Assessment of Changes in Drinking Water Quality Before and After Floods in Jamalpur District Primary Schools of Bangladesh

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DOI: https://doi.org/10.51244/IJRSI.2024.11150075P

Received: 05 December 2024; Accepted: 16 December 2024; Published: 15 January 2025

ABSTRACT

Water is essential for the survival and health of living organisms. In rural Bangladesh, 96% of the population relies on untreated water from shallow tube wells, but groundwater quality has declined, posing health risks, particularly to children. This study aims to assess the drinking water quality in flood-prone areas and its potential health risks to primary school children. A cross-sectional, quantitative approach was adopted, focusing on physicochemical parameters such as Total Dissolved Solids (TDS), Turbidity, and Electrical Conductivity (EC). Paired sample t-tests revealed significant post-flood increases in water contamination. TDS rose by an average of 532.818 mg/L ($p < .001$), EC increased by 1040.727 µS/cm ($p < .001$), and Turbidity escalated by 8.617 NTU ($p < .001$), while pH levels slightly decreased by 0.492 units ($p = .004$). These findings underscore the adverse impact of floods on water quality, highlighting the increased risk of consuming contaminated water for schoolchildren in these areas. Despite these changes, the study concludes that the drinking water quality in the selected primary schools of the Jamalpur district still meets WHO and Bangladesh safety standards. However, continuous monitoring is recommended to ensure the ongoing safety of drinking water and protect public health in flood-affected regions.

Key Words: Drinking water quality, Health risk, Primary school, Pre-flood, Post-flood, Physicochemical

INTRODUCTION

Water is the most crucial resource for sustaining life (WHO, 2011). Water is an essential component for all forms of life on Earth. Only 3% of the Earth's water is freshwater, and less than 0.01% of this freshwater is accessible for human use. Unfortunately, this limited amount of available drinking water, both surface and groundwater, is increasingly being polluted by various contaminants such as coliform bacteria, toxic metals, pesticides, and other emerging pollutants worldwide (Li et al., 2021; Parvin et al., 2022). Safe drinking water is crucial for human health (Dinka, 2018). Trace element impurities in surface and groundwater pose significant health risks, particularly for children who are more vulnerable to toxic metals. Thus, it is essential to monitor potable water for trace elements and assess their physicochemical properties (Rahman et al., 2016). Bangladesh, a highly populated and developing nation, has recently experienced significant issues with water pollution, scarcity, and security. In this country, 75% of the population without access to piped water systems rely on hand tube wells, and 96% of rural residents depend entirely on untreated groundwater for their daily needs. Over the past two to three decades, the quality of groundwater in Bangladesh has become a major concern. Most rural inhabitants use untreated shallow groundwater from privately owned hand tube wells, typically at depths of 20-40 meters (Shajedul, 2022). Groundwater is the world's largest and most crucial source of fresh potable water, serving an estimated 1.5 billion people daily and being the most reliable resource for meeting rural water demands. Groundwater quality can vary significantly depending on location, seasonal changes, and the types of soils, rocks, and surfaces it passes through (Chowdhury and Rahnuma, 2023). Analyzing the physical, chemical, and bacteriological properties of natural water, including trace elements, is essential for public health studies, particularly for children. These analyses are also a key component of environmental pollution studies. Children

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XI Issue XV December 2024 | Special Issue on Public Health

aged 5-10 are drinking water from the investigated sources, and approximately five thousand children attend the school each year. Both the schoolchildren and local villagers rely on these tube-well water sources for their drinking water (Rahman et al., 2015). To achieve true development, it is crucial to ensure the comprehensive growth of a nation's children, encompassing both intellectual and emotional development, so they can support and advance the nation in all respects (*DPHE_ EMR_ July to Dec 20.Pdf*, n.d.). According to the World Health Organization (WHO), approximately 2.2 million individuals worldwide, including 1.9 million children, succumb to various foodborne and waterborne diarrheal diseases annually (Mou et al., 2023). Drinking water sources are increasingly polluted by both natural and human activities, including natural geochemical processes, urbanization, industrial development, and agricultural practices (Kormoker et al., 2022). In this study, the drinking water of a primary school in Jamalpur district, Bangladesh, was monitored to ensure its safety for the school children. Jamalpur, being a flood-prone district, experiences annual flooding, which significantly impacts the physicochemical parameters of groundwater and compromises the quality of potable water. The aim of this study is to assess the health risks to children in the post-flood period when the groundwater quality is affected.

METHODOLOGY

The cross-sectional method was applied to conduct the study. To accomplish the aim of the research targeted locations were visited and a GIS-based illustration was provided. A coordinated and systematic approach was adopted for collecting and processing data and for other purposes.

