Assessment of Water Quality and Treatment Efficiency in the Southwestern Region of Bangladesh: A Case Study on KUET Campus

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Abstract: Rapidly growing population and migration to urban areas in developing countries have resulted in a vital need for the establishment of centralized water supply systems to distribute potable water to households. In the south-western region of Bangladesh at the KUET campus, there is a shortage of drinking water due to an unacceptable level of salinity and iron in the groundwater source. This study was conducted to assess the quality of water that is supplied to the people and students of the KUET campus. The sample water was collected from different locations and assessed through various water tests. The investigation shows that the values of water parameters after treatment were within the standard limit, except for iron, whose value was 0.37 mg/L. The parameters, such as TDS, hardness, and chloride, were quite high. The WQI before treatment was found to be almost 31, but after treatment, the value decreased to 10. However, at the distribution sites, the value of WQI again rose to 22 due to some microbiological contamination. The removal efficiency of all the parameters was quite satisfactory, except some parameters such as TDS (46.30%), hardness (20.37%), and chloride (50.70%). The analysis indicates that the treatment plant's performance is satisfactory, but it is not suitable for drinking purposes due to the comparatively high levels of iron, color, hardness, and TDS. This water is well enough for domestic use. For maintaining proper water quality and a sustainable water supply, the treatment plant requires routine monitoring, post-treatment remineralization, and stakeholder education.

Keywords: *Water Quality, Treatment Efficiency, KUET Campus, and Sustainable Water Supply*.

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I. INTRODUCTION

Water is the most abundant and important natural resource in the world, covering more than 70% of its surface and supporting all forms of life. Water, which can be found in seas, rivers, lakes, groundwater, and even the atmosphere, is an essential component of human survival, economic progress, and environmental sustainability (Bănăduc et al., 2022) .Water is important not only biologically, but also in agriculture, industry, transportation, and recreation. Globally, agriculture consumes around 70% of freshwater, with the remaining supporting residential and industrial uses. However, access to clean and safe water remains a critical issue, particularly in emerging nations, where growing urbanization, industrial expansion, and population increase put increasing demand on water supplies.

Bangladesh, located in the northeastern region of the Central Himalayas, is a riverine and densely populated country with a population of over 160 million. Despite its abundant surface water resources, the country has considerable issues in assuring long-term water availability and quality. Unregulated discharge of domestic, agricultural, and industrial wastewater into natural water bodies has severely compromised water quality across the nation (Hasan et al., 2019). In urban areas, especially in cities like Khulna, inadequate sanitation, poor waste management, and insufficient water treatment infrastructure exacerbate this crisis (Ridika et al., 2023). These issues not only pose serious health risks to the population but also threaten aquatic ecosystems and economic stability.

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Surface water resources in Bangladesh, particularly rivers, are rapidly declining due to a mix of natural and anthropogenic influences. Large-scale flood control, drainage, and irrigation infrastructures have all contributed to river siltation. This has not only limited the water supply but also restricted river transportation and resulted in a significant decline in fish population. Simultaneously, both surface and groundwater sources are being more contaminated by uncontrolled industrial discharges, particularly from textile mills and tanneries, as well as harmful agricultural pesticides (Harvey et al., 2004). The pollution load is exacerbated by the dumping of untreated home sewage, which causes extensive fecal contamination. A particularly concerning issue is naturally occurring arsenic pollution in groundwater, which affects an estimated 50 to 80 million people in Bangladesh, with no definitive cure yet found.

Groundwater, previously the primary supply of drinkable water in Bangladesh, is becoming increasingly unreliable due to over-extraction and contamination from arsenic, iron, and saline intrusion, particularly in the southern regions. Khulna, the third-largest city in the country, exemplifies the intensity of the situation (Naus et al., 2019). With only around 17% of the population having access to piped water, the bulk must rely on alternate sources, including shallow and deep tube wells, which are frequently dangerous. Overreliance on deep aquifers has resulted in worrying groundwater depletion rates, raising concerns about the region's long-term water resource sustainability.

Water quality is influenced by a variety of physical, chemical, and biological contaminants that might come from mineral, organic, microbial, or even radioactive sources. While some characteristics, like as turbidity, color, taste, and odor, are observable by the human senses, more harmful pollutants, such as infections or poisonous substances, frequently go undetected without laboratory testing. To be deemed safe for drinking, water must be devoid of disease-causing microbes and hazardous chemical substances, as well as aesthetically pleasing, non-corrosive, and free of disagreeable tastes, odors, or high salinity (Shah et al., 2023). Ensuring compliance with these criteria is crucial for protecting public health and preserving trust in water supply systems.

