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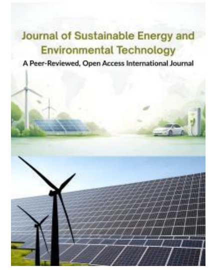

Research Article

Comparative Analysis of Inlet and Outlet Water Quality Using Water Quality Index from the Ghorashal Fertilizer Industry, Dhaka.

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Abstract: Industrial wastewater from fertilizer industries is a major source of environmental degradation in Bangladesh, especially for rivers near clusters. This study focuses on the inflow and outflow of the official water from the GUFI (Urea Fertilizer Industry) in Dhaka. Samples were collected fortnightly for two months, and all the methods recommended by APHA (2017) were followed when determining physical parameters (temperature, color, odor) or chemical parameters (pH, electrical conductivity [EC], total dissolved solids [TDS], dissolved oxygen [DO], biological oxygen demand [BOD], and chemical oxygen demand [COD]). Wastewater from the GHURASAL UREA factory was effective in practice, initially altering pH values to an average of 8.2. Both BOD and COD levels were cut by about 60% relative to their raw values, again meeting DoE standards. Outlet EC values (mean 1405 µS/cm) exceeded the DoE specifications of 1200 µS/cm, outlet TDS (1715 mg/L) surpassed the WHO's recommended limit, and outlet DO levels (mean 3.6 mg/L) fell short of the WHO's and USEPA's criteria for aquatic life, which require a minimum of 5 mg/L. The inlet wastewater, with a WQI of 148, is unequivocally classified as "Unsuitable" or "Polluted." This extreme value is a quantitative manifestation of the heavily contaminated nature of the raw industrial discharge, corroborating the observed high organic loads, critical oxygen depletion, and elevated ionic strength. The treated effluent shows a marked improvement, with the WQI falling to 78, placing it in the "Very Poor" category. This 52% reduction in the index value is a strong quantitative testament to the overall functionality of the wastewater treatment plant. These results suggest that, although the treated effluent meets national standards, it is ecologically problematic on a global scale. Over time, this situation may lead to gradual pollution, land degradation, and even public health problems due to infectious diseases.

Keywords: *Wastewater; Physico-chemical parameters; Fertilizer industry; Water Quality Index.*

1. Introduction

Water is one of the most vital natural resources, and its quality is directly linked to human health, agriculture, and ecological balance. However, industrialization has become one of the major causes of water pollution in developing countries, including Bangladesh (Rahman *et al.,* 2019). Among the various industries, fertilizer factories play a critical role in ensuring agricultural productivity but also contribute significantly to environmental degradation through effluent discharge (Sultana & Jahan, 2021).

The Ghurasal Urea Fertilizer Industry, located in Narsingdi district near Dhaka, is one of the largest fertilizer plants in Bangladesh, producing a substantial portion of the country's urea demand (Bangladesh Chemical Industries Corporation [BCIC], 2020). Like many large-scale industrial complexes, it generates considerable wastewater from production processes, cooling systems, and cleaning operations. This wastewater contains varying levels of salts, organic compounds, and chemical pollutants that may deteriorate the quality of receiving water bodies if not adequately treated (Hossain & Haque, 2020). Industrial effluents

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from fertilizer plants have been reported to cause oxygen depletion, elevated total dissolved solids, and increased concentrations of chemical oxygen demand (COD) and biological oxygen demand (BOD) in adjacent rivers (Ahmed *et al.,* 2018). If untreated or insufficiently treated wastewater is discharged into rivers, it not only endangers aquatic life but also threatens communities relying on surface water for irrigation, fishing, or domestic purposes (World Health Organization [WHO], 2017). In response, Waste Water Treatment Units (WWTUs) are installed to reduce pollutant concentrations before final discharge. Yet, the efficiency of such systems in Bangladesh varies across industries, often due to outdated technology, poor operation, or limited monitoring (Kabir *et al.,* 2022).

