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The Performance Analysis of Effluent Treatment Plants (ETPs) of Different Industries in Chittagong City

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ABSTRACT

The study was executed at Kalurghat industrial area to determine the efficiency of ETPs by testing different physicochemical parameters. Results revealed that only 3 out of 9 industries treated their effluents efficiently and discharged following the standards of DoE. The remaining industries viz. Alfa Textile treated their effluent but the values of pH (10.2), DO (3.6 mg/L), BOD (89 mg/L), COD (282 mg/L), TSS (221 mg/L), and EC (4003 µS/cm) exceeded the standards, and released untreated effluents directly into the environment. Smart Jeans didn't maintain the standard of EC (1927 µS/cm), DO (3.2 mg/L), BOD (96 mg/L) and COD (216 mg/L). Asian Apparels EC (1973 µS/cm), DO (4 mg/L), BOD (79 mg/L), and COD (221 mg/L) weren't up to the standards. Similarly, Mans Fashion EC (1243 µS/cm), DO (3.7 mg/L), TSS (180 mg/L), BOD (78 mg/L), and COD (255 mg/L) also exceeded the standards. In addition, Well Group TSS (160 mg/L), EC (3201 µS/cm), DO (4.2 mg/L), and COD (235 mg/L) while Golden Height only EC (1762 µS/cm) crossed the prescribed limits. Inversely, all the sampled industries volleyed effluents containing metals within the standards level except Alfa Textile (Cu, Zn, & Cr), Well Group (Cr) and Asian Apparels (Ni).

Key words: *Effluents, ETP, Efficiency, Environment, Industry, and Pollution.*

1. Introduction

Bangladesh has a great vicissitude limiting pollution by taking lessons from industrialized countries yet [1,2]. Speedy industrial growth has greatly improved economic status as well quality of life, inversely has contributed awfully on environmental degradation [3,4]. Initially, industrial growth and development eventuated during then Pakistan reign; after 1971, government induced to denationalize all the industries, especially textile and fabrics to achieve more than profits [5,6]. Generally, effluent is considered to be pollution (e.g., the discharge from industrial works) but effluent water is used water [7,8,9]. Amidst different types of industries, wet processing of textiles, steels, paper, fertilizers, cements, and pharmaceuticals produce huge quantity of effluents [10 – 13]. Consequently, pollution from industrial effluent is one of the major environmental concerns recently faced by the country [1, 14]. Thereby, it requires on-site treatment before releasing into public sewage system [15, 16].

The key environmental issues inter-linked with textile manufacturers are use of water, its treatment and disposal of liquid effluents [17] [9] [18]. Here, dyes are contributing to overall toxicity at all processing stages; therefore, it is responsible for high level of BOD, COD, colour, surfactants, fibres, turbidity, and contains toxic heavy metals [19,20,21]. In addition, dyeing process usually contributes chromium, lead, zinc and copper to effluents [22,23]. Hence, the released effluents from the effluent treatment plants (ETPs) of industries must meet the national effluent discharge quality standards [24,25] where common effluent treatment plant (CETP) facilitates the industries in easier control of pollution with low-cost as well acts as a step towards cleaner environment. Inasmuch efficiency and effectiveness of an ETP is very important [1, 26] so the CETP is a better and economically viable option for industrial effluents treatment [27,28].

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There are, currently, above 30,000 industrial units in Bangladesh; thereof, about 24,000 are small and cottage industries [29, 30]. The DoE, recently, has identified 900 large polluting industries, have no treatment facilities for effluents and straightly discharge to adjacent soils and water bodies [31, 9] else, release their daily generated wastes into the ecosystem, on which local people depend on for their livelihoods [32, 13]. Amidst, textile is one of the most important and rapidly developing industrial sectors in Bangladesh based on earning foreign exchange and labor employment [33]. But these industries generate commingled a large quantity of contaminated effluents that pollute the environment [10, 34]. To mitigate the risks associated with the discharge of textile effluents, an ETP is required [25, 9] but due to high installation and operation cost, most of the textile industries in Chittagong don't run ETP; occasionally, operate when buyers or DoE inspect the factory [32]. Anyway, recently many industries are making progress in establishing and operating their own ETPs to comply with national and international requirements [27, 9].

Regretfully, advanced wastewater treatment technologies; e.g. - advanced oxidation process, aerated lagoon, bioreactor, constructed wetland, membrane bioreactor, nano-technology, ion-exchange, desalination, and reverse osmosis etc. are not popular for industrial and municipal wastewater treatment in Bangladesh till now [27, 33] inversely, technologically ahead countries are recovering valuable nutrients, elements and metals from wastewater but Bangladesh lags behind yet [25,9,16]. Further, ETP, which is closely linked to remove excess level of different pollutants from industrial effluents, has not really been quested to explore their efficiency of effluents treatment hereto in Bangladesh. Therefore, the absence of any known study on the efficiency of established ETPs has coupled the problems. Thereat, efficiency analysis of ETPs is momentous to improve its current performance and so the research work was carried out to assess the efficiency of ETPs.

2. Materials and Methods

2.1 Selection of Study Area

Fig. 1: The enclosure area by red circle in the map showing the study area (Kalurghat).

Kalurghat Industrial Area (KIA) is located at the north side of Chittagong city, mainly famed for several heavy industries and Kalurghat Bridge on the Karnaphuli River. Bangladesh Small and Cottage Industries Corporation (BSCIC) established an industrial area on a 12-acre land of Kalurghat in 1980, is now one of the main industrial parks in Chittagong where many small and medium scale industries (1200) are located [35]. These industries are clustered into three zones (i.e., Kalurghat-BSCIC, Kalurghat-Mohora, and Kalurghat-Boalkhali industrial area). The study was conducted at Kalurghat-BSCIC heavy industrial area (Fig. 1) targeting three pollution-intensive sectors viz. textile, washing, and dyeing industries that currently use ETPs. A preliminary survey was accomplished based on data supplied by Department of Environment (DoE); thereafter, purposively 3 textile, 3 washing, and 3 dying industries were selected namely – Asian Apparels Ltd, Sanzi Textile Ltd, Alfa Textile Ltd, Golden Height Ltd, Mans Fashion Ltd, Smart Jeans Ltd, Well Group Ltd, Chin Hung Fibers Ltd, and Royal Tech Bangladesh Ltd.

