Assessment of phytoremediation efficiency of selected aquatic plants for treating textile effluent

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Abstract

The Objective of the current study was to evaluate the water quality of textile effluents collected from three distinct zones in the Jaipur region of Rajasthan, India, viz. Sitapura, Sanganer, and Bagru. Results show high pH (8.62), TDS (73003mgL^{-1}), BOD (70.66mgL^{-1}), and COD (2851.9mgL^{-1}) levels including metals Cr (2.5mgL^{-1}), Cu (2.46mgL^{-1}), Zn (2.13mgL^{-1}), Mn (1.63mgL^{-1}), and Cd (2.06mgL^{-1}). For the phytoremediation study, fresh plants of *Eichhornia crassipes*, *Pistia stratiotes*, and *Spirodela polyrhiza* collected from the Dravyavati River, acclimatized, and grownat different concentrationsof textile effluent (5%, 10%, and 15%)in lab condition with a set of control plants for 15 days.The phytoremediation efficiency of selected plants was assessed during the entire experiment duration and observed that *Eichhornia crassipes* efficiently reduced BOD (32.81%), COD (40.44%), total suspended solids (28.94%), and total dissolved solids (21.82%) including metals (Cr (29.87%), Co (20.94%), Zn (25.78%), and Cd (26.19%) grown in 15% of textile effluent. Results indicate that *Eichhornia crassipes* emerged as an efficient phytoremediator plant for the treatment of textile effluents as compared to *Pistia stratiotes, and Spirodela polyrhiza*, however, employing all three aquatic plantsin combination could be more effective for developing biological wastewater treatment system for environmental protection and management.

Keywords: Textile effluents, Phytoremediation, Metals, Wastewater Quality, BOD

I. INTRODUCTION

At present textile industry is one of the most profitable industries in the Jaipur region. However, the industry may experience considerable operational costs and environmental issues because of the massive amounts of effluent that result from these processes [1]. Textile wastewater typically contains nitrogen, phosphates, hazardous compounds, oil, grease, and sulphides among other things. It is also frequently pigmented, extremely alkaline, and suspended solids (SS) with high COD [2].It is known that the dyes found in textile effluent are hazardous to both aquatic life and humans [3]. Consequently, releasing wastewater that hasn't been properly treated into the environment could harm both the ecosystem and human health [4]. However, due to the high costs associated with these technologies, many small and medium-sized enterprises find it challenging to utilize upgraded technology and commit resources to waste treatment operations. This circumstance frequently results in the illegal discharge of incompletely or improperlytreated effluent into the environment [5]. Therefore, finding new environmentally acceptable, economically viable wastewater treatment technologies is crucial for helping these sectors to effectively implement their wastewater treatment procedures.

Phytoremediation is the use of plant materials to remediate environmental toxins, it is a new, low-cost green technology that is adopted to treat effluents [5, 6,7]. It is a technique that is used to remediate soil texture and contaminated water by using aquatic plant species. In comparison to other physio-chemical and biological strategies for environmental cleanup, phytoremediation has become a more environmentally friendly, passive, solar energy-driven, and economical strategy [8, 9].For the recovery of polluted soil, wastewater, and land, phytoremediation is a technology that employs plants (Macrophytes) and algae [10, 11, 12]. The unique aspect of this work is the utilization of three macrophytes to treat the textile effluent, which is significantly contaminated with Cd, Fe, Cr, and Cu: *Pistia stratiotes*, *Eichornia crassipies* and *Spirodela polyrhiza*. *Pistia stratiotes*, often known as water lettuce, is one of the most productive freshwater aquatic plants in the world and is also regarded as an invasive species since it growsin wastewaters with high nutrient content, especially those that have been contaminated by fertilizers [13, 14]. The water hyacinth, *Eichhornia crassipes*, is a floating plant native to tropicaland subtropical areas and is regarded as the best plant for the rhizofiltration of toxic substances [15].The current study's objective is to evaluate how well the plants *Eichhornia crassipes, Pistia stratiotes*, and *Spirodella polyrhiza* can remediate textile wastewater using the phytoremediation mechanisms. For phytoremediation to be effective and cut down on the amount of time needed for treatment, the plants used in the process must have a considerable capacity for metal absorption, accumulation, and strength [16, 17].As a result, it was alsoplanned to evaluate the efficacy of pollutant removal and research the processes by which the selected floating macrophytes remove metals.

