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Research Paper

Physicochemical Assessment of Textile Effluents in Chittagong Region of Bangladesh and Their Possible Effects on Environment

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Abstract: *This study was carried out to assess the untreated textile effluent quality in Chittagong region of Bangladesh. In order to study the different physicochemical parameters, effluent samples from fifteen selected textile industries were collected and analyzed during the period 2010-2011. Collected samples were analyzed for the parameters temperature, pH, EC, TDS, TSS, DO, BOD, COD, %NaCl, transparency, acidity, CO_2, alkalinity, total hardness, chloride, sulfate, phosphate, nitrate, nitrite, lithium, chromium, iron, manganese, cobalt, nickel, copper, zinc, arsenic, silver, cadmium and lead using the procedure outlined in the standard methods. The laboratory findings were compared with the recommended values set by the Department of Environment (DoE). Except the metals Li, Mn, Co, Ni, Cu, As, Ag, Cd, Zn and Pb, and the anion nitrate the other parameters for most of the textile industries were found beyond the standard limit set by the DoE. Besides these the parameters namely color, transparency, acidity, CO_2, alkalinity, total hardness, %NaCl etc. for which no standard values are recommended by DoE were also not in good conditions. From Pearson Correlation program, significant positive and negative correlations were found for different parameters. These assessment data indicated that textile effluents of Chittagong region are highly polluted and these effluents, when discharged, leads to pollution of the nearby water body which affects not only the aquatic environment and human beings of the surroundings but also poses a serious threat to ground and surface water resources of the adjoining areas.*

Keywords: Textile effluents, Chittagong, physicochemical parameters, environmental impact.

Introduction

Textile is one of the most important and rapidly developing industrial sectors of Bangladesh based on earning foreign exchange and labor employment[1]. The different wet processes e.g. dying, washing etc. of textile industry produce an enormous quantity of contaminated effluents which pollute the environment highly[2]. These effluents are notoriously known to contain strong color, a large amount of suspended solids, a highly fluctuating pH, a high temperature, COD, BOD etc.[3]. Because of these characteristics, wastewater from the textile industry must be treated before being discharged into the natural water system[4].

To mitigate the risks from the discharge of textile effluent, an effluent treatment plant (ETP) is required and the treated effluent must meet the national effluent discharge quality standards[5]. But due to the high cost, almost all textile industries in Chittagong of Bangladesh do not use ETP though they have ETP. They use the ETP occasionally when the buyers want or during inspection by the Department of Environment (DoE), otherwise they frequently discharge the untreated effluent directly into the environment, causing pollution of nearby soil and water. Thus the present research work has been carried out to assess the quality and effects of textile effluent in Chittagong region of Bangladesh.

Chittagong is a city in southeastern Bangladesh and the capital of an eponymous district and division[6]. It is situated within 22°-14' and 22°-24'-30" N Latitude and between 91°-46' and 91°-53' E Longitude. Chittagong is the largest port city of Bangladesh based on commerce and industries. Therefore Chittagong is also called the commercial capital of Bangladesh[7].

Material and Methods

Industry Selection: For the current study fifteen textile industries were selected randomly from the different industrial zones (*viz.* CEPZ, Kalurghat I/A, Nasirabad I/A etc.) of Chittagong. These are Sanzi Textile, KDS Textile, Fabian Thread, C & A Textile, Vast Thread, Ctg. Mokka Composite Textile, Base Textile, Qualitex, RTT Textile, Young International, Al-Hamedi Textiles, Super Knitting & Dying Mills, Ambia Knitting and Dying, Shah Amanat Ctg. Textile and G. F. Textile.

Sample Collection: Samples were collected in amber color polyethylene bottle previously washed with 8M HNO_3 and distilled water. The total volume of the bottle was filled completely and a cap was locked enough so that no air space can be remained inside the bottle. The bottles were then labeled by mentioning the name and location of the sample site, date and time of collection. Collected samples were shifted to the laboratory as soon as possible for the analysis of various physicochemical parameters. Some parameters namely temperature, DO, pH etc. were analyzed at the sampling spot. The collected samples were preserved using suitable preserving agents and techniques for different parameters[8,9,10].