2.2 Collection of Sample

Samples were collected from two points (i.e., pre-treatment/inlet and post-treatment/outlet). Samples were collected diligently in a 1-litre plastic bottle and filled the total volume to avoid any air space inside the bottle and then locked in-favor-of accurate assessment of the effluents quality. Plastic bottles were first washed thoroughly with soda water (HNO_3 was not available), following distilled water before collecting the samples. Then the bottles were labeled accurately and preserved in ice cool temperature for testing the target parameters in the laboratory of WASA.

2.3 Reagents and Instruments

The required instruments for conducting the planned experiments are – beaker (i.e., 150 ml & 250 ml), measuring cylinder (i.e., 100 ml & 1000 ml), funnel, dropping pipette, filter paper, stirrer, DO meter, Sension156 Portable Multiparameter, pH meter, conductivity meter, Spectrophotometer (Model-HACH: DR/4000V), electric balance, reagent bottles, and volumetric flasks. In contrast, the required reagents are – dilution water; seed (mixed microorganisms solution); concentrated H_2SO_4; $HgSO_4$; Ag_2SO_4; KCN; $C_6H_{10}O$; standard 5.0 N NaOH, $K_2Cr_2O_7$, $C_8H_5KO_4$ (KHP), $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$, & buffer solutions; chloroform; and potassium 1, chromo Ver 3, Cu Ver 1, & Zinco Ver 5 buffer powder pillow.

2.4 Determination of Physical Parameters

Total Dissolved Solid (TDS) – It was measured by using sension156 Portable Multi-parameter and based on a measurement of conductivity that can be correlated with dissolved solids. A calibrated conductivity meter had to be completely submerged into sample (a small amount of representative sample). Then it was stirred gently for a while until the meter gave a stable TDS reading in mg/L unit.

Total Suspended Solid (TSS) – Firstly, a filter paper was weighted and then 20 ml water sample was filtered through whatman filter paper and taken into evaporating dish. The filter paper was kept in oven at (103±2) °C temperature until whole water was evaporated. Then, the weight of filter paper was taken after cooling it in desiccators and TSS was calculated by using following formula –

TSS (mg/L) = (Final weight of filter paper with the residue - Initial weight of filter paper)/ volume of the sample taken (ml) ×1000 (ml) ×1000

2.5 Determination of Chemical Parameter

Acidity (pH), Dissolve Oxygen (DO), Electric Conductivity (EC) – pH meter and sension156 Portable Multi-parameter were used to measure acidity. At first pH meter was calibrated by using several types of buffer solutions (i.e., pH 4/7/10). Then the protective cap was removed and turned on the meter by sliding switch, on top of the meter. Then it was immersed into the solution to test, without exceeding the maximum level. The meter was gently stirred and waited for the reading to be stabilized. Similarly, DO and EC were measured by following same processes just different is DO meter and Conductivity meter were used respectively as substitute of pH meter and sension156 Portable Multi-parameter.

Chemical Oxygen Demand (COD) – Accurately 0.4 g $HgSO_4$ was placed in reflux flask; then 20 ml is added or an aliquot of sample diluted to 20 ml of distilled water. Then 10 ml standard $K_2Cr_2O_7$ was added slowly followed by 30 ml H_2SO_4, which already contains Ag_2SO_4. This slow addition along with swirling prevents loss of volatile materials (e.g. fatty acids in the sample). Then it was mixed well with the glass beads where final concentration of the conc. H_2SO_4 should be always 50%. The flask was connected to condenser and refluxed for 2 hours. Then cooled and washed down with condenser with small quantity of distilled water. The flask is removed and added about 80 ml distilled water. Then cooled and titrated against standard $(NH_4)_2.Fe(SO_4)_2•6H_2O$ using ferroin as indicator. Colour changed sharply from green blue to wine red. In the reflux, a reagent blank reading under identical condition simultaneously with sample was taken.

COD, (mg/L) = Here, a = ml. $(NH_4)_2.Fe(SO_4)_2•6H_2O$ required for blank, b = ml. $(NH_4)_2.Fe(SO_4)_2•6H_2O$ required for sample, and N = normality of $(NH_4)_2.Fe(SO_4)_2•6H_2O$

Biochemical Oxygen Demand (BOD) – It was carried out by diluting the sample with de-ionized water saturated with oxygen, inoculating it with a fixed aliquot of seed, measuring the DO and sealing the sample. The sample was kept at 20 °C in the dark to prevent photosynthesis for 5 days, and DO was measured again. The difference between the final DO and initial DO is the BOD; the apparent BOD for the control is subtracted from the control result to provide the corrected value.

2.6 Determination of Heavy Metals

Chromium (hexavalent) – Spectrophotometer (model-HACH: DR/4000V) was used to determine the quantity of Cr, Zn, Cu, Pb and Ni in the effluents. It is a multifunctional instrument that is used in WASA lab for measuring different water quality parameters. In case of Cr, at first 25 ml of sample was filtered by filter paper and then a cell of sample was filled with 10 ml of filtered sample. Contents of one 'Chroma Ver 3' reagent powder pillow were added to the sample cell (prepared sample) and swirled to mix. Similarly, another sample cell was filled with 10 ml of sample (blank). The prepared sample was placed into the cell holder and hexavalent Cr (Cr^{6+}) was displayed in mg/L unit.

Zinc (Zn) – Here, 50 ml sample was filtered and then 25 ml graduated mixing cylinder was filled with 20 ml of filtered sample. A content of one 'Zinco Ver 5' reagent powder pillow was added to the sample cell (prepared sample) and was swirled to mix. 10 ml of the solution was poured into a sample cell (blank) and 0.5 ml of $C_6H_{10}O$ was added respectively to the remaining solution. Then cylinder was stoppered and shacked vigorously for 30 seconds. During reaction, the solution from the cylinder was poured into sample cell (prepared sample). Similarly, the result was showed in mg/L Zn unit.