2. Methodology

2.1 Sampling Site

A total of ten sites along with the SitaPura, Sanganer, and Bagru textile area, located in the Jaipur region (Rajasthan, India) were collected for plants as well as for water sample collection. These sites were near Sitapura industrial area, Sanganer industrial area, and Bagru textile area where the mixing point was the Dravyavati River. First of all water samples were collected into fresh and acidified plastic bottles (2L) and preserved at 4^0C in the laboratory. Plant samples werealso collected randomly from the same places and river sites from where water samples were collected and directly brought to the lab, thoroughly washed with distilled water, and then planted into normal tap water [18].

2.2 Initial water quality parameters

Some parameters were analyzed on the same sampling sites like pH, Conductivity, Turbidity, and Temperature with the help of the water analysis kit. Unacidified water was also collected for the determination of BOD and COD. To evaluate the quality of wastewater all the physicochemical parameters were determined in triplicate form by using standard method [18, 19]. Heavy metals like Cr, Pb, Zn, Mn, and Cu were determined by atomic absorption spectrophotometer after digestion with HNO_3.

2.3 Phytoremediation potential assessment

First of all four different dilutions i.e. 5%, 10%, 15%, and 20% were prepared to examine the plant growth within 24 hours. In three dilutions plants survived but in 20% dilutions plants died within 24 hours, hence a total of three dilutions (5%, 10%, and 15%) were prepared with the one control sample into separate containers. Experiments were performed for all ten samples intriplicate form over the 15 days of the experimental period. For sunlight exposure containerswere placed in open sunlight. Loss in water due to evaporation was compensated by adding distilled water on a routine basis.

2.4 Post-Experimental Setup

The physicochemical parameters were analyzed for water and plant samples before and after treatment including all dilutions (5%, 10%, 15%, and control condition) to evaluate the percentage of the reduction of the effluent after 1week of the following equation were used i.e.

Percentage Reduction -

$$\frac{The\ initialconcentrationof\quad Effluent\ - Concentrationaftertime}{the\ initialconcentrationofEffluent} \times 100$$

To determine the statistically significant level between the controls and the treated samples, the mean concentration from all the effluents was compared by one-way ANOVA test in Microsoft Excel by statistical formula. To identify the heavy metal absorption capacity plant material Bioconcentration factor (BCFs) were also calculated to identify the heavy metal absorption capacity of the plant by the following equation

$$\text{BCF's} = \frac{C}{Cw}$$

Where C - Contaminant concentration in the plant tissue

Cw- Contaminant concentration in the effluent water

Translocation factor (TFs) (ratio of metal in shoot versus roots) [Table 3.] were also studied which shows the accumulation of metals was largely retained in roots as compared to shoot. This translocation factor mainly depends upon the concentration of metal on the root and shoot.Phytoremediation in textile effluent treatment.TF = $\frac{As}{Ar}$

Where As- Amount of trace element i.e. accumulated in shoots (mg/kg) dry weight

Ar- Amount of trace element i.e. accumulated in roots (mg/kg) dry weight

3. Results & Discussion

All the physicochemical parameters of the different textile effluent collected from the Jaipur region, Rajasthan, India have been depicted in Table 1.

3.1 Variations in pH

The pH of the wastewater in the control and treatment tanks varied during the experiment, varying from 7.2 to 8.2 (Table.1). For the reduction of the pH total of three plant species were used, and there was a small pH reduction in those water treatment tanks as compared to the reference. The pH levels observed across all media were favorable for microbial activity to breakdown the organic materials contained in the wastewater [20].

