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From Source to Use: Performance Evaluation of Water Treatment Plant in KUET, Khulna, Bangladesh

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Abstract

This study focuses on assessing the performance efficiency of Khulna University of Engineering & Technology's (KUET) water treatment plant (WTP). The treatment process involves a combined sedimentation and flocculation chamber, followed by four roughing filter units with horizontal and up-flow filtration capabilities, and finally two sand filter units in series. Performance evaluation encompassed pH, turbidity, color, chloride, TDS, TC, and EC tests conducted over a month at weekly intervals. Challenges arise due to the region's elevated salinity levels, posing difficulties in achieving quality output. Moreover, the source water, drawn from 2 ponds and 9 tube wells, exhibited high TDS and chloride contamination. Findings from the majority of the test results reveal that most of the unit parameters were within acceptable limits according to ECR'23, though chloride content was not within allowable levels and TDS was found to be poorly acceptable limits. Furthermore, the overall efficiency of the treatment plant was found to be in the range of 100% for physical parameters, 65 to 79% for chemical parameters, and 100% for bacterial parameters. Notably, the WTP exhibited an overall qualitative efficiency of 91%, signifying the suitability of its treated water for domestic use in the region.

Keywords: *bacterial contamination; performance assessment; water quality; total dissolved solid; Khulna city.*

1 Introduction

Water is one of the vital components of the physical environment. Safe, adequate, and accessible supplies of water are the basic needs and essential components of primary health care. Inadequate provision of safe drinking water is one of the main origins of communicable diseases and allied health risks. Therefore, providing safe drinking water is one of the important public health priorities in the recent age. The World Health Organization (WHO) estimated that up to 80% of all sickness in the world is caused by inadequate sanitation, polluted water, or unavailability of safe water (Ibrahim et al., 2014). Over the last half-century, there has been an increasing tendency of population settlement in developing countries like Bangladesh. The increase in the human population poses great pressure on the provision of safe drinking water especially in developing countries (Debnath et al., 2019). Water treatment plants play a critical role in providing safe and clean drinking water to communities (Muller 1977). However, the efficiency and effectiveness of these plants can vary depending on several factors, including the source of the water, the treatment processes used, and the management and operation of the facility (Okonko et al., 2009). The water treatment process can vary depending on the source of the water and the desired level of purification but typically includes a combination of physical, chemical, and biological processes (Amber et al., 2004). Insufficient access to safe drinking water is a major cause of communicable diseases and health risks. As a result, providing safe drinking water has become a significant public health priority. WHO estimates that over 3.4 million people die each year from water-related diseases, making it the leading cause of disease and death globally. Most of the victims are young children, who succumb to illnesses caused by microorganisms thriving in water sources contaminated by raw sewage (Hossain & Hassan, 2015). Poor access to safe water sources in both urban and rural areas is a major factor contributing to the prevalence of waterborne diseases in Bangladesh.

Khulna, a prominent district headquarters in Bangladesh, faces the challenge of inadequate drinking water supply and water quality issues. The increasing population settlement in developing countries like Bangladesh, including Khulna, puts immense pressure on providing safe drinking water (Shahid et al., 2018). The current population of Khulna district is 2.984 million and is continually rising, exacerbating water demand issues. However, most of the groundwater sources in Khulna are contaminated with high levels of arsenic and iron, making surface water sources the only viable option for supplying safe drinking water. However, the study focused on the existing water treatment facilities at the Khulna University of Engineering & Technology (KUET) campus. The KUET water treatment plant in Khulna-9203, Bangladesh is one such facility that provides purified domestic water to the university campus and surrounding areas. The aim of this study is to evaluate the performance of the KUET water treatment plant in terms of its ability to provide safe and clean drinking water. The study will assess the plant's water quality by monitoring various parameters such as pH, color, turbidity, iron, total dissolved solids (TDS), and chloride, and will compare the results with the Bangladesh Standards for Drinking Water Quality. The study will also investigate the challenges faced by the plant during the monsoon season, when the source water may become contaminated due to flooding and high levels of turbidity. The results of this study will provide valuable information on the performance of the KUET water treatment plant and will inform recommendations for improving the plant's operations and ensuring that the community has access to safe and clean water for domestic use.