Water treatment is the process of improving the quality of water so that it meets the water quality criteria required for its intended purpose. Water treatment plants are facilities that treat ground or surface water to create drinkable water for public use. The drinking water supply requires proper and constant monitoring till water reaches the client households, as user requirements in terms of color, pH, taste, and odor, which is the major purpose of water treatment. There is also mismanagement of the distribution system and network issues, as well as poor treatment performance of treatment plants due to poor functional and maintenance state, and a lack of replacement parts in all treatment plants (Razali et al., 2023). This results in proper access to drinking water for customers, and the government is unable to meet the water supply demand. The primary goal is to operate and maintain the valley's water supply and sanitation system by delivering quantitative, qualitative, and reliable service to consumers at the lowest possible cost .

A typical water treatment facility treats drinking water through coagulation, sedimentation, filtration, and chlorination. The Water Treatment Plant (WTP) uses conventional purifying techniques and operates on a gravitational flow system.

The establishment and efficient operation of water treatment plants are essential to address these challenges. Treatment facilities remove physical, chemical, and biological impurities from water to make it safe for human consumption and release it into the environment. Their performance is critical to maintaining public health and environmental protection. In this context, assessing the operating efficiency of such facilities and the quality of treated water is critical (Bărbulescu & Barbeș, 2023).

The Khulna University of Engineering & Technology (KUET) campus offers a specific case study for evaluating water supply quality and the efficacy of its water treatment system. This study intends to provide insights into the effectiveness of existing treatment technologies and recommendations for sustainable water management by evaluating water samples from various sites on campus and comparing the results to national and international standards.

II. MATERIALS AND METHODS

➢ *Study Area*

This study was carried out at the Water Treatment Plant (WTP) on the Khulna University of Engineering & Technology (KUET) campus in Khulna, Bangladesh (22.8058° N, 89.5697° E). The plant provides drinkable water to the university campus and the surrounding communities. Khulna is located in the Ganges-Brahmaputra delta and receives an average annual rainfall of 2,500 mm(Ayers et al., 2016). During the monsoon season, the region experiences flooding and high turbidity, posing substantial obstacles to water treatment operations. The WTP obtains raw water from a combination of surface water sources (three ponds) and groundwater (eight shallow tube wells and one deep tube well), with groundwater sources containing high salt.

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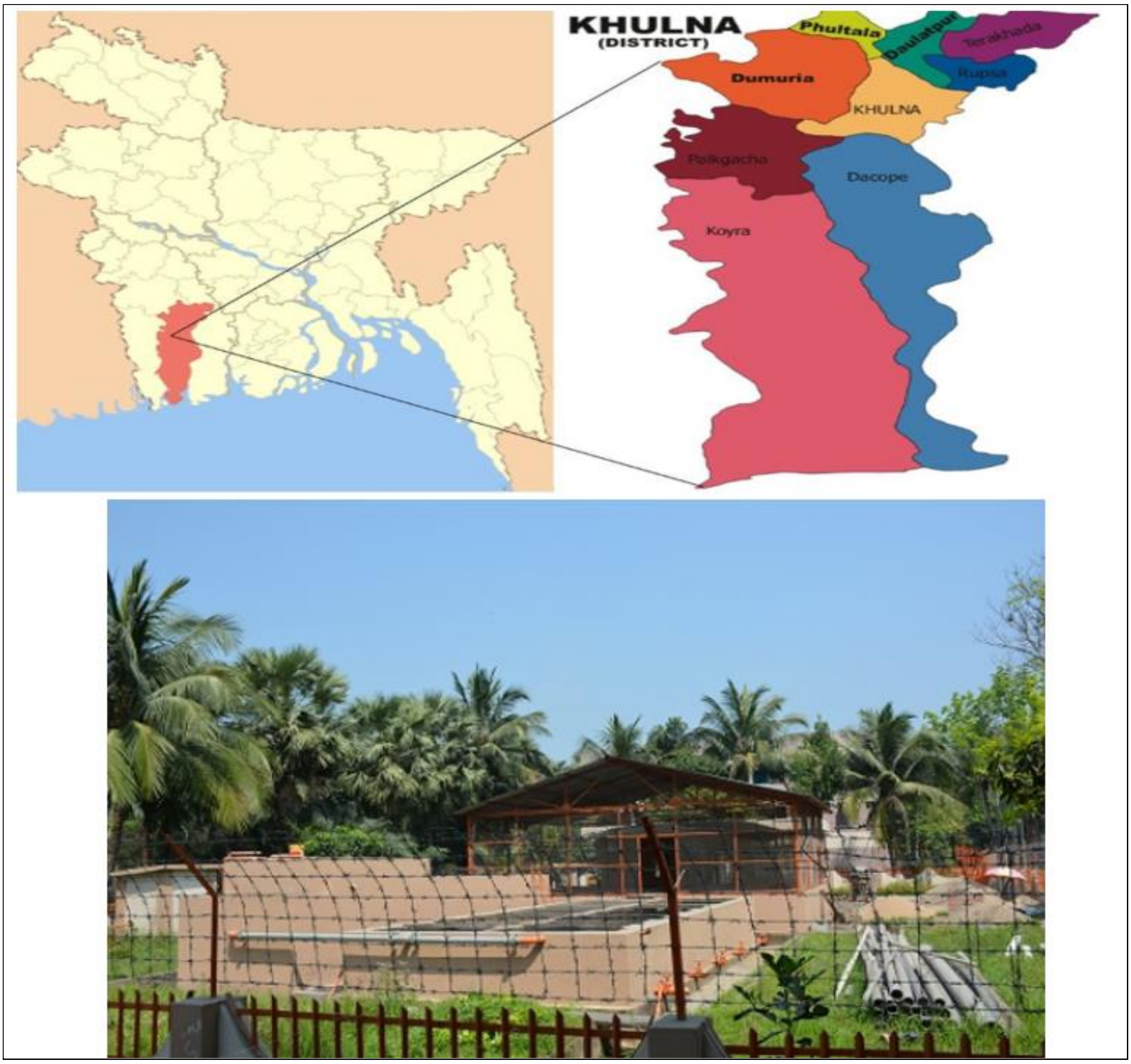

