Impacts of Dyeing Effluent on Surface Water Around Cottage Industrial Areas

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Abstract

The cottage textile dyeing industry discharges untreated effluent into water bodies, posing threats to the water quality and the environment in developing countries like Bangladesh. The study aimed to assess the impacts of untreated effluent on surface water in some selected areas of Bangladesh. A total of 96 surface water samples were collected from different locations in three seasons, covering two years from sixteen locations in the Sirajganj district. Most of the parameters exceeded the standards of the DoE-BD, WHO, and FAO. The FTIR analysis showed that the surface water samples contained toxic functional groups, like azo, cyano, etc., indicating a higher level of pollution. The study analyzed various indices, including the contamination factor (C_f^i) and ecological risk factors (E_r^i), indicating moderate to ultra-high contamination levels and a higher to serious ecological risk for Cd poisoning of the surface water in the areas. The study observed that the dyeing effluent must be treated before discharging, and a Central Effluent Treatment Plan (CETP) for each cottage industrial area or zone should be installed for building sustainable effluent management, and reducing environmental pollution.

Introduction

The cottage industry is one of the sectors of the small textile industry. Various kinds of natural, azo, and toxic dyes are used in the cottage textile industries.[1,2] Discharge of untreated effluent, sewage, sludge, and solid waste into open spaces and water bodies causes environmental digression.[1-5] The cottage textile dyeing effluents have contained a higher amount of heavy metals, such as Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb, which are broadly used in the production of color.[6-8] Important parameters in effluent from the textile dyeing industry are ammonia (NH_3), COD, BOD, pH, TSS, TDS, TOC, EC, DO, Cl-, and NO_3-, which exceed the standard permissible limit. As a result, environmental deterioration has become a threat to many villages

in the studied areas.[9-11] According to the quantity of industries and their effluent discharge rates, the waste management processes of the cottage textile dyeing industries are insufficient.[12-14] In this area, there isn't a single treatment plant. The cottage industry areas grow more, and as a result, they discharge untreated effluent into the environment, creating huge pollution.[15,16] A proper evaluation is required to explore the pollution levels for keeping a sustainable environment in the areas.[17-20] Very few reports were found about the characterization of textile dye effluents on the environment, located at Savar in Dhaka, Tongi in Gazipur, and Narayanganj districts.

There is no detailed research on the untreated textile dyeing effluent. The objective of the study was to characterize the cottage textile dyeing effluent and assess the impacts on the surface water around industries of the Sirajganj District.

Materials and Methods
Study Area
The study area is a district of Rajshahi division in Bangladesh, named Sirajganj. It consisted of four Upazilas, named Kazipur, Belkuchi, Shajadpur, and Sirajganj Sadar (Figure 1).
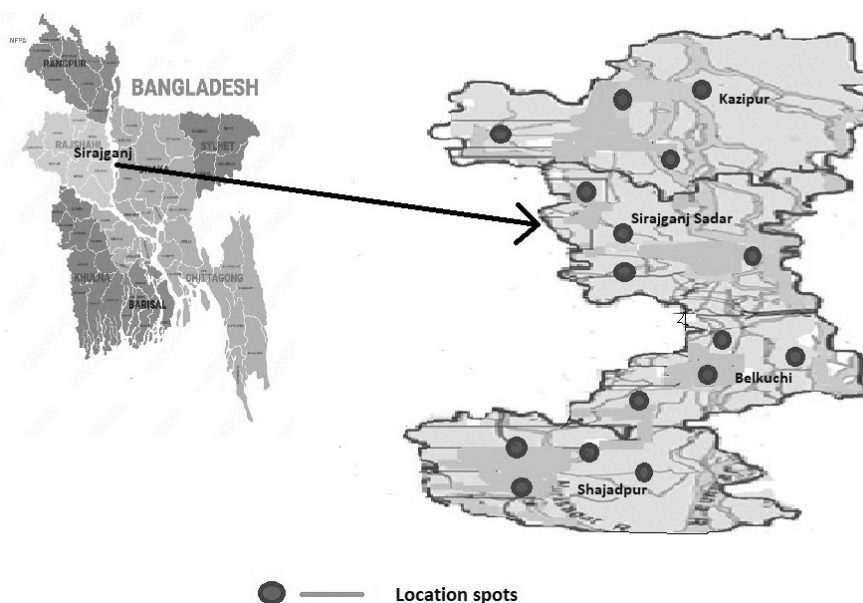