2 Study Area

The KUET Water Treatment Plant (KUET-WTP) is situated on the Khulna University of Engineering and Technology (KUET) campus in the Khulna division of Bangladesh. It sources water from the nearby Rupsha River, known for its turbidity and high total dissolved solids (TDS). The plant serves clean drinking water to the university and surrounding areas at coordinates 22.8058° N, 89.5697° E. The region experiences an annual rainfall of approximately 2,500 mm due to its location in the Ganges-Brahmaputra delta, making it prone to flooding and cyclones during the monsoon season, affecting plant operations.

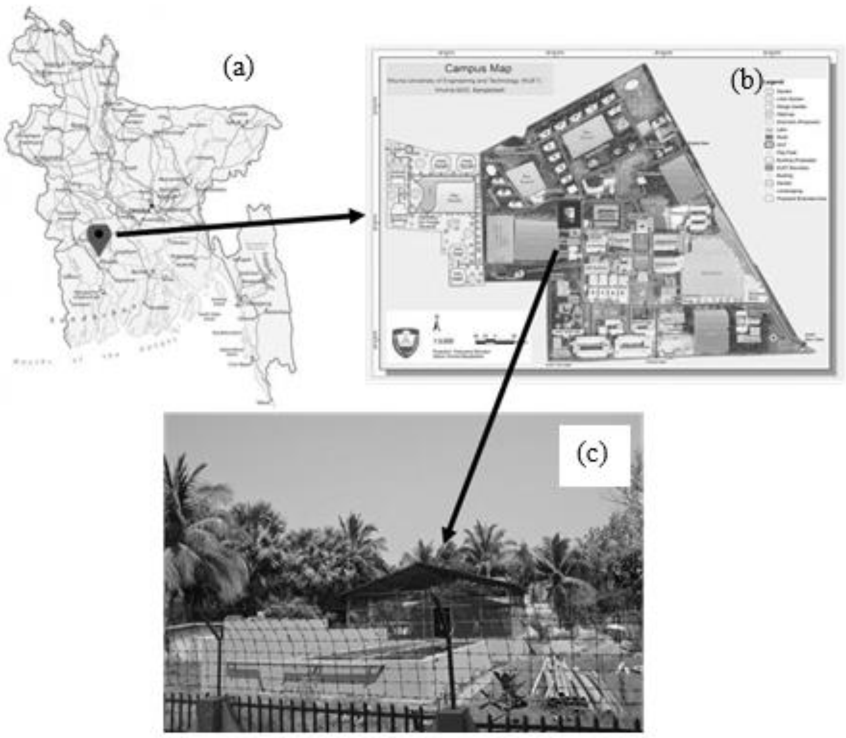

Figure 1: (a) map of Bangladesh locating Khulna: (b) map of KUET indicating KUET water treatment plant; (c) the visual image of the KUET water treatment plant.

3 Materials and Methodology

3.1 Water Treatment Method at KUET-WTP

The water treatment technology involves pre-settling, flocculation, sedimentation, roughing filter, slow sand filter (SSF) and post-chlorination as shown in Figure 2. Presently, surface water from three ponds and eight shallow tube wells have been using as the raw water sources in the WTP. The groundwater sources in this area are contaminated with high salinity content. The treatment operation is done for a period of 18 hours in a day. After post chlorination, purified water is collected in a ground water reservoir. Furthermore, the water is stored in an overhead tank with the help of pumps from where the water is served all over the campus.