Industrialization in Bangladesh has rapidly expanded over the last four decades, contributing to economic growth but also creating serious environmental challenges (Rahman *et al.,* 2019). Fertilizer industries, particularly urea plants, are among the major contributors of wastewater discharge containing high levels of dissolved salts, organic matter, and nitrogenous compounds (Kabir *et al.,* 2022). If this wastewater is not adequately treated, its discharge into nearby rivers leads to deterioration of water quality, threatening aquatic biodiversity and human livelihoods (Ahmed *et al.,* 2018). This problem raises concerns about the adequacy of the existing wastewater treatment system at Ghorashal and its ability to comply with the standards set by the Department of Environment (DoE), Bangladesh, and international guidelines such as those of the World Health Organization (WHO, 2017). Without systematic monitoring and comparative analysis of inlet and outlet water quality, it is difficult to determine whether the treatment system effectively reduces pollutants or whether untreated discharges are harming the surrounding environment. The objective of this research is (i) To measure selected Physical parameters (Temperature, Color, Odor) and Chemical parameters (pH, Electrical Conductivity, Total Dissolved Solids, Dissolved Oxygen, Biological Oxygen Demand, and Chemical Oxygen Demand) of Inlet and Outlet water from the Ghorashal Urea Fertilizer Industry, (ii) To assess Inlet and Outlet water quality using Water Quality Index (WQI), (iii) To compare Inlet and Outlet values with the standards of the Department of Environment (DoE), Bangladesh and International guidelines.

2. Methodology

2.1 Study Area: Ghorashal Urea Fertilizer

The study was conducted at the Ghorashal Urea Fertilizer Industry (GUFI), formerly known as Sunshine Chemicals (Bangladesh) Limited. Established in the late 1970s under the Bangladesh Chemical Industries Corporation (BCIC), GUFI is one of the largest urea production complexes in the country, with an annual production capacity of more than 500,000 metric tons. The industry is located near the Shitalakhya River, which receives the treated effluent from the plant. The site was selected for this study due to its large production scale, its significance in Bangladesh's fertilizer sector, and increasing concerns regarding the management and environmental impact of its effluent discharge.

2.2 Research Design

The study used a comparative experimental design to measure the physicochemical characteristics of inlet and outlet water from the fertilizer industry. The aim was to evaluate the performance of the wastewater treatment plant (WWTP) by comparing key water quality parameters before and after treatment. A quantitative approach was followed, and all measurements were conducted according to standard methods recommended by the American Public Health Association (APHA, 2017). This design allowed statistical comparison between inlet and outlet samples to assess pollutant reduction and compliance with regulatory standards.

2.3 The sampling procedure

Wastewater samples were taken from two areas, such as Inlet water samples and Outlet water samples. Inlet water samples represent a composite of industrial wastewater before treatment. Outlet water samples represent the wastewater that enters the Shitalakhya River upstream of the discharge point. Samples were taken over a period of two months at weekly intervals to reflect short- term changes in production. A total of sixteen samples were collected eight inlet and eight outlets. Each sample was obtained with sterilized polyethylene bottles (2 L capacity), washed with water from the sampling site three times before filling. Grab sampling was chosen for practicality, with efforts made to sample at approximately the same time each day to minimize variability (APHA, 2017).

2.4 Sample preservation and transportation

Samples were stored in iceboxes at 4°C immediately after collection, then transferred to the Laboratory for Environmental Science and Technology of German University Bangladesh, Gazipur, Bangladesh. No doubt, samples had to be kept dark for BOD analysis. Other treatment conditions were: concentrated sulfuric acid was added to a pH below 2 for COD analysis instead of chlorine; Winkler's reagents were used on-site for oxygen solubility measurements to avoid fluctuation during transportation. All these analyses began within 24 hours of collection to minimize changes in sample properties (APHA 2017).

2.5 Analytical methods

2.5.1 Physiological parameters:

Temperature is one of the most important physical parameters of water. It is usually measured directly at the sampling site using a calibrated thermometer or a digital temperature probe. The thermometer is immersed in the water sample for a few minutes until a stable reading is obtained. Temperature affects the solubility of gases, chemical reaction rates, and biological processes in water bodies.

Color of water is determined by visual comparison or by using a colorimeter. In the visual comparison method, the color of the water sample is compared with standard color solutions prepared from platinum–cobalt standards. The color is then expressed in standard color units (PCU). Color in water may originate from dissolved organic matter, industrial effluents, or natural substances such as humic acids.