Fig 1: Water Treatment Plant of KUET Campus

➢ *Water Treatment Process of KUET Campus*

The water treatment processes at the KUET Water Treatment Plant (WTP) encompass seven key stages: raw water collection and storage, aeration, coagulation-flocculation, sedimentation, filtration, disinfection, and final storage and distribution. Each stage is designed to improve water quality by removing physical, chemical, and biological contaminants.

➢ *Intake and Raw Water Storage*

Water comes from surface and groundwater supply, which is transported to the treatment facility by pipes and intake structures. Large debris, including leaves, branches, and floating solids that could impede downstream operations, is removed from surface water through an initial screening procedure. Because groundwater has a lower particle level, it usually skips this phase.

In order to allow for gravity sedimentation, which causes suspended particles, such as silt and some microbes, to sink to the bottom, the stored water is kept in reservoirs. This procedure can eliminate 90–95% of the water's bacterial burden while also greatly reducing turbidity and color.

➢ *Aeration*

In addition to oxidizing volatile organic compounds (VOCs) and dissolved metals including iron, manganese, and hydrogen sulfide, aeration is used to raise the concentration of dissolved oxygen (DO) in the water, improving taste and odor(Rosli et al., 2015). Particularly useful for treating groundwater, aeration is frequently combined with lime softening. Gravity, fountain, diffused, and mechanical systems are common aeration methods that are all intended to increase the surface area of air-water interaction.

➢ *Coagulation and Flocculation*

The colloidal particles aggregate into bigger particles known as flocs, and coagulants, usually aluminum or ferric salts, are added. These coagulants neutralize the negative charges of the colloidal particles(Sulistyo et al., 2012). Following coagulation, flocculation is a mild mixing procedure that encourages floc formation and even coagulant dispersion throughout the water matrix. For efficient mixing,

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techniques like air agitation, mechanical paddles, and baffled flow channels are used. To promote floc formation and lower water hardness, polymers and precipitating agents such as soda ash or lime are occasionally added.

➢ *Sedimentation*

The floc-filled water enters a sedimentation basin, sometimes referred to as a clarifier, where suspended materials settle more easily due to gravity(Banaś & Hilger, 2024). Depending on the depth and flow velocity of the basin, the detention period usually lasts between two and four hours. A large percentage of the flocs and other particles settle out during sedimentation, producing clearer water with a much lower turbidity and pollutant load.

➢ *Filtration*

The last physical barrier in the water treatment train is filtration. To get rid of any last bits of suspended particles, water is run through porous materials, usually sand and gravel(Maiyo et al., 2023). Three layers make up a standard gravity sand filter: a fine sand layer at the top (~1 m), a coarse sand layer in the center (0.3–0.5 m), and a gravel layer at the bottom (0.3–0.5 m).