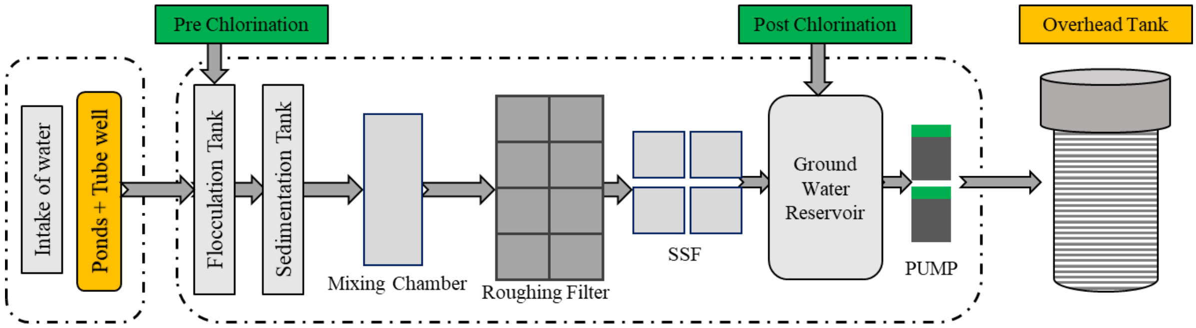

Figure 2: KUET-WTP treatment process flow diagram

3.2 Study Methodology

The study has intended to field observation of KUET-WTP, comparison of water demand and capacity of WTP. Performance evaluation will include an examination of the various parameters that are used to assess the quality of treated water, such as pH, turbidity, total dissolved solids, and chloride contents following ASTM guidelines. The study duration was 1 month where data has been taken in 1-week intervals. This paper will provide a comprehensive understanding of the water quality analysis, efficiency assessment and finally proposals of some initiatives for the future development.

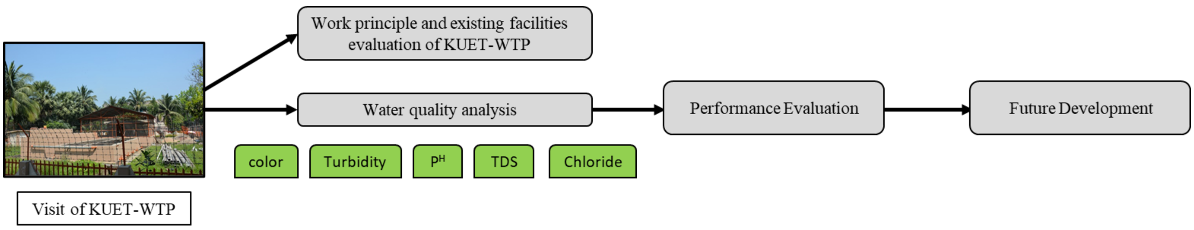

Figure 3. Workflow diagram

3.3 Sampling, laboratory testing, and analysis

Based on the existing unit operation of WTP a total number of five points have been selected for sampling. Sample water from the selected points was collected and all the samples were transported immediately to the environmental engineering laboratory of the Department of Civil Engineering, KUET for the analysis of the qualitative efficiency of the water treatment plant. All the sampling and tasting were implemented according to the standard methods and procedures. The quality of water has been analyzed based on the drinking water standard recommended by ECR'23, Bangladesh. Plant efficiency is measured as the ratio of the concentration removal to the initial concentration of any parameter (Equation 1).

Efficiency = ((Initial concentration ~ Final concentration) / Initial concentration) × 100%.................... (1)

4 Results and discussion

4.1 Raw water quality

4.1.1 pH, Color, and Turbidity

Water is collected from 8 shallow tube wells, 1 deep tube well, and 2 ponds. Deep tube well water is used to reduce the salinity of the raw water. During the study period, the pH value of the raw water source remained within the acceptable range of BDS value (6.5-8.5), with recorded values ranging from 7.1 to 7.9, as illustrated in Figure 4(a). Figure 4(b) shows the seasonal changes in turbidity values, revealing the highest readings of 16 NTU recorded in pond B (week 3), and the lowest 0.9 NTU was found in several sources throughout the study period. It is noteworthy that the turbidity content remained at an acceptable limit for most of the analyzed samples. However, the color content exhibited variations, with the maximum and minimum values of 15 Pt. Co and 14 Pt.Co observed for deep tube well, respectively. For all other samples, throughout the study period, color content was found zero. Notably, the color content surpassed the acceptable BDS limit of 15 Pt.Co.

