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Improvement of wastewater quality of Dhaleswari river, Bangladesh using submerged macrophyte *Egeria densa*

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Abstract. Clean water is one of the significant goals among the 17 Sustainable Development Goals (SDGs), which will be achieved by at least 2030. It includes six outcome-oriented targets- improve water quality, wastewater treatment, ensure freshwater supplies are three of them. In Bangladesh, Freshwater ecosystem is continuously degraded due to rapid industrialization, which occurred along the riverside areas. In this context, laboratory-based work has been conducted to analyze the water quality of Dhaleshwari River, Bangladesh, which has already been polluted by industrial waste. The collected water samples were treated by submerged macrophyte *Egeria densa* to observe the changing water quality parameters. The growth of plants and roots were assessed after 10 days of exposure to three categories of water treatment. Initial and final water quality parameters were observed by the analysis of pH, EC, TDS, TSS, Acidity, Alkalinity, Total Hardness, Ca Hardness, COD, Sulphate (SO_4^{2-}), Phosphate (PO_4^{3}) Total Chlorine (Cl^-) and Copper (Cu^{2+}). The result showed that almost all the toxic parameters of water were reduced significantly at the end of the experiment. The present study hypothesized that submerged macrophyte *E. densa* can be used as a potential tool to upgrade the water quality of polluted rivers.

Keyword:
Clean water, Submerged macrophyte, SDG 6, Dhaleswari River, Freshwater ecosystem

1. Introduction

In 2015 the 17 Sustainable Development Goals (SDGs) were adopted by the United Nations, which will be ensured by 2030. The 6th one is to ensure availability and sustainable management of water and sanitation. Among the 6 specific targets of this goal improving water quality by reducing pollution, eliminating dumping, minimizing release of hazardous chemicals and materials, and ensuring freshwater supplies are major concerns for the environment and society. Freshwater ecosystem is the most vital ecosystem for the survival of Earth's Biosphere. As a riverine country Bangladesh is covered by several mighty rivers which are enriched with freshwater ecosystems. Nowadays, river water pollution and degradation become a major concern for the country due to rapid industrialization along the riverside without proper planning and environmental consideration [1].

In Bangladesh the leather processing industry/the tannery industry has grown rapidly and occupies 3.0% of the world's leather and leather products market by volume [2]. During the 1970s tanneries were started to establish in an unplanned way beside the mighty river Buriganga having no effluent treatment plant (ETP) and resulted in severe pollution of that river [3], [4]. In 2017, all the tanneries were shifted in a planned way from the Hazaribagh to Savar tannery village adjacent to the Dhaleswari River with setting of a central effluent treatment plant (CETP), which was not fully functional from the beginning [5]–[8].

Dhaleshwari River, the primary left bank of the Jamuna River, flows alongside central Bangladesh and contributes tremendously to the socio-economic prosperity of the surrounding region and the country. A number of previous researches reported that the physico-chemical properties of Dhaleshwari river water deteriorating after the shifting of tannery factories [2], [6], [8]. Massive quantities of liquid effluents such as organic matter, chromium (Cr), sulphide and solid wastes (fleshing, trimmings, shavings, buffing dusts) are produced from light leather manufacturing and difficult to dispose of [9], [10]. Around 60% of the overall chromium salts react with the hides, and about 40% of the chromium is left in the solid and liquid wastes[11]. Chromium is dangerous to humans, animals, and the environment [9], [12], [13]. To reduce the effect of tannery waste in the aquatic environment organic matter, solids, nutrients, and other contaminants like BOD, COD, TSS, TDS, and Cr levels need to keep acceptable levels [4]. Because of the existence of a number of chemicals with low biodegradability, treating tannery effluent is difficult and poses a significant environmental and technical issue, also becoming a major concern of the country [14].

Different types of techniques and strategies used for the remediations to treat tannery wastewater such as chemical coagulation, electrocoagulation, activated sludge, and chemical precipitation [15]. However, some of these physicochemical processes can be very costly, and they frequently generate large quantities of toxic chemical sludge, which can be difficult to dispose of.