Table 1
Effluent quality of different textile industries in Chittagong Region

Industries / Parameters	**Sanzi Textile Ltd.**	**Base Textile Ltd.**	**Fabian Thread Ltd.**	**C & A Textile Ltd.**	**Shah Amanat Ctg. Textile Mills Ltd.**
Color	Light Green	White	Brown	Brown	Light Red
Ambient temp. (°C)	29.08	24.90	29.20	29.08	29.08
Effluent temp. (°C)	87.80	31.80	86.38	81.55	29.08
Transparency (cm)	09.50	15.00	12.00	15.50	11.50
pH	9.46	10.19	9.54	7.36	7.12
EC(μScm^{-1})	1125	1217	487	5110	6225
TDS(mgL^{-1})	561	611	233	2500	3120
TSS(mgL^{-1})	100.00	16	40.00	220	440
%NaCl	2.20	2.30	1.00	10.00	12.20
DO(mgL^{-1})	3.20	1.30	0.20	0.10	0.10
BOD(mgL^{-1})	107.29±1.55	117.00±1.61	82.67±0.93	12.40±0.14	136.00±1.87
COD(mgL^{-1})	145.47±1.43	164.75±1.30	509.15±6.62	327.31±4.34	172.74±2.06
CO_2 (mgL^{-1})	13.09±0.00	BDL	8.73±0.00	8.80±0.00	4.37±0.00
Acidity (mgL^{-1})	14.88±0.00	BDL	9.92±0.00	10.0±0.00	4.96±0.00
Alkalinity (mgL^{-1})	617.88±0.00	869.33±12.92	634.14±5.67	666.66±0.00	504.06±0.00
T.Hardness (mgL^{-1})	40.00±0.00	192±2.97	40.00±0.00	9.20±0.00	108.00±2.00
Chloride (mgL^{-1})	201±0.00	995.05±11.81	22.35±0.00	1199.31±15.11	1670.55±12.97
SO_4^{2-}(mgL^{-1})	183.68±0.98	14.79±0.08	400.25±1.12	154.51±0.74	338.45±1.02
PO_4^{3-}(mgL^{-1})	105.97±0.76	5.31±0.04	253.96±1.11	10.33±0.04	5.30±0.02
NO_2^- (mgL^{-1})	0.35±0.002	BDL	0.16±0.001	0.09±0.00	0.10±0.00
NO_3^- (mgL^{-1})	0.56±0.002	2.41±0.00	BDL	1.23±0.00	BDL
Fe (mgL^{-1})	1.33±0.02	0.89±0.003	11.22±0.03	4.27±0.03	6.71±0.08
Mn (mgL^{-1})	0.13±0.00	BDL	0.34±0.00	0.09±0.00	0.01±0.00
Li (mgL^{-1})	0.1114±0.004	0.0926±0.001	0.3834±0.005	0.0144±0.00	0.0542±0.001
Cr (mgL^{-1})	0.0244±0.00	0.1086±0.004	BDL	0.0017±0.00	0.0458±0.001
Co (mgL^{-1})	0.0211±0.001	0.0031±0.00	0.0062±0.00	0.0052±0.00	0.0168±0.00
Ni (mgL^{-1})	0.1741±0.004	0.0421±0.00	0.0720±0.001	0.0691±0.00	0.1421±0.003
Cu (mgL^{-1})	0.0507±0.00	0.2327±0.005	0.1427±0.003	BDL	BDL
Zn (mgL^{-1})	3.41±0.05	1.86±0.01	2.02±0.03	1.21±0.02	3.11±0.04
As (mgL^{-1})	0.0209±0.001	0.0418±0.001	0.0146±0.00	BDL	0.0109±0.00
Ag (mgL^{-1})	0.0033±0.00	0.0237±0.001	0.0036±0.00	0.0008±0.00	0.0104±0.00
Cd (mgL^{-1})	BDL	BDL	BDL	BDL	0.00018±0.00

Pb (mgL^{-1})	0.0111±0.00	0.0348±0.001	0.0231±0.001	0.0029±0.00	0.0325±0.001

Table 1
Effluent quality of different textile industries in Chittagong Region (continued)

