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Efficiency of Effluent Treatment Plants and Threat to Human Health and Aquatic Environment in Bangladesh

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Bangladesh is a low-lying riverine country. It has about 230 small and large rivers and a large portion of the country's 140 million people depends on them for a living and for transportation. Most of the rivers and canals are becoming increasingly polluted from industrial wastewater dumped by factories, many of them in the textile, leather tanneries, pulp and paper, pharmaceutical, engineering workshops as well as chemicals and pesticide industry. Nonetheless, the wastewaters discharged from them are harshly ruinous to the environment, contains various kinds of contaminant which contaminate the water bodies, aquatic sediments, soil and ultimately incorporated into the muscles of fish, vegetables, *etc*. Many researchers have tried to find out the percentages of a contaminant available in different rivers and their effect on agriculture, environment and human health. Some of their research on discharging industrial wastewater quality, but none of them find out, the effectiveness of industrial effluent treatment plants. The emphasis of this research is to give a detail indication of the discharging contaminants from the five experimental industries and their effluent treatment plants (ETP). Most of our experimental industrial effluent treatment plants were able to reduce their physical parameter (BOD, COD, TSS, TDS, TS, turbidity, pH and EC) in moderate stages and two or three industry effluents were below the standard discharge limit prescribed by the Environmental Protection Agency (EPA), Bangladesh and their effluents were unsuitable for discharging into water bodies, but these are not fulfilled the US EPA guideline ranges. Whereas most of our experimental industries effluent treatment plants reduce small or less portions of metal content from their effluent which were not follow the EPA, Bangladesh and US EPA guideline ranges. They discharge their effluents into water bodies because of the lacking of a very efficient and economic treatment system.

Keywords: Effluent treatment plants, Heavy metal, Influent, effluent, Aquatic environment.

INTRODUCTION

Bangladesh is a diuretic land generated and flown over by numerous rivers; the land is also consistently nourished by their water flows. Bangladesh had 1400 to 1500 rivers in the 11th century, but reduced to 1200 to 1300 due to various natural, anthropogenic factors. Only around 100 rivers have navigable depth around the year at the moment. Total river route across the country in 1971 was 24,140 km is covering 8 % country area now that has been reduced to 3800 km simply during the lean flow period [1].

Rapid industrialization and urban development during the last few decades shave provoked some serious concerns for the environment results in the inclusion of a variety of physical and chemical pollutants into rivers, including heavy metals. Usually, most of the heavy metals enter in river from various sources. It can be either natural by erosion and weathering and or anthropogenic [2-4]. Generally in unaffected environments, most of the heavy metals concentration is very low and is mostly derived from the weathering [5,6]. The most important anthropogenic sources of heavy metals are various industries and domestic sewage. The industries which attribute heavy metals in river water are generally metal industries, paints and pigment industries, pulp and paper industries, cotton textile, steel plant, galvanization of iron products and mining industries as well as the indiscriminate use of heavy metal-containing fertilizer and pesticides in agricultural fields [7-10]. These heavy metals have an accumulative effect at a low level in drinking water and ground water [11]. Due to overpopulation and urbanization for the last few decades' water quality and sanitation infrastructure of the aquatic eco-system has not been maintained accordingly and as a result river contaminated with heavy metal poses a great threat.

The practice of discharging waste from industries and untreated domestic sewage into the aquatic eco-system is continually going on that leads to the increase as the concentration of heavy metals in river water. About 11 % of the rivers in Bangladesh are polluted by industrial wastes. There was a governmental study by the Institute of Water Modelling (IWM) in 2007 on the pollutions in the water courses around Dhaka namely: Buriganga, Shitalakshya, Turag, Balu, Bangshi, Dhaleswary and Tongi Khal [12]. The study correctly revealed that 60 % pollutions were caused by the industries, 30 % of municipal house-hold and city drainage of toilet waste and the rest by others. They also showed these rivers receive 1.5 million cubic meters of waste water every day from 7,000 industrial units in surrounding areas and another 0.5 million cubic meters from other sources. More than 60,000 cubic meters of toxic waste (textile dyeing, printing, washing and pharmaceuticals) enter the Dhaka through the canals and river system every day [12]. Approximately 30 million gallons of untreated industrial wastewater are discharged every day in and around Dhaka city. Thus, billions of gallons of industrial effluent are mixing daily with our environment, mainly with water [13]. Khan *et al.* [14] reported that a semi-automated composite textile industry of 10 tonne capacity produces 1250 m^3 of effluent each day, which contains an assortment of chemicals, including salts, dyes and bleaches. Though some metals like Cu, Fe, Mn, Ni and Zn are required as nutrients in trace amount for life processes in plants and microorganisms, while many other metals like Cd, Cr, Co and Pb have no known physiological activity [15,16]. These heavy metals are not readily degradable in the environment and accumulate in the animal and human bodies to a very high toxicity level leading to undesirable effects beyond a certain limit [17,18]. Therefore, monitoring of these metals is important for safety assessment of the environment and human health in particular.

In Bangladesh, industrial units are mostly located along the banks of the rivers. There are obvious reasons for this such as a provision of transportation for incoming raw materials and outgoing finished products. Unfortunately, industrial unit's drain their wastes directly into the rivers without any consideration of the environmental degradation. The most problematic industries within the water sector are textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical production and refineries. A complex mixture of hazardous chemicals, both organic and inorganic, is discharged into the water bodies from most of the industries usually without treatment.

