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Research Article

Environmental Sustainability of Wastewater Qualitatively Discharged from Pharmaceutical, Alloy Tech, and Textile Industries through Effluent Analysis: Industrial Investigation in Bangladesh

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***Abstract*—** Pharmaceutical, alloy tech, and textile assorted productions effectively contribute to Bangladesh's domestic economy, where the regular treatment of pollutants from effluent wastewater is a basic demand to assure a good life and environmental sustainability. The concentration of the physicochemical analysis of wastewater emitted by industry is the goal of this current research. The samples were immediately allowed into the laboratory and characterized for pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), dissolved oxygen (DO), total dissolved solids (TDS), and total suspended solids (TSS). The research findings indicate that the pH, BOD_5, COD, DO, TSS, and TDS concentrations ranged from 6.8 to 8.57, 28.2-420 mg/L, 102-1238 mg/L, 1.15-5.5 mg/L, 78-306 mg/L, and 1188-3927 mg/L, in that order. Wastewater's pH levels before and after treatment were determined to be within the permissible range for the environment, however, the levels of BOD_5, COD, DO, TSS, and TDS before treatment were much higher. The improvement of freshwater's characteristics indicates that it can be harmful to the aquatic chemistry nearby. This endeavor will create an effort for pharmaceuticals, alloy tech, and textile wastewater to be discharged with the standard allowable environmental quality through proper and accountable effluent analysis.

***Keywords*—** Wastewater, pH, BOD_5, COD, DO, TSS, TDS, Industrial effluents.

1. Introduction

Bangladesh's pharmaceutical, alloy tech, and textile industries are the most crucial sectors to enhance the country's economic growth. Besides the nation, it is the second-largest textile trader globally, after China. These industries are considered the major waste generators due to the handling of large amounts of chemicals and water. Industrialized wastewater offers caustic soda, oil, grease, Glauber salt, sulfide, ammonia, and heavy metals (cadmium, mercury, arsenic, lead, etc.) in processing attributes to waste sources and pollution. Different chemicals, including strong acids, strong alkalis, organic compounds, inorganic chlorinated compounds, sodium hypochlorite, etc., were also used during each phase.

The following complementary components throw off the qualitative parameters: Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5), and Potential of Hydrogen (pH) [1, 2]. Metals from waste creation are promptly released into water flows, increasing the requirement for chemical and biological oxygen (BOD_5 and COD). The dyes may experience anaerobic degradation, constituting potentially carcinogenic compounds that are in solution in the food chain [3]. The discharge of wastewater into the watercourses is causing a significant amount of sludge and effluent, which poses a risk to human health and the environment. This can lead to allergic skin reactions, kidney failure, or even cancerous diseases. A significant source of continuous, direct pollution input into aquatic systems that has long-term, substantial effects on ecosystem function is industrial wastewater [4]. The purpose of this study is to assess the possibility of contamination of industrial effluents from six companies at wastewater dumping sites in Bangladesh's Gazipur, Narayanganj, and Dhaka.

Due to rapid industrialization, 3.4 million people worldwide pass away from waterborne illnesses every year. Typical operations and the industries' geographic locations determine how polluted the wastewater is in each industry. Industrial wastewater represents an acute hazard to the natural water system. In Bangladesh, the physical health of workers, as well as those who live close to chemical synthesis companies and farmers, is negatively impacted by the fact that one-third of all water pollution originates from solid wastes, industrial effluent discharge, and other hazardous wastes [5, 6]. Given that groundwater is the primary source of manufacturing for the disposal of wastewater, worldwide development, and efficient industrialization have contributed to the interrelationship between contamination, public health, and the environment. Due to heavy metals, fossil organic components, and other pollutants, even though the amount of untreated or partially treated industrial effluent is small, it contains a wide spectrum of pollutants. The impact of these typical industrial chemicals demands an increasing concern for public health and their ambiance owing to their toxicity, acute toxicity, and mutagenic essences [7, 8].

Assessment and depiction of wastewater are the most crucial to evaluating the precision of wastewater in Bangladesh. Among other methods, one of the most modern and widely applied approaches for treating wastewater from the textile, metal tech, and pharmaceutical sectors is bioremediation [9-11].

The current research provides a thorough assessment of the work that is already accessible in the field, highlighting the necessity for further investigation in light of the gaps and paucity of costly work completed. This research aims to examine the qualitative characterization of environmentally sustainable patterns of effluents against recommended levels for Bangladesh’s typical industries in terms of pH, BOD_5, COD, DO, TSS, and TDS values of wastewater.