Industries / Parameters	KDS Textile Ltd.	Vast Thread (pvt) Ltd.	Ctg. Mokka Composite Textile Mills Ltd.	Super Knitting & Dying Mills Ltd.	Ambia Knitting and Dying Ltd.
Color	Pink	White	Lemon Color	Light Yellow	Light Brown
Ambient temp. (ºC)	25.20	29.60	29.60	25.10	25.20
Effluent temp. (ºC)	90.40	92.00	65.50	29.00	28.90
Transparency (cm)	07.00	27.00	25.50	17.50	15.50
pH	9.65	2.85	10.21	6.80	9.80
EC(μScm^{-1})	1821	868	25150	3120	6540
TDS(mgL^{-1})	911	443	12570	1560	3270
TSS(mgL^{-1})	120.00	38	480	257	154
%NaCl	3.60	1.70	48.80	3.7	4.6
DO(mgL^{-1})	3.10	1.10	3.60	2.10	2.40
BOD(mgL^{-1})	416.00±3.34	197.60±2.21	276.90±2.02	46±0.61	164±3.10
COD(mgL^{-1})	1854.61±20.72	752.94±8.83	282.43±2.62	184±2.78	682±7.24
CO_2 (mgL^{-1})	261.18±0.00	72.22±0.00	BDL	172.31±0.00	BDL
Acidity (mgL^{-1})	296.8±0.00	82.07±0.00	BDL	180.82±0.00	BDL
Alkalinity (mgL^{-1})	900.60±13.45	13.42±0.00	3995.50±15.64	32.02±0.00	1184.5±0.00
T.Hardness (mgL^{-1})	10.00±0.00	120.00±1.75	100±0.00	116.00±2.10	45.00±0.00
Chloride (mgL^{-1})	30.35±0.00	184.78±2.58	10533.6±18.65	546.23±6.35	643.56±8.92
SO_4^{2-}(mgL^{-1})	95.37±1.02	39.58±0.76	389.92±0.97	36.32±0.06	12.46±0.00
PO_4^{3-}(mgL^{-1})	24.23±0.05	36.24±0.09	10.02±0.07	14.92±0.01	5.53±0.00
NO_2^- (mgL^{-1})	0.07±0.001	0.06±0.00	0.06±0.00	0.11±0.001	0.09±0.001
NO_3^- (mgL^{-1})	BDL	1.56±0.02	3.83±0.004	2.41±0.01	1.76±0.00
Fe (mgL^{-1})	0.951±0.004	0.27±0.00	4.44±0.03	1.24±0.00	1.12±0.04
Mn (mgL^{-1})	5.424±0.02	BDL	1.24±0.05	0.23±0.00	0.29±0.01
Li (mgL^{-1})	0.0864±0.001	0.0315±0.00	0.0264±0.00	0.0365±0.001	0.0134±0.00
Cr (mgL^{-1})	0.0063±0.00	0.0530±0.00	0.1126±0.003	0.0047±0.00	0.1116±0.003
Co (mgL^{-1})	0.0085±0.00	BDL	0.0001±0.00	0.0289±0.001	0.0026±0.00
Ni (mgL^{-1})	0.1401±0.003	0.0132±0.00	0.0283±0.00	0.0710±0.001	0.0328±0.001
Cu (mgL^{-1})	BDL	BDL	0.0717±0.001	0.3517±0.05	0.0447±0.001
Zn (mgL^{-1})	8.77±0.09	4.39±0.06	3.55±0.04	1.72±0.03	3.35±0.05
As (mgL^{-1})	0.0147±0.00	BDL	BDL	0.0191±0.001	BDL
Ag (mgL^{-1})	0.0235±0.01	0.0043±0.00	0.0259±0.001	BDL	0.0183±0.00
Cd (mgL^{-1})	0.0044±0.00	BDL	BDL	0.0023±0.00	BDL
Pb (mgL^{-1})	0.0234±0.00	0.0198±0.00	0.0312±0.001	0.0887±0.002	0.0593±0.001

Temperature was determined by using thermometer while transparency was determined by using Sacchi disc. HANNA Combo Meter Model –HI 98129 was used to determine pH, EC, TDS and % NaCl. Drying and weighing method, Open reflux method and Argentometric method were employed to determine TSS, COD and chloride respectively. DO and BOD were measured by using Hanna HI-9142 portable DO meter. Titrimetric method was used to determine acidity, CO_2, alkalinity and hardness while spectrophotometric method was employed to determine sulfate, phosphate, nitrite, nitrate, iron and manganese. All the metals, except zinc which was determined by Varian Model-AA240FS atomic absorption spectrophotometer, were determined by using Varian inductively coupled plasma - mass spectrometer [11,12]. Data were analyzed by Excel 2003 software and SPSS 11.5 software was used for statistical analysis[13].

Table 1
Effluent quality of different textile industries in Chittagong Region (continued)