The aim of this research is to determine the effectiveness of the effluent treatment processes (ETPs) used in Bangladesh and identifying the drawback of the existing effluent treatment plants as well as give an idea for proper and safe wastewater disposal into the environment.

EXPERIMENTAL

Study area: During this research, five different industries influent and effluent were collected and tested their physio-chemical parameters, namely at site **1**, textile industry (Fakhruddin Textile Mills Ltd.); site **2**, pulp and paper Industry (Hakkani pulp & paper mills limited); site **3**, consumer goods industry (Unilever Bangladesh Ltd); site **4**, tannery industry [Palco (BD) Limited] and site **5**, pharmaceuticals industry (Globe Pharmaceuticals Ltd.).

Sample collection: Water samples were collected from five different industries in the months of July, 2013 and tested physical qualities and chemical contents. The samples were well-kept in 1.5 L polyethylene plastic bottles, which had been formerly cleaned with metal-free detergents, washed continually with distilled water, saturated in 10 % nitric acid for 24 h and finally rinsed with deionized water. The sample bottles were labeled with date and sampling location. All samples were kept at 4 °C for further processing and analysis [19,20].

Analytical methods: Standard procedures were used to analyze the physico-chemical parameters of the water sample. Gravimetric method for TSS and TS, single electrode pH meter (Microprocessor-based pH meter, HANNA pH 211) for pH, Portable Conductivity and TDS Meters (HANNA instruments: HI 98130) for conductivity and total dissolved solid (TDS); turbidity meter (HANNA instruments: HI 93703) for turbidity, 5-Day BOD test for BOD by Fixed control dilution method, closed reflux titrimetric method for the determination of COD, In the laboratory, the water samples were filtered using fine filter paper (Whatman filter paper 41, diameter 125 mm) to remove the suspended materials and flame emission atomic absorption spectrophotometer (FL-AAS model: Shimadzu, Japan, AA6800) were used for the determination of metal concentration (Na, K, Ca, Mg, Fe, Cu, Cr, Pb, Mn, As, Cd, Ni, Hg). Sample spike, blank spike and quality control (QC) protocol was followed for each type of sample analysis, including replicate analysis, checking of method blanks, standards of various parameters, *etc*.

RESULTS AND DISCUSSION

The BOD ranges of textile industry, pulp and paper mill, consumer goods industry, tannery industry, pharmaceuticals industries in the influent were 175, 112, 97, 197, 109 mg/L and effluent were 109, 48, 42, 135, 46 mg/L respectively. The average effluent discharge signifies that the biological method can treat the wastewater by biodegradation of organic matter. The BOD of effluent of sites 2 (48), 3 (42) and 5 (46) were below the EPA, Bangladesh guideline range of 50 mg/L (Table-1). The continued disposal of biodegradable organic waste into receiving waters will lead to increased consumption of dissolved oxygen thus affecting the aquatic life. The COD values of our consecutive industry's influent were 359, 264, 203, 397, 213 mg/L and effluent were 249, 127, 102, 285, 136 mg/L respectively (Fig. 1b). Though all the effluent COD values were low as compared to the influent values, but site 2 (pulp and paper mill), site 3 (consumer goods industry) and site 5 (pharmaceuticals industry) meet the EPA Bangladesh

TABLE-1
VALUES OF VARIOUS INDUSTRIES INFLUENT AND EFFLUENT PARAMETERS

Parameter	Standard limit by DoE	Textile industry		Pulp & paper industry		Consumer goods industry		Tannery industry		Pharmaceutical industry	
		B	A	B	A	B	A	B	A	B	A
BOD_5 (mg/L)	50	175	109	112	48	97	42	197	135	109	46
COD (mg/L)	200	359	249	264	127	203	102	397	285	213	136
TSS (mg/L)	150	349	233	319	236	159	118	457	381	119	93
TDS (mg/L)	2100	2365	2262	2186	2025	1060	740	2467	2331	1743	1265
TS (mg/L)	2250	2714	2495	2505	2261	1219	858	2924	2712	1862	1358
Turbidity (NTU)	-	373.4	249.3	341.3	252.5	170.1	126.3	489.0	407.7	127.3	99.5
pH	6	8.98	9.67	7.45	7.19	7.5	7.8	6.6	7.2	6.8	7.6
EC (μmho/cm)	1200	1584.55	1515.54	1464.62	1356.75	710.2	495.8	1652.89	1561.77	1167.81	847.55
Na (mg/L)	-	4.5	2.95	2.63	1.48	10.8	8.9	14.9	12.67	3.4	2.55
K (mg/L)	-	2.3	1.89	nd	nd	2.9	2.1	1.7	1.2	3.3	2.7
Ca (mg/L)	0.5	11.2	9.78	10.5	0.89	14.9	5.7	57	45	8.3	3.2
Mg (mg/L)	5	2.28	1.74	nd	nd	1.1	0.83	0.92	0.64	nd	nd
Fe (mg/L)	2	2.75	2.18	3.85	2.87	2.45	1.13	3.1	2.29	3.67	1.05
Cu (mg/L)	0.5	1.19	0.97	0.142	0.11	0.67	0.47	0.92	0.85	1.06	0.79
Cr (mg/L)	0.5	0.94	0.78	nd	nd	0.05	0.032	6.5	4.8	0.89	0.56
Pb (mg/L)	0.1	1.23	0.88	nd	nd	0.06	0.045	1.23	1.03	nd	nd
Mn (mg/L)	5	0.89	0.45	0.034	0.02	0.09	0.06	0.25	0.15	0.36	0.13
As (mg/L)	0.2	nd	nd	nd	nd	0.05	0.025	1.24	0.99	nd	nd
Cd (mg/L)	0.05	nd	nd	0.095	0.08	0.008	0.006	nd	nd	nd	nd
Ni (mg/L)	1	nd	nd	nd	nd	nd	nd	1.03	0.94	nd	nd
Hg (mg/L)	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

