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Characterization of Textile Effluents from Dhaka Export Processing Zone (DEPZ) Area in Dhaka, Bangladesh

Kamal, A.K.I.[1, 2], Ahmed, F.[1], Hassan, M.[1*], Uddin, M.K.[1] and Hossain, S.M.[3]

1. Department of Environmental Sciences, Jahangirnagar University, Dhaka-1342, Bangladesh

2. Department of Public and Environmental Health Sciences, University of Birmingham, UK

3. Institute of Nuclear Science and Technology (INST), Atomic Energy Research Establishment (AERE), Dhaka-1000, Bangladesh

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ABSTRACT: The present study has been undertaken in a laboratory scale to characterize and investigate pollution potential of textile effluents from DEPZ area in Dhaka, Bangladesh. Collected effluent samples from five different industries were analyzed for physico-chemical parameters using field kits and Standard Methods, and for metals using Flame Atomic Absorption Spectrophotometer (FAAS). The average physico-chemical parameters such as temperature, color, pH, DO, EC, BOD, COD, TS, total alkalinity and total hardness were found 52.4 °C, 2646 PCU, 9.788, 1.492 mg/L, 7473.2 µS/cm, 157 mg/L, 508.8 mg/L, 9140.8 mg/L, 761.2 mg/L and 189.6 mg/L, respectively. The average concentrations of metal found in the textile effluents were in the order of Na (4611.762 mg/L) > Ca (9.166 mg/L) > Mg (3.578 mg/L) > Zn (0.113 mg/L) > Ni (0.0074 mg/L) > Cu (0.0032 mg/L). All the measured physico-chemical parameter values are negatively deviated but metal concentrations (except Na) are positively deviated from standard limits of wastewater discharge set by Department of Environment and US Environmental Protection Agency. In view of those characteristics, the textile industry effluents should be considered to be treated by setting eco-friendly effluent treatment plant (ETP) before directly discharging into the water bodies.

Keywords: analysis, industrial pollution, metal, physico-chemical parameter, wastewater.

INTRODUCTION

Industrial revolution started to spring up slowly in Bangladesh since early sixties and the development of new industries throughout the country is still continuing (Jolly *et al*., 2013). Textile industries are considered as the largest, vital and key industrial sectors of Bangladesh as 78% of the total export earning comes from textile and textile related goods contributing 12% to GDP (Ahmed *et al*., 2015). Huge volume of water-based effluent is generated in the various activities of wet processing of textiles due to use of enormous volume of water either in the actual chemical processing or during re-processing in preparatory, dyeing, printing and finishing (Ridoutt and Pfister, 2010; Khan *et al*., 2014). Quantity and nature of waste generated depends on the fabric being processed, chemicals being used, operating practices and technology being employed (Qadir and Chhipa, 2015a). Most of these effluents from the textile industries are discharged untreated into rivers, as a result, a considerable portion of the

[*] Corresponding Author Email: arifmahmudhasan@yahoo.com, Tel: +8801725608402

available water is being polluted by the textile effluents, and about two thirds of diseases are related to water-borne diseases in Bangladesh (Hannan *et al*., 2011). Textile effluents are usually extremely heterogeneous in composition with a large extent of toxic and sometimes unmanageable objects coming from dyeing and finishing processes. These processes involve the input of a wide range of chemicals and dyestuffs, which are generally organic compounds with complex structures (Al-kdasi *et al*., 2004; Sabur *et al*., 2012). The effluents contain a wide range of contaminants such as salts, enzymes, surfactants, oxidizing and reducing agents (Badani *et al*., 2005; Jo *et al*., 2008).

Industrial effluents which offer a wide scope of environmental problems and health hazards are becoming more complex and critical not only in developing countries but also in developed countries (Deepali and Gangwar, 2010). Industrial emission and waste effluent generated from factories are associated with heavy disease burden and this could be part of the reasons for the current shorter life expectancy for both male and female in the country compared to the developed nations (Hannan *et al*., 2011). Major problem in textile industry is the presence of color due to extensive use of dyes. The wastewater containing dyed effluents has been found to be hazardous to aquatic ecosystem. Because it reduces the rate of photosynthesis due to the reduced penetration of sunlight in colored waters. It not only leads to toxicity of fishes and mammals but also inhibits the activity and growth of microorganisms (Qadir and Chhipa, 2015b). In addition to dyes, various salts and chemicals are major sources of heavy metals in wastewater (Wagner, 1993). Metal and contaminants like dyes tend to persist indefinitely, circulating and eventually accumulating throughout the food chain (Niu *et al*., 1993; Simmons *et al*., 1995). Heavy metals contained in these effluents from the industries have been found to be carcinogenic (Tamburlaine *et al*., 2002), while other chemicals equally present are poisonous depending on the dose and exposure duration (Lawrence and McCabe, 2002) for algae, plants, and different animals including human being.