Fig. 1: Sample location map of the study area

Sample Collection
A total 96 surface water samples were collected from different textile dyeing industries effluent discharged into surface water bodies in three seasons of 2020 and 2021. All the water samples were collected and stored according to standard sampling methods.[21-23]

Sample Preparation and Analysis
Some physicochemical parameters, including temperature (Model: HANNA instrument Thermometer, 2018), EC (Model: HANNA instrument EC 2014), pH (Model: HANNA instrument pH 2009), and DO (Model: HANNA instrument; YK 22DO) of water samples, were instantaneously measured in the field using a multi-meter. The other physicochemical parameters, such as TSS, TDS, turbidity(Model: TU-2016), TH, BOD, COD, TOC, anionic parameters, including Cl-, HCO_3-, SO_4^{2-}, NO_3-, and PO_4^{3-}, cationic parameters, including Na^+, K^+, Mg^{2+}, Ca^{2+}, and heavy metals of the samples, were investigated following the standard methods of analysis.[24] The empirical data were then analyzed using different computer software.[25,26]

Results and Discussion
This study was tried to characterize the discharged untreated effluents from cottage industries in Sirajganj District, Bangladesh, and the results are discussed here.

Characterization of Surface Water
Physicochemical Characteristics of Surface Water
The major parameters of surface water samples and their period-based characteristics for two years of the study (Table 1 and Figure 2), are interpreted below.

Temperature
The maximum and minimum temperatures were found to be 37.74 °C and 17.80 °C in the monsoon period and the post-monsoon periods of 2021, respectively, those were within the standards of the DoE-BD and WHO. The results indicate that the surface water temperature varies with seasonal temperature.

Dissolved Oxygen (DO)
The maximum and minimum dissolved oxygen (DO) were found to be in the post-monsoon and pre-monsoon periods of 2021, which is very logical, as the water volume decreased in these seasons. The biannual mean value of DO was found to be 6.68 mg/L with a standard deviation of 0.47 (Table 1). The dissolved oxygen (DO) of most of the surface water samples was found to be very low from the standard permissible limit recommended by the DoE-BD and WHO.

The various dissolved oxygen (DO) values of the collected surface water sample showed seasonal variations (Figure 2). The overall dissolved oxygen (DO) concentration of surface water samples was very low, which indicates that the water is unsuitable for drinking purposes as well as unfavorable for fisheries.[13,27]
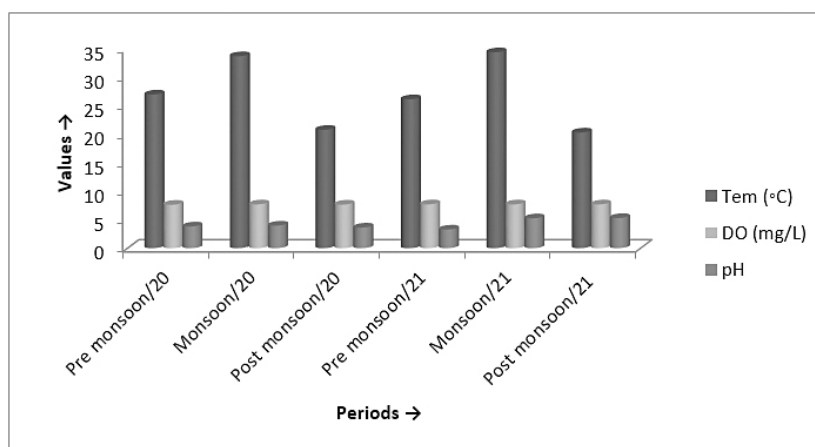
Fig. 2: Seasonal variation of average temperature, DO and pH of surface water sample for 2020-21.

Table 1: Biannual descriptive statistics of some parameters during 2020 and 2021.

Parameters	Minimum	Maximum	Mean ± SD	Standard	
				DoE-BD, 2008	WHO
DO (mg/L)	0.28	6.27	6.68±0.47	4.5-8	6
pH	6.91	10.12	8.17±1.44	6-9	6-9
EC (µS/cm)	824.20	1316.97	1414.2±484.24	1200	1200
TDS(mg/L)	439	4639	2530±35.54	2100	2100
TSS(mg/L)	91	485	293±29.84	150	100-150
TH (mg/L)	178.60	808.34	168.38±26.44	20-50	50
Turbidity (NTU)	19.83	157.42	87.32±18.28	--	5

pH

The biannual mean concentration of pH was found to be 8.1705 with a standard deviation of 1.445 (Table 1), indicating that the surface water was basic or alkaline. The pH of most of the surface water samples was found high than the standard of DoE-BD and WHO.