B = Before treatment or influent; A = After treatment or effluent; nd = Not detected

guideline value of 200 mg/L. The TSS of effluent at sites 3 (118) and 5 (93) were below the EPA, Bangladesh guideline range of 150 mg/L (Fig. 1c). All other influent and effluent values were above the standard discharge limit. This result suggests that, pulp and paper, textile and leather industrial effluents were unsuitable for discharging into the surface-water bodies which pose potential threats to human health and the environment. This study illustrates that sludge settlement during the sedimentation process could reduce certain pollution levels but not sufficient enough to consider the process alone using in effluent treatment. We also observe, use of coagulants or flocculates and later sand-stone filtration showed the best efficiency to settle the suspended solid in the consumer goods and pharmaceutical industry, which were well below the standard prescribed limits for Inland Surface Water-Bangladesh Standard (ISW-BDS). The TDS of effluent at sites 2 (2025), 3 (740) and 5 (1265) were below the EPA, Bangladesh guideline range of 2100 mg/L (Fig. 1d) and all other values were slightly above the standard discharge limit. The TS of effluent at sites 3 (858), 5 (1358) and influent at sites 3 (1219), 5 (1862) were below the discharge limit of DoE, Bangladesh guideline range of 2250 mg/L (Fig. 2a) and all other values were above the standard discharge limit. The study reveals that total solid of influence of consumer goods and pharmaceutical industries were below the standard discharge limit and their effluent treatment plant plants reduced higher. We observe others industry reduced pollution levels by the settlement during the sedimentation process, but not sufficient enough to consider the process alone using in effluent treatment.

The turbidity ranges of textile, pulp and paper mill, consumer goods, tannery and pha industries in the influent were 373.4, 341.3, 170.1, 489.0, 127.3 NTU and effluent were 249.3, 252.5, 126.3, 407.7, 99.5 NTU respectively (Fig. 2b). Though all the effluent turbidity values were low as compared to the influent values, but site 3 (consumer goods industry) and 5 (pharmaceuticals industry) were very low and there is no standard discharge limit for turbidity in Bangladesh. The pH values of our experimental industry's influent were 8.38, 7.45, 7.5, 6.6, 6.8 and effluents were 8.97, 7.19, 7.8, 7.2, 7.6 respectively. All the effluent values were within EPA, Bangladesh guideline range of 6 to 9 (Fig. 2c). The electrical conductivity of our consecutive industry's influent were 1584.55, 1464.62, 710.2, 1652.89, 1167.81 μmho/cm and effluent were 1515.54, 1356.75, 495.8, 1561.77, 847.55 μmho/cm respectively (Fig. 2d). The electrical conductivity (EC) of effluent at consumer goods (495.8 μmho/cm) and pharmaceuticals (847.55 μmho/cm) industries were below the EPA, Bangladesh guideline range of 1200 μmho/cm and all other values were above the standard discharge limit. The highest value of electrical conductivity is measured in the effluent from tannery industry (1561.77 μmho/cm) indicating higher amounts of total dissolved solids (TDS) emanating from the various chemicals used as aniline, tanning and finishing in leather processing industry. The high values of electrical conductivity in effluent from textile industry (1515.54 μmho/cm) could be due to release of the huge volume of colouring substances containing nitrogenous compounds into their waste effluent, which were nitrified to ammonium-nitrogen and nitrate resulting in high electrical conductivity. The high value of electrical conductivity in the effluent from pulp and paper mill (1356.75 μmho/cm) is attributed to the high content of chemicals used a cleaning and bleaching in these industry (Fig. 2d).

Most of our experimental industries used the same types of effluent treatment plants (ETP) and their common treatment system, reduce a small amount of metal contents from influent to effluent and ineffective to maintain the standard discharge