3.2 Reduction level of TDS and TSS

The initial TDSlevel for the effluent was 73003 mg/L and for TSS it was 7000 mg/L, respectively. After a 15-day testing period, Table 2 shows the average values for TDS and TSS after treatment. After 15 days, the average values in the control tanks and the plant-filled tanks were significantly (p 0.05) lower. After 15 days, the *E. crassipes* treatment showed the largest TDS reduction (26.22%). Also, there were noticeable variations in the TDS levels between the control and treatment tanks (Table. 2). TSS was efficiently reduced from the initial levels by *E. crassipes* (30.68%), *P. stratiotes* (27.05%), and *S. polyrhiza* (28.94%) [21]. The average TSS levels found in the treatment tanks and the control tanks are shown in Figure 1. *E. crassipes* treatment tanks demonstrated the largest TSS reduction compared to other treatments and the control (30.68%). However, *P. stratiotes* and *S. polyrhiza* were also effective but they did not report a substantial decrease in average TSS; instead, they recorded greater levels of TSS thanthe control tanks [21]. The interrelationship between TDS and TSS also represented by linear regression in Figure.2.

3.3 Reduction level of BOD and COD

The wastewater's initial BOD and COD concentration was 70.66 mg/L and 2851 mg/L.Table 2 displays the average BOD and COD levels for all three treatment tanks as well as for the control tanks after a 15-day testing period. After 15 days, there was a substantial (p 0.05) decrease in the average BOD and COD values measured in the control tanks and the plant-filled tanks i.e. 27.64, 30.63 and 30.15mg/L for BOD and for COD it was 952.6, 1013.7, and 995.8mg/L. However, the concentrations of COD in the tanks housing the three plant groupings did not differ noticeably from one another. After 15 days, a relatively highest reduction percentage for BOD (38.3%) and COD (43.48%) for COD was noted for the control by *E. crassipes* [21, 22]

3.4 Reduction in Cr concentration

The effluent had 2.5 mg/L of chromium at its initial concentration. The average Cr values after a 15-day study period (After treatment) are shown in Table 2. The difference between the *E. crassipes*, *P. stratiotes*, and *S. polyrhiza*-infested tanks and the control tanks was statistically significant (p 0.05). Yet, over a 15-day testing period, *P. stratiotes* and *S. polyrhiza* showed significantly different chromium levels from *E. crassipes* and the control tanks. The above table shows the percentage reduction in the treatment tank *by E.crassipes* and control tanks during the 15-day experiment. Chromium levels considerably dropped by 32.67%, 29.69%, and 29.87% in the tanks containing *E. crassipes, P. stratiotes*, and *S. Polyrhiza*, respectively.

3.5 Reduction in Cd concentration

The wastewater's initial Cd content was 2.06 mg/L following a 15-day trial period, Table 2 displays the average Cd levels for all treatment tanks. The average Cd values in the control tanks and the tanks filled with plants both significantly (p 0.05) decreased after 15 days. One of the tanks treated with *E. crassipes* had the highest Cd reduction of the three plant species tested (29.56%), while *P. stratiotes* and *S. polyrhiza* revealed a similar decrease in efficiency (nearly 25%).

Table 1: Wastewater quality parameters of textile effluent collected from Sitapura, Sanganer, and Bagru sites, in the Jaipur regions of Rajasthan, India.