To prevent the above adverse effects, the textile industry wastewater needs to be treated and discharged as per the national discharge quality standards laid down under Environment Conservation Act (1995) and Rules (1997), legislated by the Government of Bangladesh. Under the 1997 Rules fabric dyeing 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. Due to increased awareness of worldwide environmental issues, there has been a great interest in the development of eco-friendly wet processing textile techniques in recent years (Padma *et al*., 2006). But before treatment, characterization of textile effluent is very important to develop strategies for water treatment and reuse (Savin and Butnaru, 2008; Mountassir *et al*., 2013). The objective of the present research was to characterize textile effluents for the investigation of pollution potential from five textile industries of DEPZ area in Dhaka, Bangladesh.

MATERIALS and METHODS

Effluents Sample Collection and Treatment

The effluents samples were collected in cleaned poly-propylene bottles pre-washed with 20% HNO_3 acid and rinsed repeatedly with deionized water from the effluent outlets just before the treatment plant for five individual textile and dying industries which are located in the extended area of DEPZ (Dhaka Export Processing Zone), Dhaka, Bangladesh. For metals analysis, 65% concentrated ultra-pure HNO_3 acid was added to each samples by dropper after immediately collection of effluent sample to bring the pH blow 2 to minimize precipitation and adsorption onto container walls (APHA, 1998). Then these samples were transported by an ice box to the laboratory, and properly labeled and preserved in refrigerator at 4°C.

For metals determination, effluent sample was digested according to Singh and Chandel (2006). 100 ml well-mixed and acid-preserved sample was transferred into clean beaker and 5 ml 65% concentrated HNO_3 acid was added and covered with a clean watch glass. The beaker was heated (120-150º C) slowly on a sand bath hotplate in a fume chamber and evaporating until the sample is reduced to about 10 ml. The suspension was kept for cooling at room temperature and later added 5 ml 65% concentrated HNO_3 acid and 10 ml 70% concentrated $HClO_4$ acid. Again the suspensions were heated gently at 200˚C and evaporated to about 10 ml. After cooling at room temperature, the suspensions were diluted to 100 ml in a 100 ml volumetric flask with deionized water. Then the solution was filtered using Whatman No. 41 (0.45 µm pore size) into plastic bottle and kept the solution in the refrigerator until analysis.

Effluent Sample Analysis for Characterization

Temperature, color, pH, dissolved oxygen (DO) and electrical conductivity (EC) of textile effluent were measured using thermometer, portable photometer (Model: HI96727, HANNA instrument), glass electrode pH meter (Model: Lab 851, SCHOTT instrument), DO meter (Model: H19143, HANNA instrument) and EC meter (Model: EC 241, HANNA instrument), respectively. Total solids (TS) and chemical oxygen demand (COD) were determined by gravimetric method (Kazi *et al*., 2009) and titrimetric method (Huq and Didarul-ul-Alam, 2005), respectively. Biological oxygen demand (BOD), total alkalinity and total hardness were determined by 5-days incubation (20˚C) method, standard titrimetric method and EDTA titrimetric method, respectively according to APHA (1998). The digested effluent samples were analyzed by Flame Atomic Absorption Spectrophotometer (Model: AA-6800, Shimadzu) to determine calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), nickel (Ni), lead (Pb) and cadmium (Cd). Sodium (Na) was determined by Flame Photometer (Model: PFP7, Jenway).

During the overall process of sample preparation and analysis, special care was taken to minimize contaminants from air, glassware and reagents. All glassware were washed with deionized water before using in this study. All reagents used during analysis were prepared from analytical-reagent or higher-grade chemicals. All instruments were calibrated with standard solutions in accordance with manufacturer's instructions.