Study Area

Jamalpur district is located between latitudes 24° 40′ N to 25° 20′ N and longitudes 89° 40′ E to 90° 10′ E. The district is prone to frequent flooding due to the presence of the Jamuna and old Brahmaputra rivers, making it a hotspot in the river system and estuaries(Hoque et al., n.d.). It falls within the floodplain of Brahmaputra. The annual average temperature ranges from a maximum of 33.3°C to a minimum of 12°C. The average annual rainfall is 2174 mm, and the average annual humidity is 79.3%. Agriculture is the primary source of income due to the low literacy rate and education (38.44%). The district experiences flooding at least once a year due to its geographical location and the presence of both the Jamuna and Brahmaputra rivers. The most recent flood saw the Jamuna river rise by 38 cm, reaching 64 cm above the red mark (19.50 m) at Bahadurabad ghat point, as reported by the Bangladesh Water Development Board. A total of 13 unions in Islampur and Dewanganj upazilas were affected by this flood (Nahin et al., 2023).

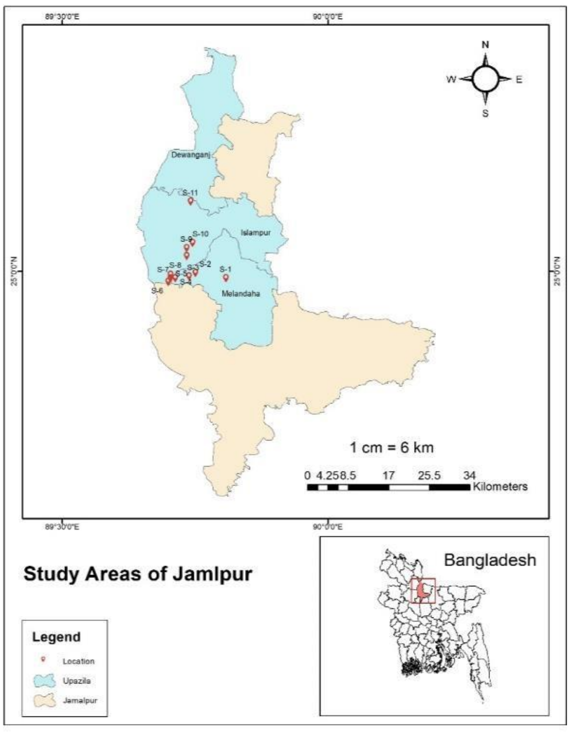

Figure 1: Study area of the flood-prone areas indicating the points of sampling

Sample Site Selection

A flood is the overflow of a significant amount of water beyond its usual boundaries, inundating areas that are typically dry. Floods can damage public infrastructure, properties, agriculture, and the economy, and may even result in the loss of human lives (Ogoko et al., 2015). Choosing the sampling sites was a critical component of this study. The process of selecting these sites was meticulously planned and carried out to guarantee that the collected data would be precise and truly representative of the study area. The sites were selected according to their geology and exposure to flood vulnerabilities.

Table 1: List of Sampling Sites

Sample No.	School Names	Upazilla	Longitude	Latitude
S-1	Gobindapur Govt. Primary School	Melandaha	89.80726	24.98705
S-2	13 no West Mahmudpur Govt. Primary School	Melandaha	89.74952	24.99685
S-3	Chor Mahmudpur Govt. Primary School	Melandaha	89.73773	24.99024
S-4	18 no, Chorgobindi Govt. Primary School	Melandaha	89.7118	24.98676
S-5	29 no Shukhchor Govt. Primary School	Islampur	89.70303	24.99349
S-6	Kathma Govt. Primary School	Islampur	89.69882	24.97985
S-7	54 no Bir Toga Govt. Primary School	Islampur	89.70253	24.98632
S-8	Korirtair M.H. Govt. Primary School	Islampur	89.73337	25.02971
S-9	Dokkhin Chinaduli Govt. Primary School	Islampur	89.7333	25.04479
S-10	Debrai Pech Govt. Primary School	Islampur	89.7444	25.05496
S-11	Shashariabari Govt. Primary School	Islampur	89.74083	25.13448

Data Collection

All the data are collected as primary data using feasible and portable water-quality multiparameter HANNA-HI9811-51 and turbidity meter Lutron TU- 2016. These instruments provide a high level of accuracy and portability which make it an ideal choice for field data collection. The monitor was placed at the desired locations to collect comprehensive data. Eleven precise locations were selected to collect the desired data. Samples were collected on-site. The initial samples were gathered in March 2024, a time when this region experiences the onset of Spring. During this period, precipitation is minimal, ensuring that the water table remains undisturbed. Proper guidelines and instructions from the supervisor were followed to preserve the purity and accuracy of data. It ensured the robust and comprehensive analysis of collected data. The second phase of data collection was conducted in July 2024, during a period of severe flooding caused by heavy rainfall and the overflow of the Jamuna River. The focus was on low-lying areas that were significantly impacted by the flood. To ensure the accuracy and reliability of the data, necessary precautions were taken to eliminate errors and ensure pure data collection.

Data Processing and Cleaning

After collecting the data, it was essential to process it to guarantee its quality and readiness for analysis. This involved a meticulous cleaning process to eliminate any errors or inconsistencies that might have arisen during data collection. To ensure the data met the required standards and was suitable for analysis, quality checks were performed. Furthermore, the data was transformed into an appropriate format for efficient analysis. MS Excel was utilized for data preprocessing, leveraging its various tools and functions for data manipulation, filtering, and aggregation. This step was crucial to maintain the accuracy and reliability of the subsequent analysis results. Statistical analysis of parameters was conducted by SPSS Statistics 26 software. The entire data processing phase was overseen by the supervisor, who ensured that all procedures adhered to the recommended guidelines for data analysis.