Copper (Cu) – 50 ml of sample was filtered and then a sample cell was filled with 10 ml of sample, following added the contents of one Cu Ver 1 reagent powder pillow to the sample cell (prepared sample) and swirled to mix. Then cylinder was stoppered and shacked vigorously for 30 seconds. Likewise, the result was displayed in mg/L Cu unit.

Lead (Pb) – 500 ml sample was filtered first and then a 250 ml graduated cylinder was filled to mark with sample and transferred into 500 ml through funnel. Then the content of one buffer powder pillow was added, citrated for heavy metals. It was stoppered and shacked to dissolve. Similarly, 50 ml of chloroform was added to a 50 ml graduated mixing cylinder; then the content of one Dithi Ver metal reagent powder pillow was added, stoppered and inverted repeatedly to mix. 30 ml of this dithizone solution was poured into a second graduated cylinder; similarly, 30 ml of the dithizone solution was added to the separator funnel. Opened stopcock to vent then close and 5 ml of 5.0 N NaOH standard solution was added, stoppered, inverted and again opened to vent. Then closed the stopcock and shacked the funnel once or twice and vented again. And continued adding 5.0 N NaOH standard solution drop-wise and shaking the funnel after every few drops until the color of the solution being changed from blue-green to orange. Then 5 more drops of 5.0 N NaOH standard solution were added and 2 heaping 1.0 g scoops KCN was added to the funnel then stoppered and shacked vigorously until the KCN was dissolved. Then pea size cotton was inserted into the delivery tube of the funnel and slowly drained the bottom layer into a dry 25 ml sample cell. Finally, stoppered the sample cell and filled another sample cell with chloroform (blank) and again stoppered. Similarly, the result was obtained in mg/L Pb unit.

Nickel (Ni) – Firstly 50 ml sample was filtered and then a sample cell was filled with 10 ml of deionized water (blank); again a second cell also filled with 10 ml of bath sample. The content of one potassium 1 reagent powder pillow was added to the sample (prepared sample). Then it was stoppered and shacked to dissolve. Analogously, the result was found in mg/L Ni unit.

2.7 Data Compilation and Analysis

All the collected data were compiled into MS-Excel sheet, and then analyzed by using MS- Excel sheet and statistical software Minitab.

3. Results and Discussion

3.1 Analysis of Physical Parameters

Industrial effluents contaminate surface water, soil and groundwater due to presence of different pollutants (e.g., soluble solids, suspended solids, organic matter, heavy metals and toxic chemicals). Therefore, pre-treatment of discharged wastewater and determining the effluents quality is momentous [9]. The study was conducted to characterize the effluents quality of inlet and outlet of ETPs. So, the difference between inlet and outlet effluent's TDS and TSS values of the investigated industries are shown in (Table 1). The highest TDS value (2687 mg/L) was found at Well Group while the lowest (276 mg/ L) at Royal Tec BD in inlet effluent; perhaps due to containing mobile charged ions including calcium bicarbonate, nitrogen, iron phosphorous, sulfur, and other minerals discharged from textile, washing and dyeing process. Inversely, TDS of outlet effluent varied from 247 mg/L to 2001 mg/L and remained within the DoE standard limit (i.e., 2100 mg/L) in all industries though individual values weren't analogous. Hence, it is crystal clear that pollution intensity and treatment efficiency is varied from industry to industry, because of using different types of chemical in textile dyeing and washing process along with followed different treatment methods (physical, chemical, biological and combined) as well expert technicians. Water having high TDS values can cause osmotic stress at the root zone of plants which makes more difficult for a plant to absorb water for growth; thereby, increased TDS in irrigation water leads to lower crops production [36].

The maximum concentration (800 mg/L) of TSS was observed at Well Group but the minimum (331 mg/L) at Golden Height in inlet effluents while the rest industries effluents contained higher TSS in terms of DoE standard (i.e., 150mg/L) (Table 2). TSS is mainly floating in nature and can be removed from the wastewater by physical treatment (i.e., screening). Inversely, the outlet effluents TSS varied from 26 mg/L to 221 mg/L where 6 out of 9 industries remained within the DoE standard but Mans Fashion (180 mg/L), Well Group (160 mg/L), and Alfa Textile (221 mg/L) were not within DoE prescribed water quality criteria. Anyway, a significant variation was observed both in inlet and outlet effluents of all industries due to difference of pollution intensity and treatment efficiency respect to TSS values. High TSS reduces light penetration and decreases photosynthetic rates of green aquatic macrophytes, algae and cells that are served as food sources for many invertebrates [37] [21].

Table 1: Determined values of different physical parameters of studied industries.

Name of industry	TDS (mg/L)			TSS (mg/L)		
	Pre-treatment	Post-treatment	DoE Standard	Pre-treatment	Post-treatment	DoE Standard
Mans Fashion Ltd	410±20.5	672±33.6	2100	378±26.5	180±6.3	150
Golden Height Ltd	311±6.4	880±61.6		331±3.3	26±1.3	
Smart Jeans Ltd	1156±92.5	964±28.9		427±25.6	112±2.8	
Royal Tec BD Ltd	276±8.28	247±22.3		516±10.3	142±7.8	
Chin Hung Fiber Ltd	1896±19.78	524±26.2		445±34.5	52±3.6	
Well Group Ltd	2687±134.5	1600±17		800±24.3	160±9.6	
Alfa Textile Ltd	2361±94.5	2001±80.1		670±10.1	221±9.5	
Sanzi Textile Ltd	1541±107.8	514±25.7		441±11.7	80±1.6	
Asian Apparels Ltd	1790±53.7	986±29.6		411±17.2	100±4.5	

ETP is very important to protect the environment and different lives from threat of toxic industrial wastewater. So the efficiency of ETPs must be regularly monitored, particularly after major repair or replacement work [1]. However, the study showed that amongst 9 industries, most of the industries discharged water within DoE prescribed limit and only 3 industries crossed the standards in case of physical parameters. Here, all industries discharged water within the DoE standard limit of TDS but 3 industries exceeded DoE permissible limit of TSS that indicates inefficiency of treatment method and processes. Well Group (160 mg/L), Mans Fashion (180 mg/L), and Alfa Textile (221 mg/L) exceeded the limit of TSS standards according to DoE prescribed water quality parameter (Fig. 2). Studies conducted in wastewater treatment plants (WWTPs) showed good performance in the removal of excess level of TSS from treated wastewater that was agreement with national standards [19] [21] [9] found that the CETPs were efficient in the removal of TDS in case of membrane bioreactor.

