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Characterization of tannery wastewater and its treatment by aquatic macrophytes and algae

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Abstract

Tannery wastewater contains large amount of chemical compounds including toxic substances. So an attempt was made to characterize physiochemical parameters of tannery wastewater and investigate the efficacy, and applicability of the biological treatment utilizing aquatic plants macrophytes and algae. Total suspended solids TSS and total Dissolved solid in the original wastewater were found 1250 mg/l and 21300 mg/l respectively. The pH and temperature were 8.3 and 29°C. Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were 2.72 mg/l, 4464 mg/l and 12840 mg/l respectively. Electrical conductivity (EC) was 42500 μS/cm anions $PO4^{3}$- and Cl- were 17.1 mg/l and 13.8 mg/l respectively. Heavy metals were also analysed. Fe, Na, Zn, Cr, Pb and Ca were found 14.675 mg/l, 12006 mg/l, 1.5241 mg/l, 10.348 mg/l, 0.1818 mg/l and 0.4112 mg/l respectively. Biological treatment with aquatic plants, algae and their combination treatments were found to be effective for the reduction of some physiochemical parameters. Treatment conducted with *Eichhornia crassipes* was found most effective in reducing COD, EC, TDS and TSS. Mixed treatment resulted reduction of pH from 8.3 to 6.21. Both macrophytes and algae exhibited good heavy metal uptake tendency, but *Eichhornia crassips* was identified as most effective for the removal of heavy metals in the wastewater because of its extensive root system which provides to help the uptake of pollutants from the wastewater.

Key words : Tannery effluents; Toxic effects; Phytochemical parameter; Aquatic macrophytes; Algae

Introduction :

Leather is one of the most important export item of Bangladesh earning foreign exchange. The leather tanning industry has been identified as one of the main causes of environmental and water pollution in the Capital city of Dhaka of 10 million people. About 60,000 tons of row hides and skins are processed every year using dehairing, ammonium salt sulphate and chloride during deliming, solvent vapours which releases a huge quantity of untreated effluent into the open causing air pollution and water bodies (Aslam *et al.* 2001).

Groundwater contamination occurs when wastewater and chemicals seep through the soil from unlined ponds, pipes and drains, or from dumps and spills. Groundwater may take a long time to cleanse itself because it moves slowly and is out of contact with air, (Wierenga, 1996). Studies on toxicity of chlorophenols have been conducted involving plants (e.g. *Lemna gibba*), (Hulzebos *et al.* 1993.) In general, tannery wastewaters are basic, have a dark brown and have a high content of organic substances that vary according to the chemicals used (Kongjao *et al.* 2008).

The major public concern over tanneries has traditionally been about odours and water pollution from untreated discharges. Important pollutants associated with the tanning industry include chlorides, tannins, chromium, sulphate and sulphides as addition to trace organic chemicals and increasing use of synthetic chemicals such as pesticides, dyes and finishing agents, as well as from the use of newer processing chemical solvents, (Anonymous, 2009). These substances are frequently toxic and persistent, and affect both human health and the environment, (Anonymous, 1994). Tannery effluent is among one of the hazardous pollutants of industry. Major problems are due to wastewater containing heavy metals, toxic chemicals, chloride, lime with high dissolved and suspended salt and other pollutants (Uberoi, 2003). Bioremediation technology to treat hazardous waste has gained considerable attention as it is ecologically sound and economical relative to other technologies and it has been used successfully in many countries of the world (Ritmann *et al.* 1988; Enrica, 1994).

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Many conventional processes were carried out to treat wastewater from tannery industry such as biological process (Ahn, *et al.* 1996, Wiemann *et al.* 1998, Farabegoli, *et al.* 2004), oxidation process (Schrank, *et al.* 2003, Sekaran, *et al.*1996, Dogruel, *et al.* 2004) and chemical process (Iaconi, *et al.* 2001, Orhon *et al.* 1998, Song, *et al.* 2004) etc. Among these, physical and chemical methods are considered very expensive in terms of energy and reagents consumption (Churchley, 1994, Stern, *et al.* 2003). And generation of excessive sludge, (Chu, 2001). Various physiochemical techniques used for wastewater treatment can be applied to tannery wastewater (to the entire process or to individual step in the process) but these processes are expensive. Biological treatment of wastewater is more favorable and cost effective as compared to other physiochemical methods. Various microorganisms are capable of reducing the content of pollutants significantly by utilizing them as energy and nutrient source in the presence or absence of oxygen (Metcalf & Eddy, 2003).

The main advantages of biological treatment methods are (i) Low capital and operating costs compared to alternatives such as chemical-oxidation processes (ii) True destruction of organics, versus mere phase separation, such as with air stripping or carbon adsorption (iii) Oxidation of a wide variety of organic compounds (iv) Removal of reduced inorganic compounds, such as sulphides and ammonia, and total nitrogen removal possible through denitrification (v) Operational flexibility to handle a wide range of flows and wastewater characteristics (vi) Reduction of aquatic toxicity. In this study batch experiments are conducted for the removal of organic matters from the tannery wastewater using mixed culture obtained from tannery wastewater treatment plant, (Durai *et al*. 2010).

