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Impact of Textile Effluents on *Pistia stratiotes* L. and *Ludwigia adscendens* L. Using Hydroponic Culture

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Abstract

The study was carried out to assess the impacts of textile effluents on aquatic plants by using hydroponic culture. Effluent water of three textile industries and effluent free water were collected from Savar region. The higher contents of pH (10.47), total suspended solids (1407.33 mg/L), total dissolved solids (19014 mg/L) and biochemical oxygen demand (735 mg/L) were recorded in industrial effluents comparing with control. The lowest content of DO in industrial effluents (0.87 mg/L) was much lower than the control (5.65 mg/L). Hydroponic test showed that 100, 75, 50, 25 and 1% textile effluents caused the death of *Pistia stratiotes* L. and *Ludwigia adscendens* L. within 1-4, 2-6, 3-9, 5-12 and 14-17 days, respectively. When *P. stratiotes* was grown in 100% effluent water its concentrations of Cr, Cd, Cu, Mn, Ni and Zn were 8.00, 1.4375, 189.06, 1843.1, 5.075 and 261.87 ppm, respectively and the test species died within 1 - 3 days. When *L. adscendens* was grown in 100% effluent water, its concentrations of Cr, Cd, Cu, Mn, Ni and Zn were 7.25, 0.975, 312.87, 1621.2, 5.0125 and 138.75 ppm, respectively and the test species died within 2-4 days. The uptake of heavy metals increased with raising effluent concentration comparing with control culture. The uptake of Cr, Cd, Cu, Mn, Ni and Zn were significantly higher at 50%, 75% and 100% ($p = 0.01^{**}$ at 1% level of significance) effluent which caused the death of both test species.

Key words: Textile effluents, *Pistia stratiotes* L., *Ludwigia adscendens* L., Hydroponic culture.

Introduction

Aquatic plants are used for testing the toxicity of single substance and mixtures of substances in the water, soil and sediments. The important members of the aquatic ecosystem are sensitive to many pollutants and in many cases they are more sensitive than animals (Walsh *et al*., 1980). Thus, the studies using plant as test species are necessary in any battery of tests for evaluation of toxicity of municipal and industrial effluents (Gorsuch *et al.*, 1991). The effluents from the most of textile industries contain toxic elements and are directly discharged in the aquatic environment without treatment. The discharges of effluent into an aquatic body can seriously affect its flora, fauna and abiotic components (Goutam, 1992). The aquatic environment is more susceptible to the harmful effects of heavy metal pollution because aquatic flora and fauna are in close and prolonged contact with the soluble metals (Chow, 1968). Hydroponic test are very useful for determining whether or not an effluent is toxic because this affects the growth rate of seedlings (Walsh *et al.*, 1991).

Savar, one of the largest industrial belts near Dhaka in Bangladesh, has more than 100 local and foreign industries. These generate a large amount of effluents everyday which are being directly discharged into the surrounding land, agricultural fields, irrigation channels and surface water that finally enter into the river (Sultana *et al*., 2003). With these backgrounds, the present study was performed to investigate the physico-chemical parameters and heavy metal content of textile effluents, the growth performance of aquatic macrophytes in hydroponic culture and the determination of the concentration of heavy metals in test plant species after hydroponic culture.

Materials and Methods

Sample collection

The wastewater samples were collected from the point source of the three textile industries namely two in Ulail, Savar, (S-1, S-2) and the remaining in DEPZ (Dhaka Export Processing Zone) (S-3). To have a representative sample, 4 L of water sample was collected from each site. For com-

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parison, one control sample (S-4) was collected from the wetland of Bangladesh Livestock Research Institute (BLRI), Savar that does not receive any industrial discharge. For hydroponic culture *Ludwigia adscendens* L. and *Pistia stratiotes* L. were taken as test species (Plate-1 and 2).

Plate 1. *Ludwigia adscendens* L. and *Pistia stratiotes* L.