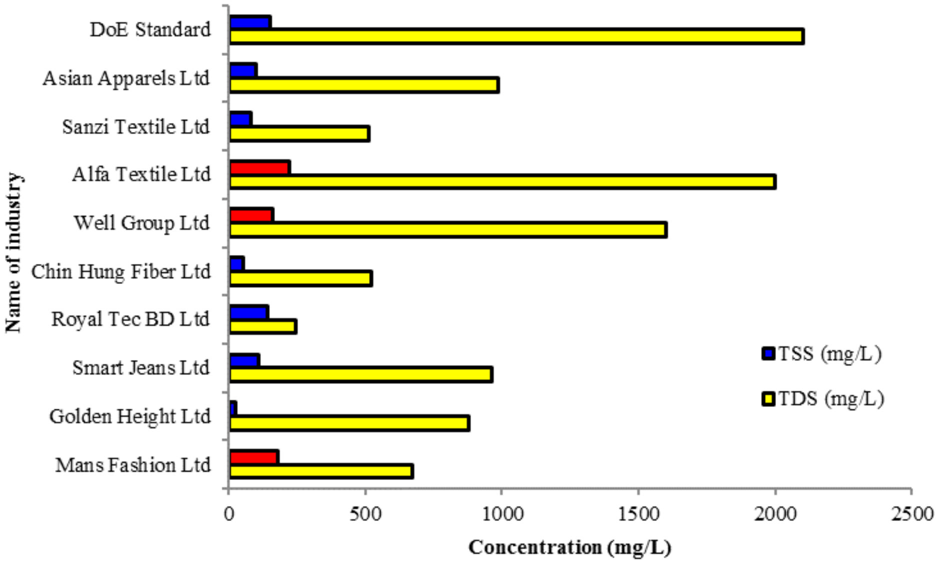

Fig. 2: Comparative analysis of TDS and TSS in outlet effluents of ETPs of different industries (Red color indicates that the value has crossed the DoE standard limit).

3.2 Analysis of Chemical Parameters

To evaluate the efficiency of ETPs in different industries, different chemical parameters (e.g., DO, BOD, COD, pH and EC) were analyzed in the study. Low DO concentrations (<3mg/L) in fresh water aquatic systems indicate high pollution and cause negative effects on lives [38] . Results showed (Table 2) that DO in inlet effluents differed from 1.2 mg/L to 3.6 mg/L where the highest DO (3.6 mg/L) was found at Golden Height but the lowest (1.2 mg/L) at Smart Jeans. The rest industries were also below DoE prescribed standards (i.e., 4.5-8.0 mg/L), probably due to the presence of chemically oxidized and biodegradable organic compounds in the effluents. The result also presented that DO in outlet effluents increased by all the industries against the inlet results due to the optimum rate of chemical dozing and bacterial activities during treatment while DO at Mans Fashion, Smart Jeans, Well Group, Alfa Textile and Asian Apparels industries still didn't fulfill the DoE requirement; inversely, Golden Height (4.7 mg/L), Royal Tec BD (4.8 mg/L), Chin Hung Fiber (4.9 mg/L) and Sanzi Textile (4.6 mg/L) industries fulfilled. Inasmuch DO levels below 4 mg/L in water puts aquatic life under stress, so reduced DO affects adversely on all aquatic lives. If DO levels remain below 1-2 mg/L for a few hours that can result in large fish kills [39]; however, constructed wetland can facilitate to increase DO level in industrial wastewater [16].

From (Table 2), it is seen that in inlet the maximum concentration (240 mg/L) of BOD was observed at Smart Jeans while the minimum (72 mg/L) at Royal Tec BD; similarly the rest industries also generated higher BOD contents against the DoE standards (i.e., 50 mg/L). BOD value indicates the strength of the wastewater in which oxygen was consumed by microorganism in biodegrading the organic maters. The BOD in outlet effluent varied from 29 mg/L to 96 mg/L where BOD at Golden Height, Royal Tec BD, Chin Hung Fiber, Well Group, and Sanzi Textile industries remained within the DoE water quality standards, but crossed the limit by Alfa Textile (89 mg/L), Asian Apparels (79 mg/L), Smart Jeans (96 mg/L), Mans Fashion (78 mg/L). Else, the efficiency difference between inlet and outlet effluents was noticed in all industries. Excessive BOD is harmful to aquatic life (e.g. fish and microorganisms). It also causes bad taste to the drinking water and too high BOD level keeps water at risk for further contamination [39]. A study in South-Eastern Tunisia found that effluent quality in terms of BOD was in agreement with water quality standard after treatment [19].

It was observed that the concentration of COD in inlet effluents differed from 291 mg/L to 442 mg/L among the studied industries (Table 2), where the highest value (442 mg/L) was found at Mans Fashion but the lowest at Smart Jeans (289 mg/L). Besides, all the industries generated higher value of COD compared to DoE standards (i.e., 200 mg/L). Generally, COD test gives an indication of the impact of discharged waters on aquatic life by means of depleting DO level. Result showed that COD contents in outlet effluents was varied from 111 mg/L to 282 mg/L where COD at Golden Height, Sanzi Textile, Royal Tec BD and Chin Hung Fiber industries remained within the DoE standards (200 mg/L), but exceeded the limit by other 5 industries, the highest in Alfa Textile (282 mg/L). In addition, a clear difference between inlet and outlet were noticed in all industries. Anyway, COD test is commonly performed to measure, indirectly, the quantity of organic compounds in water. From (Table 2), it is seen that the amount of COD was high in all industries before treatment depending on the types of fibers, dyes, and additives that were used in various industrial activities (Demmin & Uhrich, 1998). Similarly, both inlet and outlet effluent's COD content varied significantly in all industries due to containing different chemically oxidized organic compounds and followed treatment facilities (Xu et al., 2007). Bhandari et al. (2016) found that the characterization of fertilizer wastewaters from different streams revealed huge variation in COD from 50 to 140,000 mg/kg in inlet that showed high reduction of COD (85%) after treating wastewaters in outlet and Silva et al., (2014) also found analogous results.