2. Experimental Method

Study Area

There are primarily industrial regions in the study area. Numerous industries have been established, such as those in the fields of fertilizer, textiles and dyeing, chemicals, paper and pulp, tanneries, battery manufacturing, food processing, and so forth. These industries release large amounts of wastewater that is either untreated or only partially treated, which is alarmingly polluting the river water. Pharmaceuticals, alloy techs, and textile industries situated in Tongi-Gazipur, Sonargoan-Narayanganj, and Savar-Dhaka (Figure 1), respectively, were picked out to assess the qualitative environmental stability concentration in effluents for our investigation.

Sample collection

The industrial effluent samples (A_1, B_1, C_1, D_1, E_1, F_1, A_2, B_2, C_2, D_2, E_2, and F_2) were collected during January 2022-August 2022 from effluent dispatching drains of six different industries (coding as two pharmaceuticals: PI-1 and PI-2; two alloy techs: AI-1 and AI-2; two textiles: TI-1 and TI-2) outlets shown in Table 1. Samples (Figure 2A) were maintained for laboratory analysis with proper guidance. Plastic containers were used to collect both treated (gathered from the plant's releasing point following treatment) and untreated (gathered from the ETP plant's equalization tank) effluents. The samples were analyzed for effluent analysis within 24 to 60 hours of collection and stored in a refrigerator at about 4°C [12].

Analytical Procedures

pH Evaluation

Before and after treatment, the wastewater's hydrogen potency (pH) was assessed using APHA 23rd EDN. 2017 (4500 H+B). On the day of sample collection, the assessments were evaluated using a Mettler Toledo pH meter (Figure 2B).

Biochemical Oxygen Demand (BOD_5) Evaluation

The tested samples' BOD_5 was measured by APHA 23rd EDN. 2017 (5210 B). The BOD_5 value is typically used to show how sewage and other organic wastes affect the amount of dissolved oxygen in groundwater. It has been employed and taken into consideration for many purposes. Brown glass bottles were used (300 mL bottles including a ground-glass stopper and flared mouth were designed). Incubation bottles were washed with a detergent, rinsed thoroughly, and drained before use. The air incubator (Figure 2C) was thermostatically controlled at 20±1°C for 5 days.

Chemical Oxygen Demand (COD) Evaluation

APHA 23rd EDN.2017 (5220 D) states that the COD reactor (Figure 2D) determined the COD values.

Dissolved Oxygen (DO) Evaluation

The DO values were prescribed by the dissolved meter (Figure 2E) concerning APHA 23rd EDN.2017 (4500-O G).

Total Suspended Solid (TSS) Evaluation

After evaluation, the TSS values were granted to APHA for the 23rd EDN of 2017 (2540 D). Glass microfiber filter paper was cooled in a desiccator for fifteen minutes after being dried in an oven at 105°C for an hour. Next, the filter paper's dry weight was determined, and it was found on the filtration device (Figure 2F). After passing through the filter paper and being rinsed with 10 mL of deionized water, 100 mL of sample water was used. The filter paper was carefully removed from the filtering device and baked for one hour at 105°C to dry it off. Ultimately, the filter paper was allowed to cool in a desiccator for fifteen minutes while a steady weight was applied. However, the overall method is described by the mathematical equation (1).

TSS= [(Weight of the filter paper after drying – The filter paper’s weight)/Measured volume of the water sample] × 1000 × 1000 mgL^{-1} ………………… (1)

Total Dissolved Solid (TDS) Evaluation

The samples' TDS values were calculated by equation (2), and the whole experiment was tested using the APHA 23rd EDN.2017 (2540C) method. Firstly, a 250-mL glass beaker was heated at 180°C for 1 hour. After cooling it down, the beaker's dry weight was determined. Filter sheets were used to filter the collected samples. The entire washing solution and filtrate were transferred to a beaker on a hot plate (Figure 2G) to evaporate until dry, and they were then evaporated for one hour at 180°C in an oven. Up until the set weight was obtained, the processes of drying, cooling, and weighing were repeated.

TDS= [(Weighing the beaker dry – The beaker's weight)/Measured volume of the water sample] × 1000 × 1000 mgL^{-1} ………………… (2)

Data analysis
The studied parametric quantities were computed with Origin Lab and the SPSS software. Range, standard deviation (SD), and other metrics were used to illustrate the varied quantities and provide assortment.