Odor is assessed by sensory evaluation. The water sample is gently warmed and smelled to detect any unusual or unpleasant odor. The presence of odor may indicate contamination by organic matter, chemicals, or microbial activity.

2.5.2 Chemical Parameters

pH is measured using the electrometric method with a digital pH meter equipped with a glass electrode. The instrument determines the hydrogen ion concentration in the water sample and provides the pH value directly. Before measurement, the pH meter is calibrated using standard buffer solutions (usually pH 4.0, 7.0, and 10.0) to ensure accuracy.

Electrical Conductivity (EC) is determined using a conductivity meter. This method measures the ability of water to conduct an electric current, which depends on the presence of dissolved ions such as salts and minerals. The conductivity probe is immersed in the water sample, and the instrument records the conductivity value, usually expressed in microsiemens per centimeter (µS/cm). Total Dissolved Solids (TDS) represent the total amount of dissolved inorganic and organic substances present in water.

TDS can be measured using a digital TDS meter or by the gravimetric method. In the gravimetric method, the water sample is filtered and then evaporated in a pre-weighed dish at a specified temperature. The remaining residue represents the dissolved solids, and its mass is used to calculate the TDS concentration in mg/L.

Dissolved Oxygen (DO) is determined either by the Winkler titration method or by using a digital dissolved oxygen meter. In the Winkler method, oxygen present in the water sample reacts with manganese sulfate and alkaline iodide reagents to form a precipitate. After acidification, iodine equivalent to the dissolved oxygen is released and titrated with sodium thiosulfate solution to determine the oxygen concentration.

Biological Oxygen Demand (BOD) measures the amount of oxygen required by microorganisms to decompose organic matter in water. The standard BOD test, commonly known as BOD_5, involves incubating a diluted water sample in a sealed bottle at 20°C for five days. The difference between the initial and final dissolved oxygen concentrations indicates the BOD value.

Chemical Oxygen Demand (COD) is determined using the dichromate reflux method. In this method, the water sample is digested with a strong oxidizing agent, potassium dichromate, in the presence of sulfuric acid and a catalyst under reflux conditions. The organic matter in the sample is oxidized, and the amount of dichromate consumed is measured by titration. The COD value represents the total amount of oxygen required to chemically oxidize the organic and inorganic substances in the water.

2.6 Water Quality Assessment Using a Water Quality Index (WQI)

To synthesize the multifaceted water quality data into a comprehensive assessment, a Water Quality Index (WQI) was calculated. The final WQI value was computed by aggregating the weighted sub-indices. The most common approach, the Weighted Arithmetic Mean Method, was employed:

$$WQI = (\Sigma(Wi \times Qi)) / (\Sigma Wi)$$

The resulting WQI value provides a single score representing overall water quality. The interpretation of this score follows a generalized classification scheme, as detailed in Table 1.

Table 1: Weighted Arithmetic Water Quality Index (WAWQI) classification system derived from the Brown *et al.,* 1972.

WQI Range	Classification	General Implication
0-25	Excellent	Very low pollution, suitable for sensitive ecosystem
26-50	Good	Light pollution, generally suitable for aquatic life
51-75	Poor	Moderate pollution, significant environmental stress
76-100	Very Poor	Heavy pollution, unsuitable for most aquatic life
100	Unsuitable/ Polluted	Severe pollution, represents a major environmental hazard

3. Results and Discussion

3.1. Assessment of Different Parameters

These parameters in this study, the physical parameters of inlet and outlet wastewater from the Ghorashal Urea Fertilizer Industry were analyzed and compared with both national standards and international guidelines where available.