RESULTS AND DISCUSSION

Table 1 shows the physico-chemical and metals characteristics of effluents from five different textile industries of DEPZ area, Dhaka. In the effluent samples, temperature varied between 47 and 58˚C with average value of 52.4˚C which are above the effluent discharge standards of DoE (2008) [45˚C] and EPA (2002) [40˚C]. High temperature reduces the solubility of gases in water that ultimately expresses high BOD/COD (Ali *et al*., 2009). Short term temperature fluctuations in streams near the textile and dying industries might lead fish to die, fish eggs that won't hatch or a total change in the fish population (Roy *et al*., 2010). The average temperature of the present study was measured higher than average value of 41.675, 40.40, 35.23, 41.7 and 30.2˚C reported by Roy *et al*. (2010), in Bangladesh, Ali *et al*. (2009), in Pakistan, Muntassir *et al*. (2013), in Morocco, Ntuli *et al*. (2009), and Ohioma *et al*. (2009), respectively in the textiles effluents.

Color was found in raw effluents ranging from 2465 to 2900 PCU which are from 164.33 to 193.33 times higher than the permissible limit of color in wastewater to discharge (IWS, 2002) [15 PCU]. Textile effluents were found highly colored because 10-15% of the dyes are lost in the effluents of textile units (Boer *et al*., 2004; Xian-Chun *et al*., 2007; Roy *et al*., 2010). Color is imparted to water body by dissolved constituents (dyes and pigments) that absorb white light and emit light at specific wavelengths (Ali *et al*., 2009). Roy *et al*. (2010) reported the average value of 3216.25 PCU which was higher than average value of 2646.4 PCU of the present study.

pH appeared in the range of 9.45 to 10.50 with average value of 9.788 and show that the measured effluents were typically alkaline. The measured pH values are higher than the standards of DoE (2008) [5-9] and EPA (2002) [6-9]. These results are in accordance with the result of Junkins (1982) who reported that the textile wastes are highly alkaline. Generally, alkaline pH of textile effluents is associated with the process of bleaching and is extremely undesirable in water ecology (Chhikara *et al*., 2013; Effler *et al*., 1990). The average pH values were reported 8.18, 8.25, 9.26 and 8.8 in textiles effluents in Bangladesh (Kanan *et al*., 2014), in India (Hussain *et al*., 2004), in Nigeria (Ohioma *et al*., 2009) and in Russia (Ntuli *et al*., 2009), respectively.

Table 1. Physico-chemical and metals characteristics of effluents of five textile industries

Characteristics	Sample ID					Average
	Industry-1	Industry-2	Industry-3	Industry-4	Industry-5	
Temperature (ºC)	55±3.33	47±3.165	58±4.872	49±2.50	53±3.75	52.4±4.449
Colour (PCU)	2900±152.962	2465±201.502	2500±180.843	2872±173.11	2495±210.03	2646.4±219.356
pH	9.45±0.5	9.56±0.675	10.1±0.984	9.33±0.902	10.50±0.261	9.788±0.495
DO (mg/L)	1.41±0.325	1.03±0.532	1.89±0.183	1.67±0.099	1.46±0.303	1.492±0.3206
EC (µS/cm)	7390±211.33	7853±234.98	7430±199.50	7139±201.50	7554±311.90	7473.2±260.410
BOD (mg/L)	143±21.66	160±13.94	138±9.52	181±17.55	163±13.66	157±17.161
COD (mg/L)	448±27.35	520±17.06	459±31.89	578±31.01	539±29.00	508.8±54.778
TS (mg/L)	9950±558.72	8230±502.09	9120±481.44	8823±509.23	9581±410.02	9140.8±667.002
Total Alkalinity (mg/L)	801±18.99	760±31.65	750±23.49	794±9.41	701±23.99	761.2±40.033
Total Hardness (mg/L)	170±10.05	210±16.33	190±20.00	175±12.11	203±16.31	189.6±17.271
Ca (mg/L)	9.090±0.0553	9.136±0.0839	9.333±0.0573	9.171±0.0599	9.103±0.0911	9.166±0.098
Mg (mg/L)	3.648±0.0213	3.186±0.0143	3.462±0.0951	4.002±0.0376	3.591±0.0722	3.578±0.296
Na (mg/L)	4,659.890±230.902	4,807±123.936	4390.372±119.533	4421±150.44	4780±291.420	4611.762±196.418
Zn (mg/L)	0.141±0.0066	0.091±0.0021	0.119±0.0042	0.099±0.0061	0.117±0.0035	0.113±0.0194
Ni (mg/L)	0.006±0.0015	0.009±0.0014	0.007±0.0023	0.007±0.0017	0.008±0.002	0.0074±0.00114
Cu (mg/L)	0.012±0.0002	0.016±0.0007	0.020±0.0011	0.013±0.0009	0.017±0.0005	0.0032±0.0032
Pb (mg/L)	BDL	BDL	BDL	BDL	BDL	
Cd (mg/L)	BDL	BDL	BDL	BDL	BDL	