3. Results and Discussion

Pharmaceuticals, Alloy Techs, and Textile: Impact on the Environment
Bangladesh's pharmaceutical industry has grown significantly in the last two decades, with interior companies and herbal manufacturers making up over 65% of the industry. However, many companies do not use effluent treatment plants regularly, leading to harmful effects on the environment and human health. Discharging antibiotics and penicillin waste into streams has negative effects on the biological ecosystem. Measuring the pH and dissolved oxygen, as well as the presence of toxic substances, is necessary to enhance biological processes.

Pharmaceutical industries in Gazipur produce a wide variety of products using both organic and inorganic contents as raw materials, and therefore the complex toxic organic liquid wastes generate a high concentration of inorganic TDS, BOD, and COD. A physicochemical study of pharmaceutical wastewater efficiency found a fluctuation in wastewater characteristics from inlet to outlet [13]. This study detected a diminution in the adopting parametric quantity: pH 12.9±0.28, BOD 4800 ± 316.23 mg/L, COD 8480 ±414.73 mg/L, TSS 20030 ± 317.4 mg/L, and TDS 16190 ±108.4 mg/L. A report on the water quality of Turag Khal explored the encroachment of pharmaceutical industry-treated effluents [14]. It was analyzed for the water quality of the river except for the following parameters (mean value): pH 7-8, TDS between 354.38 and 873.81 mg/L, TSS 50–348.75 mg/L, BOD 3.69–5.78 mg/L, and COD 131.31-218.42 mg/L. It was eventually concluded that the effluent developed by pharmaceutical industries has a substantial negative impact on the water quality of Turag Khal. This study served to design a suitable treatment plan using microbial syndicates for the pharmaceutical industry's wastewater, which contains organic pollutants. Again, estrogens were discovered in wastewater during the late 1990s, which resulted in the feminization of fish. It was another agent that caused greater tendencies toward pharmaceuticals in the environment. However, the low concentrations of pharmaceuticals can induce negative impacts on freshwater ecosystems.

The textile industry, particularly denim manufacturing, has a huge environmental impact due to the amount of water and chemicals used [15]. The production of 2 billion pairs of jeans requires 1.7 million metric tons of chemicals and 11.4 billion liters of water, which leads to the release of carbon dioxide and various types of waste. 80% of effluents discharged into water sources are caused by textile wet finishing, which poses health, environmental, and climate-related risks [16]. As much as possible, alloy techniques are being imparted to different types of wet industrial processes. Normal wash, accelerator wash, and potassium permanganate spray are broadly exploited among them. The subtractive leaching process is also conceived as a feasible wet processing advance that bestows the limitation of alloy properties. These dampening techniques evolved due to the generation of a potential effluent intensity controlling several chemical remainders [17]. The discharged chemicals dissemble air, water, and soil and cause wicked injury and even death to human and aquatic life. Their water system stimulates impediment to light incursion into the lower profundity of water. As a consequence, photosynthesis is prevented in aquatic plants, which has increased the toxicity levels (pH, BOD, COD, DO, TSS, and TDS) in the aquatic ecosystem [18].

Effluent features and satisfactory limit points
Bangladesh's government has dictated an effluent treatment policy for pharmaceuticals, alloys, and textiles and brought out particularly satisfactory wastewater arguments before expelling them into the local environment. According to the Environment Conservation Rules of 1997, Bangladesh's standard values are listed in Table 2. The effluent discharged by pharmaceuticals, alloy technologies, and textile industries is an optical source of high COD, BOD, TDS, TSS, and DO containing both organic and inorganic components out of the standard range. When such wastewater is confounded with a freshwater source, it has to step up the toxicity that can result in skin diseases including liver damage, dermatitis, and kidney carcinogenic troubles. Research remarks that if eco-friendly chemicals are practiced widely in the completing action of industries, environmental pollution could be understated to a heavier extent. However, the consented values vary from country to country due to the atmosphere's clear-cut nature (such as water, soil, temperature, etc.). For instance, both the USA and China do their most skilled practices and set parameters in comparison to the other mentioned countries. However, the parameters sanctioned by the Bangladeshi government are established with other Asian countries. An effluent treatment plant's (ETP) flow chart for effluent processing is displayed in Figure 3. To treat wastewater in an ETP, the zero discharge of hazardous compounds must be correctly maintained [19]. The outcome parameters obtained from six industries' effluents were equated with the standard values determined by the Bangladesh government as demonstrated in Table 3 in terms of pH, BOD, COD, DO, TSS, and TDS of the effluents.