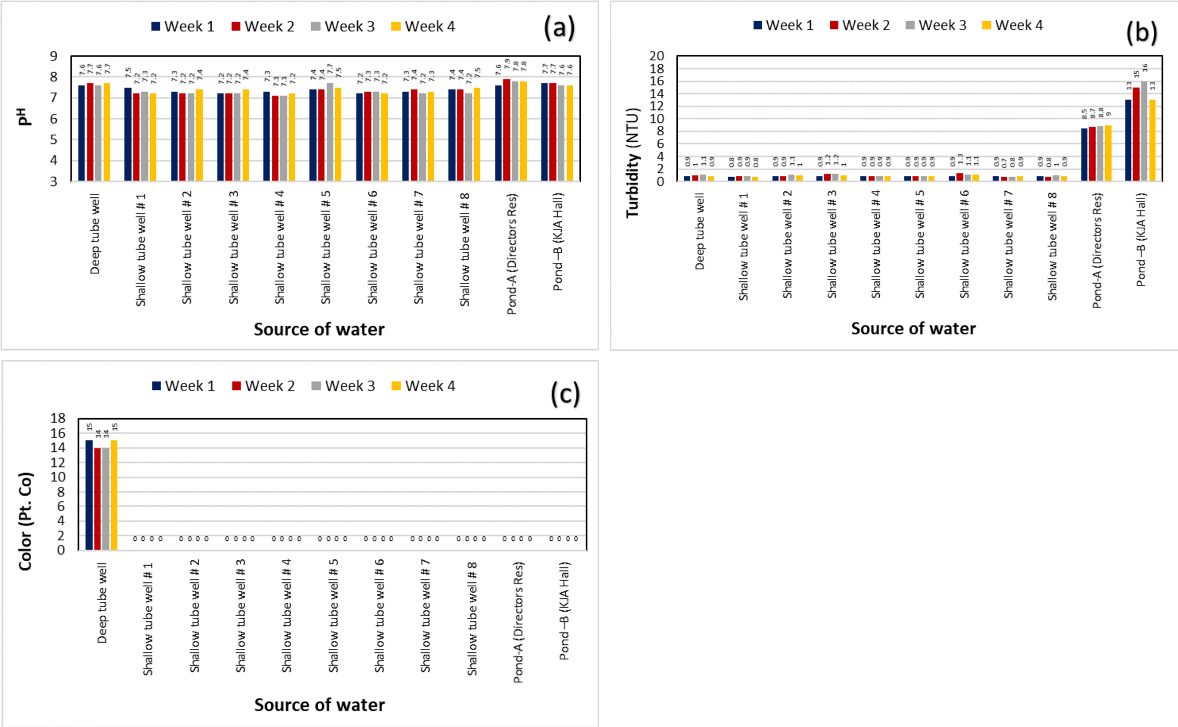

Figure 4. Weekly variation of (a) pH value, (b) Color, and (c) Turbidity value in raw water source

4.1.2 Chlorides and Total Dissolved Solids (TDS)

This study reveals that the chloride content in the surface water source exceeded the WHO standard limit (250 mg/L) in most of the samples except for pond A, pond B, shallow tube well #3, and shallow tube well #6. However, deep tube well and shallow tube well #2 also not remained within the acceptable BDS limit (600 mg/L), as indicated in Figure 5(a). The highest and lowest chloride content values of 1230 mg/L and 35 mg/L were recorded in the deep tube well and pond B, respectively. While chloride concentrations exceeding the WHO limit of 250 mg/L may result in an undesirable salty taste in the water (Jiwa et al., 1991). However, the total dissolved solids (TDS) values were found to be in the range of 900-2330 mg/L, not within the BDS standard value (1000 mg/L). The maximum and minimum TDS content values were recorded in the deep tube well (2330 mg/L) and pond A 2014 (900 mg/L), respectively as mentioned in Figure 5(b).