Aquatic plants, especially submerged macrophyte can be used as potential removal medium of pollutant from the water polluted by tannery effluents. The metal accumulation characteristics of submerged aquatic macrophytes makes them an interesting research object for testing and modeling ecological theories on evolution and plant succession, as well as on nutrient and metal cycling [16]–[19]. Submerged vascular macrophytes influence the oxygen concentrations in water by releasing oxygen through their roots [20], [21]. Egeria densa is a fresh water submerged macrophyte, native to South America's subtropical region and can be found in all the continents except Antarctica. E. densa can be applied as a Cr(VI) biomonitor in aquatic environments [22]. Also this plant has the capability to reduce BOD (93%) and COD (95%) from textile wastewater [23]

In Bangladesh, Phragmites australis an emergent aquatic plant has been used before to treat the tannery waste water from a local tannery industry [24], however submerged macrophytes are not studied yet to treat the river water polluted by tannery effluents. In this context, the present study is designed to treat the polluted water (tannery effluent) collected from Dhaleshwari river using submerged macrophyte Egeria densa.

Thus, the purpose of the present study was to assess the use of E. densa for the upgradation of water quality of Dhaleshwari river polluted by tannery effluent, in laboratory context.

2. Methodology

The present study consists of two parts; 1st one Field work and 2nd one Laboratory based work. Field investigation has been carried out along the Dhaleshwari river, Savar, Bangladesh to collect the water samples, which are further analyzed in the laboratory and used for the experiment using submerged macrophyte *E. densa*. Laboratory experiment and all the analysis has been conducted in the Environmental Science Laboratory, Daffodil International University, Ashulia, Dhaka.

2.1 Study area and water sample collection

The study area covered a specified segment of Dhaleshwari River starting from Hazratpur Bridge (Kadamtoli) to Tetuljhora Bridge in the vicinity of Savar Tannery Industrial Park. Water samples were collected from six locations (S1, S2, S3, S4, S5, S6) (Fig. 1) covering approximately 2.5 miles of area. Sampling locations were selected on the basis of pollution level of water identified by literature review and preliminary observations. First three water samples were collected from the downstream zones, which are considered as River Water. Another three samples were collected from the effluent discharge point by the tannery industries and Central Effluent Treatment Plant (CETP). Sampling was conducted in November 2020. Total eighteen (6x3) water samples were collected by a 5L water container, which rinsed before with diluted Nitric acid (HNO_3). To avoid surface debris water samples were collected approximately 50 cm below from the river surface. The water samples were immediately carried to the laboratory for further analysis and laboratory treatment.

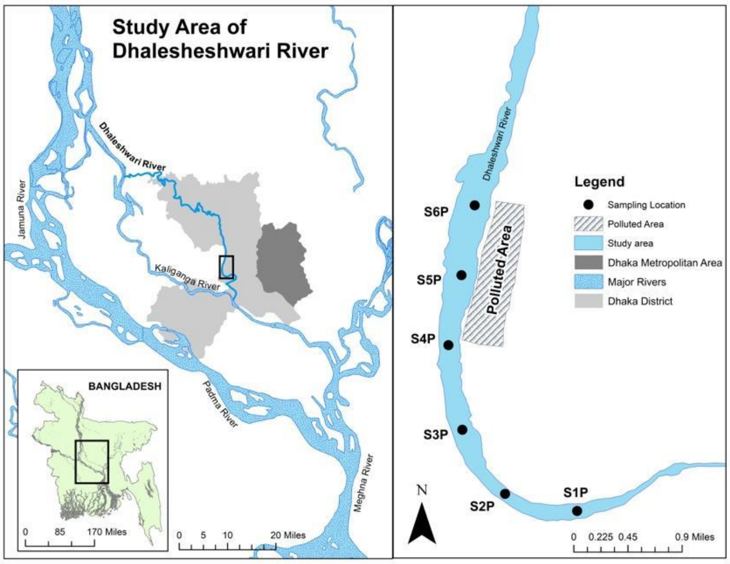

Figure 1. Location map of study area with sampling locations.