Approach of pH
pH values [20] of water inauspiciously detriment plants, human health, and almost the whole aquatic ecosystem. This

measure, which indicates the sequence of several microorganisms' biochemical reactions, emphasizes the wastewater's acidity and basicity [13]. For both treated and untreated wastewater, these ranges were 6.8–8.2 and 7.88–8.57, respectively (Figure 4). Environmental sustainability relies on the aquatic cycle having a specified pH level of approximately 6–9. Before treatment, the wastewater's highest pH for AI-2 was found to be 8.57, whereas the lowest pH for TI-2 was 6.8. Before and after treatment, the pH values of the wastewater from all industries were within the recommended range. The pH value of water relies on the contamination of chemical pollutants, water flow, temperature, etc. [21]. The electrocoagulation process's primary efficacy in treating wastewater was determined by the initial pH [22].

Approach of Biochemical Oxygen Demand (BOD_5)

BOD_5 of wastewater is the amount of dissolved oxygen that aerobic bacteria need to biodegrade organic substrate [23]. Generally, 150 mg/L of BOD_5 is acceptable for direct discharge into the environment; however, this is mostly dependent on the water's total and particle organic carbon contents [24]. Lower oxygen levels prevented photosynthesis and caused abrupt partitions in aquatic ecosystems, which highlighted ancillary issues during the ETP discussion.

The maximum BOD_5 concentration was discovered to be 420 mg/L for TI-1. The BOD_5 values varied from 216-420 mg/L for untreated wastewater to 28.2-79.2 mg/L for treated water (Figure 5). It was noted that all of the water samples from the six industries listed had BOD_5 values that were higher than what was advised for Bangladesh. Since the BOD_5 values were received within the standard range after treatment, the wastewater containing organic matter should be possible to discharge into local water [25]. The basic demand for the presence of living organisms in wastewater vigorously validates the recommended pollution of local water sources by concentrating the dissolved oxygen. The lower the BOD_5 values, the more aquatic organisms use the dissolved oxygen to balance environmental sustainability.

Approach of Chemical Oxygen Demand (COD)

Chemical oxygen demand is the amount of oxygen needed to break down both organic and inorganic substrates. Because COD levels influence the anaerobic conditions in aquatic environments, which completely convert organic substrates into CO_2 while consuming less oxygen, lower COD values are employed in the non-hazardous and non-toxic chemical washing process [26]. COD values are always high and thereby should be diminished to below the acceptable limit through wastewater practices in the environment [27]. The COD values of samples from all tested industries were noted before and after treatment. It is seen that the COD evaluations of wastewater (940–1238 mg/L) and 102-228 mg/L were obtained before and after treatment, respectively. The pharmaceutical and alloy tech sectors in the Gazipur region had higher COD values than the textile and alloy tech industries, where the highest value for PI-1 was reported to be 1238 mg/L. However, it has been noteworthy that the COD values of AI-1, AI-2, TI-1, and TI-2 were within the permissible limit after treatment (Figure 6).

Approach of Dissolved Oxygen (DO) values

Dissolved oxygen (DO) is the most crucial parameter in wastewater quality evaluation because it reflects both the biological and physical processes persisting in the water [28]. Since the DO values possessed small quantities, both the respiration rate and organic degradation were high with the same rate of photosynthesis. Whereas 6.0 mg/L is required for drinking water, the standard dissolved oxygen content for aquatic life support is 4.5 mg/L. However, the wastewater possessed large amounts of organic substrates, and consequently, the biological metabolites altered the function of aquatic ecosystems by consuming dissolved oxygen [29]. The descending dissolved oxygen level of the inlet is in the order of TI-2>PI-2>TI-1>PI-1>AI-1>AI-2 (Figure 7). DO values should be 6.0 mg/L, 4.0–6.0 mg/L, and 5.0 mg/L for drinking, aquatic environments, and industries, respectively, by the environmental quality standard (EQS). Furthermore, according to the United States Public Health Service (USPH), the standard DO level of the local water system is 4.0–6.0 mg/L and >5.0 mg/l for fish living. It has been discussed concerning the above analysis that the obtained DO values did not exist in the recommended range against good: 5–9 mg/L, or excellent: ≥8–9 mg/L, which is detrimental to the aquatic environment [30].