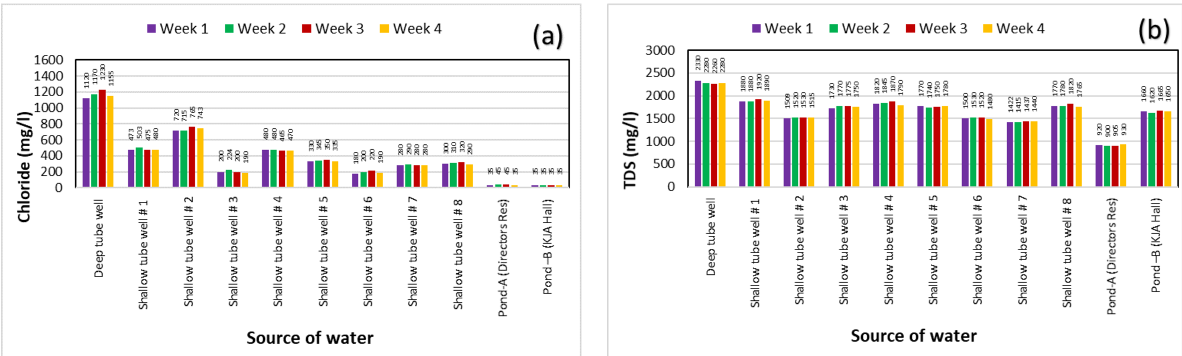

Figure 5. weekly variation of (a) Chlorides, and (b) Total Dissolved Solids (TDS) value in raw water source

4.2 Water quality in various Unit Operations

In this study, four sampling points were selected to assess the treatment efficiency of various unit operations in the water treatment plant. The results indicate that the water quality did not meet the acceptable limits for color, turbidity, and microbial concentration at the impending reservoir and the exit of the roughing filter. However, the color and turbidity were successfully reduced after undergoing slow sand filtration (SSF). Despite this improvement, the water treatment plant still struggled to bring bacterial contamination within the BDS standard value, as shown in Figure 6. On the positive side, the TDS and chloride content remained within acceptable limits throughout all unit operations.

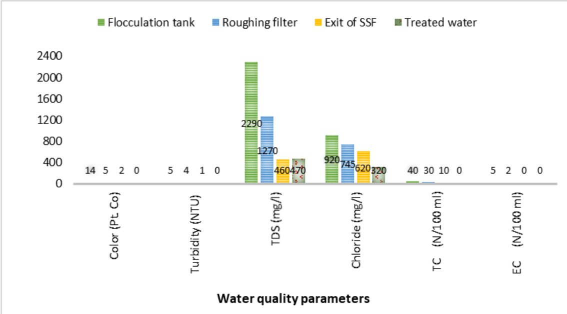

Figure 6: Water quality in various unit operation points of the Water Treatment Plant

4.3 Removal Efficiency (RE) and Cumulative Removal Efficiency (CRE)

4.3.1 Removal Efficiency for Physical and chemical and biological parameters

The data from Figure 7 indicates a direct relationship between the removal efficiency (RE) of each parameter: as RE increases, removal efficiency improves, and vice versa. At the roughing filter, the water treatment plant (WTP) achieved a color removal efficiency of 66.7% and a turbidity removal efficiency of 20%. After that, increased to 20% for color and 60% for turbidity at the exit of the SSF. The findings of this investigation also revealed that the chloride and TDS removal efficiencies of the water treatment plant (WTP) at the roughing filter were 44.5% and 19%, respectively. At the exit of the slow sand filter, filtration values improved to more than 22.3% for chloride and 13.6% for TDS. The chloride and TDS removal efficiencies were notably lower compared to other parameters, indicating a need for improvement in treating these components. Total Coliform (TC) and E. coli (EC) bacteria removal efficiency of 25% and 60%, respectively, at the roughing filter. These values improved to 50% for TC and 40% for EC at the exit of the SSF. the TC and EC removal efficiencies were considered satisfactory.