Sites	pH	Turb. (NTU)	Cond.(μ s cm-1)	DO	BOD	COD	TSS	TDS	Cu	Cr	Cd	Zn	Mn
Gajala Dyeing	7.93	18.33	1340.66	7.05	41.1	1902.63	7000.33	54005	1.06	0.16	N.D	1.26	1.23
Sanganer	± 0.05	± 0.57	± 4.61	± 0.05	± 5.19	± 3.17	± 0.57	± 8.66	± 0.11	± 0.05		± 0.05	± 0.05
Bambala	7.04	10.66	1476.66	NIL	44.4	2851.9	1000.66	3014.33	1.26	0.83	N.D	1.36	1.26
Sanganer	± 0.01	± 0.57	± 1.52		± 1.03	± 1.21	± 1.15	± 1.15	± 0.05	± 0.05		± 0.11	± 0.05
Paradai	7.33	133.66	1173.33	8.49	55.53	1901.8	599.33	3498.66	1.43	0.86	N.D	N.D	1.06
Industry	± 0.30	± 1.15	± 4.61	± 0.05	± 0.46	± 1.73	± 1.15	± 2.30	± 0.11	± 0.05			± 0.11
Aryan	8.06	106.66	3271.66	1.47	35.4	1123.33	1502	11450.67	2.46	0.7	N.D	1.46	1.16
Dyeing	± 0.15	± 1.15	± 6.35	± 0.05	± 0.51	± 0.57	± 3.46	± 9.81	± 0.05	± 0.17		± 0.05	± 0.15
KR/CA	7.03	61.66	2576	3.75	40.8	777.73	1004	7021.66	1.43	0.66	2.06	1.53	1.63
Sanganer	± 0.05	± 2.30	± 1.73	± 0.05	± 0.51	± 0.23	± 6.92	± 1.52	± 0.01	± 0.11	± 0.05	± 0.05	± 0.05
Cheer Sagar	7.65	88.33	1789.33	1.26	70.66	1730.33	1000.66	3793	1.4	2.5	N.D	N.D	1.23
Sitapura	± 0.07	± 1.15	± 2.08	± 0.15	± 1.15	± 4.04	± 1.15	± 6.08	± 1.56	± 0.1			± 0.05
Somani	8.26	22.33	1529.33	7.77	53.4	1803.33	502	3684.66	1.33	1	N.D	1.46	1.13
Fabrics	± 0.11	± 0.57	± 3.21	± 0.05	± 0.51	± 1.52	± 3.46	± 3.78	± 0.05			± 0.05	± 0.11
Bagru textile	8.62	7.66	3329.66	3.27	25.8	1986.56	601	9556.66	1.06	1.63	N.D	2.13	1.16
Area	± 0.34	± 0.57	± 4.61	± 0.05	± 1.03	± 1.09	± 1.73	± 1.15	± 0.11	± 0.05		± 0.11	± 0.15
Bagru textile	8.01	7.33	3995	96	51	951.03	999.33	15003.33	1.56	1.53	N.D	N.D	1.23
Area	± 0.05	± 0.57	± 1.73	± 0.25	± 0.05	± 1.09	± 1.15	± 5.77	± 0.05	± 0.05			± 0.05
Bagru textile	7.43	379	1903.33	4.89	25.8	1814.36	5500.66	73003	2..16	1.56	N.D	N.D	1.36
Area	± 0.01	± 1.73	± 0.57	± 0.05	± 0.51	± 0.05	± 1.15	± 5.77	± 0.05	± 0.11			± 0.05

All units are in mgL^{-1} or otherwise stated*Turb* turbidity, *Cond* conductivity, *DO* dissolve oxygen,*BOD* biological oxygen demand, *TSS* total suspended solids, *TDS* total dissolved solids, and *COD* chemical oxygen demand.

3.6 Reduction in Cu concentration

The initial maximum Copper concentration in the effluent was 2.46 mg/L. Table 2 shows the average Cu levels after a 15-day experiment in three treatment tanks and the control tank period. The average Cu values obtained in the plant-filled tanks were significantly (p 0.0 5) lower after 15 days than in the control tanks. *E. crassipes'* tank, as compared to *P. stratiotes'* tank (19.88%) and *S. polyrhiza's* tank (20.94%) had the highest Cu reduction percentage (22.07%) [23].

Table 2: Changes (%) in wastewater quality parameters of textile effluent treated with *Eichhornia crassipes, Pistia stratiotes,* and *Spirodela polyrhiza* after 15 days of treatment duration.

