spectral lines are then isolated using interference filters or suitable slit arrangements. The intensity of light is measured by the phototube. The filter of the flame photometer is set at 766.5 nm (marked for Potassium, K) the flame is adjusted for blue colour. The scale is set to zero and maximum using the highest standard value. A standard curve of different concentration is prepared by

feeding the standard solutions. The sample is filtered through the filter paper and fed into the flame photometer. The concentration is found from the standard curve or as direct reading [17].

2.3.5 Chloride

Chloride was measured by titration method [17]. 50 mL of sample in a conical flask was taken. 2 mL of Potassium chromate was added to the sample solution. It was titrated against 0.02N silver nitrate until a persistent brick red color was appeared which the end point of the titration. A blank by placing 50 mL of chloride free distilled sample water was also conducted.

Calculation:

$$\text{Chloride (mg/L)} = (a-b) \times N \times 35.5 \times 1000V$$

Where,

a = Volume of titrant (silver nitrate) for sample
b = Volume of titrant (silver nitrate) for blank

V = Volume of the sample in mL
N = normality of silver nitrate.

2.4 Analysis of Microbial Variables

Microbiological examination of drinking water is an attempt to determine the relation of the possible transmission of water borne disease. It is usually not practical to examine water supplies for the various pathogens that may be present. Therefore, the routine monitoring of water is based on the testing of indicator organisms.

2.4.1 Total viable bacterial count

A plate count like the Heterotrophic Plate Count (Total viable bacterial count) is commonly determined using the pour plate technique. 1 ml of a water sample or a decimal dilution series is transferred to separate Petri dishes. 15 ml of Nutrient agar medium is then added to each Petri dish (no stacking of plates when pouring agar). The sample is thoroughly mixed by rotation (three times left, three times right and once through the centre). The agar is left to solidify (no stacking of plates during solidification) on a flat level, preferably cool, surface. After complete solidification (check by ticking the Petri dish on the side; solidification occurs latest in the centre) the plates are inverted and incubated (Bacteriological analytical manual requires 48 ± 2 h at 35°C). Plates showing 25 to 250 colonies (including pinpoint colonies) should be considered in determining the standard plate count. A count is designated as standard plate count at temperature of incubation. The incubation temperature can either be 20, 30 or $35\text{-}37^{\circ}\text{C}$. Depending on incubation temperature and atmosphere, the counts are termed psychotropic aerobic or anaerobic standard count (20°C) or mesophilic aerobic or anaerobic plate counts (30 or $35\text{-}37^{\circ}\text{C}$) [17].

2.4.2 Total coliform and fecal coliform

Total coliform (TC) was measured by Most Probable Number method and MacConkey agar plate was used for the enumeration of gram-negative bacteria count at 37°C for 48 hours' presumptive test and BGLB (Brilliant Green Lactose Bile) at 37°C for 48 hours for conformation. For estimating the fecal coliform bacteria, 100 ml of water sample was passed through the membrane filter which was then put over MFC medium and incubated at 44.5°C for 48 hours [17].

2.5 Statistical Analysis

Correlation among various water quality parameters were analyzed by using SPSS 25.

3. RESULTS

3.1 Physicochemical Parameters

In this study, physicochemical parameters were analyzed to determine the groundwater quality. Physicochemical parameter pH, TDS, salinity, EC, Turbidity, DO, Total hardness, phosphate, sulphate, potassium, chloride were measured in collected groundwater samples. The average values of the physicochemical parameters of various locations are given in Table 1. And the values are compared with standard value of drinking water by WHO and Bangladesh standard [18]. Maximum tube-wells contain huge amount of TDS (6040 mg/l), EC ($1786 \mu\text{s}/\text{cm}$), Salinity (6.8%) and hardness (1050 mg/l) which exceeded the standard limit recommended by WHO and Bangladesh standard. But DO, Potassium, Sulphate, Chloride, and Phosphate were within limit.

3.2 Microbial Variables

The analysis of microbial parameters (Table 2) showed the presence of bacteria in many of the water samples. Maximum value of the Total coliform found from the ground water was TNTC (Too numerous to count) and fecal coliform was 3×10^1 CFU/ml.

3.3 Correlation Analysis

Correlations among various physicochemical parameters were showed in Table 3.