Table 2: Assessment of inlet and outlet wastewater quality

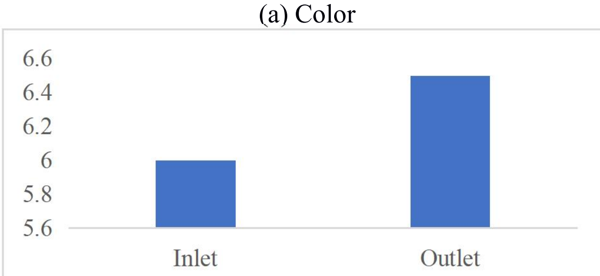
Parameter	Inlet	Outlet	Change (%)	DoE Limit	WHO Standard
Temp (°C)	35.0	35.8	Increase 2.29%	≤ 40°C (for discharge to surface water)	No specific guideline value
pH	6.0	6.5	Increase 8.33%	6.0 – 9.0	6.5 – 8.5
EC (µS/cm)	1590	1460	Reduce 8.18%	Not specifically fixed	~1400 µS/cm
TDS (mg/L)	1985	1780	Reduce 10.33%	≤ 2100 mg/L	≤ 1000 mg/L
DO (mg/L)	1.6	3.5	Increase 118.75%	≥ 5 mg/L (for aquatic life protection)	No specific drinking water limit
BOD (mg/L)	130	55	Reduce 57.69%	≤ 50 mg/L (industrial effluent discharge)	Not specified for drinking water
COD (mg/L)	320	185	Reduce 42.19%	≤ 200 mg/L (industrial effluent discharge)	Not specified for drinking water

In table 2 represents, the comparison of inlet and outlet water quality parameters indicates a noticeable improvement in effluent quality after treatment. Temperature slightly increased from 35.0°C to 35.8°C (2.29%), but it remains within the permissible limit set by the Department of Environment Bangladesh (DoE). Similarly, pH increased from 6.0 to 6.5, bringing it within the acceptable range recommended by both DoE and the World Health Organization (WHO). Electrical Conductivity (EC) and Total Dissolved Solids (TDS) showed moderate reductions of 8.18% and 10.33%, respectively, indicating partial removal of dissolved ions. However, the outlet TDS value (1780 mg/L) still exceeds the WHO guideline for drinking water, though it remains within the DoE discharge limit. Dissolved Oxygen (DO) significantly increased from 1.6 mg/L to 3.5 mg/L (118.75%), suggesting improved oxygen availability after treatment, although it is still below the recommended ≥5 mg/L level for supporting aquatic life. The most notable improvements were observed in organic pollution indicators. Biochemical Oxygen Demand (BOD) decreased by 57.69%, while Chemical Oxygen Demand (COD) decreased by 42.19%, demonstrating substantial removal of organic contaminants. The outlet COD value falls within the DoE discharge limit, while BOD is slightly above the recommended standard. Overall, the treatment process effectively reduced organic pollution and improved several water quality parameters, though some parameters such as DO and TDS still require further improvement to fully meet all environmental and drinking water standards.

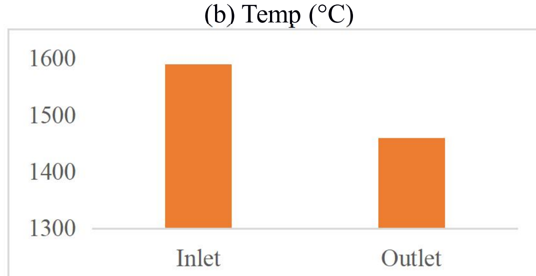
3.2 Comparative Analysis of Different Parameters

(a) Color

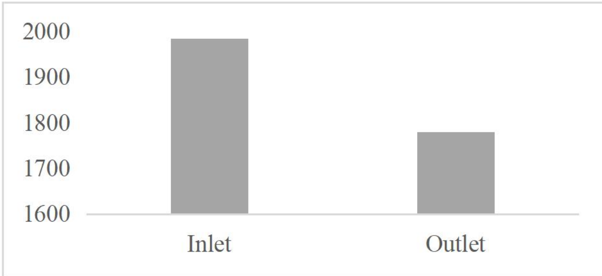
(b) Temp (°C)