While quick sand filters, which are more frequently used in urban WTPs, support high throughput, slow sand filters use biological activity to remove contaminants and are appropriate for low-flow applications(Abdiyev et al., 2023). Following aeration, pressure filters are used for groundwater sources with high levels of iron or manganese. Steel tanks, either horizontal or vertical, contain these filters. Furthermore, severely turbid water (>50 NTU) is pre-treated with roughing filters, which are made of coarse gravel or broken stones and enable both physical and gravitational filtration.

➢ *Disinfection*

Chlorination is still the most popular disinfection technique because of its affordability, ease of use, and residual antibacterial properties. Chlorine suppresses algae, oxidizes iron and manganese, inactivates harmful microbes, and lessens problems with taste and odor. Although they are less prevalent in small-scale WTPs, further disinfection methods include ozonation, UV light, advanced oxidation processes, chlorine dioxide, and chlorination(Vijaya Kumar & Vijaya Kumar, 2021).

➢ *Storage and Distribution*

Water that has been treated is first kept in covered reservoirs before being distributed. It is distributed through a system of pipes to the university community. To make sure that the water satisfies safety regulations and that the treatment procedures continue to work, routine sampling and quality analysis are carried out.

➢ *Sampling Strategies*

Between September to January 2025, triplicate grab samples were collected once monthly from:

- Raw Source (RS): Surface water sources (three ponds) and groundwater sources (eight shallow tube wells and one deep tube well)
- Post-Treatment (PT): Treated water from the KUET water treatment plant.
- Distribution (DI): Tap water at the Teachers' Dormitory and surrounding areas.

All samples (2 L each) were collected in sterile polyethylene bottles, preserved properly, and transported to the Environmental Engineering Laboratory at KUET within a few hours for analysis.

➢ *Laboratory Analysis and Data Interpretation of Water Samples*

Three crucial locations throughout the supply chain such as the intake source, the water treatment facility (post-treatment), and the distribution network (end-user point) were used to gather water samples. The efficiency of treatment was evaluated based on the amount of sample water purification.

pH, total hardness, chloride, turbidity, color, iron, manganese, total dissolved solids (TDS), and total coliform and fecal coliform (TC-FC) are among the physicochemical and microbiological parameters that are examined. To guarantee accuracy and dependability, standard laboratory methods were used in accordance with APHA (2017) recommendations.

To assess water safety and compliance, the measured values for each parameter were methodically documented and compared to the World Health Organization's (WHO) guidelines and the Bangladesh Drinking Water Quality Standards (BDWQS). Whether the treated and distributed water satisfies allowable limitations for potable use is determined in part by this comparative study.

The findings show that the KUET Water Treatment Plant's (WTP) effectiveness and whether more development is required to guarantee campus residents have access to safe drinking water.

➢ *Water Quality Index (WQI)*

The Water Quality Index (WQI) is a widely recognized and effective tool for evaluating the overall quality of water resources and determining the extent of pollution in groundwater and surface water systems. It simplifies complex water quality data by aggregating various parameters into a single numerical value. It provides a clear and concise representation of water quality that is easy to interpret for policymakers, researchers, and the general public. The WQI is a critical indicator in water quality monitoring programs, aiding in assessing pollution sources, prioritizing remediation efforts, and developing sustainable water management strategies. In this study, the weighted arithmetic method was employed to calculate the WQI (equation 4), as initially proposed by Brown et al. (1972). The calculations of unit weight (W_n) for each parameter and the quality rating of the nth parameter (Q_n) were performed using the equations (1-3).

$$W_n = \frac{K}{S_n}, \tag{1}$$

$$K = \frac{1}{\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}+\cdots+\frac{1}{S_n}}, \tag{2}$$

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$$Q_n = \frac{(Vn-V0)}{(Sn-V0)} \times 100, \quad (3)$$

$$WQI = \frac{Wn \times Qn}{Wn}, \quad (4)$$

where K denotes the proportionality constant, S_n resembles the standard desired value of the n-th parameter, V_n denotes the concentration of the nth parameters, S_n represents the standard desirable value of the nth parameters, and V_o resembles the actual values of the parameters in pure water (generally Vo=0, for most parameters except for pH). The summation of all unit weight factors should satisfy the condition of $\sum W_n = 1\ (unity)$, ensuring that the relative importance of all selected parameters is appropriately balanced(Bora & Goswami, 2017).