Standards of Water Physicochemical Parameters

Table 1: Standards of Drinking water according to WHO and Bangladesh

Parameters	WHO	Bangladesh Standards
Temperature (ºC)	30	20-30
pH	6.5-8.5	6.5-8.5
Turbidity (NTU)	5	10
Electrical Conductivity (µS)	1000	1000
Total Dissolved Solids (mg/l)	500	1000

Source: (Chowdhury and Chowdhury, 2021); Water Quality Parameters Bangladesh Standards & WHO Guide Lines, 15 May, 2019.

Project Framework

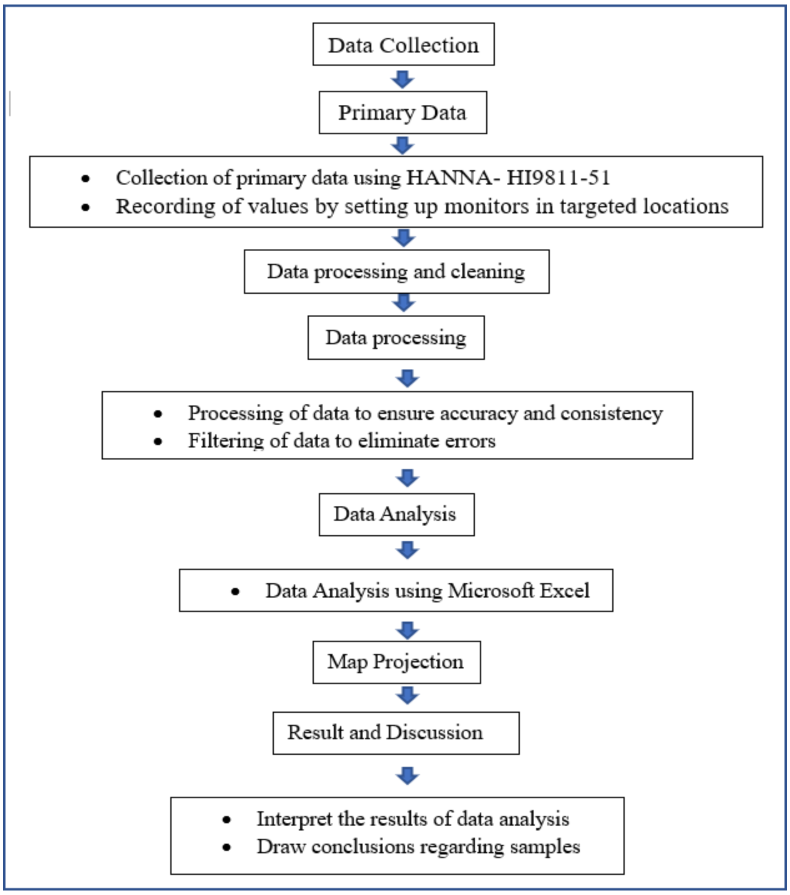

Figure 2: Framework of the project describing the workflow

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XI Issue XV December 2024 | Special Issue on Public Health

RESULT AND DISCUSSION

The physicochemical properties of water reflect the condition of water and their mischief can be a threat to children's health. pH measures the acidity or alkalinity of water. According to WHO and BDS standards, the pH of water should range between 6.5 and 8.5. Reduced photosynthetic activity leads to lower assimilation of carbon dioxide and bicarbonates, which in turn increases pH levels. Additionally, factors such as temperature can alter the pH of water. Higher pH values indicate that changes in the physicochemical conditions are significantly affecting the carbon dioxide and carbonate-bicarbonate equilibrium. Electrical conductivity (EC) quantifies a solution's ability to conduct an electric current. It depends on the concentration, mobility, and valence of the ions present. As ion concentration increases, the electrical conductivity of the water also rises (Bilewu et al., 2022; Rahman et al., 2015). Turbidity measures the cloudiness of water caused by fine suspended colloidal particles such as clay or silt, waste effluents, or microorganisms. It is measured in nephelometric turbidity units (NTU). Turbidity measures the cloudiness of water caused by fine suspended colloidal particles such as clay or silt, waste effluents, or microorganisms. It is measured in nephelometric turbidity units (NTU). Total dissolved solids (TDS) primarily consist of calcium, magnesium, sodium, bicarbonates, chlorides, and sulfates. TDS levels can affect the taste of drinking water (Chukwu, 2008). All the parameters that are considered during the first sampling to assess the condition of drinking water were within the standard level and it can be certified safe to consume.

Pre-Flood Condition:

Precipitation affects regional groundwater hydrochemistry by increasing recharge, which reduces ion concentration in groundwater due to the low ion content in rainwater(Liu et al., 2023). Parameters were considered before the monsoon to assess the pre-flood condition. To monitor the quality of drinking water in the primary schools of Jamalpur district, the parameters pH, EC (electrical conductivity), TDS (total dissolved solids), and turbidity have been selected. Many of these schools are affected by floods and are also used as shelters for local residents during such events. The status of drinking water quality in the pre-flood period is presented here.