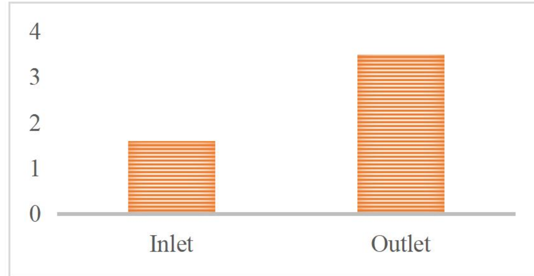
(c) pH



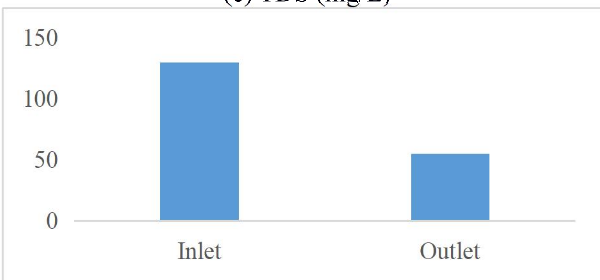
(d) EC (µS/cm)



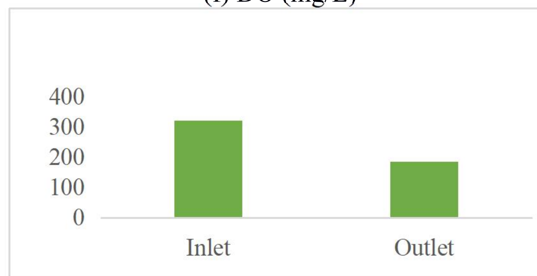
(e) TDS (mg/L)



(f) DO (mg/L)



(g) BOD (mg/L)



(h) COD (mg/L)

Figure 1: Qualitative assessment of inlet and outlet wastewater

In figure 1(a) represents, The color of the inlet water is dark yellow-brown, indicating the presence of suspended particles and organic impurities, while the outlet water appears much clearer, showing effective removal of contaminants. 1(b) The temperature slightly increased from about 35°C to 35.8°C, which is still within the Department of Environment (DoE) permissible limit of below 40°C. 1(c) The pH increased from 6.0 to about 6.5, moving toward a neutral condition. This value falls within the WHO recommended range of 6.5–8.5 and the DoE standard of 6–9. 1(d) The electrical conductivity (EC) decreased from approximately 1590 µS/cm to 1460 µS/cm, indicating a reduction in dissolved salts and ions. 1(e)Total dissolved solids (TDS) decreased from about 1980 mg/L to 1780 mg/L, showing partial removal of dissolved substances. The outlet value meets the DoE limit (≤2100 mg/L) but still exceeds the WHO desirable limit of 1000 mg/L for drinking water. 1(f) The dissolved oxygen (DO) increased from 1.5 mg/L to 3.5 mg/L, suggesting improved oxygen availability, although it remains below the ideal level of 5 mg/L for healthy aquatic environments. 1(g) Biochemical oxygen demand (BOD) decreased from 130 mg/L to about 55 mg/L, indicating reduced biodegradable organic matter and approaching the DoE limit of 50 mg/L. 1(h)Chemical oxygen demand (COD) also decreased from 320 mg/L to 190 mg/L, meeting the DoE permissible limit of 200 mg/L.

3.3 Synthesis of Water Quality Through Indexing

The calculation of the Water Quality Index (WQI) provides a powerful synthesis of the data, moving beyond individual parameters to tell a cohesive story of pollution and treatment efficacy.

Table 3: Inlet Water Quality Assessment via WQI

Parameter	Inlet (Vn)	DoE Limit (Vs)	Vi	Qi	k	Wi	Qi×Wi	WQI	Class
pH	6	6	7	100	2.567	0.428	42.7742	$=\sum\frac{Qn\times Wn}{Wn}$ $=\frac{124.0021}{1}$ = 124.0021	Unsuitable/Polluted
EC (µS/cm)	1590	1200	0	132.5	2.567	0.002	0.2834		
TDS (mg/L)	1985	2100	0	94.524	2.567	0.001	0.1156		
DO (mg/L)	1.6	5	14.6	135.417	2.567	0.513	69.5081		
BOD (mg/L)	130	60	0	216.667	2.567	0.043	9.2677		
COD (mg/L)	320	200	0	160	2.567	0.012	2.0532		

In table 3 shows that's The Water Quality Index (WQI) was calculated using six parameters: pH, EC, TDS, DO, BOD, and COD. This WQI value indicates that the water quality falls under the "poor / unsuitable (polluted)" category. Among all parameters, DO, BOD, and COD contributed most significantly to the high WQI value. The low dissolved oxygen (1.6 mg/L) and very high BOD (130 mg/L) and COD (320 mg/L) suggest severe organic and chemical pollution. Although pH, EC, and TDS show moderate influence, they are not the primary causes of degradation. Overall, the water is not suitable for drinking purposes and reflects high pollution levels, likely due to wastewater or industrial discharge.