2.2 Plant cultivation and planting materials

Submerged macrophyte *Egeria densa* were collected from an aquatic plants farm in Dhaka, Bangladesh. Plants were transported to the laboratory as early as possible and immediately cultured in glass tanks under controlled conditions (temperature 23 ± 3 °C, DO

6–6.5 mg/L, pH 6–6.5). After one month acclimation experimental plants were obtained from the culture tanks for experimental treatment.

For plantation materials, fine sands were collected from a dredger of Turag river (23°50'24.0"N 90°20'28.6"E). The particle size of the sand was 0.125-0.063 mm. Dry sands are carried into a polyethylene bag and washed several times to remove organic matter, dusts and dried under the sunlight. Each experimental beaker was filled with 320g of dry sand that covers 2.60cm (1 inch) of the beaker height. All the beakers are filled up to 14.5 cm of the beaker height with wastewater of samples.

2.3 Experimental setup

The study was comprised of three treatments (1) Control- distilled water with necessary nutrients (n=3), (2) for River water- water collected from downstream area (less polluted) (n=9) and (3) for Polluted water- water collected from polluted area (n=9) (Fig. 2).

For each treatment three apical tips were clipped (approximately 13cm) and planted in a 1 liter 183 cm high glass beaker. The experimental setup was randomly designed. Initial measurements of all plant lengths, weights, root numbers, root lengths, branch numbers and branch lengths were recorded.

All the beakers were filled with appropriate water up to 14.5 cm of the beaker height. The experiment was conducted for 10 days and plants were monitored every day. Distilled water was used to fill the evaporation gap of water. The average light intensity and temperature of the experimental area were 2600 Lux and 23^oC. At the end of the experiment water samples and plant samples were collected from the beaker for further analysis.

Table 1. Pictorial presentation of Laboratory experiment setup (C, n=3; RW, n=9; PW, n=9).

Laboratory Treatment						
Control (C)	**River Water (RW)**			**Polluted Water (PW)**		
C_1	$S1P_1$	$S2P_1$	$S3P_1$	$S4P_1$	$S5P_1$	$S6P_1$
C_2	$S1P_2$	$S2P_2$	$S3P_2$	$S4P_2$	$S5P_2$	$S6P_2$
C_3	$S1P_3$	$S2P_3$	$S3P_3$	$S4P_3$	$S5P_3$	$S6P_3$

2.4 Morphological parameters of plant

After harvested plants were rinsed with distilled water and final shoot and root lengths were measured by ruler. The shoot growth rate (SGR) and root growth rate (RGR) were obtained by the difference between final and initial shoot lengths (length of the main stem and branches) and root lengths divided by experimental days and it was expressed in cm/day. Shoot weight rate (SWR) was measured by the difference between the final and initial weight of plants divided by the number of days and was calculated as mg/day.

2.5 Physico-chemical parameters of water

The physico-chemical parameters of initial and final water samples were analyzed following standard methodology [25]. The analyzed parameters included pH, Electrical Conductivity (EC), Total Dissolved Soild (TDS), Acidity, Alkalinity, Total Hardness, Ca Hardness, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Sulphate (SO_4^{2-}), Phosphate (PO_4^3), Total Chlorine (Cl^-), Copper (Cu^{2+}), Chromium Hexavalent (Cr^{6+}), Chromate (CrO_4^{2-}) and Dichromate ($Cr_2O_7^{2-}$) ion. Analytical methods for all the parameters are listed in

Removal Efficiency was calculated using following equations

$$\text{Removal efficiency, E} = \frac{Ic - Fc}{Ic} * 100,$$

Where, E= Removal efficiency (%); Ic = Initial concentration; Fc = Final concentration.

