

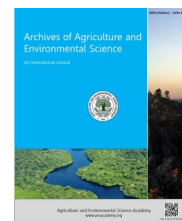


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ORIGINAL RESEARCH ARTICLE



Phyto-adsorption treatment of paper mill effluent using leaf powder of water hyacinth (*Eichhornia crassipes* [Mart.] Solms)

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ABSTRACT

In this present study, an experiment was performed to find the potential of leaf powder of water hyacinth (*Eichhornia crassipes*) in treating paper mill effluent. During the study the value of different parameters viz., pH (5.80±0.10), TDS (980.22±12.52 mgL⁻¹), EC (6.52±0.11 dS m⁻¹), BOD (86.42±4.61 mgL⁻¹), COD (281.01±8.66 mgL⁻¹), PO₄³⁻ (71.46±6.00 mgL⁻¹), TKN (84.99±3.92 mgL⁻¹), Na (136.94±6.66 mgL⁻¹), K (95.01±3.48 mgL⁻¹) and total hardness (442.39±3.78 mgL⁻¹) of paper mill effluent were recorded higher before bio-adsorption treatment using leaf powder of *E. crassipes*. The leaf powder of *E. crassipes* significantly (P<0.05/P<0.01) removed TDS, EC, BOD, COD, TKN, Na, K and total hardness of the paper mill effluent. The result of the present study on the bio-adsorption treatment using leaf powder of *E. crassipes* of paper mill effluent showed maximum reduction in the effluent characteristics viz., pH (6.62±0.08), TDS (848.42±7.67 mgL⁻¹), EC (4.08±0.17 dS m⁻¹), BOD (62.56±3.39 mgL⁻¹), COD (218.11±8.59 mgL⁻¹), PO₄³⁻ (50.13±4.33 mgL⁻¹), TKN (63.04±6.47 mgL⁻¹), Na (100.06±6.99 mgL⁻¹), K (66.00±7.38 mgL⁻¹) and total hardness (347±9.86 mgL⁻¹) of paper mill effluent after bio-adsorption treatment using leaf powder of *E. crassipes*. The maximum removal of TDS (13.45%), EC (37.43%), BOD (25.89%), COD (22.38%), PO₄³⁻ (29.85%), TKN (25.83%), Na (26.94%), K (30.54%) and total hardness (21.56%) in the paper mill effluent were recovered after phyto-adsorption treatment using leaf powder of *E. crassipes*. The decrease of paper mill effluent parameter is likely due to that the leaf powder of water hyacinth absorbs the nutrient from the effluent. Therefore, the leaf powder of can be used as phyto-adsorbent for the removal of various pollution parameters.

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INTRODUCTION

In the recent times, the industrial pollution has emerged as a major threat to water resources around the world, particularly in the Global South (developing countries) where a scenario prevails that the pollution is a price to pay for progress (Greenpeace, 2011). This view is generally associated with numerous thoughts that the dealing with pollution is too costly, pollution prevention is too difficult and impractical; and that environmental and social impacts can be dealt with in the future. In contrast, the case studies from the Global North (developed countries) have exposed the extent to which persistent and bio-accumulative substances that had contaminated the regions till date, show the immense difficulties and a very high expense of restoration programmes and the impossibility of total decontamination (Greenpeace, 2011).

The paper industries are the sixth biggest noxious waste producing industries of the world. Paper manufacturing is an agro-based industry. The fast growth in population and the higher demand for industrial establishment to meet human necessity have produced evils such as overexploitation of

obtainable resources and pollution of the land, air and water (Kumar *et al.*, 2017a, b). The effluent generated is characterised by dark colour, foul odor and high organic content and extreme quantities of chemical oxygen demand (COD), biochemical oxygen demand (BOD) and pH (Pokhrel *et al.*, 2004). The dark colour in paper mill effluent is caused due to the presence of organic ligands such as wood extractives, resins, products (Deilek *et al.*, 2001).