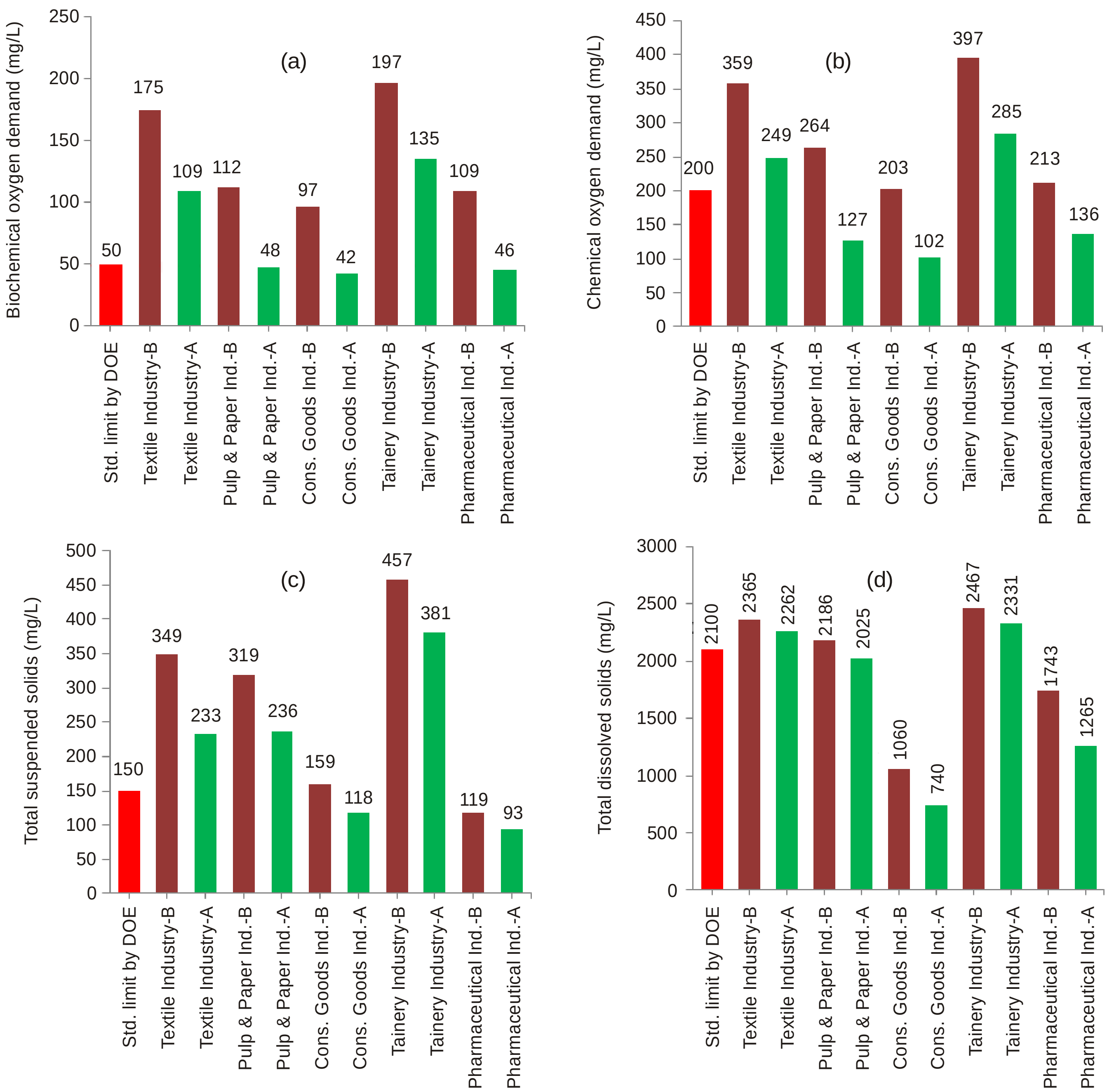

Fig. 1. (a) BOD, (b) COD, (c) TSS and (d) TDS of various industries influent and effluent

limit prescribed by the Environmental Protection Agency (EPA), Bangladesh. Two of our experimental industry, namely consumer goods industry (Unilever Bangladesh Ltd.) and pharmaceutical industry (Globe Pharmaceuticals Ltd.) modify some of their treatment systems and their effluent treatment plant is better than other three industries and they could reduce the high percentage of metal content than other industries, but they were not able to remove all the metal content of their effluent and discharge lesser amount of metal content to the surface-water bodies. We also observe, some of the metal contents (Mg, Mn) in influent and effluent of our tested industry were below the standard discharge limit (5.0 mg/L) and most of our tested industry used small or less amounts of metal contents (Ni, Hg) and two metals (Na, K) used most of the industry in their production but EPA does not prescribe it standard discharge limits on the surface water (Figs. 3-5).

From the above experimental industrial wastewater parameter, we can easily conclude that, most of our experimental industry's effluent treatment plants could reduce their physical parameter (BOD, COD, TSS, TDS, TS, turbidity, pH and EC) in moderate stages and two or three industries effluent were below the standard discharge limit prescribed by the Environmental Protection Agency (EPA), Bangladesh and their effluents were suitable for discharging into surface water bodies, but these not fulfil the United States Environmental Protection Agency (US EPA) guideline ranges. Whereas most of our experimental industries effluent treatment plant systems reduce small or less portions of metal content from their influent and