Approach of Total Suspended Solids (TSS)

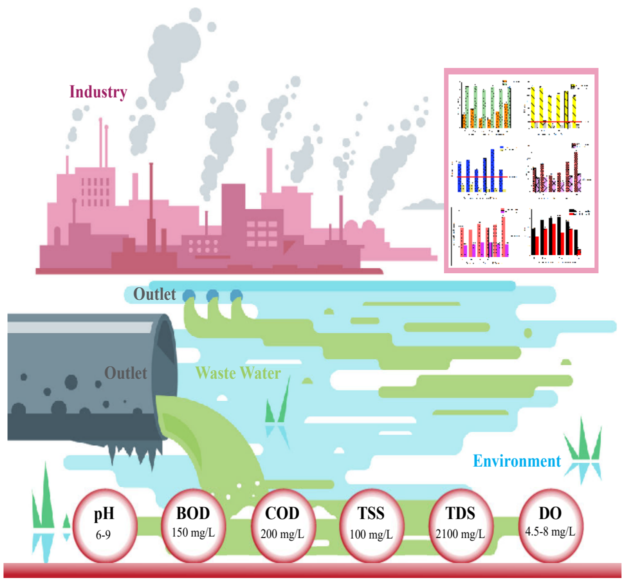
The suspended solids involve both organic and inorganic substrates in wastewater effluents, which are dispatched through masking, natural action, or flotation [31]. An adequate amount of surface-sized substrates during the photosynthesis period decreases the dissolved oxygen level with increased temperature [32]. Figure 8 shows the analysis of the comparison of suspended solids in wastewater both before and after ETP treatment. It was found that only the alloy tech industries (AI-1 and AI-2) met the recommended level after ETP treatment, though the concentrations of TSS were above the permissible range of 128–306 mg/L, and after treatment, the sample values were in the range of 78–138 mg/L. The Environment Conservation Rules 1997 state that pharmaceuticals and textile industrial effluents deviated from TSS values concerning the permissible level [33].

Approach of Total Dissolved Solids (TDS)

The appreciation of organic ($NO3^-$, CO_3^-, Cl^-, HCO_3^-), inorganic (Na, K, Mg, Ca), and other dissolved substrates in the effluent water system is completely known as total dissolved solids, which raises the hazardous level in the environment (fisheries, aquatic plants) [34]. TDS concentrations were determined to be between 2626 and 3927 mg/L before treatment and between 1188 and 1454 mg/L following treatment, which was within the allowable limit (2100 mg/L). TI-2 showed the highest TDS (3927 mg/L), and PI-2 revealed the lowest TDS (2626 mg/L) (Figure 9). However, after treatment, all the sample's TDS were within the Bangladesh standard level (2100 mg/L). The limit beyond concentrations affects the sustainability of the environment [35] and causes perniciousness through increasing salinity. The salt concentrations are highly employed in the textile industry for the dying process, in which the insoluble salts are discharged into local water. It has been regarded that the TDS concentrations are inappropriate for the environmental ecosystem when the ranges transcend 1000 mg/L since the high or low TDS concentrations might affect the outgrowth of aquatic environmental sustainability [36].

Figures and Tables

Graphical Abstract



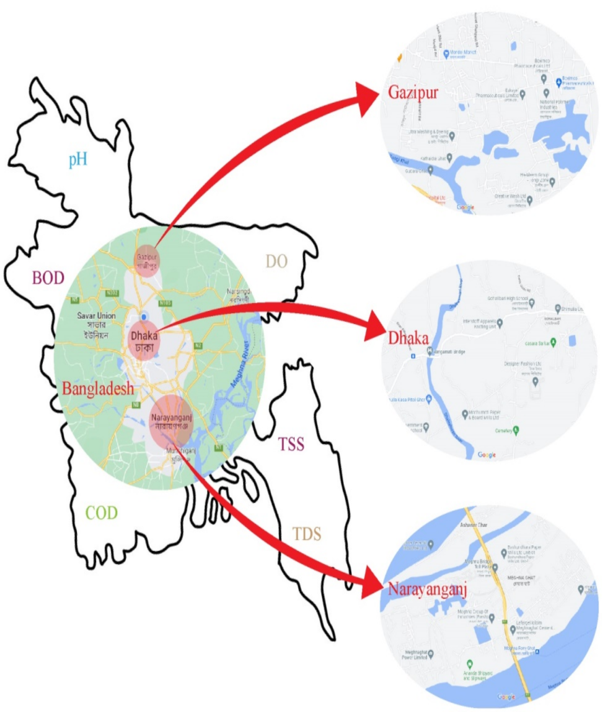


Figure 1. Position of the wastewater samples area (Depicted from Google map).