Table 4: Outlet Water Quality Assessment via WQI

Parameter	Outlet (Vn)	DoE Limit (Vs)	Vi	Qi	k	Wi	Qi×Wi	WQI	Class
pH	6.5	6	7	50.00	2.567	0.428	21.3871	$=\sum \frac{Qn\times Wn}{Wn}$ $=\frac{86.2081}{1}$ $= 86.2081$	Very Poor
EC (μS/cm)	1460	1200	0	121.667	2.567	0.002	0.2602		
TDS (mg/L)	1780	2100	0	84.762	2.567	0.001	0.1036		
DO (mg/L)	3.5	5	14.6	115.625	2.567	0.513	59.3493		
BOD (mg/L)	55	60	0	91.667	2.567	0.043	3.9210		
COD (mg/L)	185	200	0	92.50	2.567	0.012	1.1870		

In table 4 shows that's This WQI value indicates that the water quality falls under the "very poor" category. Compared to the inlet condition, there is a noticeable improvement in water quality. However, key parameters still indicate pollution. In particular, dissolved oxygen (DO = 3.5 mg/L) remains below the standard limit, while BOD (55 mg/L) and COD (185 mg/L) are still relatively high, suggesting the presence of organic and chemical contaminants. The major contribution to the WQI comes from DO due to its high weight, while EC, TDS, BOD, and COD contribute moderately. Although the outlet water shows improvement compared to the inlet, it is still not suitable for drinking purposes and reflects poor environmental quality. Further treatment is required to meet acceptable standards.

4. Conclusion

This study conducts an analysis on the comparative mechanical and chemical properties of raw sewage from outlet water in the Ghorashal Urea Fertilizer Industry, Dhaka, Bangladesh. Results indicated that the wastewater treatment plant (WWTP) had a substantial intermediate reduction in sewage pollution content but did not eliminate environmental risks. Physical parameters such as temperature, color, and odor showed evident improvements after treatment, with outlet water looking clearer and less odorous while still meeting DoE temperature standards. Chemical parameters also improved: pHs were adjusted nearly neutral; BOD decreased by about 60%, and COD dropped around 43%, both within national discharge limits; However, some things demanded attention. For instance, high conductivity of electrical current (EC), excessive total dissolved solids (TDS), and improper concentrations of oxygen in the water were all problems that could not be overlooked. Specifically, the outlet EC was in excess of DoE permissible limits; TDS exceeded WHO standards. Oxygen in water remained below the 5 mg/L threshold needed to support aquatic life. (DoE, 1997; WHO 2017; USEPA 2012). "The application of the Water Quality Index distilled the complex water quality data into an unambiguous conclusion: the treatment process transforms the wastewater from 'Unsuitable' to 'Very Poor.' This underscores a critical limitation—the plant mitigates the most severe pollution but does not produce an environmentally benign effluent." It is imperative, the findings indicate, that new technologies capable of advanced treatment be developed. Such enhancements include aeration systems with greater efficiency, nutrients retrieved in the process through reuse, and technologies for removing ions from wastewater.

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Author Declarations

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Author Contributions

Md. Mominul Haque: Conceptualization, methodology, research design, data collection, formal analysis, and manuscript drafting.

Md. Zahin Rahman: Conceptualization, supervision, manuscript review, critical revision, and editing.

All authors have read and approved the final version of the manuscript.

Data Availability Statement

The data supporting the findings of this study are included within the article. Additional data are available from the corresponding author upon reasonable request.

Ethical Approval

This study did not involve human participants, animals, or any procedures requiring institutional ethical approval. Therefore, ethical approval was not required.

Conflict of Interest

The authors declare that they have no competing interests or conflicts of interest related to this research.

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