BDL-Below detection limit

The most important measure of water quality is the dissolved oxygen (DO) (Peirce *et al*., 1997). DO values were found ranging from 1.03 to 1.89 mg/L with average value of 1.492 mg/L which are lower than DoE standard (2008) [4.5-8 mg/L]. The lower DO content could be due to intrusion of high organic load in the water which leads to oxygen depletion (Mohabansi *et al*., 2011). Roy *et al*. (2010) reported lower DO value of 0.335 mg/L in HR textile effluent, but Kanan *et al*. (2014) found higher DO value of 2.98 mg/L in textile effluent, Narshingdi in Bangladesh than the present investigation.

EC of effluent was found in the range of 7139 to 7853 µS/cm which are higher than standard (1200 µS/cm) of DoE (2008). High EC indicates a large amount of ionic substances like sodium, potassium, iron etc in textile effluent (Roy *et al*., 2010). The use of sodium carbonate and salt in the dyeing process and electrolytes (sodium sulfate) in the bleaching process causes an increase in EC of the wastewater (Mountassir *et al*., 2013). The measured average EC value of 7473.2 µS/cm in this study was found higher than the average values of 4542.5, 6709.17 and 6385 µS/cm reported by Roy *et al*. (2010) in Bangladesh, Hussain *et al*. (2004) in India and Ntuli *et al*. (2009) in Russia, respectively in textiles effluents.

BOD and COD values were measured in the range of 138 to 181 mg/L and 448 to 520 mg/L, respectively and which are higher than standards of DoE (2008) [BOD= 50 mg/L and COD= 200 mg/L] and EPA (2002) [BOD= 40 mg/L and COD= 120 mg/L]. The high levels of BOD are indications of the pollution strength of the wastewaters. They also indicate that there could be low oxygen available for living organisms in the wastewater when utilizing the organic matter present (Yusuff and Sonibare, 2004). High COD levels imply toxic condition and the presence of biologically resistant organic substances (Sawyer and McCarty, 1978). The remarkable increase in COD levels compared with BOD also indicates that significant levels of toxicants e.g. heavy metals may be possibly present in the wastewater (Chavan, 2001). The ratio of the BOD:COD obtained from the results ranged from 0.30-0.32. This indicated that the effluent contained a large proportion of non-biodegradable organic matter. A BOD:COD ratio less than 0.5 indicates that the effluent contains a large proportion of non-biodegradable matter (Ntuli *et al*., 2009). The average BOD and COD values in this study were found lower than reported by Kanan *et al*. (2014), in Bangladesh [BOD= 454 mg/L and COD= 1047 mg/L], Ntuli *et al*. (2009), in Russia [BOD= 2040 mg/L and COD= 5849 mg/L], Ali *et al*. (2009), in Pakistan [BOD= 548 mg/L and COD= 1632 mg/L] and Hussain *et al*. (2004), in India [BOD= 713.33 mg/L and COD= 2125 mg/L].

TS (includes both organic and inorganic solid constituents dissolved or suspended in the wastewater) was found ranging from 8230 to 9950 mg/L with average value of 9140.8 mg/L which was higher than the average value of 1063.33 mg/L reported by Ohioma *et al*. (2009), in textile effluent in Nigeria. It is a reflection of the oxygen amount required to synthesize both organic and inorganic solids present in the textile wastewaters (Uwidia and Ejeomo, 2013).

Total alkalinity in the studied effluent was calculated to be in the range of 701 to 801 mg/L with average value of 761.2 mg/L. Alkalinity is the sum of all treatable bases mainly carbonate, bicarbonate and hydroxide content (Imtiazuddin *et al*., 2014). Alkalinity of water is the capacity to neutralize acidic nature of the water to pre-designated pH (Mohabansi *et al*., 2011). The total alkalinity (TA) of water is the capacity to neutralize acidic nature. The presence of carbonates, bicarbonates and hydroxides are the main cause of alkalinity in the water. The average total alkalinity was found lower than value of 1590 mg/L reported by Ntuli *et al*. (2009), in Russia.