Industrialization has become an important factor to the development of a country's economy, through the establishment of plants and factories. However, the waste or by-products discharged from them are severely disastrous to the environment consists various kind of contaminant which contaminate the surface water, ground water and soil (Kumar *et al.*, 2016; Kumar and Thakur, 2017). The application of microbial or plant biomass could be an effective, low cost and ecofriendly means for removal and/or recovery of toxic metals from contaminated wastewater and industrial effluents, even at low concentrations. Certain aquatic and terrestrial plants, composed of lignin, cellulose, hemi-cellulose, pectins, phytic

acid and many proteins offer active sites such as carbonyl (CO), carboxyl (-COO), hydroxyl (-OH), amino (-NH₂) and sulfhydryl (-SH) groups for binding of metal cations and make them popular for removing metals from contaminated waters (Shweta and Rai, 2010). Application of aquatic macrophytes in phytoremediation of industrial effluent has become popular due to the high cost and energy intense treatment technologies. Phytoremediation is the use of aquatic plants to remediate the organic and inorganic contaminants present in the industrial effluent. Aquatic macrophytes are accomplished to eliminate a broad range of nutrients as well as heavy metals from industrial effluent (Kumar *et al.*, 2016; 2017c).

There is, however, a great need to undertake research to quantify the levels of damage and the costs of control, loss of livelihood, disease, and disruption of normal operations caused by water hyacinth (Nakanishi *et al.*, 2002; Okafor *et al.*, 2012; Pagnanelli *et al.*, 2003; Rahman *et al.*, 2005; Wirasmita *et al.*, 2014; Tsai *et al.*, 2006; Wan Ngah and Hanafiah, 2008; Wang *et al.*, 2010). Many researchers have been reported the removal of different pollutants parameters from wastewater, industrial effluents and synthetic aqueous solutions using various plant based phyto-adsorbents (Annadurai *et al.*, 2003; Ahmaruzzaman, 2008; Jain *et al.*, 2010; Chang *et al.*, 2012; Chairgulprasert *et al.*, 2013; Lazim *et al.*, 2015). Keeping in view the pollution due to the discharge of the paper mill effluent and ecological importance of water hyacinth (*Eichhornia crassipes*), the present research work was carried out to study the phyto-adsorption treatment of paper mill effluent using leaf powder of *Eichhornia crassipes*.

MATERIALS AND METHODS

Study sites: Star Paper Mill Ltd. Saharanpur, (Uttar Pradesh) was selected for the collection of paper mill effluent. The Star Paper Mill is located about 61.6 km away from Gurukula Kangri Vishwavidyalaya (Haridwar) in the north east. The plants of water hyacinth (*Eichhornia crassipes*) were collected from the local pond situated at Jamalpur Kalan village (29.9120°N and 78.1308°E) Haridwar (Uttarakhand), India. Fresh plants of water hyacinth were collected from local pond in Jamalpur village in Haridwar district. Leaves of the water hyacinth were plucked out and washed with double distilled water, and then it is left in sunlight until it is completely dried. Then with the help of mortar and pestle leaf samples were crushed into very fine particle. At last leaves of water hyacinth practical is sieved with a uniform particle sized 1.5 mm for experimental use and kept in air tight plastic bags.

Collection of paper mill effluent and analysis: The Star Paper mill effluent was collected from the untreated discharge channel outlet at Star Paper Mills Ltd. Saharanpur, (29° 56'13.04"N 77°34'11.28"E) Uttar Pradesh. The samples were collected in thoroughly cleaned plastic container of 10 liters capacity provides with the double cap device. Some of the parameters like pH were carried out on the spot and dissolved oxygen (DO) was also fixed on the spot because time consumed during transportation could alter the results. Remaining parameters could be carried out on composite sample. The collected effluent samples of the paper mill effluent were brought to the laboratory. The effluent was analyzed before and after phyto-adsorption for different physico-chemical parameters viz., pH, total dissolved solids (TDS), electrical conductivity (EC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate (PO₄³⁻), total Kjeldhal nitrogen (TKN), sodium (Na) and potassium (K) using water hyacinth (*E. crassipes*) at 6, 12, 24, and 48 hours,

respectively. The samples were analyzed for various physico-chemical parameters by following standard techniques (APHA, 2012; Chaturvedi and Sarkar, 2006).