Sample analysis

The parameters regarding water quality monitoring were analyzed by different standard methods. Turbidity of textile wastewater was measured by turbidity meter (Hi C-114); total suspended solids (TSS) and total dissolved solids (TDS) by gravimetric method (Kannan, 1997). Dissolved oxygen (DO) was determined by DO meter (Hi 9143) and biochemical oxygen demand (BOD_5) was measured by Winkler method (De, 1996). Water pH, total nitrogen (N), total phosphorus (P) and total potassium (K) of textile wastewater were determined by Griffin pH meter model, Micro-Kjeldahl's distillation method (Jackson, 1973), Chemita visible spectrophotometer at 882 nm wave length (Murphy and Riley, 1962) and Flame Photometer (Gallen camp), respectively.

At first the samples were digested with nitric acid for heavy metal determination as described by Baker *et al.*, (1982).

Then the determination of heavy metals like zinc (Zn), cadmium (Cd), copper (Cu), manganese (Mn), nickel and chromium (Cr) in water and plant samples were performed by Atomic Absorption Flame Emission Spectrophotometer (AA-6401F, SHIMADZU) and Fast Sequential Atomic Absorption Spectrometer (AA240FS, VARIAN).

Growth test in hydroponic culture

Hydroponics is the process whereby plants are cultivated in nutrient solution without soil. It is also known as 'hydroponic culture' or 'soil less culture'. It has been used to determine toxic effects of effluent on growth rate of plants (Walsh *et al.*, 1991).

A B

Plate 2. Hydroponic culture: (A) using different percentage of textile effluents, (B) control culture

Procedure

In the hydroponic system, the tests were conducted in 250 ml conical flask. For this purpose effluent from three textile industries and two plant species, *L. adscendens* L. and *P. stratiotes* L. were selected. In this test, the plants were grown in different percentage (1, 25, 50, 75 and 100%) of textile effluents. The growth test using test species was also conducted with effluent free water from control site. Three replications were taken for both 'treated' (with effluent water) and 'control'. The flask was wrapped with aluminum foil to prevent photodecomposition of toxicants and growth of algae. During experimental period phenotypic impacts on test species were recorded everyday. After tests, heavy metal concentrations in both test plant species were determined by Atomic Absorption Spectroscopy.

Statistical Analysis

The uptake of heavy metals by test plant species grown in different percentage of effluents were compared with the control culture by the Statistical Package for Social Science (SPSS) for Windows. Values were expressed as Mean ± SEM (Standard Error of the Mean). Unpaired "t" tests were done as the test of significance. $p < 0.01$ was considered as the minimal level of statistical significance (Daniel, 1999).

Results and Discusion

The results of physicochemical parameters of wastewater of textile industries are presented in Table I. Biochemical oxygen demand (BOD_5) is an important water quality parameter for organic matter in water. High BOD_5 is harmful to aquatic flora and fauna like fish and microorganisms (Kabir *et al.*, 2002). The average value of BOD_5 of the three textile industries was 735 mg/L which is higher than the standard of the Department of Environment (DoE) of Bangladesh (50 mg/L) (Table II). But in the control site (S-4), the value of BOD_5 was 3.7 mg/L, which is within the limit of DoE (50 mg/L). Thus, high value of BOD_5 of wastewater of textile industries can cause serious damage to the growth and development of aquatic biota. This high value of BOD_5 indicates the status of oxygen deficiency in water body. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high; so the BOD_5 level will be high. As the waste is consumed or dispersed through the water, BOD_5 level will begin to decline (Vesilind *et al.*, 1990).