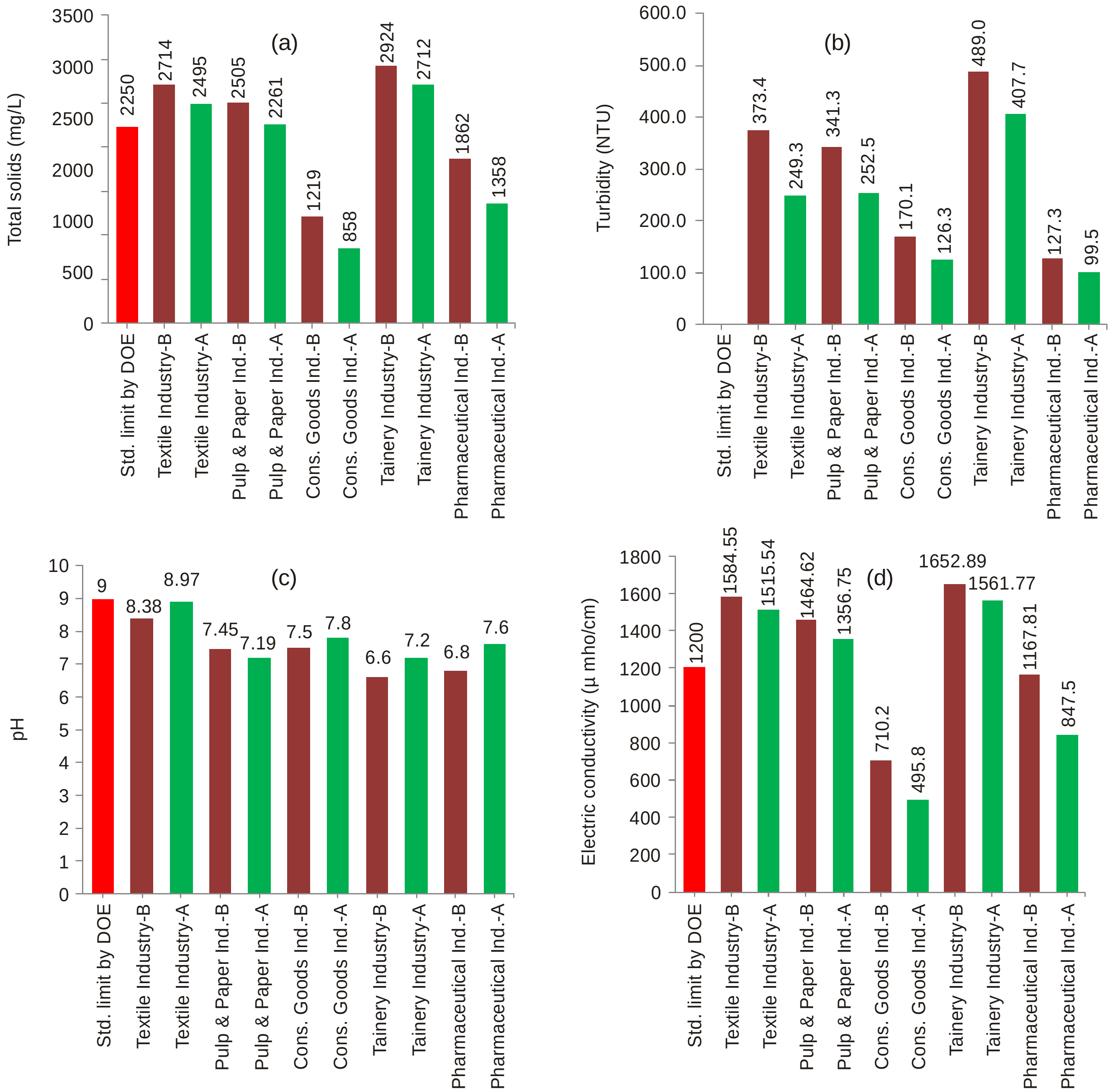

Fig. 2. (a) TS, (b) Turbidity, (c) pH and (d) Electric conductivity of various industries influent and effluent

their effluent treatment plant system were not able to follow the EPA, Bangladesh and US EPA guideline ranges. They discharge their toxic metal into the water bodies without modifying their effluent treatment plant system. As a result, water bodies and agricultural land are displaying reduced productivity and the biological diversity of these ecosystems is threatened. The result is not only environmental degradation, but also a reduction in the nutrition and incomes of families that traditionally depended on these resources and they are not always the same people who get the benefit from the jobs created by the factories.

One solution is to ensure that all the effluent is properly treated before it is discharged. The Bangladesh Environment Conservation Act (1995) and Rules (1997) make provision for this, categorizing factories according to their ability to pollute and stating the measures that must be taken to address this, including treatment. Under the 1997 rules fabric dyeing, leather tanning and chemical processing, industries are categorized as "red industries," which is the highest category in the rules and for which an effluent treatment plant (ETP) is mandatory. Under these rules factories must treat as well as monitor the quality of their wastewater and stay within national discharge quality standards. Despite these laws, factories often show a reluctance to invest money in proper treatment because they consider it to be a non-productive use of money in an industry that is still emerging and striving to remain profitable in the highly competitive global market. Even where industries already have effluent treatment plants, there is often unwilling to operate the plant correctly because of the high running costs or a lack of experience to do so effectively.