Table 2. Analytical methods for the physico-chemical parametrs of water.

	Physico-chemical parameters	Methods
1.	pH and Total Dissolved Solid (TDS)	*HANNA* Ph/EC/TDS/Temperature Meter (HI9814)
2.	Electrical Conductivity (EC)	*HANNA* EC Tester (HI98304).
3.	Dissolved oxygen (DO)	DO meter, LUTRON DO-5509
4.	COD, Sulphate (SO_4^{2-}), Phosphate (PO_4^{3}) Total Chlorine (Cl^-), Copper (Cu^{2+}), Chromium Hexavalent (Cr^{6+}), Chromate (CrO_4^{2-}) and Dichromate ($Cr_2O_7^{2-}$)	HANNA Multiparameter Photometer (HI83399) based on standard procedures as described by supplier.
5.	Total Acidity, Alkalinity, Total Hardness, Ca^{2+} Hardness	Titrimetric method

2.6 Statistical analysis

All experimental results are presented as the mean ± S.D. (n = 3, n=9). The data were analyzed using the one-way ANOVA followed by Duncan's multiple range tests to evaluate differences among means at a significance level of 0.05. Statistical analyses were performed using the software SPSS for Windows (Release v17.0, SPSS INC., Chicago, USA).

3. Results and Discussions

Submerged macrophyte *E. densa* can be able to survive and grow while exposed in all three types of treatment (Fig. 2). Though the morphological characteristics varied with treatment. The length of shoot calculated by SGR(cm/day) decreased significantly in Polluted Water treatment compared to Control and River Water treatment after 10 days exposure (Fig. 2a).

Surprisingly shoot weight rate and root growth rate increased significantly in Polluted water treatment compared to Control and River Water treatment. Previous literature already stated that high nutrient /polluted water inhibits the growth rate of aquatic plants [26], [27]. This might happen because in high nutrient conditions plants used their energy to gain weight rather than growing its length.

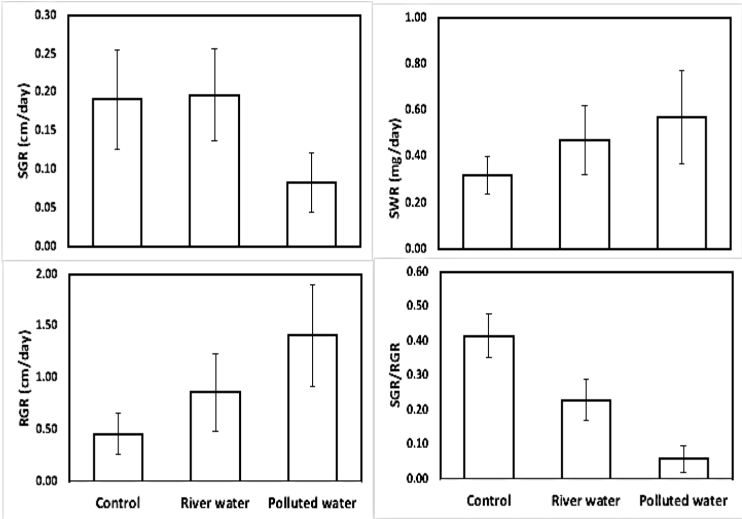

Figure 2. Morphological parameters of E. densa after 10 days exposure to control, River water and Polluted water (n=3, 9, 9 P<0.05).

Root growth rate also increases in polluted water compared to other two treatments. Aquatic plants always develop an extensive system of roots which helps them to accumulate contaminants by roots and shoots [17], [26], [28]. The ratio of SGR and RGR also expressed an indication of stress on plants. In the present study the ratio of SGR and RGR decreased significantly with the increment of pollution and indicated stress applied on *E. densa* (Fig. 2d). Previous study reported that pollution can be effected on the normal shoot and root growth rate and the ratio may decrease to overcome the stress [23], [24], [28].