Electrical Conductivity

The biannual mean value of EC was 1414.29 with a standard deviation of 484.24 (Table 1). The EC of most of the surface water sample was found to be higher than the standard permissible limits recommended by the DoE-BD and WHO. The EC of surface water samples was increased in pre-monsoon due to a decrease in water volume due to the water volume effects.

Total Dissolved Solids

The biannual mean concentration of TDS was 2530, with a standard deviation of 35.54 (Table 1). The TDS of most of the surface water sample was found to be higher than the standard permissible limits recommended by the DoE-BD and WHO. During the monsoon, the water volume increased and thus decreased in TDS.

Total Suspended Solids (TSS)

The biannual mean concentration of TSS was 293 with a standard deviation of 29.84 (Table 1). The TSS of most of the surface water sample was found to be higher than the standard permissible limit of the DoE-BD and WHO.

BOD, COD, and TOC

The analysis results showed that the BOD, COD, and TOC values of surface water were higher than the standard of DoE-BD, WHO, and BNDWQS. The possible causes behind the higher BOD, COD and TOC of the surface water were the mixing of waste water and the discharge of industrial effluent.

Anionic Characteristics of Surface Water

The anionic perimeters like Cl^-, HCO_3^-, SO_4^{2-}, NO_3-N, NO_3^-, and PO_4^{3-} of surface water samples were analyzed. Those concentrations of the effluent found that the samples contained excess that was more than three times higher than the DoE-BD, FAO, and WHO standards.

Table 1: Biannualdescriptive statistics of cation and anion parameters in surface water samples during 2020 and 2021

Parameters	Minimum	Maximum	Mean ± SD	Standard		
	Mean ± SD	Mean ± SD	Mean ± SD	DoE-BD, 2008		Mean ± SD
Cl^-	227.3±38.4	111.1±53	133.9±5.2	150-600	250	1065
HCO_3^-	107.2±5	100.1±11	107.1±5.8	200-500	--	610
SO_4^{2-}	35.6±7.3	22.8±0.9	30.7±0.4	400	250	960
NO_3^-	25.6±5.3	20.3±3.2	21.5±3.2	10	10	<10
PO_4^{3-}	1.5±0.3	1.2±0.2	0.8±0.2	--	0.1-0.05	2.0
Na^+	350.1±25.5	273.0±14.7	287.1±13.4	200	200	920
K^+	19.8±8.8	15.6±5.3	17.10±6.3	12	--	15
Mg^{2+}	42.17±13.8	36.44±9.7	40.12±11.4	30-35	--	60
Ca^{2+}	256.8±38.7	226.4±29.8	244.6±31.2	75	--	400

Characteristics Analysis of Trace Elements of Surface Water

In this study, 10 heavy metals, namely Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb, were analyzed covering two years in 2020 and 2021. The analysis results of the surface water samples are stated in Table 3 and Table 4.

Chromium (Cr)

The minimum concentration of Cr in surface water samples was found to be 0.033 mg/L, and the maximum was found to be 0.256 mg/L. The mean value of Cr was found to be 0.146 mg/L, and the standard deviation was 0.084 (Table 3). The highest mean concentration of Cr in surface water samples was obtained to be 0.158 mg/L in the post-monsoon period of 2021, and the lowest was 0.138 mg/L in the monsoon period of 2020 (Table 4). Suteu *et al*[28] illustrated a similar observation for the surface water samples, where the Cr concentration varied from 0.116 to 0.194 mg/L. Tareque *et al*[29] also did a similar observation on the surface water samples in the BSCIC industrial area of Rajshahi, where the highest mean value was 0.052 mg/L, which was similar to the present study. In the study area, the concentration of Cr was within the permissible limit of DoE-BD (Table 3).

Manganese (Mn)

The minimum concentration of Mn in surface water samples was found to be 0.089 mg/L, and the maximum was 1.65 mg/L. The value of Mn in the surface water samples was found to be 1.01 mg/L, and the standard deviation was 0.02 (Table 3).