Experimental design: Four glass jars of 4 liters capacity were used for the phytoremediation study. A total 16 liters paper mill effluent were taken into four glass jar separately. Thus each glass jar contained 4 liters of paper mill effluent. 100 g air dried biomass of water hyacinth was transferred in the effluent and mixed as well as shacked it thoroughly. The experiments were conducted for 6, 12, 24 and 48 hours of retention time.

Statistical analysis of data: The values reported in the present study were the mean of three replicates. The means were calculated with the help of MS Excel 2010 while the graphs were plotted with the help of Sigma plot, 2000.

RESULTS AND DISCUSSION

Characteristics of paper mill effluent: The mean±SE of various physico-chemicals characteristics paper mill effluent are given in Table 1. During the present study, the values of TDS (980.22 mgL⁻¹) of paper mill effluent were recorded within the prescribed limit of Indian Standards for irrigation water (BIS, 2012). The higher values of TDS in the paper mill effluent were recorded as compared to the control (Bore well water) and this is likely due to the utilization of agro-residues in the manufacturing of paper by the paper mill (Table 1). Kumar and Chopra (2012) also recorded slightly lower values of TDS (860±5.50 mgL⁻¹) in the paper mill effluent. The pH of paper mill effluent was slightly acidic (5.80) in nature and it might be due to the use of acidic matters in the production of pulp from the raw material. The value of EC in the paper mill effluent was also noted to be higher and it is likely due to the presence of more ionic species in the paper mill effluent (Table 1). Higher values of EC (6.84±0.40 dS m⁻¹) were also reported by Kumar and Chopra (2012, 2015) in the untreated paper mill effluent. The results showed that the values of BOD (106.42 mgL⁻¹), COD (281.01 mgL⁻¹) in the paper mill effluent were found beyond the irrigation standard (Table 1). The higher values of BOD and COD in the paper mill effluent are likely due to the presence of more degradable or oxidizable organic matter, inorganic chemical species or dissolved solids in the paper mill effluent as earlier reported by Kumar and Chopra (2012b). Ghaly *et al.* (2011) reported higher BOD (1874.20 mgL⁻¹) and COD (2450.60 mgL⁻¹) in the paper mill effluent.

During the present investigation, the values of Na⁺, K⁺, TKN, PO₄³⁻ and total hardness in the paper mill effluent were also found higher compared to the BIS standards (Table 1). The findings were in accordance with those of Patterson *et al.*, (2008) who reported higher values of Na⁺ (70.90 mgL⁻¹), and PO₄³⁻ (64.98 mgL⁻¹) in the paper mill effluent.

After phyto-adsorption treatment using leaf powder of water hyacinth the value of TDS (951.33±9.56, 888.49±8.53, 855.96±7.50 and 848.42.18±7.67 mgL⁻¹), EC (5.95±0.11, 4.92±0.15, 4.11±0.18 and 4.08±0.17 dSm⁻¹), pH (6.07±0.01, 6.24±0.14, 6.61±0.12 and 6.60±0.08), BOD (84.49±5.64, 77.93±4.92, 63.77±4.40 and 62.56±3.39 mgL⁻¹), COD (274.57±9.85, 248.54±4.29, 220.29±9.03 and 218.11±8.59 mgL⁻¹), PO₄³⁻ (69.51±5.02, 62.09±4.98, 51.42±4.24, and 50.13±4.33 mgL⁻¹), TKN (80.92±3.09, 75.22±5.01, 64.05±8.56 and 63.04±6.47 mgL⁻¹), Na (133.31±3.60, 127.50±4.87, 101.91±13.16 and 100.06±6.99 mgL⁻¹), K (89.90±2.34, 80.56±3.56, 66.76±7.29 and 66.00±7.38 mgL⁻¹) and total hardness (421.89±3.02, 395.74±4.54, 362.56±9.15

and $347 \pm 9.86 \text{ mgL}^{-1}$) were decreased after 6, 12, 24 and 48 hours of phyto-adsorption treatment experiments, respectively (Table 1; Figure 1-5). Moreover, application of leaf powder of *E. crassipes* as phyto-adsorbent showed significant ($P < 0.05$ / $P < 0.01$) effect on the removal of TDS, EC, BOD, COD, TKN, Na, K and hardness of the paper mill effluent at 12, 24 and 48 hours of phyto-adsorption treatment.