Industries / Parameters	Qualitex Industries (BD) Ltd.	Al-Hamedi Textiles Ltd.	RTT Textile Industries Ltd.	G.F Textile Ltd.	Young International (BD) Ltd.
Color	Colorless	White	Colorless	Light Red	Light Red
Ambient temp. (ºC)	27.00	28.50	27.00	25.00	27.00
Effluent temp. (ºC)	30.30	30.20	47.80	40.30	42.20
Transparency (cm)	26.00	18.00	16.50	10.00	09.00
pH	8.90	7.58	9.03	9.10	9.09
EC(μScm^{-1})	2850	524	652	3240	2830
TDS(mgL^{-1})	1429	230	320	1618	1415
TSS(mgL^{-1})	140	160	140	140	200
%NaCl	5.30	0.90	1.30	5.1	5.50
DO(mgL^{-1})	0.50	2.50	1.50	2.30	0.70
BOD(mgL^{-1})	169.00±3.43	143.00±2.44	26.00±0.41	81±0.65	546.00±5.98
COD(mgL^{-1})	374.98±4.98	205.55±2.37	208.32±1.41	302±4.88	812.45±12.02
CO_2 (mgL^{-1})	BDL	21.49±0.00	BDL	BDL	BDL
Acidity (mgL^{-1})	BDL	24.43±0.00	BDL	BDL	BDL
Alkalinity (mgL^{-1})	1222.50±5.43	326.00±0.00	750.70±0.00	740.70±0.00	782.40±0.00
T.Hardness (mgL^{-1})	132±0.00	88±0.00	68±0.00	108±2.00	52±0.00
Chloride (mgL^{-1})	765.01±9.61	992.21±12.76	274.62±0.00	940.54±8.74	980.78±6.88
SO_4^{2-}(mgL^{-1})	16.98±0.08	25.15±0.10	26.85±0.04	15.93±0.00	97.01±0.21
PO_4^{3-}(mgL^{-1})	10.28±0.07	3.75±0.04	5.40±0.04	5.72±0.00	2.79±0.005
NO_2^- (mgL^{-1})	0.10±0.001	0.01±0.00	0.04±0.00	0.10±0.00	0.29±0.004
NO_3^- (mgL^{-1})	2.94±0.00	BDL	1.89±0.00	BDL	4.41±0.002
Fe (mgL^{-1})	0.82±0.004	0.32±0.00	0.53±0.01	0.79±0.02	0.75±0.04
Mn (mgL^{-1})	0.22±0.008	0.13±0.001	0.13±0.001	0.15±0.00	0.21±0.01
Li (mgL^{-1})	0.0057±0.00	0.0506±0.001	0.0857±0.001	0.0055±0.00	0.0079±0.00
Cr (mgL^{-1})	0.1106±0.002	0.0004±0.00	0.0183±0.00	0.0031±0.00	0.0221±0.00
Co (mgL^{-1})	0.0011±0.00	0.0126±0.00	0.0290±0.001	0.0082±0.00	0.0028±0.00
Ni (mgL^{-1})	0.0532±0.001	0.0811±0.001	0.3721±0.004	BDL	0.0358±0.001
Cu (mgL^{-1})	0.0617±0.00	0.1527±0.003	BDL	BDL	0.1357±0.002
Zn (mgL^{-1})	1.05±0.01	6.56±0.09	2.33±0.02	4.1±0.05	2.29±0.03
As (mgL^{-1})	0.0404±0.001	0.0268±0.001	0.0916±0.002	0.0082±0.00	0.0025±0.00
Ag (mgL^{-1})	0.0106±0.00	0.0045±0.00	0.0342±0.001	0.0053±0.00	0.0135±0.00
Cd (mgL^{-1})	BDL	BDL	BDL	BDL	BDL
Pb (mgL^{-1})	0.1394±0.006	0.0144±0.00	0.0696±0.001	0.0099±0.00	0.0339±0.001