4. DISCUSSION

Water quality refers to the physical, chemical and biological characteristics of water. In the present study various physicochemical Parameters such as pH, EC, TDS, Salinity, Hardness, Turbidity, DO, Chloride, Potassium, Sulphate, Phosphate ions and microbial variables were analyzed. pH is the negative logarithm of hydrogen ion concentration. It is used to express the intensity of acidic or alkaline condition of a solution. The maximum and minimum range was found (6.8-7.9) which was within the recommended limit and this range satisfies WHO and BD standard 6.5 to 8.5. TDS values indicate the general nature of water quality and are usually related to conductivity [19].

Table 1. The average values of physicochemical parameters of different sampling locations

Sample ID	pH	EC ($\mu\text{s}/\text{cm}$)	TDS (mg/l)	Salinity (%)	Turbidity (NTU)	Hardness (mg/l)	DO (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)	K^+ (mg/l)	Cl^- (mg/l)
1	7.335	307	3090	1.6	11.25	513	7.39	0.605	7.205	0.01	21.98
2	7.245	645	6040	3.3	20.25	822	7.355	0.39	29.97	0.086	1524.35
3	7.3	525.2	5295	2.9	3.95	687	7.37	0.405	25.34	0.0835	1147.865
4	7.62	320.0	4200	2.25	3.645	385	7.35	0.385	23.775	0.044	860.015
5	7.375	257.8	2350	1.2	10.92	263	7.34	0.42	17.685	0.039	368.68
6	7.405	876	776	0.4	1.285	283	7.32	0.605	5.285	0.0245	370.805
7	7.435	1134	1135.5	0.5	1.375	257	7.3	0.51	12.135	0.029	152.43
8	7.075	880	850.5	0.4	7.065	229	7.29	0.465	5.755	0.0245	162.36
9	7.155	598	494	0.2	8.05	155	7.28	0.44	26.765	0.0925	177.955
10	7.16	363.5	463.5	0.1	5.78	138	7.29	0.52	20.825	0.022	29.78
11	7.16	470.5	470	0.1	8.575	141	7.3	0.53	14.36	0.0305	24.105
12	7.4	576.5	5765	3.15	3.085	592	7.31	0.54	26.085	0.068	687.73
13	7.7	858.5	957.5	0.4	3.3	171.5	7.27	2.34	4.68	0.035	85.08
14	7.9	229	2255	1.1	4.7	99	7.24	4.87	3.21	0.029	472.91
15	7.4	1631	1632.5	0.8	20.3	320	7.32	0.09	9.65	0.047	308.4
16	6.8	1373	1572.5	0.8	99.9	300	7.21	0.7	50.25	0.011	211.62
17	7.5	844.5	844	0.4	1.5	90	7.22	0.77	153.8	0.023	115.59
18	7.8	287.5	2870	1.5	10.6	300	7.26	3.93	36.76	0.047	649.44
19	7.5	1103	1202	6.8	35.9	780	7.32	1.21	32.17	0.098	3701.69
20	7.4	826	826	0.3	43.4	210	7.2	0.77	9.17	0.046	243.9
21	7.6	374	972.5	0.4	7	300	7.24	1.31	4.6	0.046	63.81
22	7.4	1786	1736.5	0.9	19.8	610	7.2	0.9	32.19	0.046	419.02
23	7.4	861	760.5	0.3	7.14	1050	7.19	0.93	24.52	0.07	1923.71
24	7.6	435	958.5	2.3	6.9	560	7.23	0.77	22.86	0.05	1293.14
WHO standard	6.6-8.5	1000	<1000	0	5	200-500	4-6	-	200-600	-	150-600
BD standard	6.5-8.5	-	1000	0	10	200-500	4-6	6	400	12	150-600