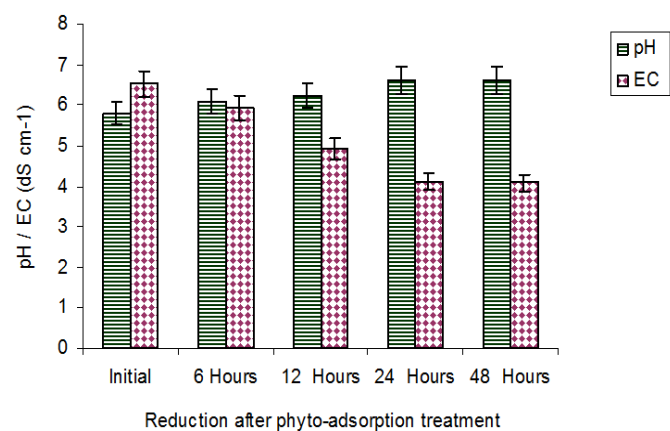
Additionally, the removal efficiency of the leaf powder of water hyacinth were recorded (2.9%, 9.3%, 12.68% and 13.45%) for TDS, (8.75%, 24.94%, 36.97% and 37.43%) for EC, (2.24%, 9.83% a, 23.89% and 25.89%) for BOD, (2.30%, 11.56%, 21.61% and 22.38%) for COD, (2.8%, 13.12%,

28.05% and 29.85%) for PO_4^{3-} , (4.79%, 11.50%, 24.64% and 25.83%) for TKN, (2.66%, 6.90%, 25.59% and 26.94%) for Na, (5.38%, 15.21%, 29.74% and 30.54%) for K and (4.64%, 10.55%, 18.05% and 21.56%) for total hardness after 6, 12, 24 and 48 hours of the treatment (Figure 6). Selvarathi and Murugalakshmi (2013) recorded the highest reduction of TDS, EC, BOD, COD, TKN, Na, K, and total hardness (TH) in paper mill effluent treated with different types of phyto-adsorbent. Chairgulprasert et al. (2013) reported that the mixture of galangal (*Alpinia galanga* Willd) leaves and pseudo stems can be used as a phytosorbent for the removal of lead and zinc ions from synthetic wastewater.

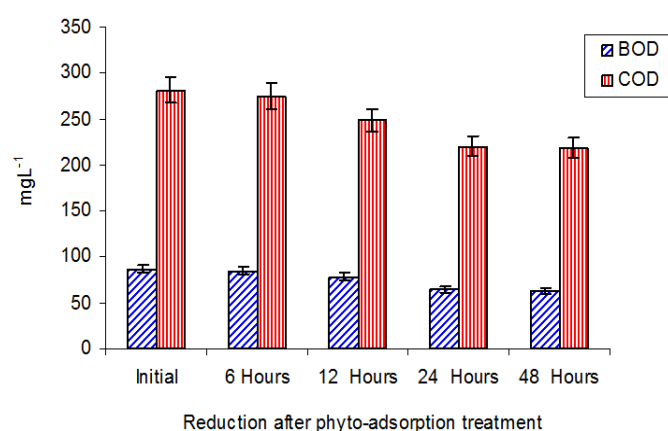
Table 1. Changes in physico-chemical characteristics of paper mill effluent using leaf powder of *E. crassipes* as bio-adsorbent.