Figure 2. (A) Wastewater samples, (B) Mettler Toledo pH meter, (C) Incubator, (D) COD reactor, (E) DO meter, (F) Filtration apparatus, (G) Hot plate.

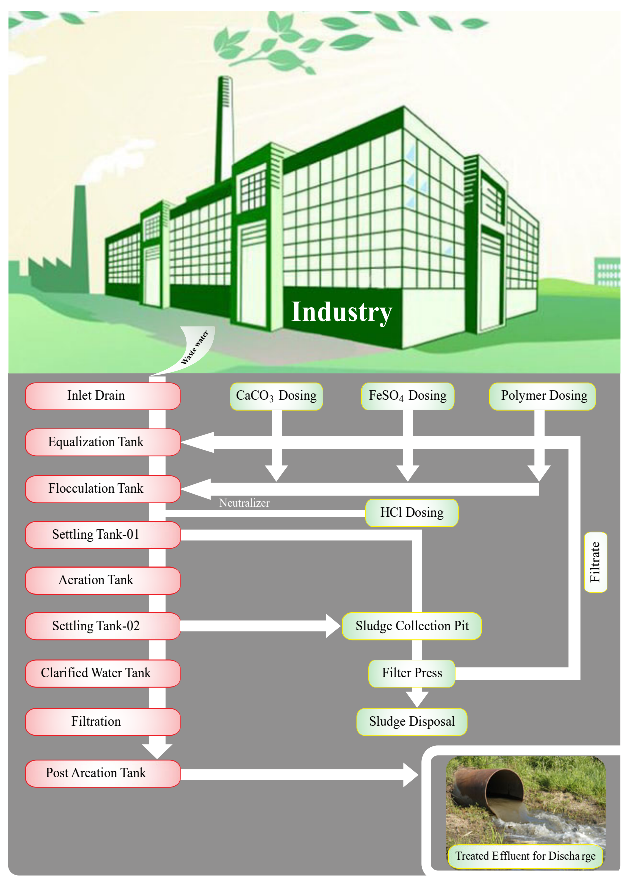


Figure 3. Process flow chart of effluent treatment plant (ETP).

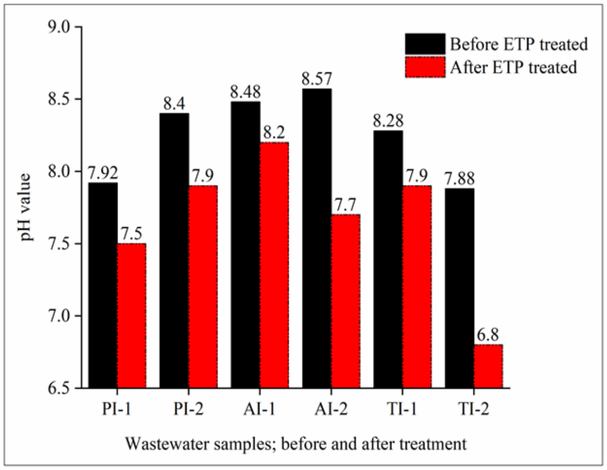


Figure 4. Effect of pH values of wastewater.

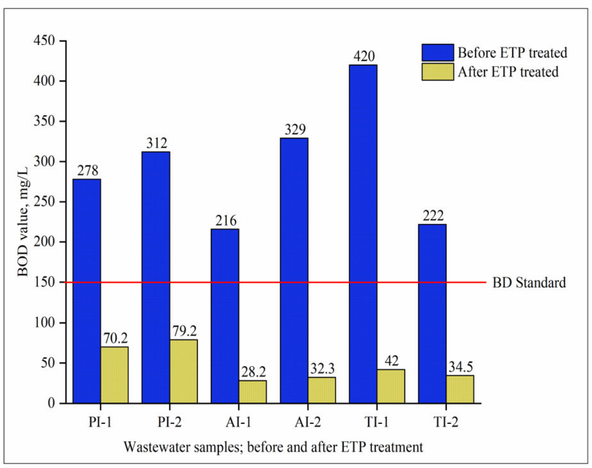


Figure 5. Effect of BOD_5 values of wastewater.