Parameters	Initial Concentration	*Eichhornia crassipes*		*Pistiastratiotes*		*Sprirodelapolyrhza*	
	in WW	Final concentration (WW)	% Change	Final concentration	% Change	Final concentration	% Change
pH	8.52 ± 0.89	7.82 ± 0.93	10.92	7.83 ± 0.93	8.1	7.80 ± 0.93	7.25
EC (μs cm^{-1})	2253.2 ± 0.520	1296.6 ± 6.80	42	1372.6 ± 6.94	38	1357.6 ± 5.27	39
Turbidity	83.5 ± 0.05	35.7 ± 8.47	51	38.3 ± 0.35	40	38.17 ± 4.37	43
BOD	45.97 ± 1.36	27.64 ± 8.51	38.3	30.63 ± 8.96	31.46	30.15 ± 9.53	32.81
COD	1684.4 ± 0.74	952.6 ± 7.45	43.48	1013.7 ± 2.07	39.36	995.8 ± 8.40	40.44
TDS	18500± 0.03	13194.5± 1.63	26.22	14028.6± 0.99	21.48	13727.5± 9.99	21.82
TSS	1960± 8.05	1341.8 ± 1.56	30.68	1404.3 ± 8.98	27.05	1371.3 ± 4.38	28.94
Cr	3.85 ± 0.16	2.59 ± 0.26	32.67	2.71 ± 0.26	29.69	2.70 ± 0.25	29.87
Co	4.70 ± 0.32	3.63 ± 0.25	22.07	3.73 ± 0.25	19.88	3.69 ± 0.24	20.94
Zn	3.34 ± 0.33	2.45 ± 0.15	28.21	2.58 ± 0.13	24.51	2.53 ± 0.10	25.78
Cd	1.88 ± 0.11	1.32 ± 0.14	29.56	1.4 ± 0.13	25.65	1.38 ± 0.12	26.19

All units are in mgL^{-1} or otherwise stated.EC: Electrical conductivity, TS: Total solid, TSS: Total suspended solids, TDS: Total dissolved solids; PO: Phosphate; NO: Nitrate; DO: Dissolveoxygen; BOD: Biological oxygen demand. All values are means ± SD.

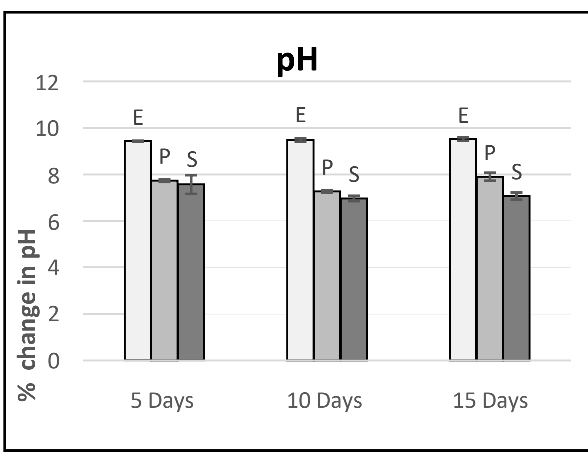
3.7 Reduction in Zn concentration

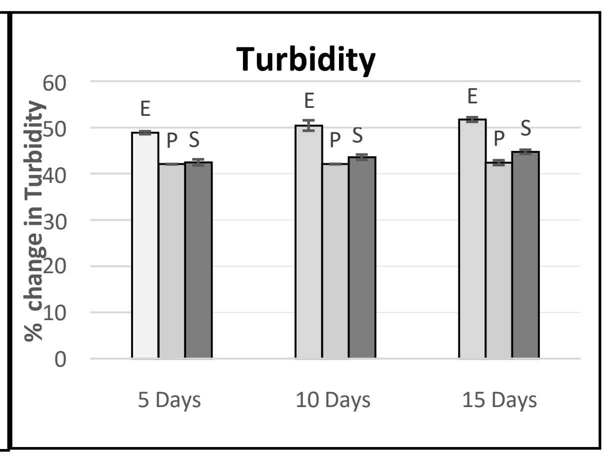
The wastewater's initial highest Zn concentration was 2.13 mg/L. After a 15-day trial, Table 2 shows the typical Zn concentrations in the three treatment tanks as well as in the control tank. After 15 days, there was a difference in the average Zn levels between the control tanks and the tanks containing statistically significant plants (p 0.05). During the trial period, there was a noticeable decrease in Zn in the treatment tanks. Zn levels were reduced by almost 100% intanks holding three different plant species the results reported earlier [23, 24].

Table 3: Comparison of the concentrations of different metals in fresh and spent plants.

	Eichhornia crassipes		*Pistia stratiotes*		*Spirodela polyrhiza*	
Metal	Fresh	Spent	Fresh	Spent	Fresh	Spent
Cr	0	1.371	0	1.298	0.0314	1.197
Cu	0.052	1.039	0.058	1.293	0.059	1.618
Zn	0.349	1.414	0.125	1.394	0.128	1.363
Mn	1.419	1.687	0.023	1.092	0.785	0.921

Values are in mg/kg.