Parameter	Before treatment		After treatment			BIS for irrigation water
	Initial	6 Hours	12 Hours	24 Hours	48 Hours	
pH	5.80±0.10	6.07ns±0.10	6.24ns±0.14	6.61ns±0.12	6.62ns±0.08	5.5-9.0
TDS (mg L ⁻¹)	980.22±12.52	951.33*±9.56	888.49*±8.53	855.96**±7.50	848.42**±7.67	1900
EC (dS cm ⁻¹)	6.52±0.11	5.95ns±0.11	4.92ns±0.15	4.11*±0.18	4.08*±0.17	-
BOD (mg L ⁻¹)	86.42±4.61	84.49ns±5.64	77.93*±4.92	63.77*±4.40	62.56*±3.39	100
COD (mg L ⁻¹)	281.01±8.66	274.57ns±9.85	248.54*±4.29	220.29*±9.03	218.11**±8.59	250
PO_4^{3-} (mg L ⁻¹)	71.46±6.00	69.51ns±5.02	62.09*±4.98	51.42*±4.24	50.13*±4.33	-
TKN (mg L ⁻¹)	84.99±3.92	80.92ns±3.09	75.22*±5.01	64.05±8.56	63.04±6.47	100
Na (mg L ⁻¹)	136.94±6.66	133.31ns±3.60	127.50*±4.87	101.91**±13.16	100.06**±6.99	-
K (mg L ⁻¹)	95.01±3.48	89.90ns±2.34	80.56*±3.56	66.76*±7.29	66.00*±7.38	-
Total hardness (mg L ⁻¹)	442.39±3.78	421.89ns±3.02	395.74**±4.54	362.56**±9.15	347**±9.86	200

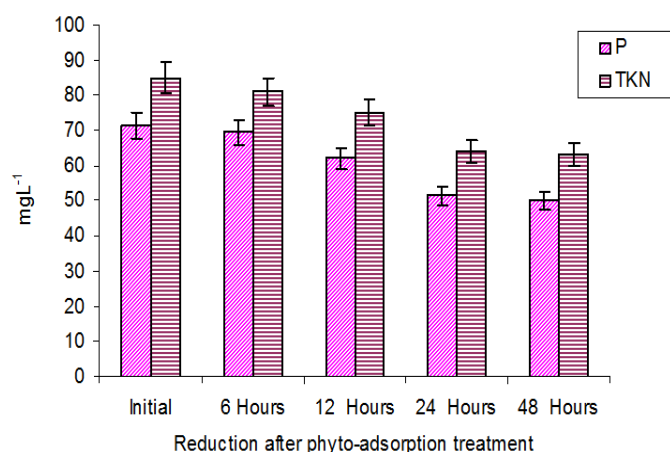
Values presented in the table are the mean ±SE of three replicates; BIS- Bureau of Indian Standards; "--Not given in standards; ns- Not significant; *, **- Significantly different at $P < 0.05$ or $P < 0.01$ level of significance of ANOVA.



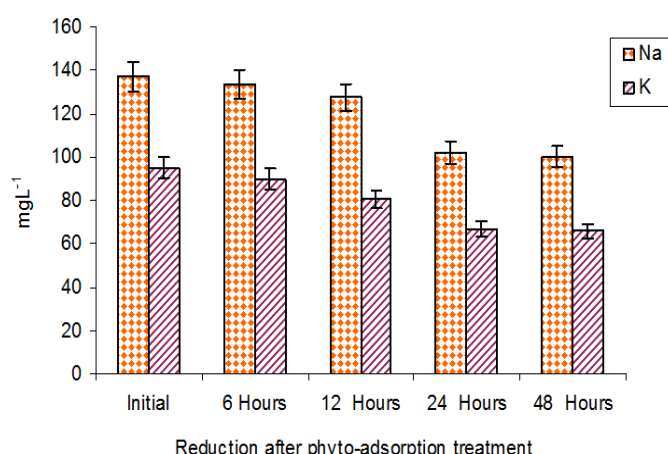
Figures 1. Reduction of pH and EC of paper mill effluent using leaf powder of *E. crassipes* as phyto-adsorbent.