Table 3: Measured values of parameters in pre-flood condition

Sample No.	pH	TDS	Turbidity	EC	Temperature
S-1	6.75	87	3.1	168	26.1
S-2	6.55	421	2.2	841	26
S-3	7.02	200	10	400	27.36
S-4	7.46	259	3.7	518	26.86
S-5	6.81	255	7	510	27.74
S-6	7.6	308	0.1	616	26.9
S-7	6.75	330	3.1	660	26.75
S-8	6.74	422	0.2	844	26.9
S-9	6.76	276	0.7	552	26.4
S-10	7.57	230	2	460	26.34
S-11	7.44	165	3.6	330	25.23

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TDS (Total Dissolved Solids):

The pre-flood data in Figure 3 from primary schools in Jamalpur district show that all measured Total Dissolved Solids (TDS) levels fall within the permissible limits set by the Bangladesh standard of 1000 mg/l and the WHO standard of 500 mg/l. Notable findings include Sample S-1, which had the lowest TDS level at 87 mg/l, significantly below both standards and Sample S-8, which recorded the highest TDS level at 422 mg/l, approaching but still within the WHO limit. Similarly, Sample S-2 had a relatively high TDS level of 421 mg/l, close to the WHO threshold. Overall, the TDS levels indicate that the water quality in these schools was safe, especially regarding dissolved solids before the flood.

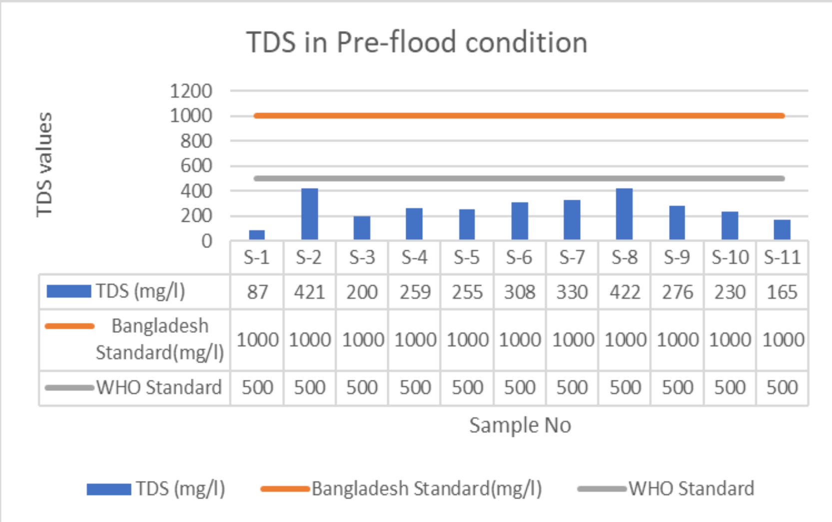

Figure 3: Showing the pre-flood condition of TDS (Total Dissolved Solids) of selected primary schools

EC (Electric Conductivity):

Figure 4 illustrates the pre-flood Electrical Conductivity (EC) data for primary schools in the Jamalpur district, showing that all samples were well within the permissible limit of 1000 µS/cm, as specified by both Bangladesh and WHO standards. Sample S-1 recorded the lowest EC value at 168 µS/cm, indicating very low ionic content in the water. In contrast, the highest EC values were observed in Samples S-8 and S-2, at 844 µS/cm and 841 µS/cm, respectively, both of which are still significantly below the allowable limit. These findings suggest that, before the flood, the water quality in terms of electrical conductivity was within safe limits.

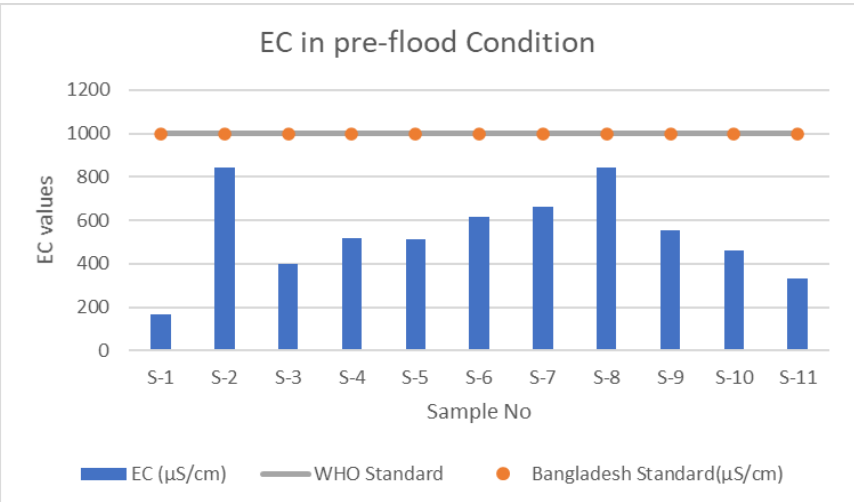

Figure 4: Showing the pre-flood condition of EC (Electric Conductivity) of selected primary schools