DO in water is essential for aquatic life. Deficiencies of DO in water give rise to odoriferous products of anaerobic decomposition. The average value of DO of the three textile industries was 1.5 mg/L, which is much below the limit of DoE (4.5-8 mg/L) (Table II). The low DO value of the effluent of the textile mill suggested that this industry was producing a lot of organic substances, most likely the dyes, which are high oxygen demanding wastes. The content of DO in site-1 (S-1) was very low (0.87 mg/L), which suggested that the industries were releasing organic substances that were high oxygen demanding wastes (Emongor *et al.*, 2005). But in the control site (S-4), the value of DO was 5.65 mg/L, (Table I) which is within the limit of DoE (4.5-8 mg/L).

Excessive pH is harmful for aquatic life like fish, microorganisms and aquatic plants (Rouse, 1979). The average value of pH of the three textile industries was 10.47, which exceeds the limit of DoE (6-9) (Table II). The highest value of pH was measured in site-1 (11.32), which exceeds the range of DoE (6-9). In control site (S-4), the value of pH was 6.73 (Table I) which lay within the permissible limit of DoE (6-9) .

The high amount of dissolved solids in water increases the water density; it influences osmoregulation of freshwater organisms and reduces solubility of gases. Increased pH value of the sample might have resulted in the dissolution of low molecular mass organic bases originating from dye

Table I. Physicochemical parameters of the wastewater of textile industries

Sites	TSS (mg/L	TDS (mg/L	pH	DO (mg/L)	BOD (mg/L)	Turbidity NTU	Total N (mg/L	Total P (μg/L)	Total K (μg/L
S-1	1537	15470	11.32	0.87	735	45	5.01	1035.1	427
S-2	1670	36451	10.34	1.49	580	57	5.21	987.15	465
S-3	1015	5157	9.75	2.15	890	35	4.29	615.96	835
S-4	96.35	597	6.73	5.65	3.7	4.5	3.16	84.70	207

industries. This also gives rise to higher TDS value (Moore *et al.*, 1960). As the value of pH of the wastewater of textile industries was high, the value of TDS was also high (Table II).

Table II. Comparison of physicochemical parameters of textile industrial effluents with standards of industrial wastewater of DoE (2001)

Parameter	Observed area (average value of S-1, S-2 and S-3)	Observed area (value of S-4)	DoE limit (2001)
BOD_5 (mg/L)	735	3.70	50
DO (mg/L)	1.50	5.65	4.5-8
TDS (mg/L)	19,014	597	2100
TSS (mg/L)	1407.33	96.35	150
pH	10.47	6.73	6-9
Total N (mg/L)	4.84	3.16	100

The average value of TSS of the three textile industries was 1407.33 mg/L, which exceeds the limit of DoE (150 mg/L)) (Table II). The highest value of TSS was measured in site-2 (1670 mg/L), which crossed the limit of DoE (150 mg/L). In control site (S-4), the value of TSS was 96.35 mg/L (Table I) which lay within the permissible limit of DoE (150 mg/L) .

So, the average value of physicochemical parameters of S-1, S-2 and S-3 (industrial site) exceeds the range of DoE (2001), but the values of control site (S-4) was within the limit of DoE (2001) (Table II). The average values of trace elements in wastewater of textile industries were within the limit of DoE (1997) (Table III). But when test aquatic plant species absorbed non-essential elements from wastewater it might affect their growth and development due to hyper-accumulation.

Table III. Comparison of trace elements of effluents of textile industries with standards for industrial waste (DoE, 1997)

Element	Observed area (average value)	DoE limit (1997)
Cr (ppm)	0.0546	0.10
Cd (ppm)	0.0015	0.05
Cu (ppm)	0.224	0.50
Mn (ppm)	0.136	5.00
Ni (ppm)	0.064	1.00
Zn (ppm)	0.673	5.00

When *P. stratiotes* was grown in 100% effluent water, the concentration of Cr was recorded 8.00 ppm in plant sample and the plants died within 1 to 3 days of growth in effluents from different textile industries (Tables IV and V). When *L. adscendens* was grown in 100% effluent water, 7.25 ppm of Cr accumulated in its plant sample and the plant died within 2 to 4 days after growing in the effluent (Tables IV and V). When *L. adscendens* and *P. stratiotes* were grown in 1% effluent, the concentrations of Cr were 3.375 and 6.12 ppm, respectively and the plants died after 14 -17 days of exposing to grow in the effluents (Tables IV and V).