Table 2: Determined values of DO, BOD, and COD of different industries in mg/L unit.

		Mans Fashion	Golden Height	Smart Jeans	Royal Tec BD	Chin Hung Fiber	Well Group	Alfa Textile	Sanzi Textile	Asian Apparels
DO	Pre	2.8±0.08	3.6±0.13	1.2±0.02	3.2±0.12	2.3±0.11	2.2±0.15	2.6±0.13	2.8±0.18	2.7±0.21
	Post	3.7±0.18	4.7±0.33	3.2±0.16	4.8±0.22	4.9±0.27	4.2±0.17	3.6±0.15	4.6±0.12	4±0.36
	Up					8				
	Low					4.5				
BOD	Pre	210±19	117±7.1	240±9.8	72±7.2	156±3.1	117±7.6	215±13	102±6.1	119±5.9
	Post	78±2.7	49±3.9	96±3.4	31±0.8	29±1.5	41±1.2	89±4.5	30±2.4	79±3.3
	DoE					50				
COD	Pre	442±9.4	296±14	289±15	291±11	364±16	312±10	398±15	313±12	381±17
	Post	255±13	176±7.8	216±9.1	117±4.8	111±4.2	235±7.9	282±8.3	142±5.1	221±7.3
	DoE					200				

N.B.: Pre = Pre-treatment, Post = Post-treatment, DoE = DoE standard Up = Upper limit of DoE standard, and Low = Lower limit of DoE standard.

The study revealed that pH in inlet effluents differed from 3.8 to 12.2 where the maximum (12.2) and the minimum (3.8) pH value were found at Alfa Textile and Well Group respectively (Table 3). The variation of pH value is primarily caused by different kinds of dye stuffs and washing ingredients used in the dyeing and washing process in industries. Similarly, pH in outlet effluents varied from 6.8 to 10.2 where pH in all industries remained within DoE standards (i.e., 6-9) but differed from standard in Alfa Textile (10.2) industry. Anyway, the industries showed the better treatment efficiency, likely due to optimum chemical dozing. Besides, both the inlet and outlet effluent's pH varied may be for using different types of chemicals in the textile dyeing and wet processing along with optimum chemical dozing during the treatment process. Here, pH indicates the suitability of water for various purposes and toxicity to aquatic lives [40]. High pH reduces fish production [41] and inhibits the growth of aquatic macrophytes [42]. Similarly, low pH can destroy the fish population accompanied by decrease in the variety of species in food chain [43].

Similarly, the results showed that EC in inlet effluents differed from 552 µS/cm to 5375 µS/cm where the highest (5375 µS/cm) EC was found at Well Group but the lowest (552 µS/cm) at Royal Tec BD. The rest industries generated highly polluting effluents in terms of EC compared to DoE standards (i.e., 1200 µS/cm) except Mans Fashion (824 µS/cm) and Golden Height (624 µS/cm) which may be due to presence of organic and inorganic matter with high ionic load (Table 3). The result of outlet effluents illustrated that in case of EC effluents quality improved within the DoE standard at Chin Hung Fiber (1048 µS/cm) and Sanzi Textile (1027 µS/cm) but the other industries still exceeded the standards without Royal Tec BD (495 µS/cm). Comparing all industries, both the inlet and outlet effluent's EC varied significantly probably due to inefficient rate of chemical dozing during effluents treatment in each of the industries. The increased EC in irrigation water leads to lower crops production; though EC itself is not a human or aquatic health concern but it can serve as an indicator of other water quality problems [36].

Table 3: Determined values of pH and EC of different industries at Kalurghat, Chittagong.

Name of industry	pH				EC (µS/cm)		
	Pre-treatment	Post-treatment	DoE Standard		Pre-treatment	Post-treatment	DoE Standard
			Upper limit	Lower limit			
Mans Fashion Ltd	11.6±0.1	8.9±0.4	9	6	824±57.6	1243±31.1	1200
Golden Height Ltd	9.23±0.5	6.9±0.3			624±21.8	1762±79.3	
Smart Jeans Ltd	9.6±0.3	8.8±0.2			2311±69.3	1927±96.4	
Royal Tec BD Ltd	6±0.4	7.2±0.1			552±27.6	495±17.3	
Chin Hung Fiber Ltd	4.9±0.1	6.8±0.1			3802±76.1	1048±57.6	
Well group Ltd	3.8±0.1	8.2±0.3			5375±215	3201±112.1	
Alfa Textile Ltd	12.2±0.5	10.2±0.4			4723±236.2	4003±40.1	
Sanzi Textile Ltd	9.56±0.3	8.4±0.2			3029±90.8	1027±71.9	
Asian Apparels Ltd	8.6±0.2	7.9±0.1			3582±161.2	1973±49.3	

Amidst 9 industries, some industries discharged water within the range of DoE permissible limit and some crossed in case of different chemical parameters. From (Table 4), it is seen that only 3 industries discharged water within the DoE prescribed limit for EC while Mans Fashion (1243 µS/cm), Golden Height (1762 µS/cm), Smart Jeans (1927 µS/cm), Well Group (3201 µS/cm), Alfa Textile (4003 µS/cm), and Asian Apparels (1973 μS/cm) crossed the limit. Similarly, all industries maintained pH value within DoE standard limit but Alfa Textile (10.2) crossed the limit. Belhaj et al. [19] found the treated wastewaters pH within the national water quality criteria. In case of DO, 4 industries discharged water within DoE prescribed limit and 5 showed below the ranges viz. Mans Fashion (3.7 mg/L), Smart Jeans (3.2 mg/L), Asian Apparels (4.2 mg/L), Alfa Textile (3.6 mg/L), and Well Group (4 mg/L). Besides, 4 industries crossed DoE standard limit for BOD such as Mans Fashion (78 mg/L), Smart Jeans (96 mg/L), Alfa Textile (89 mg/L), and Asian Apparels (79 mg/L). Xu et al. [16] found that combined constructed wetland showed better performance in case of reducing BOD and COD from industrial park wastewater. In addition, 4 industries maintained and the rest didn't maintain according to DoE prescribed water quality parameter for COD viz. Mans Fashion (225 mg/L), Smart Jeans (216 mg/L), Well Group (235 mg/L), Alfa Textile (282 mg/L), and Asian Apparels (221 mg/L). It was seen that ozonation treatment can reduce COD at 31-46% from industrial wastewater [17] while membrane filtration treatment showed better (i.e., 77–80%) reduction of COD [27].