Turbidity:

Figure 5 presents the pre-flood turbidity data for primary schools in the Jamalpur district, indicating that most

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samples comply with Bangladesh's standard of 10 NTU, though several exceed the WHO guideline of 5 NTU. Notably, Sample S-3 recorded the highest turbidity at 10.04 NTU, slightly exceeding both standards. Sample S-5 also showed elevated turbidity at 7.01 NTU, surpassing the WHO limit but remaining within the Bangladesh standard. On the lower end, Samples S-6 and S-8 exhibited very low turbidity levels of 0.12 NTU and 0.18 NTU, respectively, suggesting clearer water. Overall, while the majority of samples meet the Bangladesh standard, a few exceed the stricter WHO guidelines, indicating varying levels of water clarity across the schools prior to the flood.

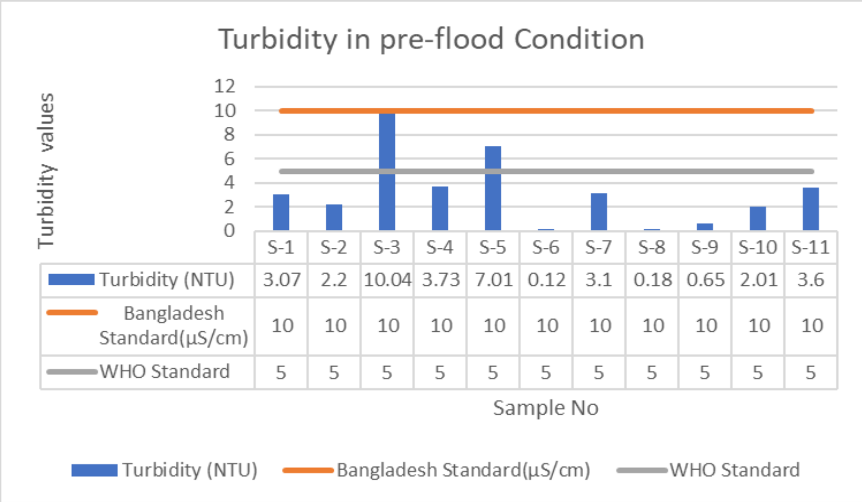

Figure 5: Showing the pre-flood condition of Turbidity of selected primary schools

pH (potential of Hydrogen):

Figure 6 takes a closer look at the pre-flood pH levels in water samples from primary schools across Jamalpur district, showing that every sample falls comfortably within the safe range of 6.5 to 8.5, as outlined by both Bangladesh and WHO guidelines. Standing out among the samples, S-4 had the highest pH at 7.46, while S-10 was slightly more alkaline at 7.57. On the other end of the spectrum, Sample S-2 had the lowest pH at 6.55, but it still stayed well within acceptable boundaries. These findings paint a reassuring picture: before the flood, the water's pH levels in these schools were well within the safety zone, offering a measure of consistency in water quality across the board.

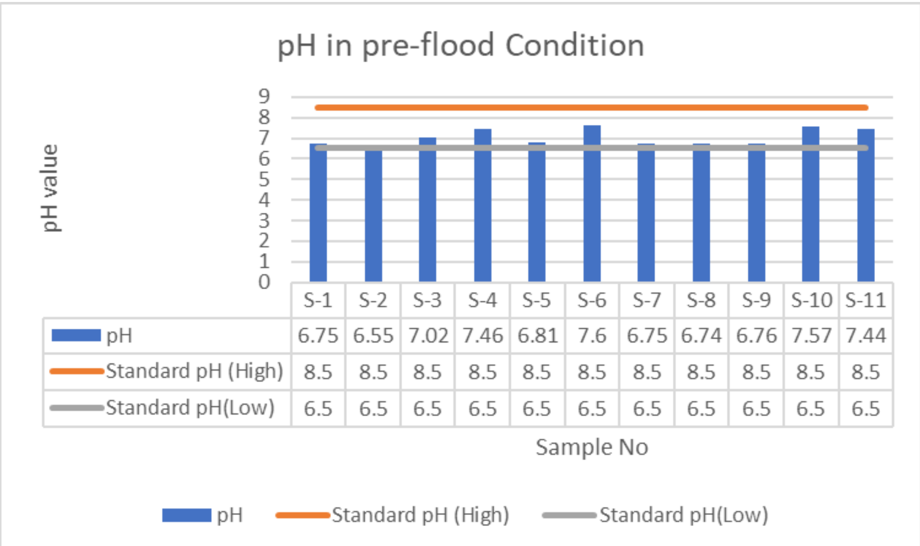

Figure 6: Showing the pre-flood condition of pH (potential of Hydrogen) of selected primary schools

Post Flood Conditions:

Floodwater creates numerous health issues due to factors such as damage to water supply systems, inadequate access to clean drinking water, and disruptions to transportation networks(Sun et al., 2016). Due to the effect of flood, the water table gets disturbed and the drinking water becomes contaminated. Changes in the measured parameters for drinking water quality are noticeable. It indicates that in most of the cases the safety level for drinking water is disrupted.