Table 2. Total viable count

Sample ID	TVBC. (CFU/ml)	TC (CFU/ml)	FC (CFU/ml)
1	4.7×10^2	5×10^1	0
2	1.3×10^2	3×10^1	0
3	1.1×10^2	2×10^1	0
4	1.2×10^2	1×10^2	0
5	1.42×10^2	6×10^1	0
6	0	0	0
7	1×10^2	1×10^1	0
8	3×10^1	1×10^1	2×10^1
9	5.2×10^2	8×10^1	3×10^1
10	7×10^1	5×10^1	0
11	TNTC	2.8×10^2	3×10^1
12	1×10^1	0	0
13	2.7×10^2	2.5×10^2	0.1×10^2
14	7.7×10^2	2.6×10^2	0.3×10^2
15	2.8×10^2	2.3×10^2	0
16	3.3×10^2	0	0
17	1.9×10^2	1.2×10^2	0
18	1.5×10^2	4.0×10^2	0
19	4.2×10^2	1.7×10^2	0
20	3.6×10^2	0.2×10^2	0
21	1.0×10^2	1.7×10^2	0
22	4.3×10^2	0.7×10^2	0
23	4.0×10^2	1.0×10^2	0.3×10^2
24	TNTC	4.0×10^2	0
BD Standard	-	0	0
WHO Standard	-	0	0

Generally, the standard limit for TDS is <1000 mg/l which is recommended by WHO. The maximum and minimum range was found 6040 mg/l -463.5 mg/l. Among these values most of them are not within an acceptable limit. These values are determined the higher amount of TDS, Higher amount of TDS in Ground water may be due to the seawater intrusion in the coastal region [15]. Water containing more than 500 mg/l of TDS is not considered desirable for drinking for drinking supplies. Water containing high solid concentration may cause constipation effects high level of TDS may aesthetically be unsatisfactory for bathing and washing [20].

The experimental analysis of electrical conductivity (EC) was carried out for the groundwater samples. It was found that the maximum and minimum ranges were found (1786-229 $\mu\text{s}/\text{cm}$) and they were not complying with standard limit of EC for drinking water is 1000 $\mu\text{s}/\text{cm}$ [21]. The results indicate that the water samples contained higher levels of dissolved mineral salts. The medium level of EC may be due to the bit higher concentration of the ionic constituents present in the water bodies. Organic compounds do not have much influence on EC because organic compounds are not very

good electrical conductors [22]. Usually standard limit of salinity for drinking water is zero [21]. The present study revealed that maximum salinity value 6.8%, and minimum value was 0.1% which was not in line with recommended limit. Khan et al. [13] reported that hypertensive disorders were associated with salinity in drinking water. Furthermore, reducing salt consumption from the global estimated levels of 9–12 g/day [23] to an acceptable limit of 5 g/day [24] would be predicted to reduce blood pressure and stroke/cardiovascular disease by 23 and 17%, respectively [25].

Standard limits for hardness are 200-500 mg/l which is recommended by WHO and Bangladesh Standard. The maximum value was 1050 mg/l and the minimum value was 90 mg/l. In this study, all the values were not found within acceptable limits. Hardness is imparted to the water mainly by calcium and magnesium ions. Total hardness was found positively correlated with TDS, chloride [19]. According to WHO and Bangladesh Standard guideline, the allowable turbidity for drinking water is 5 NTU and 10 NTU respectively. The maximum and minimum range was found (99.9-1.5NTU) in the present study.

Table 3. Correlation analysis

Correlation probability	Cl ⁻ mg/l	DO (mg/l)	EC (µs/cm)	K ⁺ mg/l	pH	PO ₄ ³⁻ mg/l	Salinity (%)	SO ₄ ²⁻ mg/l	TDS (mg/l)	Total Hardness (mg/l)	Turbidity (NTU)
Cl ⁻ mg/l	1										
DO (mg/l)	0.50**	1									
EC (µs/cm)	-0.52**	-0.65***	1								
K ⁺ mg/l	0.69***	0.04	-0.40	1							
pH	0.30	0.44	-0.21	-0.06	1						
PO ₄ ³⁻ mg/l	-0.62***	-0.12	0.39	-0.62***	-0.04	1					
Salinity(%)	0.86***	0.65***	-0.73***	0.54**	0.41	-0.39	1				
SO ₄ ²⁻ mg/l	0.65***	0.07	0.60***	0.84***	0.07	-0.66***	0.58***	1			
TDS (mg/l)	0.86***	0.66***	-0.73***	0.53**	0.42	-0.38	0.99***	0.58***	1		
THardness(mg/l)	0.84***	0.71***	-0.60***	0.50**	0.26	-0.26	0.93***	0.44	0.93***	1	
Turbidity (NTU)	0.32	0.33	-0.46	0.25	-0.37	-0.32	0.27	0.27	0.27	0.37	1

*** indicates highly significant at 95% confidence level and ** indicates significant at 90% confidence level

The maximum and minimum range of DO was found (7.39-7.19) mg/l and these ranges satisfy WHO and Bangladesh Standard 4 to 6. DO levels in water are affected by numerous features such as water heat levels, salt content and atmospheric pressure. Adequate DO is necessary for good water quality [26]. According to WHO, permissible limit for chloride is (150 to 600) mg/l and the maximum and minimum range were found (3701.69-21.98 mg/l) and all the value was not within acceptable limit.