Table 4: Comparative analysis of different chemical parameters in outlet of different ETPs.

Name of industry	EC (μS/cm)	pH	DO (mg/L)	BOD (mg/L)	COD (mg/L)
Mans Fashion Ltd	1243*	8.7	3.7*	78*	225*
Golden Height Ltd	1762*	6.9	4.7	49	176
Smart Jeans Ltd	1927*	8.8	3.2*	96*	216*
Royal Tec BD Ltd	495	7.2	4.8	31	117
Chin Hung Fiber Ltd	1048	6.8	4.9	29	111
Well Group Ltd	3201*	8.2	4.2*	41	235*
Alfa Textile Ltd	4003*	10.2*	3.6*	89*	282*
Sanzi Textile Ltd	1027	8.4	4.6	30	142
Asian Apparels Ltd	1973*	7.9	4.0*	79*	221*
DoE Standard	1200	6-9	4.5-8	50	200

N.B.: * indicates that the value has crossed the DoE standard value.

3.3 Analysis of Heavy Metals (Cu, Zn Pb, Ni, Cr)

Heavy metal pollution has become one of the most serious environmental concerns now, limiting reuse of wastewater. So, pre-treatment of wastewater is the special concern due to their recalcitrance and persistence in the environment [19]. Therefore, most common and toxic heavy metals (e.g. Cu, Pb, Cr, Zn and Ni) were evaluated in the study. Results revealed (Fig. 3) that Cu in inlet effluent varied from 1.27 mg/L to 0.15 mg/L; where the highest (1.27 mg/L) Cu was found at Royal Tec BD but the lowest at Well Group (0.15 mg/L). There were found only 5 industries, e.g., Mans Fashion, Royal Tec BD, Golden Height, Smart Jeans and Alfa Textile that possessed Cu more than the standard limit (i.e., 0.5 mg/L) in terms of inlet. Inversely, it was found that only Alfa Textile effluent crossed the standard limit of Cu in case of outlet and the rest industries discharged effluents within the DoE prescribed water quality criteria. From the study, it was also found that quantity of Cu was comparatively more in dyeing industries inlet.

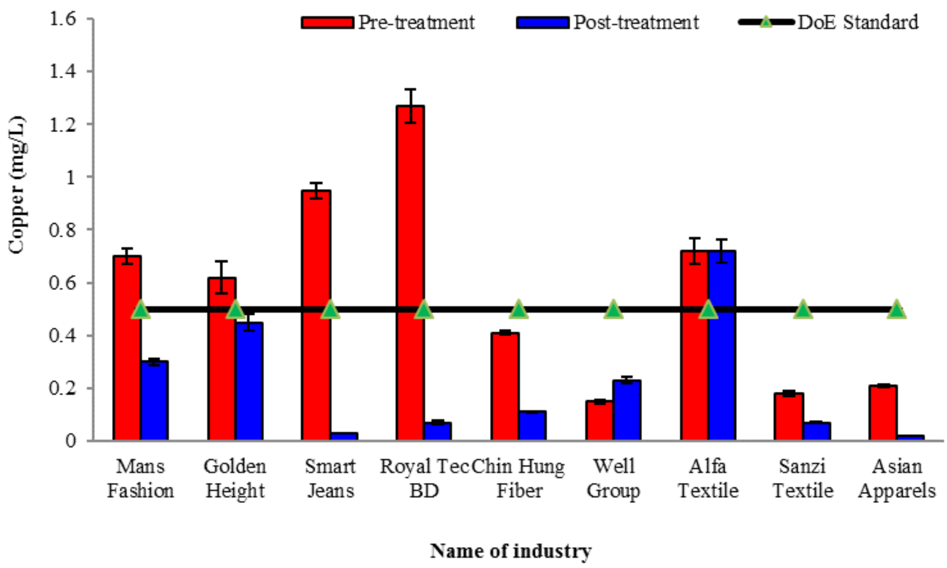

Fig. 3: Comparative analysis of Cu of inlet and outlet effluents of ETP of different industries.

The study showed (Fig. 4) that Zn content in inlet effluent differed from 6.29 mg/L to 3.29 mg/L where the highest (6.29 mg/L) Zn was found at Asian Apparels but the lowest at Chin Hung Fiber (3.29 mg/L). It was found that Golden Height, Alfa Textile, Sanzi Textile, and Asian Apparels discharged more Zn content exceeding the standard level in case of inlet and others industries within the DoE standards (i.e., 5 mg/L) value along with varying from 6.29 mg/L to 3.29 mg/L. It may be for the washing, dyeing and other wet process of textile activities. In outlet result, it was found that all the industries except Alfa Textile (5.47 mg/L), discharged effluent within the DoE standard. However, Zn content was noticed more in dyeing and textile industries but high concentration of Zn in water is more harmful to aquatic life during early stages [45] [46].