Table 4: Measured values of parameters in post-flood condition

Sample No.	School Names	pH	TDS (mg/l)	Temperature (°C)	Turbidity (NTU)	EC (µS/cm)
S-1	Gobindapur Govt. Primary School	6.4	639	29.6	11.7	1286
S-2	13 no West Mahmudpur Govt. Primary School	6.47	575	29.7	10.8	1155
S-3	Chor Mahmudpur Govt. Primary School	6.95	520	29.6	17.6	1044
S-4	18 no, Chorgobindi Govt. Primary School	6.72	530	29.8	11.8	1060
S-5	29 no Shukhchor Govt. Primary School	6.38	690	29.7	14.5	1375
S-6	Kathma Govt. Primary School	6.23	1075	29.5	8.7	2167
S-7	54 no Bir Toga Govt. Primary School	6.82	890	29.6	11.6	1774
S-8	Koritair M.H. Govt. Primary School	6.34	1195	29.7	9.2	2356
S-9	Dokkhin Chinaduli Govt. Primary School	6.44	1050	29.7	10.7	1900
S-10	Debrai Pech Govt. Primary School	6.45	1090	29.6	11.2	2120
S-11	Shashariabari Govt. Primary School	6.84	560	29.8	12.7	1110

TDS (Total Dissolved Solids):

Figure 7 highlights the Total Dissolved Solids (TDS) levels in drinking water samples collected from a primary school after a flood. The samples were assessed against the Bangladesh standard of 1000 mg/l and the stricter WHO standard of 500 mg/l. While most samples—such as S-1, S-2, S-3, S-4, S-5, S-7, and S-11—stay within the Bangladesh limit, they still exceed WHO's recommended guidelines, indicating the water may not meet ideal safety standards for consumption under WHO criteria. More concerning are Samples S-6, S-8, S-9, and S-10, which surpass both standards, with Sample S-8 showing the highest TDS level at 1195 mg/l. These elevated TDS levels raise serious concerns about the safety of drinking water for school children, as they suggest a higher likelihood of harmful contaminants being present in the water.

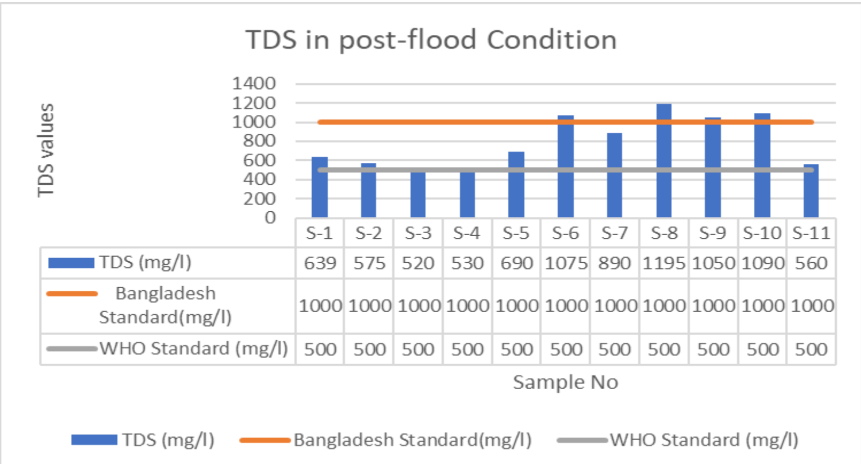

Figure 7: Showing the post-flood condition of TDS (Total Dissolved Solids) of selected primary schools

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XI Issue XV December 2024 | Special Issue on Public Health

EC (Electric Conductivity):

Figure 8 showcases the Electrical Conductivity (EC) levels in water samples taken from a primary school after a flood, comparing them against both the Bangladesh and WHO standards, which are set at 1000 µS/cm. Alarmingly, every sample exceeds these thresholds, pointing to a significant increase in dissolved salts and minerals. Samples S-6, S-8, S-9, and S-10 stand out, with Sample S-8 recording the highest EC level at 2356 µS/cm. This raises red flags about the water quality, as elevated EC can affect water's taste and often signals potential contamination. The consistent violation of both national and international standards across all samples highlights an urgent need for water quality improvements to ensure safe drinking water for the students.