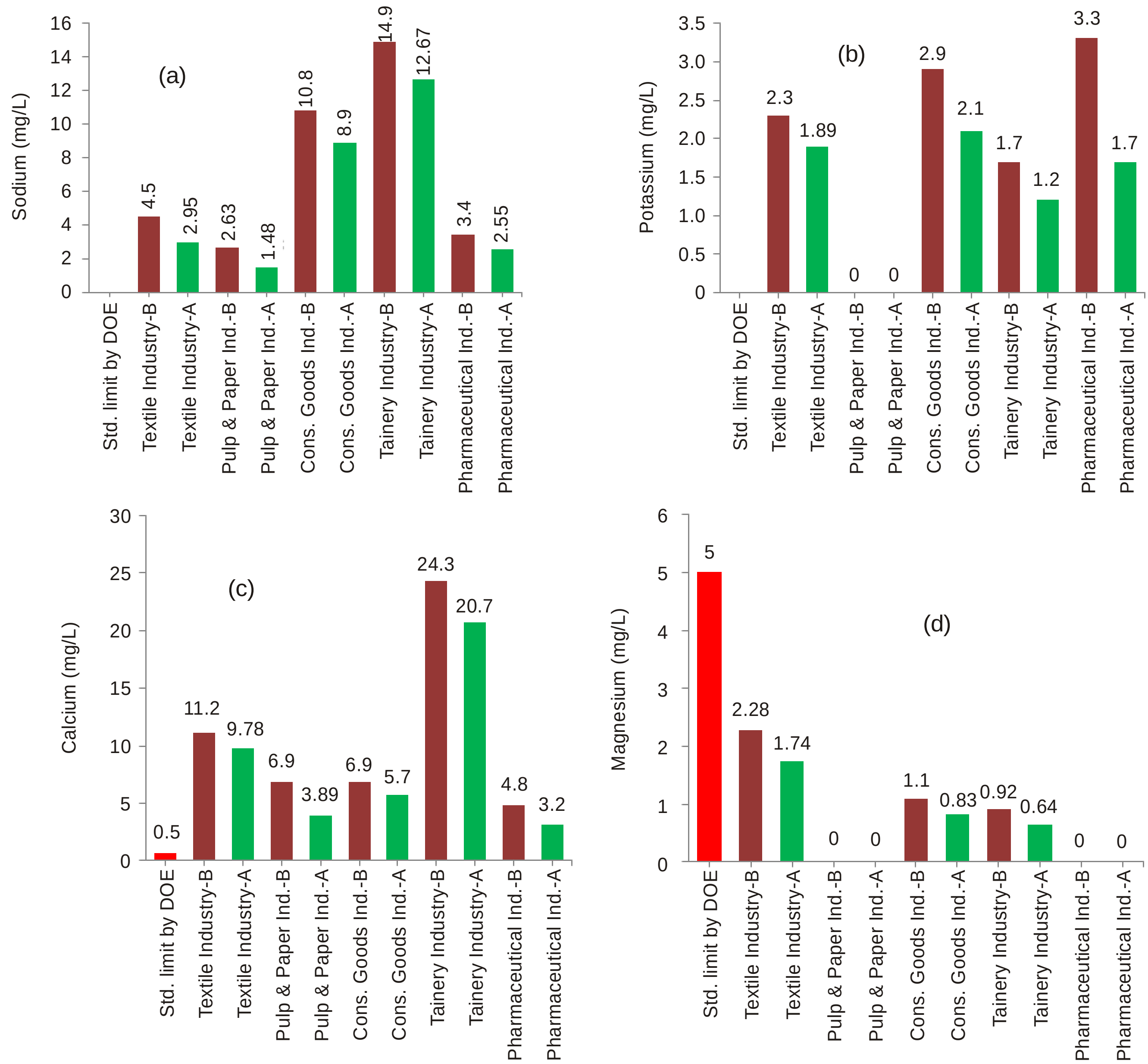

Fig. 3. (a) Sodium, (b) Potassium, (c) Calcium and (d) Magnesium of various industries influent and effluent

In Bangladesh, the effluent treatment from textile dyeing factories and other industrial processes is usually required by law and often expected by international buyers. Despite this, treatment is regularly below standards and is rarely checked either by the factory, environment departments or buyers. There are several reasons for this, but the bottom line is usually a lack of funds and technical expertise. The main problems experienced by factories with effluent treatment plants are inadequate treatment due to incorrect dosing of chemicals required for the treatment process or inactivity and even death of necessary micro-organisms, due to the pH, insufficient oxygen or lack of nutrients. All of these can be addressed through better management; usual chemical dosing. By regularly monitoring and understanding their wastewater properly effluent treatment plant managers can make effective decisions to achieve optimal effluent treatment plant functioning.

In this regard, Government's recent step to deal this matter stringently to pressurize industries to install effluent treatment plant immediately is highly appreciable. It means that industries will have to comply with the existing laws and regulation of their own country. However, medium-scale industries are not that much keen to set up effluent treatment plants since effluent treatment plant is costlier; they cannot afford. That's why; the need for invention of local technology in this respect has to be underscored. Some of the industries have their own effluent treatment plants. However, these are not performing effectively. Some factory owners are unwilling to operate their effluent treatment plants 24 h; this leads to decrease the efficiency in the treatment plant. The plant must be properly aerated and continuous operation ensures that microorganisms are provided with sufficient food that is wastewater and oxygen to keep them alive in case of a biological treatment process. If an interruption occurs during operation, biological process will be hindered. Again, aeration requires power consumption, which all leads to maintenance and operational cost. Most of the cases, factory owner doesn't possess the mentality to