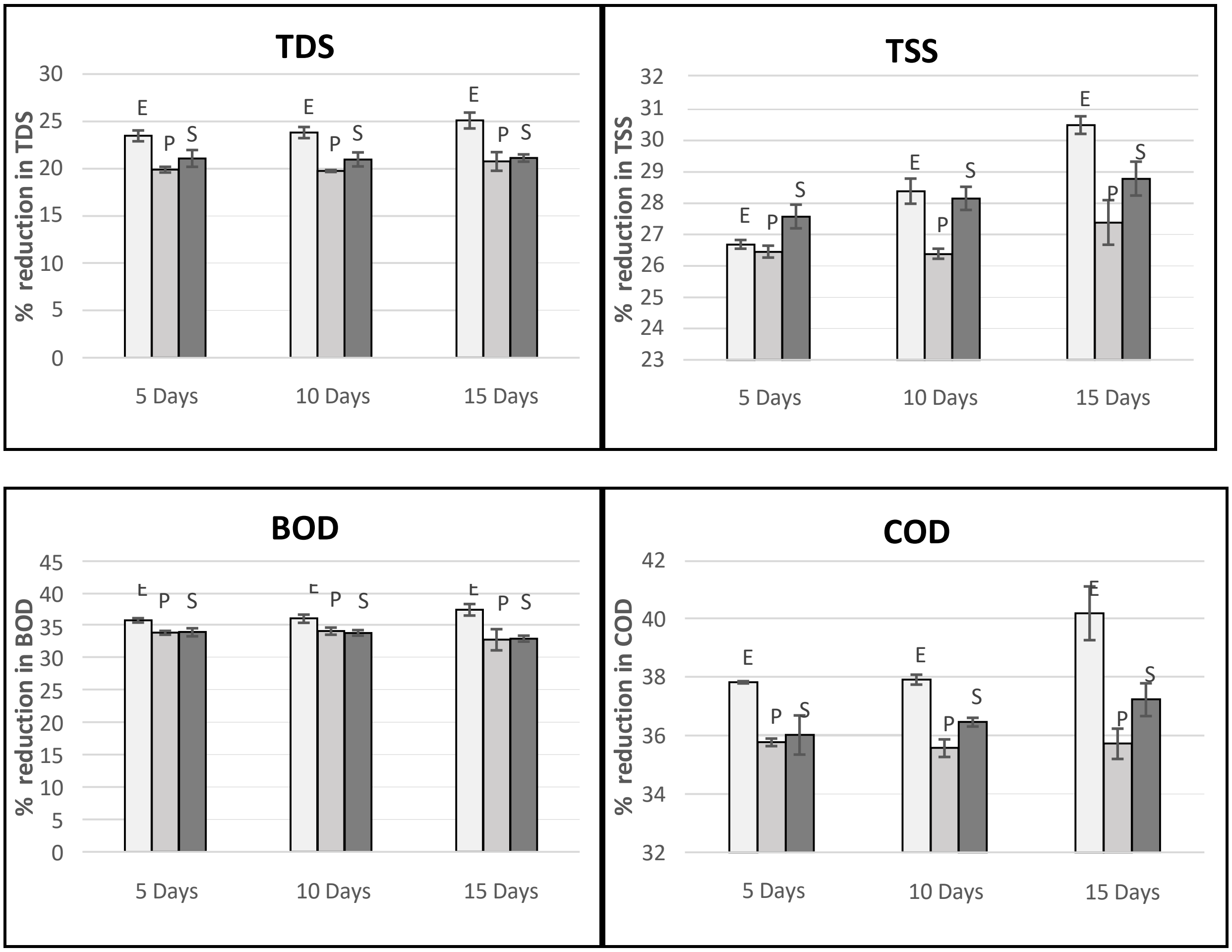


Fig. 1. Phytoremediation potential of aquatic plants i.e. *Eicchornia crassipes*, *Pistia stratiotes* and *Spirodela polyrhiza* at different retention time in 15% concentration in wastewater.