The concentration of Cd was recorded 1.4375 ppm in plant sample when *P. stratiotes* was grown in 100% effluent water. The present findings show dissimilarity with the normal range in plant material (Pendias, 1984); and the plants died within 1 to 3 days of exposures (Tables IV and V). When *L. adscendens* was grown in 100% effluent water, the concentration of Cd was 0.975 ppm in its plant sample, which was beyond the normal range in plant material (Pendias, 1984); and the plant died within 2 to 4 days (Table IV and V).

When *P. stratiotes* was grown in 100% effluent water, the concentration of Cu was recorded 189.06 ppm in plant sample which crossed the normal range in plant material (Pendias, 1984) and the plants died within 1 to 3 days after its growth in the effluents from different textile industries (Tables IV and V). When *L. adscendens* was grown in 100% effluent water, the concentration of Cu 312.875 ppm was found in its plant sample, which crossed the normal range in plant material (Pendias, 1984) and the plant died within 2 to 4 days after exposed to grow in effluents from different

Table IV. Heavy metals uptake by *Ludwigia adscendens* L. and *Pistia stratiotes* L. grown in different % of textile effluent and comparison with normal range in plant material (Pendias, 1984)

Heavy metals (ppm)	*Pistia stratiotes* L.					*Ludwigia adscendens* L.					Normal range in plant material (Pendias, 1984)
	Concentration (%) of textile effluents					Concentration (%) of textile effluents					
	1	25	50	75	100	1	25	50	75	100	
Cr	6.12	6.132	7.125	7.625	8.00	3.375	5.625	5.875	6.125	7.25	0.03-15
Cd	0.437	0.512	0.9875	1.3	1.4375	0.312	0.3625	0.5125	0.737	0.975	0.2-0.8
Cu	34.01	55.2	119.37	126.56	189.06	28.88	51.325	131.62	157.75	312.87	20-100
Mn	1060	1169.3	1121.8	1431.8	1843.1	1454	1194.4	1387.5	1515	1621.2	15-1000
Ni	4.025	3.8625	4.5	4.6625	5.075	1.925	4.337	3.9	4.925	5.0125	0.02-5
Zn	173.1	232.5	178.12	251.25	261.87	116.1	135	122.5	126.2	138.75	8-400

textile industries (Tables IV and V). When *L. adscendens* and *P. stratiotes* were grown in 1% effluent, the concentrations of Cu in plant analysis, were monitored i.e., 28.887 and 34.012 ppm, respectively. These values lay within the normal range in plant material (Pendias, 1984) and the plants were died after 14-17 days of exposing to grow the effluents (Tables IV and V).

Pistia stratiotes died within 1 to 3 days after application of 100% effluent (Tables IV and V). Then the concentration of Mn was recorded 1873.125 ppm in plant sample, which crossed the normal range in plant material (Pendias, 1984). When *L. adscendens* was grown in 100% effluent water, the concentration of Mn 1627.25 ppm was analysed to its plant sample, which also show the similar result (Pendias, 1984) and the plant died within 2 to 4 days after exposed to grow in effluents (Tables IV and V). When *L. adscendens* and *P. stratiotes* were grown in 1% effluent, the concentrations of Mn were found in plant analysis as 1454.375, and 1060.00 ppm, respectively and the plants died after 14-17 days (Tables IV and V).