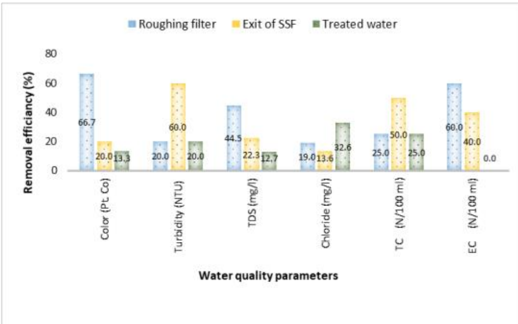

Figure 7: Removal Efficiency in various unit operation points of the Water Treatment Plant

4.3.2 Cumulative Removal Efficiency (CRE)

The Cumulative Removal Efficiency (CRE) value was used to determine the overall removal efficiency of the water treatment plant as shown in Figure 8. The results indicated that the overall color and turbidity removal efficiencies were highly effective at 100% for both. However, the overall TDS and chloride removal efficiencies were slightly lower at 79% and 65%, respectively. Moreover, the overall TC and EC removal efficiencies were 100% for both unit parameters, as shown in Figure 8. It's important to note that the acceptable removal efficiency for TC and EC is 100% to ensure the treated water meets the safety standards for drinking water. Thus, the treated water can be considered completely safe for use in domestic purposes.

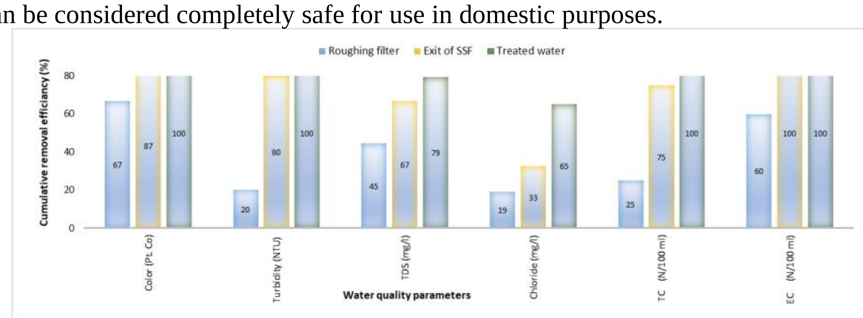

Figure 8. Cumulative Removal Efficiency (CRE) in various unit operation points of the KUET-WTP

5 Conclusions

The research on the working principle and performance evaluation of the KUET water treatment plant in Khulna-9203, Bangladesh has shown that the plant effectively purifies source water from the nearby ponds and shallow tube wells using a combination of physical, chemical, and biological treatment processes. The plant can remove impurities such as turbidity, total dissolved solids (TDS), and other contaminants to provide safe and clean drinking water to the university campus and surrounding areas. The plant's performance was evaluated by monitoring various water quality parameters such as pH, color, turbidity, iron, total dissolved solids (TDS), and chloride. The results showed that the plant was able to consistently meet the Bangladesh Standards for Drinking Water Quality for all of these parameters, indicating that the plant is operating effectively. However, during the monsoon season, the plant's performance may be affected by flooding and high levels of turbidity in the source water. The study also found that the plant's performance can be improved by regularly maintaining and upgrading the equipment, as well as by implementing a comprehensive monitoring and management system. In conclusion, the KUET water treatment plant can provide safe and clean water for domestic use to the university campus residential areas.

6 Acknowledgement

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