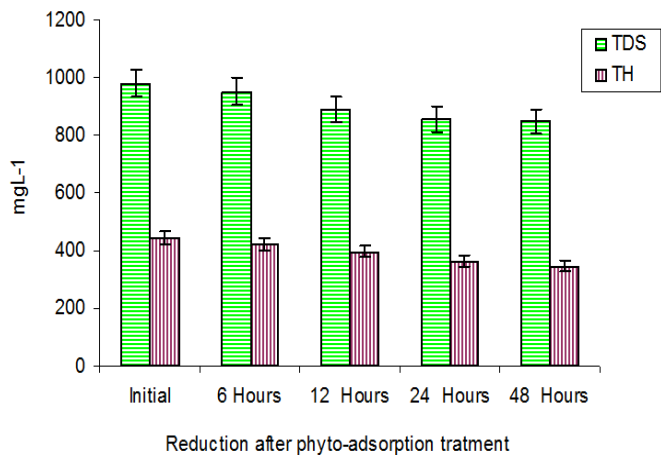
Figures 2. Reduction of BOD and COD of paper mill effluent using leaf powder of *E. crassipes* as phyto-adsorbent.



Figures 3. Reduction of P and TKN of paper mill effluent using leaf powder of *E. crassipes* as phyto-adsorbent.



Figures 4. Reduction of Na and K of paper mill effluent using leaf powder of *E. crassipes* as phyto-adsorbent.



Figures 5. Reduction of TDS and TH of paper mill effluent using leaf powder of *E. crassipes* as phyto-adsorbent.

Conclusions

In this present study, a preliminary study was made to find the potential of leaf powder of water hyacinth (*E. crassipes*) in treating paper mill effluent. Application of leaf powder of *E. crassipes* as phyto-adsorbent showed significant ($P < 0.05$ / $P < 0.01$) effect on the removal of TDS, EC, BOD, COD, TKN, Na, K, and hardness of the paper mill effluent at 12, 24 and 48 hours of phyto-adsorption treatment. It has been found that phyto-adsorbent considerably decreased the pollution load of paper mill effluent. The result of present study showed that the phyto-adsorbent can be utilized for treating of effluent. It is concluded that the leaf powder of water hyacinth (phyto-adsorbent) can be usefully employed to extract nutrients from the paper mill effluent. It is also proved useful in treating effluents polluted with various chemicals components. The study reveals the potential and effectiveness of phyto-adsorbent in the removal of nutrients on paper mill effluent. It can also be concluded that the higher density of the phyto-adsorbent on paper mill effluent, the more the absorption of nutrients (pollutants) that is, the best of purification will be obtained. Further investigation is required on the removal of pollutants like heavy metals of the paper mill effluent using different vegetative parts of water hyacinth as phyto-adsorbent.

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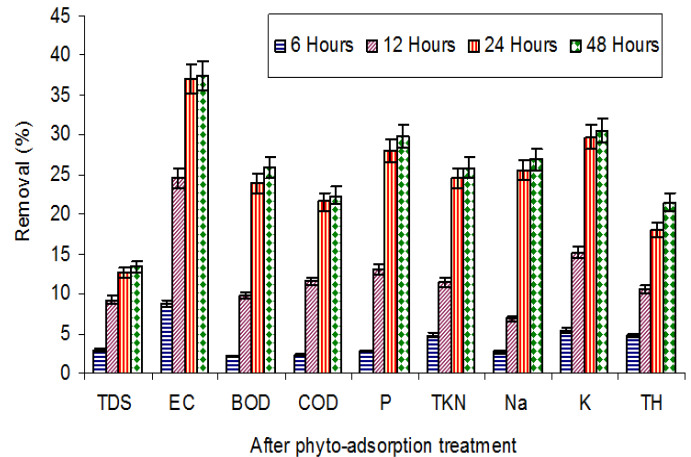


Figure 6. Removal efficiency (%) of physico-chemical characteristics of paper mill effluent using leaf powder of *E. crassipes* as phyto-adsorbent at different time.

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