It was found that the maximum and minimum range of sulphate was 0.098-0.011 mg/l which is within the recommended limit and this range satisfies Bangladesh standard. According to WHO and BDS guideline, the allowable sulphate for drinking water is (200 to 400) mg/l respectively. Maximum and minimum range of phosphate was found 153.8-3.21 ppm and all of values found were not within the recommended limit. Generally, the standard limit for Phosphate is 6 which are recommended by WHO. The maximum and minimum range of phosphate was found (4.87-0.65 mg/l) and all the values were within the acceptable limit. Though in low concentration, phosphate is an important nutrient present in water but the high amount of phosphorus in form of phosphates in aquatic environment is a major cause of eutrophication [27].

Correlation among various water quality parameters were analyzed by using SPSS software. Statistically insignificant correlations are not shown. The sign of the correlation coefficient determines whether the correlation is positive or negative. The magnitude of the correlation coefficient determines the strength of the correlation. Correlation is an effect size and so we can verbally describe the strength of the correlation using the guide [28] that suggests for the absolute value of r . The correlation matrix shows that potassium, salinity, SO_4^{2-} , TDS, Total Hardness is strongly positively correlated with chlorine (Table 3). Salinity, SO_4^{2-} , TDS, Total hardness are strongly positively correlated with DO. Only SO_4^{2-} is strongly positively correlated with EC. Salinity is strongly positively correlated with sulfate. TDS is strongly positively correlated with Total Hardness. Increase in one variable also increases other variables. Strong positive correlation indicates that variables may come from same source.

On the other hand, EC is strongly negatively correlated with chloride, DO, salinity, Total

hardness, TDS. Phosphate is also strongly negatively correlated with sulphate. That means increase in one parameter decrease the other. Thus, based on the above data set it was concluded that the correlation studies of the water quality parameters have a great significance in the study the relatively high positive correlation between some chemical parameters signifies a common origin or progressive enrichment of both parameters.

Most of the life-threatening pollutants present in drinking water are of biological origin [29]. It is an established fact that polluted drinking water can spread dangerous disease like hepatitis, cholera, dysentery, typhoid and diarrhea. Among these waterborne diseases the most important one is diarrhea [30]. Toslim et al. [14] also reported in 2016 that there is no contamination-free tube-well water in Bangladesh. According to WHO guideline value, the values of TC and FC should remain zero but the result (Table 2) showed the values were excessively above than the WHO guideline. Many authors have reported waterborne disease outbreaks in water meeting the coliform regulations [31]. The highest value of TVBC was found in Sample 11 where Total viable Bacterial count was TNTC. The present study showed that all samples are contaminated by microorganisms.

5. CONCLUSION

From the results it can be concluded that all the physicochemical parameters measured were not within the acceptable limits except pH, potassium, sulphate, phosphate and the microbial parameters did not match with the recommended level. 6.8% of salinity in ground water really threatening to life. Groundwater contaminations often correlate with areas of poor hygienic standards and sanitation. Literature also shows some of these water sources were also contaminated by their mineral-rich soils and sediments. Result of the study also indicated that almost all the samples from different locations were biologically contaminated which is the result of poor sanitization in surrounding area. So, water quality should be analyzed on the regular basis to know the correct data of all parameters. Further a gross hydro-geological investigation should be conducted to understand the ground water flow.

Finally, the present study draws the following recommendations for meeting the present as well as future water demands.

- Rainwater Harvesting must be provided and should be made compulsory for each residential unit as it is considered as the sustainable solution.
- Groundwater assessment and estimation study should be conducted each year for better understanding of groundwater quality variation.
- Public awareness programs need to be developed for sustainable management of groundwater.
- Government as well as NGO's should come forward to supply safe and adequate drinking water in this coastal region.
- Further intensive research and continuous monitoring is required to know overall groundwater and surface water quality of the greater Noakhali region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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