The highest mean value of Mn in the surface water samples was obtained to be 0.158 mg/L in the post-monsoon period of 2021, and the lowest was 0.864 mg/L in the monsoon period of 2020 (Table 4). In the study area, the concentration of Mn was within the permissible limit.

Iron (Fe)

The minimum value of Fe in the surface water samples was found to be 0.468 mg/L, and the maximum was 4.43 mg/L. The mean value of Fe was found to be 2.11 mg/L, and the standard deviation was 1.01 (Table 3). The highest mean value of Fe was obtained to be 3.11mg/L in the pre-monsoon period of 2021, and the lowest was 1.80 mg/L in the monsoon period of 2021 (Table 4). As the results the concentration of Fe followed the order of pre-monsoon > post-monsoon > monsoon. Islam *et al*[6] conducted research on the surface water samples collected from the BSCIC industrial area of Rajshahi, where the highest mean value was 0.683 mg/L, which was similar to the present study. In the study area, the maximum concentration of Fe was found within the permissible limit recommended by the DoE-BD (Table 3).

Table 3: Descriptive statistics of heavy metal concentrations in surface water during 2020 and 2021.

Parameters (mg/L)	Minimum	Maximum	Mean ± SD	DoE-BD standard (mg/L), 2008
Fe	0.468	4.43	2.10±1.01	2.0
Mn	0.089	1.65	1.01±0.02	5.0
Zn	2.15	5.12	7.13±0.08	5.0
Cr	0.033	0.256	0.14±0.08	0.5
Cd	0.001	0.091	0.04±0.01	0.05
Pb	0.101	0.423	0.26±0.08	0.1
Co	0.112	0.316	0.21± 0.02	0.2
Ni	0.105	0.315	0.21±0.05	0.1
Cu	0.104	0.107	0.15±0.08	0.1
As	0.032	0.178	0.11±0.03	0.2

Cobalt (Co)

The highest mean concentration of Co in the surface water samples was obtained to be 0.234 mg/L in the pre-monsoon period of 2021, and the lowest was

0.198 mg/L in the monsoon period of 2020 (Table 4). The results showed that the concentration of Co in the surface water samples followed the order of pre-monsoon > post-monsoon > monsoon, which may

be the cause of dilution effects. In the study area, the concentration of Co was found to be a little higher than the standard permissible limit recommended by the DoE-BD (Table 3).

Nickel (Ni)
The mean concentration of Ni in the surface water samples was obtained to be 0.228 mg/L in the pre-monsoon period of 2020, and the lowest was 0.196 mg/L in the monsoon period of 2020 (Table 4). According to the results showed the concentration of Ni in the surface water samples followed the sequences of pre-monsoon > post-monsoon > monsoon, which may be due to the dilution effects. In the study area, the concentration of Ni was found to be 2–3 times higher than the standard o DoE-BD (Table 3).

Table 4: Seasonal variation of average Cr, Mn, Fe, Co, Nice, Zn, As, Cd, and Pb of surface water samples from 2020-2021.

Period		Heavy metals (mg/L)									
		Cr	Mn	Fe	Co	Ni	Cu	Zn	Pb	Cd	As
2020	Pre-monsoon	0.151	1.008	2.104	0.224	0.228	0.167	7.238	0.268	0.0446	0.104
	Monsoon	0.141	0.864	1.853	0.198	0.196	0.143	5.294	0.236	0.0398	0.086
	Post-monsoon	0.154	1.026	2.171	0.212	0.211	0.158	6.316	0.254	0.0452	0.116
2021	Pre-monsoon	0.148	1.016	3.111	0.234	0.223	0.177	7.418	0.276	0.0448	0.112
	Monsoon	0.138	0.902	1.804	0.206	0.208	0.140	5.993	0.241	0.0401	0.092
	Post-monsoon	0.158	1.058	2.188	0.201	0.210	0.245	6.262	0.257	0.0464	0.129

Copper (Cu)
The mean Cu concentration was found to be 0.155 mg/L, and the standard deviation was 0.081 (Table 3). The highest mean was obtained to be 0.245 mg/L in the post-monsoon period of 2021, and the lowest was 0.140 mg/L in the monsoon period of 2021 (Table 4). In the study area, the concentration of Cu was found to be 1 to 1.5 times higher than the standard of DoE-BD (Table 3), indicating low Cu poisoning in the area. A report showed that the Cu values ranged from 0.109 mg/L to 0.225 mg/L near the Konabari industrial area of Gazipur district in Bangladesh which is similar to the present observation, suggesting Cu pollution of surface water around the industrial areas might be the cause of untreated effluent discharge.