The range of total hardness was found from 170 to 210 mg/L. The studied effluent samples were found to be moderately hard. Total hardness is sum of the calcium and magnesium concentrations in effluent. Hardness is a very important factor in dyeing process as most of the dyes get precipitated in the presence of calcium and magnesium ion (Hussain *et al*., 2004). Ntuli *et al*. (2009), in Russia and Hussain *et al*. (2004), in India measured average values of 113 mg/L and 136.25 mg/L, respectively in textile effluent which were lower than the present investigation.

The concentration of Na ion in textile effluent ranged from 4390.372 to 4807.000 mg/L with average value of 4619.09 mg/L which were higher than permissible limit of EPA (2002) [200 mg/L]. The higher concentration of Na in wastewater was due to the sodium compounds, which are used in almost all steps of wet processes. Among sodium compounds, sodium chloride is extensively used in water softening (Hussain *et al*., 2004). Ca and Mg concentrations were found ranging from 9.090 to 9.333 mg/L and 3.186 to 4.002 mg/L, respectively in the present study. Ca and Mg concentrations were found lower than Canadian Environmental Quality Guidelines (CCME) and Bureau of Indian Standards (BIS), respectively (Ghaly *et al*., 2014). The reason for low concentration of both Ca and Mg is the softening of water. In all industries water softening is carried out in which Ca and Mg are replaced by Na (Hussain *et al*., 2004). The average concentrations of Ca and Mg were found lower but Na concentration was found higher than reported by Hussain *et al*. (2004), in India [Ca= 19 mg/L, Mg= 21.25 mg/L and Na= 1672 mg/L] and Ohioma *et al*. (2009), in Nigeria [Ca= 69.916 mg/L, Mg= 38.75 mg/L and Na= 61.87 mg/L] in textiles effluents.

Metals arise from metal complex dyes, dye stripping agents, oxidizing agents and finishers in textile effluents (Heinfling *et al*., 1997; Zeiner *et al*., 2007; Mountassir *et al*., 2013). Pb and Cd concentrations were found below detection limits in this investigation. The range of Cu concentration was measured from 0.012 to 0.02 mg/L with a mean of 0.016 mg/L. Cu is an essential substance to human nutrition as a component of metallo-enzymes in which it acts as an electron donor or acceptor (Deepali and Gangwar, 2010). However, in high concentrations, it can cause anaemia, liver and kidney damage, stomach and intentional irritation (Imtiazuddin *et al*., 2014). Cu is toxic to aquatic plants at concentrations below 1 mg/L, whereas a concentration close to this level can be toxic to some fish (Nergis *et al*., 2005; Tuzen *et al*., 2008). The measured Zn concentration was found in the range of 0.091 to 0.141 mg/L. Zn concentration in wastewater increases due to use of chemicals impurities and process of viscous rayon fibers in textile industries (Hussain *et al*., 2004). High concentration of Zn in water is most harmful to aquatic life during early life stages (Imtiazuddin *et al*., 2014). Ni concentration in textile effluent samples varied from 0.006 to 0.009 mg/L. The most adverse harmful health effects from exposure to Ni includ lung fibrosis, cardiovascular and kidney diseases and cancer of the respiratory tract (ATSDR, 2005). The measured concentrations of Cu, Zn and Ni are lower than the permissible limit of wastewater discharge standards according to DoE (2008) [Cu= 0.5 mg/L, Zn= 5.0 mg/L and Ni= 1.0 mg/L] and EPA (2002) [Cu= 0.5 mg/L, Zn= 2.0 mg/L and Ni= 0.1 mg/L]. The mean concentrations of Cu and Zn in textile effluents in the present investigation were lower than reported by Roy *et al*. (2010), in Bangladesh [Cu= 0.1011 mg/L and Zn= 0.2172 mg/L] and Ohioma *et al*. (2009), in Nigeria [Cu= 3.433 mg/L and Zn= 7.366 mg/L], and Ni concentration also lower than reported by Ali *et al*. (2009), in Pakistan [Ni= 0.67 mg/L].

CONCLUSION

This research reveals that the measured Physico-chemical parameters such as temperature, color, pH, DO, EC, BOD, COD, TS, total alkalinity, total hardness and Na were found higher than the standard guidelines. Pb and Cd concentrations were found below detection limit but Ca, Mg, Zn, Ni and Cu concentrations were measured lower than the standard guidelines. It is recommended that the effluents of textile industries must be treated well by combined treatment processes before their disposal into the surrounding water bodies to reduce the pollution load and avoid adverse pollution effect.

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