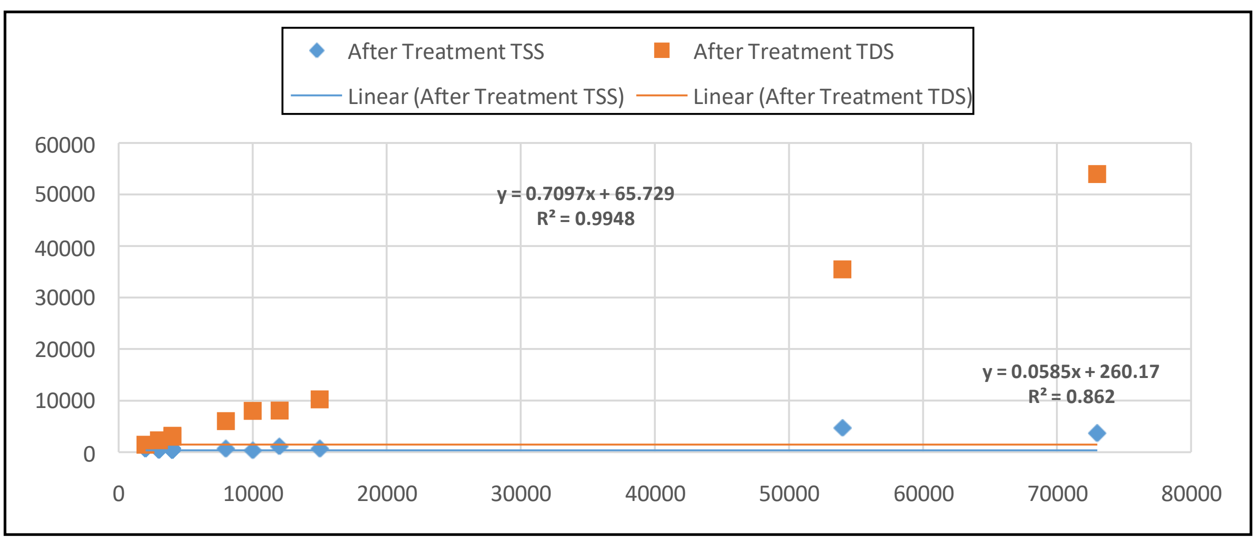


Fig. 2. Linear regression between TDS and TSS, before and after treatment in textile effluents collected from three different sites i.e. Sanganer, Sitapura, and Bagru textile area of Jaipur regions, Rajasthan, India.