BDL = Below Detection Level

	ET	TP	pH	EC	TDS	TSS	%NaCl	DO	BOD	COD	CO_2	Ac	A_T	TH	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_2^-	NO_3^-	Fe	Mn
ET	1	-.075	-.167	-.007	-.008	-.252	.060	.100	.103	.426	.288	.306	.038	-.540*	.004	.383	.536*	.271	-.259	.280	.396
TP	-.075	1	-.416	.369	.369	.138	.369	-.034	-.176	-.280	-.180	-.188	.325	.474	.414	-.085	-.210	-.448	.431	-.143	-.298
pH	-.167	-.416	1	.248	.248	.040	.222	.319	.157	.033	-.187	-.516*	.519*	-.163	.245	.172	.121	.161	.132	.122	.257
EC	-.007	.369	.248	1	1.00**	.772**	.984**	.364	.185	-.121	-.171	-.173	.911**	.050	.966**	.519*	-.219	-.131	.428	.216	.093
TDS	-.008	.369	.248	1.000**	1	.772**	.984**	.364	.186	-.120	-.171	-.172	.911**	.053	.966**	.518*	-.219	-.130	.429	.215	.094
TSS	-.252	.138	.040	.772**	.772**	1	.775**	.114	.118	-.226	-.082	-.092	.544*	-.003	.716**	.512	-.362	-.042	.240	.253	.007
%NaCl	.060	.369	.222	.984**	.984**	.775**	1	.323	.202	-.131	-.168	-.167	.908**	.069	.984**	.574*	-.190	-.120	.416	.247	.110
DO	.100	-.034	.319	.364	.364	.114	.323	1	.172	.167	.331	.333	.418	-.093	.380	-.102	-.173	.001	-.026	-.411	.434
BOD	.103	-.176	.157	.185	.186	.118	.202	.172	1	.679**	.269	.285	.269	-.189	.191	.044	-.178	.281	.405	-.200	.513
COD	.426	-.280	.033	-.121	-.120	-.226	-.131	.167	.679**	1	.676**	.698**	-.023	-.468	-.191	-.096	.021	.014	-.092	-.127	.846**
CO_2	.288	-.180	-.187	-.171	-.171	-.082	-.168	.331	.269	.676**	1	.999**	-.226	-.211	-.212	-.170	-.048	-.118	-.200	-.201	.772**
Ac	.306	-.188	-.516*	-.173	-.172	-.092	-.167	.333	.285	.698**	.999**	1	-.219	-.224	-.213	-.166	-.045	-.121	-.212	-.200	.791**
A_T	.038	.325	.519*	.911**	.911**	.544*	.908**	.418	.269	-.023	-.226	-.219	1	.034	.917**	.446	-.124	-.113	.468	.153	.204
TH	-.540*	.474	-.163	.050	.053	-.003	.069	-.093	-.189	-.468	-.211	-.224	.034	1	.155	-.247	-.309	-.418	.279	-.233	-.402
Cl^-	.004	.414	.245	.966**	.966**	.716**	.984**	.380	.191	-.191	-.212	-.213	.917**	.155	1	.517*	-.194	-.169	.443	.189	.059
SO_4^{2-}	.383	-.085	.172	.519*	.518*	.512	.574*	-.102	.044	-.096	-.170	-.166	.446	-.247	.517*	1	.548*	.242	-.107	.869**	.061
PO_4^{3-}	.536*	-.210	.121	-.219	-.219	-.362	-.190	-.173	-.178	.021	-.048	-.045	-.124	-.309	-.194	.548*	1	.386	-.359	.702**	-.025
NO_2^-	.271	-.448	.161	-.131	-.130	-.042	-.120	.001	.281	.014	-.118	-.121	-.113	-.418	-.169	.242	.386	1	.104	.105	-.117
NO_3^-	-.259	.431	.132	.428	.429	.240	.416	-.026	.405	-.092	-.200	-.212	.468	.279	.443	-.107	-.359	.104	1	-.276	-.190

Fe	.280	-.143	.122	.216	.215	.253	.247	-.411	-.200	-.127	-.201	-.200	.153	-.233	.189	.869**	.702**	.105	-.276	1	-.070
Mn	.396	-.298	.257	.093	.094	.007	.110	.434	.513	.846**	.772**	.791**	.204	-.402	.059	.061	-.025	-.117	-.190	-.070	1

* Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).; ET= Effluent temp., TP= Transparency, TH=Total Hardness, A_T = Alkalinity, Ac=Acidity

Table 2: Pearson Correlations among the different parameters of textile effluent

Results

The results of physicochemical parameters of the effluents from different textile industries are shown in Table 1 and the results of Pearson Correlations among the different parameters are shown in Table 2.

Discussion

It was observed from the result (Table 1) that the effluent temperature ranged from 28.9°C to 92°C. Effluents from eight industries had temperatures higher than that of the DoE standard (40°C). Higher temperature is harmful for aquatic life. If water temperatures vary too much, metabolic activities of aquatic life can malfunction. Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria in a water body[14]. Effluent temperature was found to be positively correlated with hardness and phosphate (Table 2).

Transparency ranged from 7 cm to 27 cm. According to WHO, although transparency is not an important wastewater quality parameter, in many cases high value of transparency indicates the purity of wastewater/effluent. Transparency was found to have no correlation with the other parameters (Table 2).

pH was found to vary from 2.87 to 10.21 (Table 1). Nine industries' effluents had pH value higher than that of the DoE standard (6 - 9) i.e. highly alkaline, one industry's effluent had pH lower than the DoE standard i.e. highly acidic and the remaining five industries had pH within the DoE standard. High pH reduces fish production[15] and also inhibits the growth of aquatic macrophytes[16]. Again low pH can destroy the fish population accompanied by decrease in the variety of species in food chain[17]. pH was found positively correlated with alkalinity and negatively correlated with acidity (Table 2).