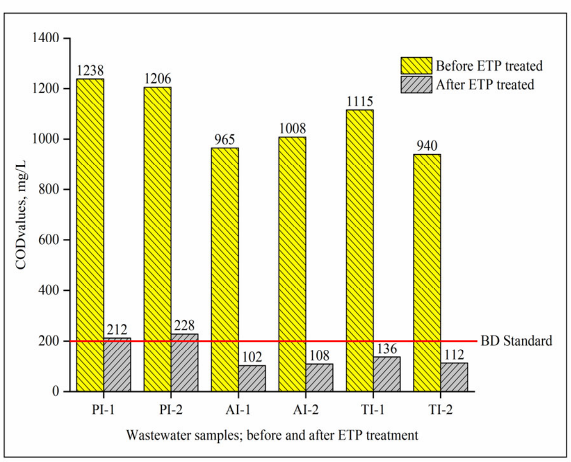


Figure 6. Effect of COD values of wastewater.

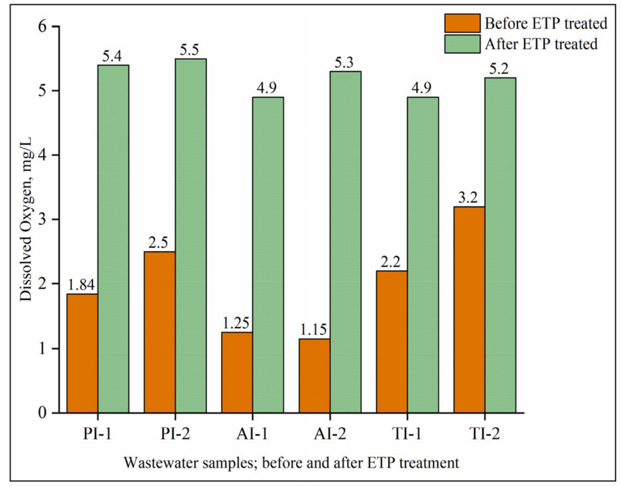


Figure 7. Effect of DO values of wastewater.

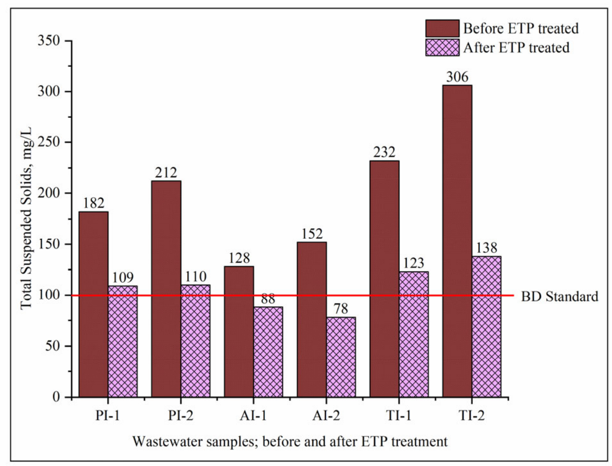


Figure 8. Effect of TSS values of wastewater.

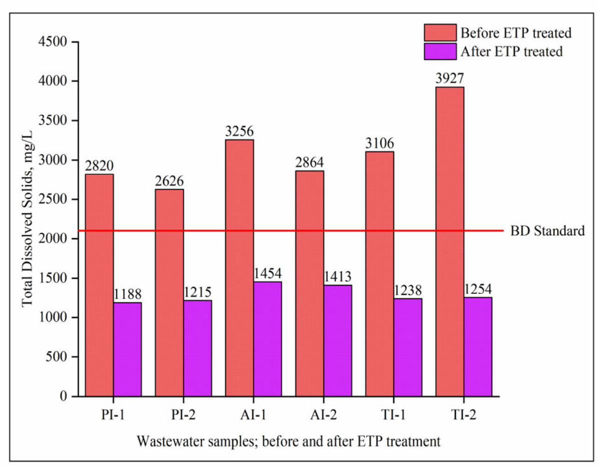


Figure 9. Effect of TDS values of wastewater.

Table 1: Sample coding from several typical industries.