Table 1. WQI Range, Status and Possible Usage of the Water Sample (Brown et al. 1972)

WQI	Water Quality Status	Possible Usage	Health Implications	Common Pollutants	Recommended Actions
0-25	Excellent	Drinking, irrigation, and industrial	No significant health risks	None or minimal pollutants	Regular monitoring and protection
26-50	Good	Drinking, irrigation, and industrial	Minor risks. It may contain trace pollutants	Trace nitrates and phosphates	Routine treatment and monitoring
51-75	Poor	Irrigation and industrial	Potential for gastrointestinal issues	Nitrates, phosphates, and organics	Basic filtration and chemical treatment
76-100	Very Poor	Irrigation	High risk of adverse health effects	Heavy metals, pathogens	Advanced treatment and restricted usage
>100	Unusable for drinking and fish culture	Proper treatment is required before use	Severe health risks (toxicity, disease)	Pathogens, heavy metals, pesticides	Comprehensive treatment before usage

➢ *Performance Evaluation*

The treatment plant removal efficiency was determined for each of the water quality parameters using the following equation (5)

$$Removal\ Efficiency(\%) = \frac{Cin-Cout}{Cin} \times 100 \quad (5)$$

Here, Cin and Cout mean the concentration of water before and after treatment. Efficiency was identified to evaluate the performance of the water treatment plant.

➢ *Methodological Approach*

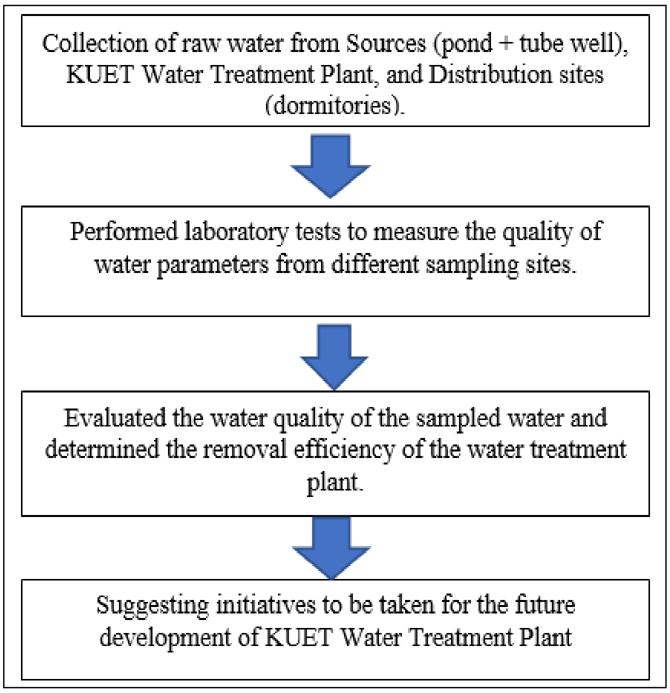

Fig 1 Methodological Approach

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III. RESULTS AND DISCUSSION

After detailed study on the design and working principal of the water treatment plant the samples were collected from various location like- source combining of surface water sources (three ponds) and groundwater (eight shallow tube wells and one deep tube well), water treatment plant and from the distribution sides combining teachers' dormitory and other parts of the campus. The collected samples were levelled, and water quality parameters were tested. The average values of all the water parameters of test results from sources, the KUET water treatment plant, and distribution sites were noted and compared with the WHO and Bangladesh standards. The performance study of the water treatment plant was conducted in this study. The average concentrations of all water quality parameters of all samples from the source, water treatment plant, and distribution sides are shown in Table 2 along with Bangladesh and WHO standards.

Table 2: Comparative Analysis of Water Quality Parameters from the Source, Water Treatment Plant, and the Distribution Sides of KUET Campus.

Parameters	Source	Water Treatment Plant	Distribution (Teachers' Dormitory)	Bangladesh Standards (ECR,1997)	WHO Standards
pH	7.5	7.61	7.5	6.5-8.5	6.5-8.85
Colour (Pt.Co.Unit)	35	0	18	15	<15
Turbidity (NTU)	5.6	1.15	1.57	10	<5
Hardness (mg/L) as CaCO3	324	258	273	200-500	200-500
Iron (mg/L)	0.57	0.15	0.37	0.3-1.0	0.3
Manganese (mg/L)	0	0	0	0.1	0.1
Chloride (mg/L)	357	176	231	150-600	250
Arsenic (mg/L)	0	0	0	0.05	0.01
TC (N/100ml)	5	0	0	0	0
FC (N/100ml)	1	0	0	0	0
TDS (mg/L)	540	290	330	1000	<1000