EC was found to range from 487 µS cm^{-1} to 25150 µS cm^{-1} (Table 1). Most of the textile effluents (11 industries out of 15) had EC values higher than that of DoE standard (1200 µS cm^{-1}). Again TDS ranged from 230 mg L^{-1} to 12570 mg L^{-1}. Four industries' effluents had TDS higher than the DoE standard (2100 mg L^{-1}). Water having high EC and TDS values can cause osmotic stress at the root zone of plants which makes it more difficult for a plant to absorb water for growth. Thus increased EC and TDS in irrigation water leads to lower crops production[18,19]. EC itself is not a human or aquatic health concern but it can serve as an indicator of other water quality problems[20]. For example EC indicates the quality of distilled water, distilled water with conductivity 2 µS cm^{-1} should not be used for water analysis[17]. EC and TDS were found positively correlated with, TSS, alkalinity, %NaCl, chloride and sulfate (Table 2).

TSS varied from 16 mg L^{-1} to 480 mg L^{-1} (Table 1). Effluents from seven industries had TSS higher than the DoE standard (150 mg L^{-1}). High TSS reduces light penetration and hence decreases photosynthetic rates of green aquatic macrophytes, algae and cells which are served as food sources for many invertebrates [21].

DO ranged from 0.1 mg L^{-1} to 3.6 mg L^{-1} (Table 1). All the textile effluents were found to have DO values lower than that of DoE limit (4.5-8 mg L^{-1}). The lower DO may be due to the use of various organic chemicals in the textile industry. The decay of organic compounds consumes much oxygen and leads to the decrease in DO level[22]. Higher temperature of textile effluent also lowers the DO level[23]. Reduced DO impact adversely on all aquatic life. As DO levels in water drop below 4 mg L^{-1}, aquatic life is put under stress. The lower the concentration, the greater is the stress. Oxygen levels that remain below 1-2 mgL^{-1} for a few hours can result in large fish kills[24]. DO was found to have no correlation with the other parameters (Table 2).

BOD was found to vary from 12.4 mg L^{-1} to 546 mg L^{-1}(Table 1). Effluents from twelve industries among the fifteen had BOD higher than the DoE standard (50 mg L^{-1}). Excessive BOD is harmful to aquatic animals like fish and microorganisms. It also causes bad taste to the drinking water. If the BOD level is too high, the water could be at risk for further contamination interfering with the treatment process and affecting the end product[26]. BOD was found to be positively correlated to COD (Table 2).

COD ranged from 145.47 mg L^{-1} to 1854.61 mg L^{-1} (Table 1). Eleven industries effluents among the fifteen had COD value above the DoE standard (200 mg L^{-1}). Nian *et al.*[25] reported that higher COD concentration can cause a substantial damage to submersed plants. Like BOD, higher COD is also harmful to all aquatic life[25]. COD was found to be positively correlated with BOD, CO_2, acidity, and Mn (Table 2).

Acidity and CO_2-ranges of textile effluents in Chittagong region were found 0 to 261.18 and 0 to 296.8 mg L^{-1} respectively (Table 1). Acidity and CO_2-content of only three industries' effluents were found at higher levels and the remaining 12 industries' effluents had acidity and CO_2-content at a considerable level. Acidity and CO_2 were found positively correlated with Mn and negatively correlated with pH (Table 2).

Alkalinity ranged from 13.42 mg L^{-1} to 3995.5 mg L^{-1} (Table 1) textile effluents of twelve industries among the fifteen had very high value of alkalinity (>500 mg L^{-1}). According to Singh *et al.* high value of alkalinity may lead to metabolic alkalosis by affecting the mucous membrane[26]. Alkalinity was found to be positively correlated with pH, EC, TDS, TSS, %NaCl, and Chloride (Table 2).

Hardness was found to vary from 9.2 to 192 mg L^{-1} (Table 1). According to WHO, the maximum allowable limit of hardness is 500 mg L^{-1}. From the results it was seen that that the hardness of all the fifteen industries remained within the WHO standard (500 mg L^{-1}). Hardness was found positively correlated effluent temperature (Table 2).

Chloride (Cl^-) varied from 22.35 to 10533.6 mg L^{-1} (Table 1). Nine industries effluents among the fifteen had chloride content above the DoE standard (600 mg L^{-1}). Chloride in plants comes mostly from water and hence high chloride containing water increases the chloride content of plants. Due to the high chloride content of plants, leaf margins become scorched, leaves become smaller and thicker and overall plant growth is reduced[27]. Chloride also contributes to the TDS in drinking water[28]. Chloride was found to be positively correlated with EC, TDS, TSS, %NaCl, alkalinity and sulfate (Table 2).

Sulfate was found to vary from 12.46 to 400.25 mg L^{-1} (Table 1). According to WHO, the maximum allowable concentration of sulfate is 400 mg L^{-1}. And sulfate content of all the fifteen industries existed within the WHO standard (400 mg L^{-1}). Sulfate was found positively correlated with EC, TDS, %NaCl, chloride, phosphate, and iron (Table 2).