Table V. Average time (days) required for death of *Ludwigia adscendens* and *Pistia stratiotes* using different percentage of textile industries effluents

% of Effluent	Time required for death of *Pistia stratiotes*	Time required for death of *Ludwigia adscendens*
100	1-3	2-4
75	2-5	3-6
50	3-7	4-9
25	5-9	7-12
1	14-16	15-17
Effluent free water (control)	Death not occurred	Death not occurred

When *P. stratiotes* was grown in 100% effluent water, the concentration of Ni was recorded 5.075 ppm in plant sample, which crossed the normal range in plant material (Pendias, 1984) and the plants died within 1 to 3 days after application of effluents (Tables IV and V). When *L. adscendens* was grown in 100% effluent water, the analysed concentration of Ni was 5.0125 ppm in its plant sample, which crossed the normal range in plant material (Pendias, 1984) and the plant died within 2 to 4 days after exposed to grow in effluents (Tables IV and V).

When *Pistia stratiotes* was grown in 100% effluent water, the recorded concentration of Zn was 261.875 ppm in plant sample. The value lay within the normal range in plant material (Pendias, 1984). The plants died within 1 to 3 days after its growth in 100% effluents (Table IV and V). When *L. adscendens* was grown in 100% effluent water, analysed the concentration of Zn was 138.75 ppm in its plant sample, which lay within the normal range in plant material (Pendias, 1984) and the plant died within 2 to 4 days after exposed to grow in effluents (Table IV and 5). When *L. adscendens* and *P. stratiotes* were grown in 1% effluent, the concentrations of Zn were 116.25, and 173.125 ppm, respectively which lay within the normal range in plant material (Pendias, 1984) and the plants died after 14-17 days of exposing to grow the effluent (Table IV and V).

Comparision of heavy metals uptake by *Ludwigia adscendens* L. and *Pistia stratiotes* L. grown in different % of textile effluent with control culture

Heavy metals uptake by *Ludwigia adscendens* L. and *Pistia stratiotes* L. increased with increasing the percentage of effluent when comparing with the control culture. The significant amount of heavy metals uptake was found after the application of 100, 75, 50 and 25% effluent water (Tables VI and VII).

Table VI. Comparision of heavy metals uptake by *Ludwigia adscendens* L. grown in different % of textile effluent with control culture

Heavy Metals		*Ludwigia adscendens* L.					
		Concentration (%) of textile effluents (n=3)					
		Control	1	25	50	75	100
Cr	Mean ± SEM	3.295±0.034	3.375±0.05	5.625±0.001	5.875±0.01	6.125±0.28	7.25±0.27
	t/p		69.282/0.08	201.839/0.01**	223.345/0.01**	245.85/0.01**	285.005/0.01**
Cd	Mean ± SEM	0.3116±0.651	0.312±0.214	0.362±0.457	0.512±0.412	0.737±0.589	0.975±0.841
	t/p		1.0392/0.408	85.257/0.01**	73.923/0.01**	368.407/0.01**	229.808/0.01**
Cu	Mean ± SEM	1453.12±0.983	28.88±0.124	51.325±0.451	131.62±0.21	157.75±0.115	312.87±0.031
	t/p		1.385/0.30	77.215/0.01**	79.475/0.01**	146.464/0.01**	245.948/0.01**
Mn	Mean ± SEM	28.872±0.045	1454±0.012	1194.4±0.01	1387.5±0.012	1515±0.015	1621.2±0.018
	t/p		0.7621/0.52	223.848/0.01**	227.143/0.02*	53.589/0.01**	245.615/0.01**
Ni	Mean ± SEM	115.995±0.874	1.925±0.04	4.337±0.07	3.9±0.024	4.925±0.054	5.0125±0.078
	t/p		3.464 / 0.074	151.585/0.01**	171.386/0.01**	260.540/0.01**	911.106/0.01**
Zn	Mean ± SEM	1.921±0.089	116.1±0.047	135±0.074	122.5±0.087	126.2±0.071	138.75±0.014
	t/p		0.812/0.502	16.459/0.01**	225.339/0.01**	88.377/0.01**	788.256/0.01**

*= Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed)