The table 2 compares water quality metrics measured at three places on the KUET campus: the Source, the Water Treatment Plant, and the Distribution point in the Teachers' Dormitory. It also offers reference standards for Bangladesh (ECR, 1997) and the World Health Organization (WHO) for comparison. The pH levels at all three locations are consistent, ranging from 7.5 to 7.61, which is well within the permitted parameters set by both WHO and Bangladesh guidelines. Color levels are extremely high at the source (35 Pt.Co.Unit), are eradicated at the treatment plant, but subsequently rise to 18 Pt.Co. Unit in the distribution system surpasses national and WHO regulations, indicating supply line contamination. Turbidity follows a similar trend, with a significant fall after treatment and a little increase at the distribution point, which is still within safe limits. Water hardness begins high at the source (324 mg/L), falls during treatment (258 mg/L), and then slightly increases in the distribution system (273 mg/L), but stays within the recommended limit. Iron levels are effectively removed in the plant, dropping from 0.57 mg/L to 0.15 mg/L before rising to 0.37 mg/L at distribution, still within permissible limits, but indicating likely pipe corrosion or silt deposit. Manganese, arsenic, and both total and fecal coliforms are not present at any point, indicating that hazardous metals and microbial pollutants have been successfully removed. Chloride concentrations are also minimized by the water treatment but rise again in distribution, potentially due to leaching or contamination within pipes. Finally, Total Dissolved Solids (TDS) decrease from a high of 540 mg/L at the source to 290 mg/L after treatment, then slightly increase to 330 mg/L in distribution, with all values remaining below permissible limits. Overall, the statistics indicate that, while the treatment process is mostly effective, some recontamination or quality deterioration occurs within the distribution network.