Phosphate ranged from 2.79 to 253.96 mg L^{-1} (Table 1). Effluents from three industries among the fifteen had phosphate concentration above the DoE standard (25 mg L^{-1}). Over enrichment of phosphate can lead to algae bloom, because of the excess nutrients. This causes more algae to grow, bacteria consumes the algae and causes more bacteria to grow in large amounts. They use all the oxygen in the water during cellular respiration, causing many fish to die[29]. Again water with high phosphate content may lead to kidney damage and osteoporosis in human health[30]. Phosphate was found to be positively correlated with effluent temperature, sulfate and iron (Table 2).

The ranges of nitrite and nitrate in the textile effluents of Chittagong were found respectively 0 to 0.35 mg L^{-1} and 0 to 4.41 mg L^{-1}. Nitrite and nitrate contents of all the fifteen textile effluents were found within the DoE limit (nitrite: 1 mg L^{-1}, nitrate: 10 mg L^{-1}). No correlation was found for nitrite and nitrate with other parameters (Table 2).

Iron was found to vary from 0.27 to 11.22 mg L^{-1} (Table 1). Four industries effluents had iron content above the DoE standard (2 mg L^{-1}) and the remaining eleven industries had iron content within the DoE standard.

Water with high iron content has little effect on aquatic life and irrigation[31]. But this water lead to staining of laundry and a metallic taste in drinking water[32]. Iron was found positively correlated with sulfate and phosphate (Table 2). Manganese varied from 0 to 5.42 mg L^{-1} (Table 1). Only one industry had Mn-content above the DoE standard (5 mg L^{-1}) and rest of the industries had Mn-content within the DoE standard. Less information is available on the effects of elevated manganese concentrations on aquatic life. Perhaps this is because manganese is usually associated with other metals which may have a more deleterious effect or mask the effect of the manganese[33]. Manganese was found to be positively correlated with COD, acidity and CO_2 (Table 2).

Lithium was found to vary from 0.0055 to 0.3834 mg L^{-1} (Table 1). The United Nations Food and Agriculture Organization recommended maximum level for lithium in irrigation waters is 2.5 mg L^{-1}. The results revealed that all of the fifteen industries had Li-content below 2.5 mg L^{-1}.

Chromium was found to range from 0 to 0.1126 mg L^{-1} (Table 1). Four industries had chromium content above the DoE standard (0.1 mg L^{-1}) and the remaining eleven industries had chromium content within the DoE standard. High concentration of Cr in water is harmful for plant growth and development. Toxic effects of Cr on plant growth and development include alterations in the germination process as well as in the growth of roots, stems and leaves, which may affect total dry matter production and yield[34]. High Cr-content of water has also detrimental effects on fish, wildlife and invertebrates[35].

Zinc was found to range from 1.05 to 8.77 mg L^{-1} (Table 1). Only two industries' effluents among the fifteen had Zn-content above the DoE standard (5 mg L^{-1}). High concentration of zinc in water is most harmful to aquatic life during early life stages, in soft water, under conditions of low pH, low DO and elevated temperatures. Again water with relatively high Zn-content is nontoxic to plants, birds and animals[36,37].

Lead was found to vary from 0.0029 to 0.1394 mg L^{-1} (Table 1). Effluent from only one industry among the fifteen had lead content above the DoE standard (0.1 mg L^{-1}). The higher concentration of lead may be due to the use of lead (II) nitrate as an oxidizing agent in textile industry, lead (II) nitrate is also used in textile industry to make textile treatment, matches etc[38]. Elevated levels of lead in the water can cause reproductive damage in some aquatic life and cause blood and neurological changes in fish and other animals that live there[39]. Again the presence of relatively high Pb-content in the environmental water has become a major threat to plant, animal and human life due to its bioaccumulation tendency and toxicity[40].

Co, Ni, Cu, As and Ag contents of textile effluents in Chittagong region were found 0 to 0.0290 mg L^{-1}, 0 to 0.3721 mg L^{-1}, 0 to 0.3517 mg L^{-1}, 0 to 0.0916 mg L^{-1} and 0 to 0.0342 mg L^{-1} respectively. All of these contents complied with the permissible limit.

Conclusion

From the present study, it can be concluded that the studied physicochemical parameters such as temperature, TSS, TDS, EC, BOD and COD of most of the textile industry's effluents in Chittagong region were found to be quite higher than the recommended values set by the Department of Environment (DoE) and the dissolved oxygen (DO) values of all the fifteen textile industries were found much lower than that of the DO limit (4.5 to 8 mg L^{-1}) recommended by DoE.