Physico-chemical parameters of the aquatic environment are considered as one of the most important factors which are capable of influencing that environment [29]. The physico-chemical parameters of initial and final experimental water were statistically analyzed (minimum, maximum, average and standard deviation) and tabulated in Table 3. The pH and DO of the water do not change significantly for all three treatments. Electrical conductivity is the measure of the ability of an aqueous solution to transmit an electric current in aquatic environments [30]. EC also did not change significantly before and after the experiment for all the treatments. However, high levels of EC were found in both River water and polluted water (Table 3.).

Total dissolved solids (TDS) are the materials dissolved in water like bicarbonate, sulfate, phosphate, nitrate, calcium, magnesium, sodium and organic ions [29].In the present study high levels of TDS were observed in polluted water 310 mg/l and River Water 266.7 mg/l. The reason for high TDS along the river might be the textile effluent debris, agricultural runoff and liquid waste from urbanization. Present findings can be correlated with previous research [2], [6] TDS also not changed significantly after 10 days treatment with *E. densa*.

Chemical Oxygen Demand (COD) is an important parameter for wastewater to measure the amount of oxygen that is required to break down pollutants (organic substances) in water. Higher COD levels expressed greater demand for oxygen to break oxidizable organic matter, which ultimately reduced dissolved oxygen (DO) in the Aquatic body. So, less COD in aquatic areas denoted waste free water. In the present study COD decreased significantly in both River Water and Polluted Water treatment after 10 days exposure by *E. densa* and can remove 44.44% and 43.47% from River Water and polluted water respectively. Previous researchers also reported that submerged macrophytes can be able to remove morethan 40% COD from water [19].

The concentration of Cu^{2+}, Cr^{6+}, CrO_4^{2-}, $Cr_2O_7^{2-}$ significantly varied in polluted water conditions compared to River Water, which confirmed that the water is polluted with tannery effluent discharged by the leather industry around Savar area. In the present study, concentration of most of the analyzed parameters in polluted areas was found lower compared to previous work [2], [6]. COVID 19 pandemic may act as a reason behind this. Due to the pandemic a country wide lockdown was imposed for 2/3 months and most of the industrial sectors could not run their general production. As a result, the pollution level of Dhaleshwari river water reduced compared to previous analysis.

Table 3. Water quality parameters analyzed before (initial) starting and after (final) finish the experiment. The results expressed as Mean ± SD, where n=3 for Control, n=9 for River Water, n=9 for Polluted Water. $P<0.05$.* significantly varied.

	Physico-chemical Parameters	Control (Mean ± SD)		River Water (Mean ± SD)		Polluted Water (Mean ± SD)	
		Initial	Final	Initial	Final	Initial	Final
1.	pH	6.8± 0.15	6.9± 0.15	6.71± 0.05	7.13± 0.23	6.5± 0.07	7.1± 0.11
2.	DO (mg/l)	6.4±0.3	6.5±0.3	5.8±0.1	6.1±0.2	5.6±0.1	6.0±0.2
3.	EC (µS/cm)	47±6.1	48.3±4.7	266.7±5.8	256.7±11.5	310±10	296.7±11.5
4.	TDS (mg/l)	49±3.6	47±5.2	256.7±15.3*	223.3±20.8	300±17.3*	246±41.6
5.	COD (mg/l)	0	0	19.8±1.8	11.0±2.7	23.1±2.3	13.3±2.3
6.	Acidity (mg/l)	0	290±10	193.3±30.6	246.7±45	200±52.9	281±36
7.	Alkalinity (mg/l)	0	185±13.2	358.7±40.3	285.3±22.7	373.3±40.5	337.3±80.8
8.	Total Hardness (mg/l)	0.7±1.2	82.7±8.3	304±10.6	204±38.1	332±24.3	236±40
9.	Ca^{2+} (mg/l)	0	21.3±6.5	122.7±6.1	52.7±10.2	139.3±8.3	73.3±9.0
10.	SO_4^{2-}(mg/l)	0	0	26.7±2.9	25.0±3.0	35.0±5.0	35.0±5.0
11.	PO_4^{3-}(mg/l)	0	0.05±0	0.39±0.03	0.19±0.05	0.43±0.1	0.19±0.03
12.	Total Cl^- (µg/l)	3.3±5.8	4.4±5.8	33.3±5.8	27.6±5.8	70.3±12.1	23.3±5.7
13.	Cu^{2+}(mg/l)	0	0	103±22.1*	31±1	369±59.6*	19.3±4.6
14.	Cr^{6+}(µg/l)	0	0.7±0.6	13.2±2.8*	2.7±0.6	27.3±3.2*	13.7±5.0