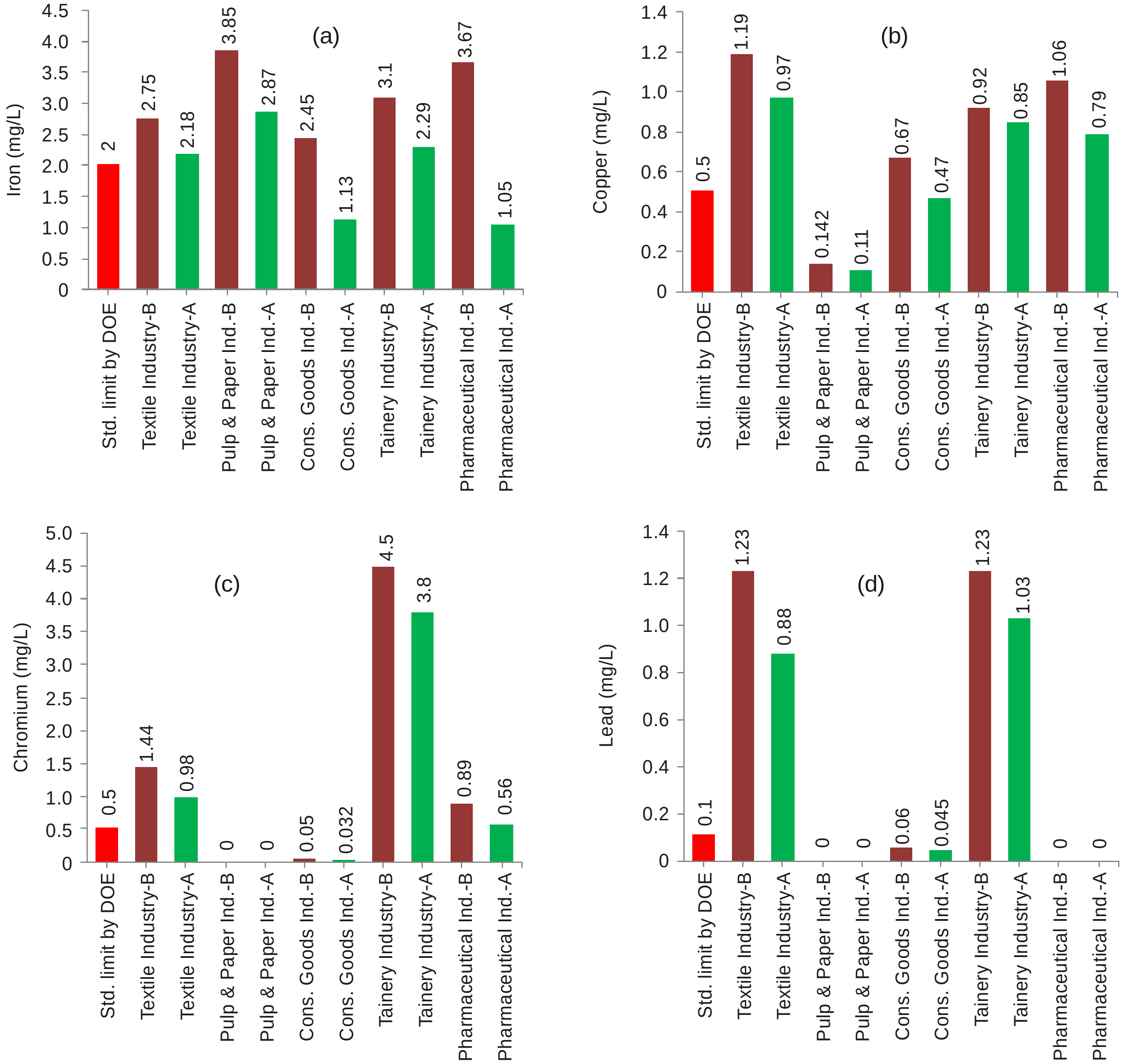

Fig. 4. (a) Iron, (b) Copper, (c) Chromium and (d) Lead of various industries influent and effluent

expend too much money in this non-productive issue. The function of effluent treatment plant is to clean the polluted water by appropriate treatment to satisfy the national standard, to meet the buyers' condition and to meet the objections from a group of affected populations. So, the satisfactory effluent treatment plant operation must be ensured by successive monitoring of different parameters in the wastewater entering the effluent treatment plant and at several stages in the effluent treatment plant process. Therefore, effluent treatment plant management requires a certain level of understanding of the overall effluent treatment plant functioning. However, in the industries, hardly, there are skilled personnel with sufficient technical capability to monitor and operate the overall effluent treatment plant process.

It was expected that effluent treatment plant would treat effluent chemically and biologically so that after treatment the discharged water is not harmful for the environment. Unfortunately, the results obtained from samples of treated water from discharge points of effluent treatment plant showed that effluent treatment plant of most industries are not even capable of treating the effluent chemically and most of the parameters were found above the DoE standards. Although only few data were analyzed, from this research, it can be well-understood that without treatment toxic effluents are harmful to the environment and unfortunately treated effluent is also detrimental as because effluent treatment plants of some industries are not well performed one.