Again the pH values of the effluents from most of the textile industries (nine industries among the fifteen) were recorded higher than the standard DoE limit (6- 9). This higher pH values indicate that the effluents are highly alkaline.

Metals namely Li, Mn, Co, Ni, Cu, As, Ag, Cd, Zn and Pb in most of the textile industries were present in trace amount. These complied with the permissible limit. But Fe and Cr in most of the industries were found to be higher than that of the standard values recommended by DoE. Again except nitrate most of the anions e.g. chloride, phosphate etc. were found much higher than that the standard DoE values. Besides these color, transparency, acidity, CO_2, alkalinity, total hardness, %NaCl etc. also are not in good conditions.

The above data indicate that the effluents of textile industries in Chittagong region are highly polluted though some anions (e.g. nitrate etc.) and some metals (e.g. Mn, Cu, As, Cd etc.) were found within the DoE standard. Therefore these effluents, when discharged, are polluting the nearby water and soil greatly rendering us a highly polluted environment.

From Pearson Correlation program, significant positive correlation was found for effluent temperature with phosphate, pH with alkalinity, EC with TDS, TSS, %NaCl, alkalinity, chloride and sulfate, BOD with COD, COD with carbon dioxide, acidity and manganese, acidity with carbon dioxide and manganese, alkalinity with pH, EC, TDS, TSS, %NaCl and chloride, chloride with EC, TDS, TSS, %NaCl, alkalinity and sulfate, sulfate with EC, TDS, %NaCl, chloride, phosphate and iron, phosphate with effluent temperature, sulfate and iron, iron with sulfate and phosphate, and manganese with COD, carbon dioxide and acidity. Significant negative correlation was observed for effluent temperature with total hardness, pH with acidity.

Untreated effluent of the industries, especially of textile industries is one of the main reasons for the critical condition of the Karnafuli River water of Chittagong. Polluted water of the Karnafuli River may affect the biodiversity of the Halda River by polluted Karnafuli River water intrusion into this river in the pre-monsoon period at high tides. This is indicated by the gradual decrease in spawning of fish fry in the Halda River. Pollution of these aqua systems may also affect the irrigation and household water need of the adjoining areas, dependent on these rivers' water. Similarly groundwater sources of the Chittagong city are being affected from the effluents of the textile and dyeing industries.

Textile effluents cause acute disorders in aquatic organisms. Uptake of textile effluents through food chain may result various physiological disorders in aquatic organisms as well as in human beings. Results from this study show that textile effluents are highly toxic in nature. This affects not only the aquatic environment and human beings of the surroundings but also poses a serious threat to ground and surface water resources of the adjoining areas. For this reason from the agricultural fields, irrigated by these polluted rivers' water of Chittagong region, it is possible that wastewater may have entered in food chain.

To obtain the acceptable effluent discharge from the textile industries and to ensure industrial eco-friendly environment activities the following recommendations should be taken into account:

1. The effluents from textile industry must be discharged into environment after proper treatment. For this purpose every textile industry must have to have an effluent treatment plant (ETP).

2. The efficiency of ETP must be high so that the quality of treated effluents meets the DoE and WHO standards.

3. In case of lower efficient ETP, the efficiency of ETP must be increased by using modern technologies. Combination of two or more technologies can also be employed to increase the efficiency of ETP.

4. The capacity of the ETP must be suitable for the size of the effluent discharge.

5. Due to the high cost, almost all textile industries in Chittagong do not use ETP though they have ETP. They use the ETP occasionally when the buyers want or during inspection by DoE, otherwise they frequently discharge the untreated effluent directly into the environment, causing pollution of nearby soil and water. In order to reduce the pollution this attitude of us must be changed. Every textile industry must have to use ETP frequently.

6. In many textile industries the effluent is only

passed through the ETP without any treatment. Therefore the inspection by DoE should be carried out regularly in order to ensure the efficiency of ETP.

7. Government should close down those industries which do not set up ETP yet.

8. Every textile industry should have an environmental expert to handle the environmental aspects properly.

9. DoE should take a lead role in organizing an efficient effort with other government and non government agencies in solving the problem of untreated effluent discharge.

10. Awareness of people about the risks, effects and remedies of pollution should be increased so that they can play important role in the abatement of pollution.

11. Government of Bangladesh should take proper action for making new national and regional policies and appropriate preventive measures on the basis of assessment data prior further deterioration of textile effluent quality of this region.

12. A recommendation may be submitted to the Ministry of Environment and Forest through the DoE to take effective measure to control the pollution of freshwater due to the discharge of untreated textile effluents.

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