Zinc (Zn)
The minimum concentration of Zn in the surface water samples was found to be 2.15 mg/L, and the maximum was 5.12 mg/L and the standard deviation was 0.087 (Table 3). The value of Zn in the surface water was obtained to be 3.41 mg/L in the pre-monsoon period of 2021, and the lowest was 2.29 mg/L in the monsoon period of 2020 (Table 4). As the results Zn in the surface water samples followed the sequence: pre-monsoon > post-monsoon > monsoon. In the study area, the concentration of Zn found a little higher than the standard permissible limit of DoE-BD (Table 3).

Lead (Pb)
The minimum concentration of Pb was found to be 0.101 mg/L, and the maximum was 0.423 mg/L. The mean Pb was found to be 0.262 mg/L, and the standard deviation was 0.08 (Table 3). The highest mean Pb in the sample was obtained to be 0.268 mg/L in the pre-monsoon period of 2020, and the lowest was 0.236 mg/L in the monsoon period of 2020 (Table 4). As the results Pb in the surface water samples followed the sequence: pre-monsoon > post-monsoon > monsoon. In the study area, the concentration of Pb was 2 to 4 times higher than the standard permissible limit of DoE-BD (Table 3). The study results indicate Pb poisoning in the area.

Cadmium (Cd)
The minimum concentration of Cd was found to be 0.001 mg/L, and the maximum was 0.091 mg/L. The mean concentration of Cd was found to be 0.045 mg/L, and the standard deviation was 0.001 (Table 3). The highest mean value of Cd in the surface water

was found to be 0.046 mg/L in the post-monsoon period of 2021, and the lowest was 0.039 mg/L in the monsoon period of 2020 (Table 4). The results showed that the Cd in the surface water samples followed the order of post-monsoon > pre-monsoon > monsoon. In the study area, the concentration of Cd was found within the standard permissible limit (Table 3).

Arsenic (As)
The minimum As concentration of As was found to be 0.032 mg/L, and the maximum was 0.178 mg/L. The mean As concentration was found to be 0.105 mg/L, and the standard deviation was 0.032 (Table 3). The highest mean value of As was obtained to be

0.013 mg/L in the post-monsoon period of 2021, and the lowest was 0.086 mg/L in the monsoon period of 2020 (Table 4). The As concentration followed the order of post-monsoon > pre-monsoon > monsoon. The As was found within the standard permissible limit recommended by the DoE-BD (Table 3). The study results indicate no As poisoning in the area.

Detection of Functional Groups in Surface Water Samples
The study displayed the presence of some organic functional groups in surface water samples using FTIR. Figure 3 showed the peaks for a large number of functional groups.
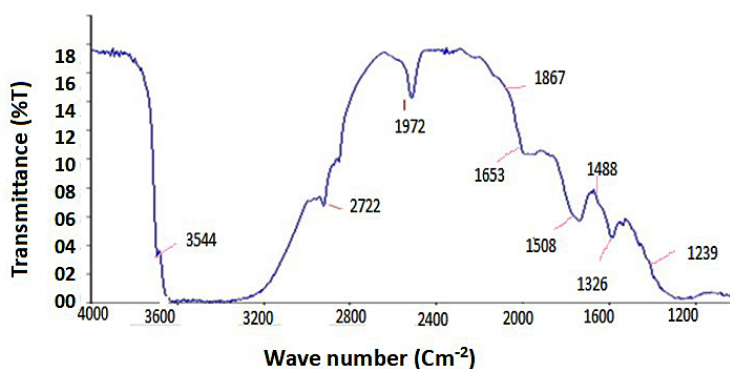

Fig. 3: Detection of functional groups in surface water by FTIR.