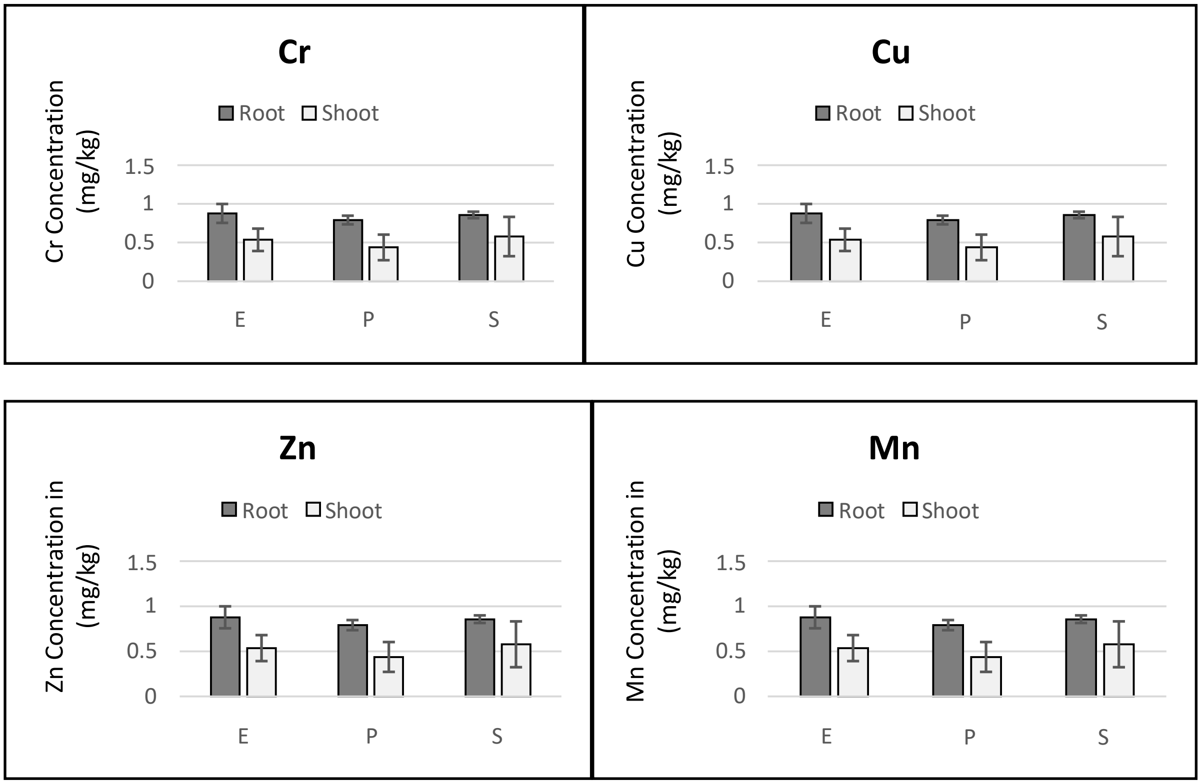


Fig.3. Metal concentration in the root and shoot of *Eichhornia crassipes*, *Pistia startiotes*, and *Spirodela polyrhiza* treated with textile effluent in 15% concentration of textile effluent for 15 days.

The findings of this study reveal the effectiveness of all three aquatic plant species in eliminating contaminants from textile effluent. In comparison to the control tank, treatment tanks supplied with three plant types showed a clear reduction of > 40% COD in textile wastewater. Results are also showing that *Eicchornia crassipes* have a higher tendency for the reduction (43%) of the COD level after 15 days as compared to *Pistia stratiotes* and *Spirodela polyrhiza*. The presence ofplants in wastewater improves the level of Dissolve Oxygen by photosynthesis reaction which directly improves the metabolic activity of aerobic microorganisms that degrades the load of organic waste in wastewater hence subsequent reduction of COD in the water sample. All three ofthe chosen plants, *Eicchornia crassipes*, *Pistia stratiotes*, and *Spirodela polyrhiza*, weresuccessful in reducing TSS and TDS in wastewater, with *Eicchornia crassipes* having thegreatest success (30.68% and 26.22%).The plant roots function as an inert solid matrix on which the microorganisms are connected in the reduction of TSS and TDS. Most of the suspendedsolids are also attached to the plant roots where microorganisms aggregate smaller particles to form larger particles that can settle down easily. These plants' roots have a strong propensity to draw oppositely charged colloidal particles, which stick to the roots and are progressivelyingested and assimilated by microbes. Plants also absorbed the nutrient and ions hence reducing TDS levels in the wastewater. High TDS levels are also taken up by plants through phytodegradation and ion uptake. Additionally, the oxidation process carried out by microorganisms removes dissolved solids. The metal concentration in the root and shoot of *E. crassipes*, *P. startiotes*, and *S. polyrhiza* exposed to a 15% concentration of textile effluent was analyzed. The results indicated varying levels of metal accumulation, highlighting the potentialof these aquatic plants for metal [Figure.3].

4. Conclusion

The wastewater from the textile industry contains high concentrations of heavy metals (Cr, Cu, Zn, and Mn) and poisonous dyes for aquatic life. It was discovered that *Eichhornia crassipes* had a relatively important role in the uptake of metals without the need for costly treatment procedures and with no energy usage. *Eichhornia crassipes* eliminate a higher percentage of metals during a six-day experiment. The *Eichhornia crassipes*, commonly known as Water hyacinth, have been discovered to be essential for eliminating metals from textile effluentwithout the use of expensive treatment methods or energy. In experiments spanning 15 days, *Eichhornia crassipes* consistently demonstrated a higher percentage of metal removal compared to other methods. Its effectiveness, coupled with its eco-friendly and cost-efficient nature, makes it the best method for treating textile effluent contaminated with heavy metals and toxic dyes. Integrating *Eichhornia crassipes* into wastewater management strategies with other efficient aquatic plants offers a sustainable solution for the textile industry's environmental challenges andtheir mitigation measures.

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