Table VII. Comparision of heavy metals uptake by *Pistia stratiotes* L. grown in different % of textile effluent with control

Heavy Metals		*Pistia stratiotes* L.					
		Concentration (%) of textile effluents (n=3)					
		Control	1	25	50	75	100
Cr	Mean ± SEM	6.001±0.120	6.125±0.08	6.132±0.01	7.125±0.01	7.625±0.01	8±1.154
	t/p		13.115/0.01**	63.449/0.01**	73.412/0.01**	146.42/0.01**	173.118/.226
Cd	Mean ± SEM	0.4225±0.237	0.437±0.01	0.512±0.01	0.9825±0.01	1.30±0.115	1.43±0.011
	t/p		12.557/0.06	77.509/0.01**	47.39/ 0.01**	7.599 / 0.01**	85.844 / 0.01**
Cu	Mean ± SEM	33.912±0.080	34.01±.320	55.2±0.57	119.37±0.01	126.56±0.01	189.06±0.01
	t/p		0.687/0.536	368.71/0.01**	740.87/0.01**	802.55/0.01**	1341.21/0.01**
Mn	Mean ± SEM	1059.1±0.550	1060±1.154	1169.30±0.115	1121.83±0.114	1431.88±0.115	1843.10±0.115
	t/p		0.779/0.517	9.36/0.01**	43.76/0.01*	256.32/0.01**	679.639/0.01**
Ni	Mean ± SEM	4.99±0.456	4.025±0.002	3.8625±0.01	4.5±0.057	4.662±0.11	5.075±0.0011
	t/p		0.36/0.01**	0.98/0.01**	8.7365/0.05*	28.714/0.01**	69.2820/0.01**
Zn	Mean ± SEM	173.01±0.245	173.1±0.115	232.5±0.04	178.12±0.24	251.25±0.02	261.87±0.01
	t/p		0.77/0.01**	215.78/0.01**	442.53/0.01**	677.782/0.05*	769.501/0.01**

*= Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed)

At 100% effluent water, Cr, Cd, Cu, Mn, Ni, and Zn uptake by *Ludwigia adscendens* L. and *Pistia stratiotes* L. were significantly higher (p = 0.01**) which causes the death of these species within short period of time (usually 1-4 days). Heavy metals uptake by *L. adscendens* L. and *P. stratiotes* L. were also significantly higher (p = 0.01**) after the application of 75%, 50% and 25% effluents but in this case average time required for the death of these species gradually increased (Tables - VI, VII and V).

So, there is an inverse relationship between exposure time and the percentage of different concentrations of effluents regarding impacts on hydroponic culture. Impacts of 25, 50, 75 and 100% effluents on growth of *L. adscendens* L. and *P. stratiotes* L. gradually increased with decreasing the exposure time.

Conclusion

In Bangladesh the rapid industrial development have significant impact on aquatic ecosystem. The reported pH (9.75-11.32) and BOD_5 (580-890 mg/L) were very high in textile industrial effluent than that of the control. DO values also varied from 0.87 to 2.15 mg/L in textile industrial effluents that were lower than the control (5.65 mg/L). Aquatic hydrophytes hardly survive in such type of conditions. Hydroponic test showed that 100, 75, 50, 25 and 1% textile effluent affected the growth of *P. stratiotes* and *L. adscendens* within 1-4, 2-6, 3-9, 5-12 and 14-17 days, respectively. Heavy metals uptake by *L. adscendens* L. and *P. stratiotes* L. increased with increasing the percentage of effluent compared with the control culture. Inspite of the content of heavy metals in effluent water was within the permissible limit of the Department of Environment (DoE) of Bangladesh, hyper-accumulation of heavy metals might cause the death of the test aquatic species. Further experiment should be conducted to determine heavy metals content of soil of nearby aquatic ecosystem of textile industries and to assess their effects on the growth of rooted attached aquatic plants.

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