In the study, a large number of functional groups were found in surface water samples, which were detected by FTIR. The frequency ranges of surface water samples were found to be 484 cm^{-1} to 3650 cm^{-1}. In the ranges of 2000 to 2640 cm^{-1} the absorption appearance was found to be strong, in the ranges of 460 to 1980 cm^{-1} the absorption appearance was found to be medium, and in the range of 2650 cm^{-1} to 3650 cm^{-1}, the absorption appearance was found to be weak.[30] The absorption frequency ranges of 600 to 1610 cm^{-1} were found for C-I, C-Br, C-Cl, N-H, and C= C stretching, which indicates the presence of alkyl halides, amines, and alkine groups. The absorption frequency ranges of 1630 to 2130 cm^{-1} were found for C=O, O-H, C-H, N-H, and C=C=N stretching, which indicate the presence of acid halide, carboxylic acids, alkanes, amides, and ketenimine, and the ranges of 2140 – 3650 cm^{-1}, for –N=N-, -N=O, =C=N-, and–OH stretching, which indicate the presence of azo, nitroso, cyano,

and hydroxyl groups.[22] So, the study results confirm that the dyes and other chemicals of cottage textiles in the study areas contain alkyl halides, amines, alkines, acid halides, carboxylic acids, alkanes, amides, ketenimine, azo, nitroso, cyano, and hydroxyl groups. Among those groups, the azo group was found to have a strong absorption appearance between 2140 and 2160 cm^{-1}, which group is very harmful for human health, aquatic life, and other microorganisms.

Pollution Indices
This study analyzed C_f^i, C_d, mC_d, and *PLI* of heavy metals in surface water in the study area from 16 locations during 2020 and 2021.

Contamination Factor (C^i)
The study illustrated that the values of the C_f^i were found in the order of Mn<Pb<Cr in the discharged surface water samples in a drain or pond at the

cottage industrial zone in the study area. The lowest mean value of Cr was 0.432 in sample no. SW-11, and the highest was found to be 1.04 in SW-1 (Table 5). The lowest mean value of Cd was found to be 4.59 in sample no. SW-11 and the highest was found to be 11.71 in SW-1 (Table 5). The lowest mean value of Zn was 1.52 in SW-7 and the highest was found to be 2.96 in SW-11 (Table 5). Similarly, the lowest value of Pb was 0.11 in SW-8 and the highest value was found to be 0.90 in SW-11 (Table 5). Castro-Gonz´alez *et al*[4] illustrated a similar observation for the Surface water, where the Cr contamination factor varied from 0.22 to 0.09, Mn 0.02 to 1.12, Cd 1.10 to 10.12, Zn 1.43 to 3.09, and Pb 0.42 to 2.90.

Degree of Contamination (C_d)
The degree of contamination (C_d) of heavy metals in the surface water of the study area was analyzed between 2020 and 2021. The lowest value was 9.28 in sample no. SW-4 and the highest value was 18.04 in ES-1 (Table 5). The lowest value was indicated as the moderate ($8 \leq C_d < 16$) contamination level and the

highest value was indicated as the high ($16 \leq C_d < 32$) contamination level (Table 6). The analysis results showed that among the sixteen samples, one was high; two were low, and the other nine samples had a moderate contamination level.[22] conducted a research on surface water samples where the degree of contamination (C_d) varied from 6.26 to 15.22, and the highest degree of contamination was found in the pre-monsoon period.

The Modified Contamination Degree (mC_d)
The heavy metals mC_d in the surface water of the study area was analyzed for 2020 and 2021. The lowest value was 1.81 in sample no. ES-4, and the highest value was 4.11 in sample no. ES-1 (Table 5). The lowest value was indicated as the low ($1.5 \leq mC_d < 2$) contamination level, and the highest value was indicated as the high ($4 \leq mC_d < 8$) contamination level (Table 6). The analysis results showed that among sixteen samples, one was high; three were low, and others had a moderate contamination level.

Table 5: Average of contamination factors, degree of contamination (C_d), modified degree of contamination (mC_d), and pollution load index *(PLI)* of heavy metals in surface water for 2020 to 2021.