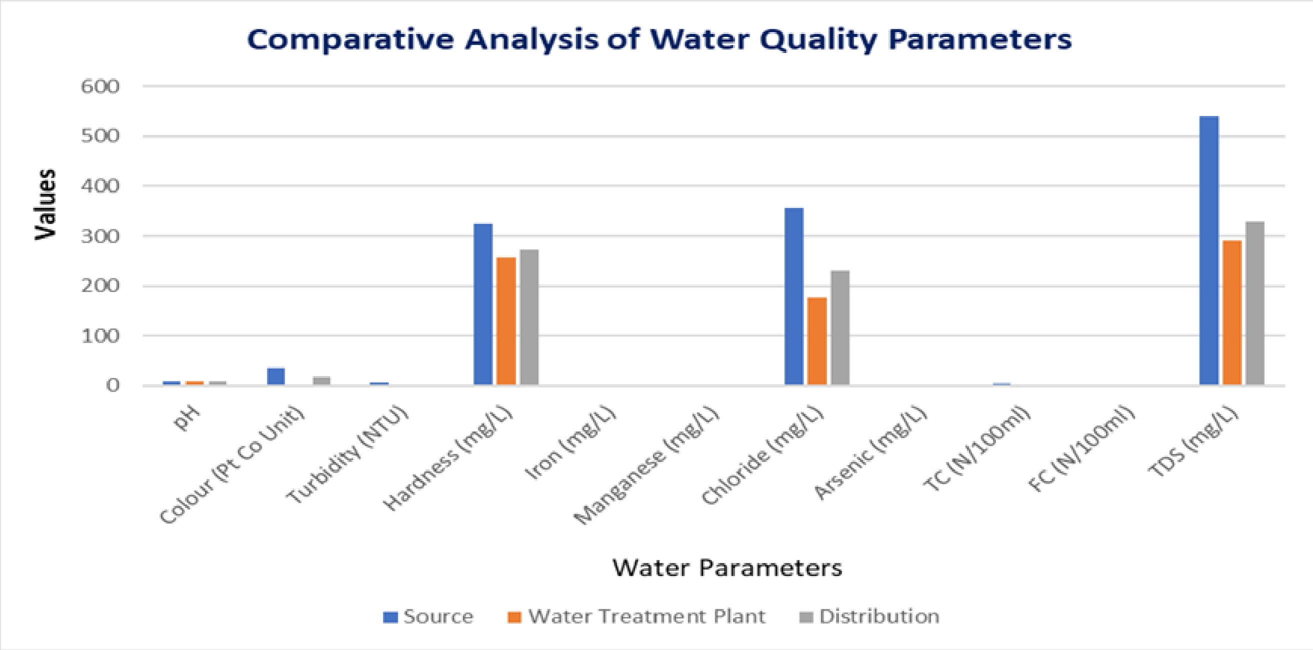

Fig 2: Water Quality Parameters Analysis

➢ *Assessment of Water Parameters Using Bangladesh and WHO Standards*

The accompanying bar graph (Figure 2) illustrates the water quality metrics at three locations: source, treatment plant, and distribution. The graphical trends are consistent with the tabular data, demonstrating both the effectiveness of the treatment process and potential flaws in the distribution network. Total Dissolved Solids (TDS) have the highest measured values, with a significant decrease from 540 mg/L at the source to 290 mg/L following treatment, before slightly increasing to 330 mg/L in the distribution system. A similar pattern is seen for chloride, which decreases considerably after treatment but then rises again in the distribution line, potentially due to interactions with pipeline components or slight infiltration. Hardness and iron concentrations likewise decrease after treatment, but increase slightly in distribution, raising the possibility that some quality degradation occurs after treatment. Color and turbidity, both important for aesthetic and health reasons, are greatly decreased in the treatment plant but reappeared at the distribution point, indicating secondary pollution. Meanwhile, microbiological indicators like Total Coliforms and Fecal Coliforms are absolutely absent from all three locations, which is good news for public health. The pH levels remain stable throughout, showing a consistent chemical balance in the water. Overall, the graph clearly shows that, while the water treatment plant effectively improves water quality, there is a noticeable decline in certain parameters during distribution, highlighting the need for better monitoring and maintenance of the campus' water distribution infrastructure.

➢ *Water Quality Index Analysis*

The bar graph (Figure 3) illustrates the Water Quality Index (WQI) values at three major locations on the KUET campus: the source, the water treatment plant, and the distribution point. The WQI is an integrated indicator of total water quality, with lower values indicating higher water quality. As indicated in the graph, the Source has the highest WQI of around 31, suggesting rather poor water quality due to higher levels of turbidity, hardness, iron, chloride, and total dissolved solids. However, there is a notable improvement at the Water Treatment Plant, where the WQI lowers significantly to about 10, indicating that the treatment procedure is effective in lowering contaminants and putting most metrics within acceptable limits. This improvement shows the treatment plant's ability to produce safe and potable water. Nonetheless, the WQI rises again at the Distribution point, reaching a value of around 22, which, while better than the Source, indicates a decline in water quality over the distribution process. This drop is due to the old pipeline system, microbiological contamination. Overall, the graph demonstrates the treatment plant's effective performance while also emphasizing the importance of monitoring and maintaining the distribution system to ensure water quality up to the point of consumption.

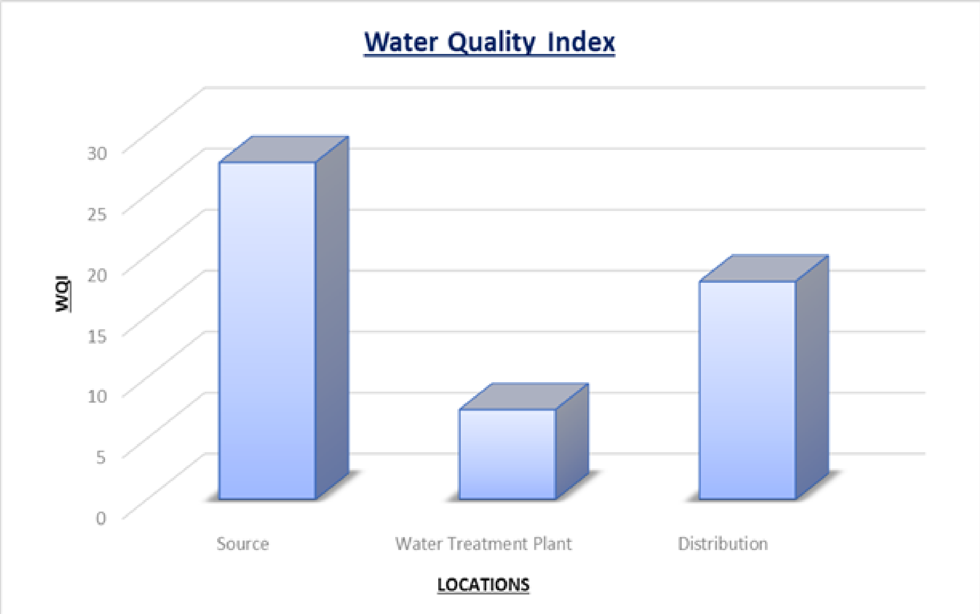

Fig 3: Water Quality Index Analysis

➢ *Performance Evaluation of Water Treatment*

The removal performance effectiveness of the tested water parameters varies significantly, as shown in the line graph (Figure 4). Color, total coliform (TC), and fecal coliform (FC) had the highest removal efficiencies of 100%, suggesting complete elimination during the treatment process. Turbidity and iron removal efficiencies were moderately high (79.46% and 73.68%, respectively), but chloride had a lower efficiency of 50.70%. In contrast, hardness had the weakest removal success at only 20.37%, showing the treatment method's limited effectiveness in addressing this characteristic. Total dissolved solids (TDS) showed a comparatively poor removal effectiveness of 46.30%. Overall, the system performed exceptionally well in removing microbial and aesthetic contaminants (color, TC, FC), moderately with particulate and some chemical contaminants (turbidity, iron, chloride), but was less effective in reducing hardness and TDS, indicating the need for process optimization or additional treatment stages to improve chemical contaminant removal.