Industry codes	Untreated Effluents	Treated Effluents	Remarks
PI-1	A_1	A_2	The industries had revealed disinclination to their names and data owing to concealment. The effluent samples from pharmaceuticals, alloytech, and textile processing industries have been named PI-1, PI-2, AI-1, AI-2, TI-1, and TI-2 respectively. These industries were practicing manual treatment during the sampling time as per the research pattern.
PI-2	B_1	B_2	
AI-1	C_1	C_2	
AI-2	D_1	D_2	
TI-1	E_1	E_2	
TI-2	F_1	F_2	

Table 2: Wastewater parameters set by the Government of Bangladesh.

Title	Accepted and Approved by the Government of Bangladesh	Level Grading		
		Poor	Good	Excellent
pH	6-9	≥100	6-8	7
BOD	50	>30	10-20	≤10
COD	200	>200	100-200	≤100
DO	9	≤4	5-9	≥9
TSS	100	>200	100-200	<100
TDS	300	>600	300-600	<300

Table 3. Quality of wastewater before and after treatment from the six industries.

Water quality parameters		PI-1	PI-2	AI-1	AI-2	TI-1	TI-2	ECR, 1997 Standard
pH	BT	7.92±0.03	8.40±0.07	8.48±0.06	8.57±0.04	8.28±0.04	7.88±0.05	6.5-9.0
	AT	7.50±0.02	7.90±0.02	8.20±0.02	7.70±0.03	7.90±0.03	6.80±0.02	
BO_5 (mg/L)	BT	278±18.59	312±13.75	216±9.54	329±9.80	420±6.86	222±16.66	≤150
	AT	70.20±6.70	79.20±8.60	28.20±7.20	32.30±6.15	42±3.48	34.50±6.62	
COD (mg/L)	BT	1238±9.41	1206±8.16	965±29.50	1008±16.28	1115±18.20	940±62.56	≤200
	AT	212±5.28	228±2.23	102±5.75	108±6.38	136±5.66	112±14.00	
DO (mg/L)	BT	1.84±0.03	2.50±0.08	1.25±0.20	1.15±0.29	2.20±0.04	3.20±0.09	4.5-8.0
	AT	5.40±0.01	5.50±0.04	4.90±0.19	5.30±0.28	4.90±0.04	5.20±0.06	
TSS (mg/L)	BT	182±7.20	212±6.20	128±12.10	152±13.65	232±6.58	306±17.87	≤100
	AT	109±4.28	110±5.10	88±5.20	78±4.40	123±8.23	138±12.01	
TDS (mg/L)	BT	2820±26.13	2626±32.42	3256±28.12	2864±33.10	3106±28.66	3927±31.40	≤2100
	AT	1188±13.20	1215±27.30	1454±16.80	1413±30.25	1238±29.30	1254±32.71	

PI = Pharmaceutical Industry; **AI** = Alloy Industry; **TI** = Textile Industry; **BT** = Before Treatment; **AT** = After Treatment; **ECR** = Environment Conservation Rules

4. Conclusion

According to the results of the tests and laboratory studies, the alloy tech, textile, and pharmaceutical industries are classified as highly polluting, moderately polluting, and less polluting, respectively, due to the high levels of parametric contamination in the collected wastewater. According to this study, there may be an environmental influence on wastewater's pH, BOD_5, COD, DO, TSS, and TDS levels before and after treatment for each of the six businesses. Based on the data, it can be concluded that these parameters were within the suggested range, even if the values of BOD_5, COD, TSS, and TDS were found to be over the standard ranges even following treatment. Thus, the case recommends future investigation into the running of ETP to discover the qualitatively balanced level between before and after treatment under analytical studies. Typically, companies need to assess the level of issues and compile an effluent treatment data chart, which will help them steer their entire operations in the direction of environmental sustainability. Biological oxygen demand, chemical oxygen demand, and total suspended solids values of pharmaceuticals, alloys, and textiles are always found against the recommended limit. As a consequence, the outlet water should be properly discharged into the environment. The future scope of the research is paying attention to regular, standard, and explicable effluent analysis and protecting the eco-environment and human health from long-term damage.

Data Availability (Size 10 Bold)
Declared none

Conflict of Interest
The author declares no conflict of interest, financial or otherwise.

Funding Source
Declared none

Authors' Contributions
Authors -1,2 researched literature, conceived the study and wrote the first draft of the manuscript. Author-3 involved in protocol development. Author-4,5 involved in data analysis. Author-6 supervised the overall work. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Acknowledgements
Declared none

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