Sample No.	C_f^i					C_d	Contamination level	mC_d	PLI
	Cr	Mn	Cd	Zn	Pb				
SW-1	1.04	0.112	11.71	2.59	0.59	18.04	High	4.11	1.67
SW-2	0.736	0.128	8.59	2.30	0.31	14.06	Moderate	2.81	1.30
SW-3	0.768	0.096	9.36	2.20	0.22	14.64	Moderate	2.92	1.35
SW-4	0.464	0.064	5.10	1.82	0.72	9.28	Low	1.81	0.86
SW-5	0.641	0.096	11.23	2.68	0.65	17.34	Moderate	3.46	1.60
SW-6	0.832	0.112	8.99	2.51	0.52	14.96	Moderate	2.99	1.38
SW-7	0.496	0.080	11.39	1.52	0.54	15.00	Moderate	3.01	1.38
SW-8	0.640	0.064	9.34	2.06	0.11	14.17	Moderate	2.83	1.31
SW-9	0.624	0.128	9.81	2.38	0.38	15.32	Moderate	3.06	1.41
SW-10	0.768	0.096	6.59	1.69	0.69	10.84	Moderate	2.16	1.01
SW-11	0.432	0.048	4.59	2.96	0.90	9.95	Low	1.99	0.92
SW-12	0.736	0.096	9.37	2.16	0.16	14.52	Moderate	2.90	1.34
SW-13	0.464	0.064	5.10	1.82	0.72	9.28	Low	1.85	0.85
SW-14	0.641	0.096	11.23	2.69	0.65	17.34	Moderate	3.46	1.60
SW-15	0.832	0.112	8.99	2.55	0.52	14.96	Moderate	2.99	1.38
SW-16	0.496	0.080	11.39	1.53	0.54	15.00	Moderate	3.01	1.38

The Mollution Load Index (PLI)
The PLI of heavy metals in the surface water were analyzed for 2020 and 2021. The lowest value was

0.85 in sample no. SW-13, and the highest value was 1.67 in sample no. SW-1 (Table 5). The highest value was found within the range of (>1), which indicated

that pollutant was present and contaminated, and the lowest value was found within the range of (<1), which indicated nil to low pollution (Table 7). The results showed that all the samples were lowly polluted. A similar research study was conducted by[2] on effluent samples, where the pollution load indexes (*PLI*) varied from 0.654 to 1.09, which supported to the present study.

Table 6: The contamination factor (Cif), contamination degree (Cd), modified contamination degree (mCd), and pollution level (Hakanson 1980, Abrahim and Parker 2008).

C^i_f	C_d	mC_d	Pollution level.
--	--	$1.5 \geq mC_d$	very low or nil
$C^i f < 1$	$C_d < 8$	$1.5 \leq mC_d < 2$	Low
$1 \leq C^i_f < 3$	$8 \leq C_d < 16$	$2 \leq mC_d < 4$	Moderate
$3 \leq C^i_f < 6$	$16 \leq C_d < 32$	$4 \leq mC_d < 8,$	High
$C^i_f \geq 6$	$C_d \geq 32$	$16 \geq mC_d \geq 8$	Very high
--	--	$32 \geq mC_d \geq 16$	Extremely high
		$32 \leq mC_d$	Ultra high

Table 7: Pollution load index (*PLI*) and contamination level (Tomlinson 1980).

Polution load index (*PLI*)	Contamination level
0	Perfection
< 1	Nil to low pollution
1	Pollutants present
>1	Contaminated

In the study, the *PLI* values of three samples were found to be below one, and those of the other samples were found to be higher than one (Table 5). So the study results indicated that the surface water is going to be contaminated by dyeing effluent around the cottage textile zone in Bangladesh.

Potential Ecological Risk Assessment
The E^i_r and RI of heavy metals in the surface water of the study area were analyzed for 2020 and 2021 and the cottage industrial zone of study area was found to be in the following order: Cd > Pb > Zn >Cr > Mn.

The E^i_r of Cd were found within the range of 133.81 to 359.70 (Table 8), which belong to higher and higher ecological risk.[31] Mn, Cr, Zn, and Pb were all found to be lower than 40, which belong to low ecological risk.[31] On the other hand, the risk indexes (RI) were found within the range of 133.81 to 359.70, which belong to low, moderate, and severe ecological risk.[31] The results indicated that there was low, moderate, and severe ecological risk for surface water in the study area.