IV. CONCLUSION

The study on the water quality of the KUET campus underlines the continuous difficulty in providing safe drinking water, especially due to the high salinity of groundwater, which remains the primary source of supplies. A thorough laboratory analysis of key water quality parameters such as arsenic, TDS, turbidity, color, pH, hardness, chloride, iron, manganese, total coliform (TC), and fecal coliform (FC) revealed that, while the treatment plant performs satisfactorily in reducing most contaminants, parameters such as color, iron, TDS and hardness remained high in distribution sites due to the microbiological contamination inside the pipe system. The water quality index value was high at the source but significantly reduced after treatment, which shows quite improvement in water quality. However, the water quality at the distribution site rose again, indicating inaccuracy in the pipe network system and its improper maintenance. The evaluation of the removal efficiency of specific water parameters gave a clear idea about the performance of the treatment plant. The performance of the removal efficiency of all the parameters was quite satisfactory, but some of the water parameters, such as chloride (50.70%), TDS (46.30%), and hardness (20.37%), were not up to the mark. This is due to the presence of some specific metal ions in the water of the south-western region. The treated water is currently unsafe to drink directly, even if it is considered appropriate for everyday domestic usage. Therefore, to ensure that the campus community has access to clean drinking water, immediate attention is needed to improve treatment procedures, assure systematic operation and maintenance, and strengthen monitoring activities. Long-term sustainable and successful water management will also depend on increasing public knowledge, implementing proper rules and regulations for a suitable and healthy environment.

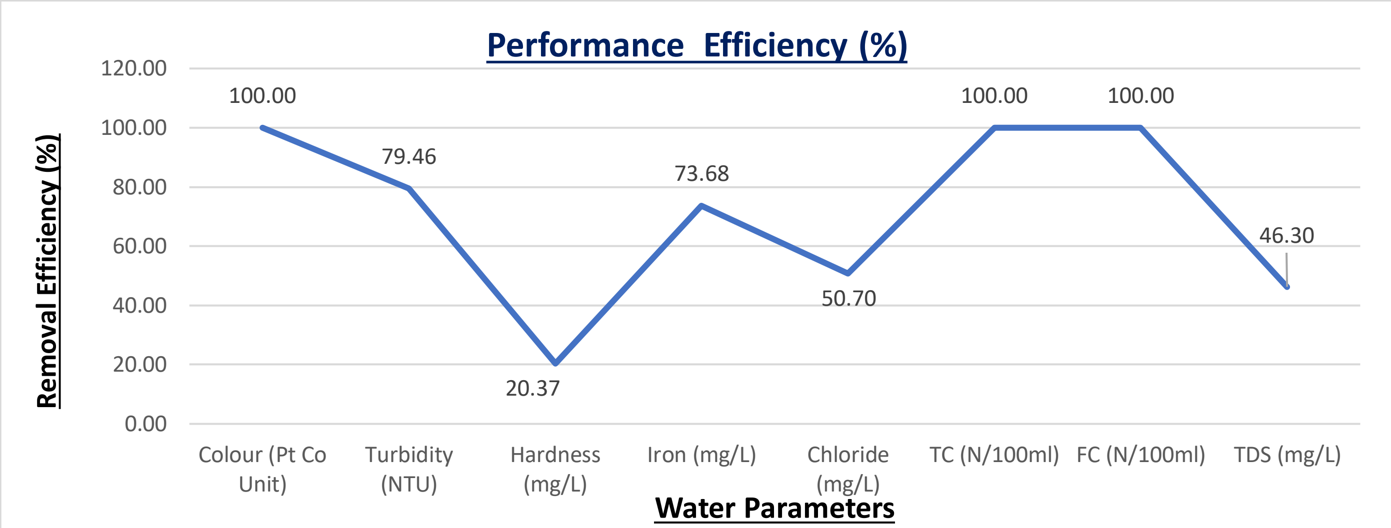

Fig 4: Performance Efficiency Analysis

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