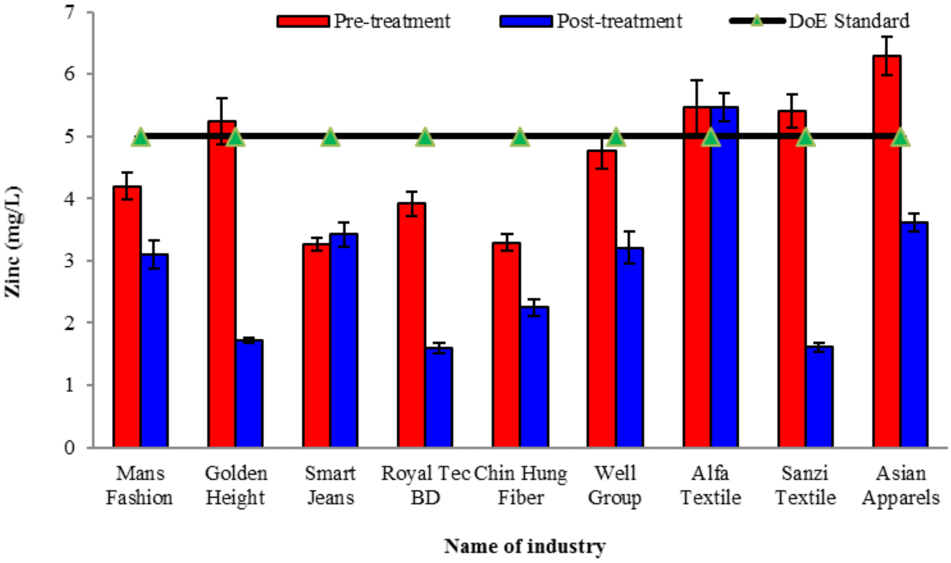

Fig. 4: Comparative analysis of Zn of inlet and outlet effluents of ETP of different industries.

The study showed that Pb content in inlet effluent differed from 0.15 mg/L to 0.02 mg/L (Fig. 5) where the highest (0.15 mg/L) Pb was found at Asian Apparels but the lowest at Well Group (0.02 mg/L). Only 1 textile industries produced polluting effluents in terms of Pb against the DoE standard (i.e. 0.1 mg/L), may be due to the washing, dyeing and other wet process of textile activities. In outlet result, it was seen that all the industries discharged effluents within the DoE standards. However, Pb content was varied significantly among the category of industries both in inlet and outlet but in inlet it was highly important and found more in quantity at textile industries. The higher concentration of Pb is due to the use of Pb (II) nitrate as an oxidizing agent in textile industry and it is used in textile industry to make textile treatment and matches etc. Elevated levels of Pb in the water can cause reproductive damage in some aquatic life and also cause blood and neurological changes in fish and animals in water [47]. A study found that the use of biomass fly ashes in coagulation–flocculation assays can reduce significant concentration of Pb in wastewater (0.35 mg/L) [48].

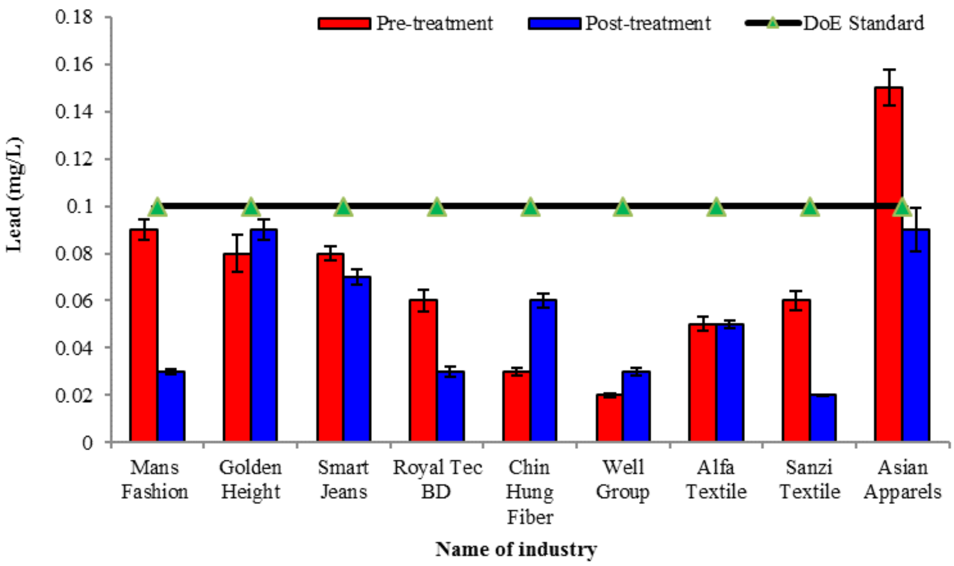

Fig. 5: Comparative analysis of Pb of inlet and outlet ETP of different industries.

Fig. 6 showed that Ni content in inlet effluent varied from 0.56 mg/L to 1.36 mg/L; where the highest (1.36 mg/L) Ni was found at Asian Apparels and the lowest at Mans Fashion (0.56 mg/L) that means all the industries generated effluents within the DoE standard (i.e., 1 mg/L) except Chin Hung Fiber (1.22 mg/L) and Asian Apparels

(1.36 mg/L). In outlet result, it was found that all the industries discharged water within the standards without Asian Apparels that exceeded prescribed water quality criteria. Amidst the industries, both inlet and outlet effluent's Ni varied significantly but no significance difference was noticed in each type of industry; it may be due to the influence of related factors.

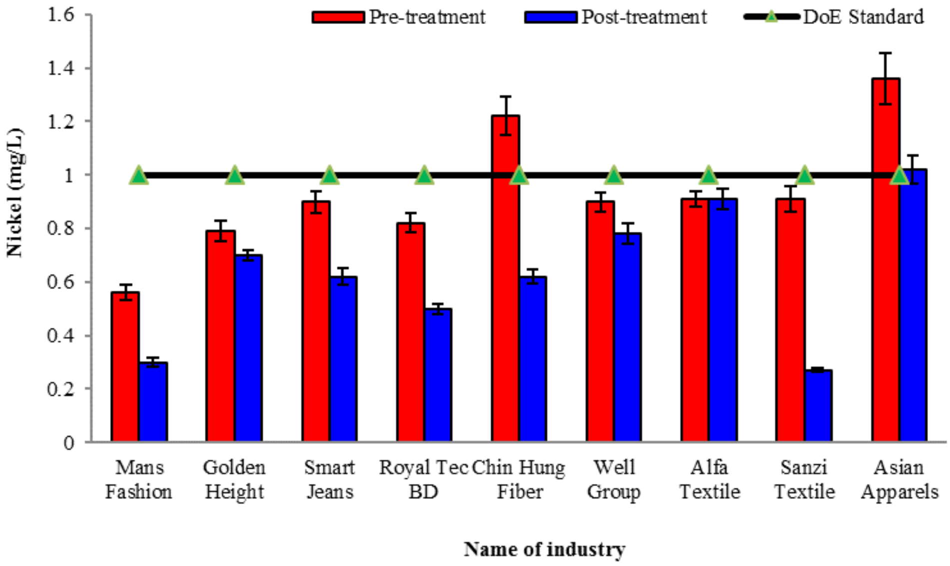

Fig. 6: Comparative analysis of Ni of inlet and outlet effluents of ETP of different industries.