15.	CrO_4^{2-} (µg/l) (I)	0	0	24.3±10.25*	5.7±1.3	70.3±12.1*	29.7±13.1
16.	$Cr_2O_7^{2-}$ (µg/l) (I)	0	0	19.7±3.1*	5.3±1.2	62.7±7.1*	25±8.1

The graphic distribution of Figure 3 established that submerged macrophyte *E. densa* has the ability to remove toxic metals from polluted water. Highest removal efficiency has been observed for Cu^{2+}(around 90%) from polluted water. The RE of Cr^{6+}, CrO_4^{2-} and $Cr_2O_7^{2-}$ for River Water and Polluted Water varies from 80%-73% and 50%-60%. Previous studies suggested that *E. densa* can segregate Cr species within its tissues and subsequently effuse them, which allow it to apply as a potential Cr(VI) biomonitor for aquatic environment [22].

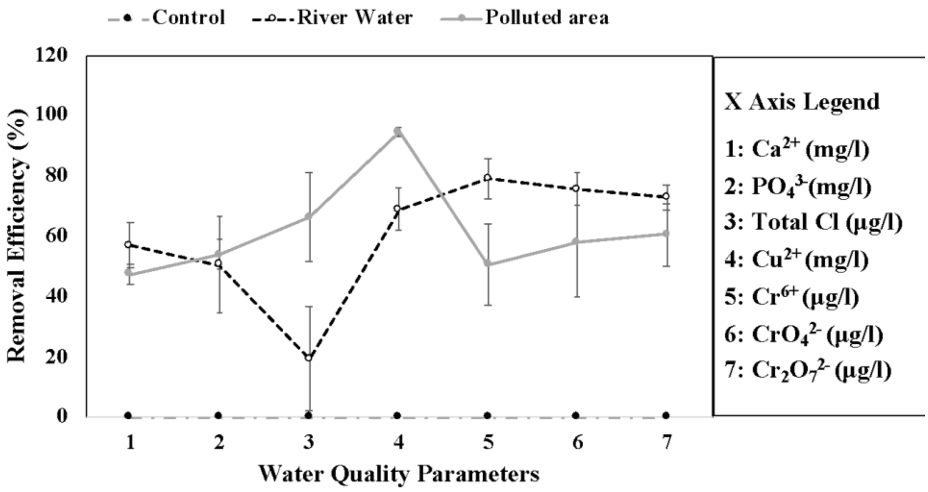

Figure 3. Removal efficiency of pollutants using E. densa after 10 days exposure to Control, River Water and Polluted Water (Dhaleshwari river) treatment.

4. Conclusion Remarks

The present study confirmed that the submergent macrophyte *E.densa* can be able to survive in both river water and polluted river of Dhaleshwari river in terms of morphological characteristics. Also *E. densa* has the ability to upgrade the water quality by removing some toxic elements (Cu^{2+},Cr^{6+}, CrO_4^{2-} and $Cr_2O_7^{2-}$) from water. Despite some limitations (heavy metal analysis of water and plant samples, biochemical analysis of plants) this study confirmed that submerged macrophyte *E. densa* can be used as a potential tool to upgrade the water quality of river polluted by tannery effluent.

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