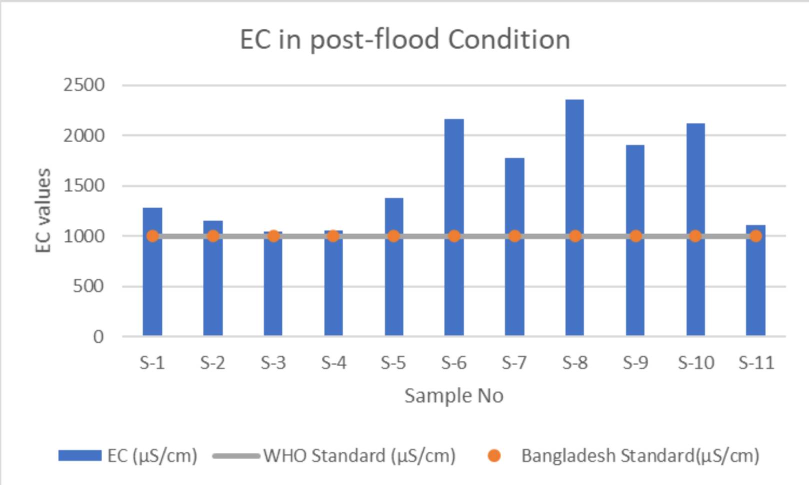

Figure 8: Showing the post-flood condition of EC (Electric Conductivity) of selected primary schools

pH (potential of Hydrogen):

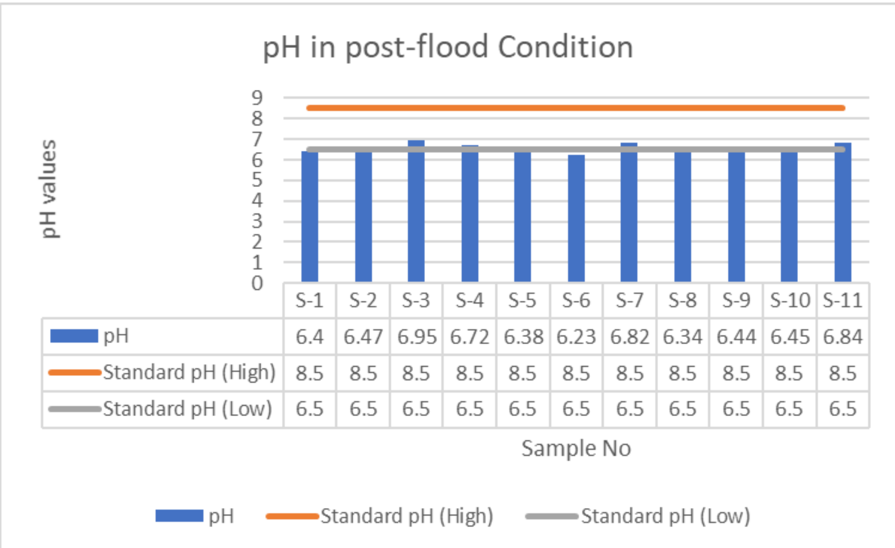

Figure 9: Showing the post-flood condition of pH (potential of Hydrogen) of selected primary schools

Figure 9 shows the pH levels of water samples taken from a primary school in a post-flood scenario, compared against the acceptable range of 6.5 to 8.5 as per both Bangladesh and WHO standards. The data indicates that all samples fall below the lower threshold of the recommended range, with pH values ranging from 6.23 to 6.95. Notably, samples S-1, S-2, S-5, S-6, S-8, S-9, and S-10 have pH levels particularly close to the lower end, with sample S-6 at 6.23 being the most acidic. This indicates a slight acidity in the water, which could be problematic for consumption, as water with pH levels below 6.5 can lead to corrosion of pipes and fixtures, potentially introducing metals and other contaminants into the water supply. The observed acidity suggests the need for immediate attention to adjust the water pH to safer levels for drinking, ensuring the health and safety of the schoolchildren.

Turbidity:

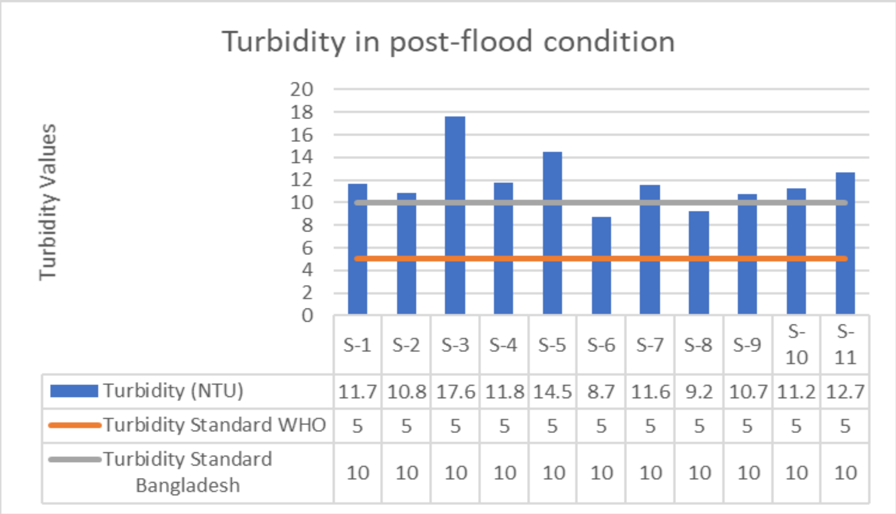

Figure 10: Showing the post-flood condition of Turbidity of selected primary schools

Figure 10 presents a graphical representation of turbidity levels in drinking water samples taken from a primary school, highlighting the potential health risks for children. The data shows that all 11 samples (S-1 to S-11) exceed the WHO turbidity standard of 5 NTU, with values ranging from 8.7 NTU to 17.6 NTU. Specifically, sample S-3 exhibits the highest turbidity at 17.6 NTU, followed by S-5 at 14.5 NTU, and S-11 at 12.7 NTU. These elevated turbidity levels surpass the Bangladesh standard of 10 NTU in several samples, indicating a serious concern for the safety of drinking water provided to the students. Samples S-3, S-5, and S-11 are particularly noteworthy, as they significantly exceed both the WHO and Bangladesh standards, suggesting an urgent need for water quality interventions to protect children's health.