The RI lowest value of heavy metals indicated a low (RI < 150) pollution level, and the highest value indicated a severe (300 ≤ RI < 600) pollution level. The analysis results showed that three samples had a low pollution level, six samples had moderate pollution, and others had a severe pollution level among the sixteen surface water samples. Confirmative research was done by Chang *et al.*[30] on surface water samples, where the RI of heavy metals in surface water was found in the range of 124.67 to 432.09. The analysis results express that the highest pollution factor (C^i_f) was found in the range of 1.10 to 10.12, expressing moderate to ultra-high pollution levels of Cd. The degree of contamination was found 6.26 to 15.22, the ^mC_d varied from 0.953 to 5.24, and the pollution load indexes (PLI) varied from 0.654 to 1.09, indicating low to moderate contamination levels. The highest ecological risk factors (E^i_r) were found in the range of 124.25 to 357.71, indicating a higher to serious ecological risk for Cd in the study areas. The ecological risk index (RI) varied from 124.67 to 432.09, expressing moderate to serious ecological risk. The study observation showed that the contamination level belonged to a high of 3%, a

moderate of 78%, and a low of 19%, of samples, and the pollution degree belonged to a severe of 22%, a moderate of 61%, and a low of 17% of surface water samples (not mention in Table).

Table 8 Average E_r^i and RI of heavy metals in surface water samples for 2020 to 2021.

Sample ID	Potential ecological risk factors (E_r^i)					Risk index	Pollution degree
	Cr	Mn	Cd	Zn	Pb		
SW-1	2.16	0.121	351.10	2.70	3.60	359.70	Severe
SW-2	1.33	0.121	258.32	2.25	2.61	264.64	Moderate
SW-3	1.54	0.107	281.07	2.20	2.73	287.66	Moderate
SW-4	1.45	0.094	127.24	2.014	3.00	133.83	Low
SW-5	1.56	0.107	336.76	2.68	2.55	343.61	Severe
SW-6	1.68	0.105	270.04	2.47	3.73	278.04	Moderate
SW-7	1.22	0.072	341.5	1.49	2.27	346.55	Severe
SW-8	1.36	0.060	281.21	2.06	2.69	287.39	Moderate
SW-9	1.11	0.126	293.69	2.32	4.17	301.44	Severe
SW-10	1.52	0.107	196.94	2.85	2.50	203.94	Moderate
SW-11	1.83	0.126	136.84	2.50	4.88	146.21	Low
SW-12	1.57	0.104	280.72	2.33	3.17	287.91	Moderate
SW-13	1.45	0.094	127.24	2.014	3.00	133.81	Low
SW-14	1.56	0.107	336.76	2.68	2.55	343.67	Severe
SW-15	1.68	0.105	270.04	2.47	3.73	278.04	Moderate
SW-16	1.22	0.072	341.5	1.49	2.27	346.59	Severe

Conclusion

The analysis results showed that the EC, pH, TSS, turbidity, TDS, BOD, COD, Cl-, HCO_3-, CO_3^{2-}, SO_4^{2-}, NO_3-, Cr, Cu, Pb, Zn, As, and Cd, in surface water were found to be higher than the DoE-BD standard. The most toxic heavy metals, such as Cr, Mn, Cd, and Pb, were found to be higher than the standard values in all collected samples, which showed that the cottage textile industries are creating pollution in the study areas. The FTIR analysis showed that the surface water samples contained toxic functional groups like azo, cyano, etc. The analysis reports showed that the highest contamination factor (Cif) was found to be moderate to ultra-high contamination levels, and the highest ecological risk factors (E_r^i) were found to be higher to serious ecological risk in surface water samples for C_d, indicating serious Cd poisoning in the sampling area. The C_d, ^mC_d, and *PLI* were found to be low to moderate contamination levels, and the risk index (RI) was found to be moderate to serious ecological risk in surface water samples in the sequence of Cd> Zn > Cr > Pb >Mn. The pollution level and degree of all types of samples were followed in the order of post-monsoon > pre-monsoon > monsoon. Overall observation showed that most of the parameters of surface water samples exceeded the DoE-BD, WHO, and BNDWQ standard permissible levels. There is no treatment plant found in any cottage dyeing industry in the area. The pollution load will continue to increase and further reduce the water quality. The study illustrated the discharged untreated effluents into nearby water bodies. The study recommends using a few poisonous Cd less dyes in cottage industries in the study areas. To install an effluent treatment plant (ETP) in the study area to indemnify water quality and the environment. In this discretion, embed an ETP for each industry or a central effluent treatment plant (CETP) for an industrial hub is advice for sustainable wastewater management and environmental sustainability. The people must be aware and take proper steps for a better world to outlive and for the improvement of the future generation.

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