The recent awareness of the effluent treatment plant requirement should be directed in a constructive way. We realize that effluent should be treated before drainage. Government must come forward to facilitate effluent treatment plant installation with technical guidance and also with financing. Consideration for common effluent treatment plant can be made by the Government, which will encourage small-scale industries

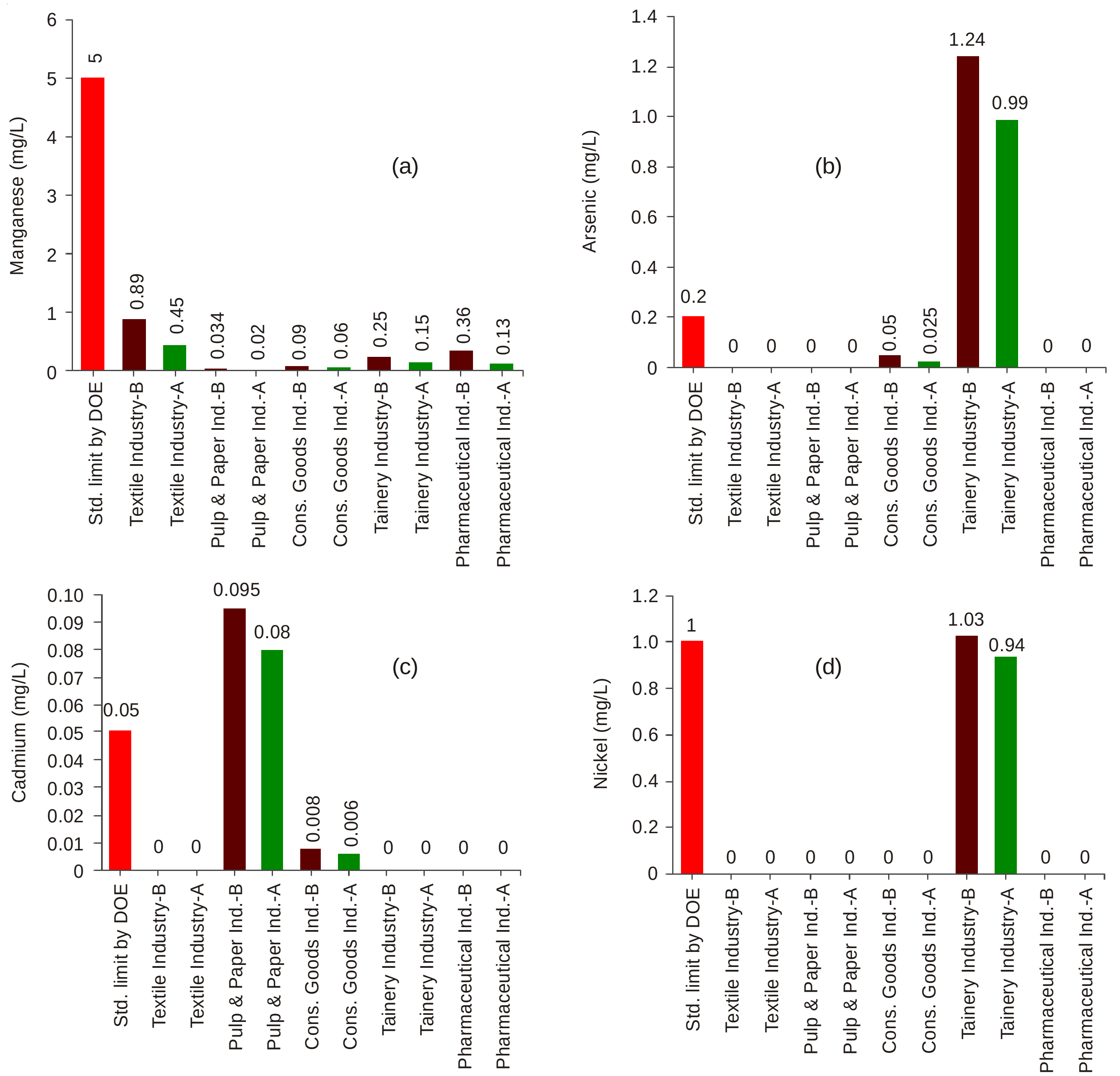

Fig 5. (a) Manganese, (b) Arsenic, (c) Cadmium and (d) Nickel of various industries influent and effluent

to establish effluent treatment plants within their cost limitations. Government's recent stringent role against the industry owner may pressurize them to come up with a compliance measure regarding effluent treatment plant installation, but in the long run, a good result can only be ensured by proper monitoring and environmental audit by Government afterward. Neither industry and private sector nor the public sector alone can be left responsible for realization on the intensity of the problem. The government and the private sector should come into with its full glory to solve the problem mutually, which aims at burning issue like environmental conservation.

Conclusion

From the above discussion, we can easily conclude that, most of our experimental industries used similar types of effluent treatment plants (ETP) and their common treatment system were able to reduces their physical parameter in moderate stages and metal content reduces small or less portion and ineffective to maintain the standard discharge limit prescribed by the EPA, Bangladesh and US EPA guideline ranges.

Installation of effluent treatment plant (ETP) is essential in the factories, which create water pollution in the country on priority basis for sustainable growth of the sector and protect the environment from degradation. There is no alternative to the installation of effluent treatment plant in this export based industries to keep pace with the quota-free global market, especially in the wake of growing international consumers' awareness of social and environmental obedience. As industries are mainly clustered in Bangladesh, setting up of centralized effluent treatment plants by the government is highly appreciable, would help factory owners a lot in reducing maintenance costs. The government can easily acquire land to set up specialized industrial areas where effluent treatment plant projects are easy to implement. If so, the existing factories as well as new entrepreneurs will feel encouraged to invest more in this sector. So, small-scale industries, which are incapable to install full capacity effluent treatment plant, will also be able to meet the environmental compliance.

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