Comparative Statistical Analysis of Parameters Before and After Flood Conditions:

To identify the difference between parameters in a statistical way and to compare with the standards paired sample t-test and one sample t-test are performed. Paired sample variables are taken for the pre and post-flood condition and one sample t-test is compared with the Bangladeshi drinking water standard.

Paired Sample T-test:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pre-flood TDS (mg/l) - Post-flood TDS (mg/l)	-532.818	237.646	71.653	-692.471	-373.165	-7.436	10	.000
Pair 2	Pre-flood pH - Post-flood pH	.49182	.44319	.13363	.19408	.78956	3.681	10	.004
Pair 3	pre-flood EC (µS/cm) - Post-flood EC (µS/cm)	-1040.727	447.755	135.003	-1341.533	-739.921	-7.709	10	.000
Pair 4	Pre-flood Turbidity - Post-flood Turbidity	-8.61727	.74024	.22319	-9.11458	-8.11997	-38.609	10	.000

Figure 11: Paired sample t-test of parameters which are collected from pre-flood and post-flood condition

The paired sample t-test results indicate significant changes in water quality parameters following the flood. Post-flood TDS levels increased by an average of 532.818 mg/l ($p < .001$), and electrical conductivity (EC) rose by 1040.727 µS/cm ($p < .001$). Turbidity also saw a substantial increase of 8.617 NTU ($p < .001$). Conversely, pH levels decreased slightly by 0.492 units ($p = .004$). These significant shifts in TDS, EC, turbidity, and pH highlight the considerable impact of the flood on water quality, posing potential health risks, especially for

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XI Issue XV December 2024 | Special Issue on Public Health

schoolchildren consuming this water. The World Health Organization estimates that unclean water, inadequate sanitation, and poor hygiene contribute to up to 80% of diseases, 3.1% of global deaths, and 3.7% of disability-adjusted life years lost worldwide. Waterborne diseases are a major cause of death and suffering for millions, particularly among children in developing countries (Birhan et al., 2023).

DISCUSSION

The study focused on a new dimension of physicochemical analysis of drinking water that signifies the changes in drinking water quality due to floods and its impact on the health of school-going children from primary schools in Jamlpur, Bangladesh. Such type of water quality evaluation has previously been done on primary schools (Rahman et al., 2015), (Hossain et al., 2022). Internationally other practices are done such as (Hung et al., 2020). But no pre-flood and post-flood condition was applied to those works. This study reveals that flood has a significant influence on the drinking water quality as it influences the physicochemical parameters. Other studies (Mou et al., 2023; Mst. Khodeza Khatun et al., 2022; Prosun et al., 2018) reveal that the physicochemical attributes are about to be within the range of Bangladeshi standards. Pre flood condition of this research is also within the range. However, this study has a few limitations due to a lack of logistics and funding. Studies (Hossain et al., n.d., 2022; Miah et al., 2022) applied other parametric tests. More study with more technical and logistic approaches in this regard can open a new lifestyle opportunity for the folks of these regions or other territories of the world with the same geographical settings. This study illustrates that the authority and other working persons related to this field should draw their attention to the drinking water quality especially when the flood visits. It is a matter of concern because the child's health is more exposed to such risks.

CONCLUSION

The study indicates significant changes in drinking water quality at primary schools before and after a flood, with adverse effects on water safety. Children are vulnerable to the exposure of such kinds of risks. Flooding, particularly during the monsoon season when rivers and channels overflow, disrupts sources of clean drinking water. Residents in these areas should draw their concern and the practice of technological aspects should be induced. Logistics and awareness campaigns should be introduced to all classes of folks. This issue highlights the need for concerted action from relevant authorities to address the impact on water quality, as it directly affects the well-being of children, who are the future of the nation.

Acknowledgments: We would like to express my gratitude to the Department of Local Government and Urban Development of Jatiya Kabi Kazi Nazrul Islam University for their cooperative attitude and informative instructions. Additionally, I am thankful to the Department of Environmental Science and Engineering of Jatiya Kabi Kazi Nazrul Islam University for their logistic support.

Funding: The authors have personally covered all financial expenses related to this work. No external funding or institutional financial support was received.

Data Availability Statement: Here is the datasheet which is uploaded to Google Drive for your examination and further uses. The Excel file is enriched with all information related to research and used for analysis.

https://drive.google.com/drive/folders/1HUODsqWPhZoUhPih_K_7eGGxKJkGaN-U?usp=drive_link

Conflict of Interest: We declare that there is no conflict among us.

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