The study revealed (Fig. 7) that Cr content in inlet effluent varied from 0.05 mg/L to 0.62 mg/L; similarly, the highest (0.62 mg/L) Cr was found at Chin Hung Fiber but the lowest at Mans Fashion (0.05 mg/L). The 6 industries – Royal Tec BD, Chin Hung Fiber, Well Group, Alfa Textile, Sanzi Textile, and Asian Apparels generated polluting effluents in terms of Cr compared to the DoE standard (i.e., 0.1 mg/L) and the rest industries generated effluents within the limit. In outlet result, it was found that all the industries except Alfa Textile (0.30 mg/L) and Well Group (0.12 mg/L) discharged water within the DoE prescribed standards; but the value differed from 0.07 to 0.02 mg/L. Amongst the industries, both the inlet and outlet effluent's Cr content was not differed significantly. Anyway, high concentration of Cr in water is harmful for plant growth and development; similarly, has detrimental effects on fish, wildlife and invertebrates [49].

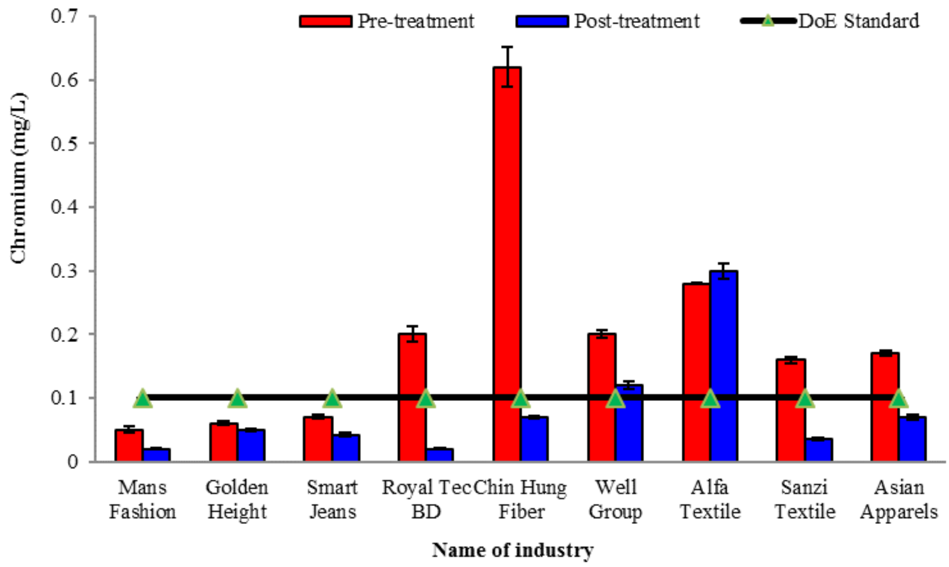

Fig. 7: Comparative analysis of Cr of inlet and outlet effluents of ETP of different industries.

The availability of toxic heavy metals in industrial wastewater limits its discharge into water bodies or for reusing [13]. The evaluation of ETP's efficiency is very important to protect environment and public health from dangers of industrial wastewater. Hence, the efficiency of ETPs must be, regularly, monitored [1] and present study evaluated the performance of ETPs of different industries at Kalurghat, Chittagong. From (Table 5), it is seen that the study was carried to analyze target heavy metals parameter (e.g., Cr, Pb, Zn, Cu, and Ni) of the outlet of ETPs; there is only Alfa Textile for (Cu, Zn, & Cr), Well Group for Cr and Asian Apparels for Ni that metals content were not within the DoE standards and in the rest industries such parameters were within the DoE prescribed water quality parameters. Prabha et al. (2015) found that the membrane bioreactor system was more efficient than conventional system in removal of Zn, Pb, and Cr from industrial effluents. Another study evaluated the performance of an industrial WWTP in South-Eastern Tunisia where average influent concentrations of Zn and Cr were 16 mg/L and 167.21 mg/L respectively. Results showed after treatment the effluent quality in terms of Cu and Zn levels were in agreement with standards, but Cr and Ni residual loads were still above the values required by Tunisian water quality criteria [19].

Table 5: Comparative analysis of heavy metals in outlet of ETPs of different industries.

Name of industry	Cu (mg/L)	Zn (mg/L)	Pb (mg/L)	Ni (mg/L)	Cr (mg/L)
Mans Fashion Ltd	0.30	3.10	0.03	0.30	0.02
Golden Height Ltd	0.45	1.72	0.09	0.70	0.05
Smart Jeans Ltd	0.03	3.42	0.07	0.62	0.04
Royal Tec BD Ltd	0.07	1.60	0.03	0.50	0.02
Chin Hung Fiber Ltd	0.11	2.25	0.06	0.62	0.07
Well Group Ltd	0.23	3.21	0.03	0.78	0.12*
Alfa Textile Ltd	0.72*	5.47*	0.05	0.91	0.30*
Sanzi Textile Ltd	0.07	1.61	0.02	0.27	0.04
Asian Apparels Ltd	0.02	3.61	0.09	1.02*	0.07
DoE Standard	0.50	5.00	0.10	1.00	0.10

N.B.: * indicates that the value has crossed the DoE standard value.

4. Conclusion

Most of the industries in Chittagong district don’t have ETPs or the established ones are not run in a regular basis. Consequently, among 9 studied industries 4 industries, e.g. Royal Tech BD, Sanzi Textile, Chin Hung Fiber, and Golden Height (except EC) treat their effluent efficiently and discharge water within the DoE prescribed water quality standards. All others industries except Alfa Textile treat their effluent but not efficiently. This may be happened due to inefficient rate of chemical dozing, improper monitoring system and negative attitude towards running ETPs. As a result, all the parameters were not up to the standards. Untreated effluents from such industries, particularly from textile industries are one of the main reasons for the critical condition of the Karnafuli River in Chittagong.

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