The Hazaribagh area in Dhaka of Bangladesh was selected because of its long history of widely known untreated discharge of tanning effluents (Gain, 2002). There are no report to investigate the toxic effects of Hazaribagh's tannery effluents on aquatic macrophytes and algae.

Therefore the goal of the present research was to characterize physiochemical parameters of local tannery wastewater and evaluate the toxic effects of its effluents on aquatic macrophytes and algae.

Materials and methods:

Collection of effluent samples

The effluent was collected from R M M Leather industries Ltd., which is located at 119, Hazaribagh, Dhaka-1209. This company is also working in clothing and accessories business activities. Effluent samples were collected from individual drainage line of different operational sectors named: a. white fix, b. black fix, c. soaking, d. batting and e. liming. The sample was collected after the end of each individual operation. So it took 24 hours to collect sample from all those different sector of the industry.

Analysis of physicochemical parameters

Sampling protocol was followed carefully to inhibit the intrusion of any foreign particles that may affect the results. Color of the samples was measured by colorimeter Hanna instrument: HI93727. Temperature was measured at the time of sample collection by mercury thermometer graduated 0 to 100°C. A quantitative analysis for the determination of total suspended solid (TSS) and total dissolved solid (TDS) was carried out by simple laboratory method (Tufekci *et al.* 1998). Dissolved oxygen (DO), Electrical Conductivity (EC) and Salinity of the effluent samples were measured by Hanna Instruments: H19829. The pH of water was determined by using Hanna Instruments pH meter, Model pH-600AQ. BOD and COD were determined by 5-Day BOD test and Closed Reflux, Titrimetric Method, respectively (Anonymous, 1998). Heavy metals lead (Pb), cupper (Cu), iron (Fe), sodium (Na), chromium (Cr), cadmium (Cd), zinc (Zn) and nickel (Ni) were measured by Atomic Absorption Spectroscopy (SIMADZU, Model-AA6401F AAS).

Collection of aquatic macrophytes and algae

Aquatic macrophytes were collected from the Jahangirnagar University campus lakes because those lakes had no connection with the delivery chambers of textile effluent. The aquatic macrophytes were preserved in the artificial pond in Biological Research Division of Bangladesh Council of Scientific and Industrial Research (BCSIR) using tap water at normal temperature and with no adding nutrient. Inoculum of Nostoc was provided by the Biological Research Division, BCSIR, Dhaka.

Methods for toxicity testing on aquatic macrophytes and algae

Collected effluent sample was taken on a big plastic bowl and settled it for 3 days. After settlement the effluent was taken for toxicity testing. The experiments were designed in three sets. In 1st and 2nd sets each earthen vessel of dimension 16" diameter × 10" depth containing four liter of effluent and 3rd set 30" diameter × 20" depth containing ten liter of effluent were used. Before starting experiment, every vessel was washed properly with tap water followed by rinsing with effluent. Each treatment has 3 replica.

Treatment with Macrophytes:

The 1st set of experiments was conducted with three types of aquatic *macrophytes, Spirodella polyrrhiza, Pistia stratiotes, Eichhornia crassipes* and one algae (Nostoc), taken separately in separate vessel. The body and root part of the plants were washed very well to remove sediments and other impurities by tap water. Six fresh plants of weight 200-250gm Pistia stratiotes and 50gm of Spirodella polyrrhiza (Tiwari *et al.* 2007), and three fresh Eichhornia crassipes plants of weight 400-450gm were separately used for toxicity test. To evaluate the toxic effect of tannery effluents, 50 gm of fresh algae (Nostoc) were taken into separate earthen vessel. The effluent was shaken by a stick at two to three hours interval to maintain the equal distribution of algae all over the effluent. In this investigation, 4 cycles of plants were used. The first and second cycle lasted for 1 day, third cycle for 2 days, and the last cycle had been continued for 3 days. After every cycle the plants were replaced with fresh plants. Thus the effluent was kept in exposure to the plants for a total period of 7 days.

Combined Treatment with Aquatic Macrophytes and Algae:

In the 2nd set of experiments, 3 types of aquatic macrophytes were used separately in combination with algae. Two fresh Eichhornia crassipes + 25 gm of Nostoc, 3 fresh Pistia stratiotes + 25 gm of Nostoc and 50 gm of Spirodella polyrrhiza + 25 gm of Nostoc were taken to the treatment vessels

Mixed Treatment

In the 3rd set of experiments, 3 types of aquatic macrophytes, 2 fresh Eichhornia crassipes plants, 3 fresh Pistia stratiotes plants, 50gm of fresh Spirodella polyrrhiza plants were taken along with 25 gm of Nostoc, algae in the same treatment vessel. 4 cycles of plants were used.

Results and discussion:

In the present study, attempts were made to treat the effluent in biological way which is more environmentally friendly, cheap and easy.

Analysis of the Characteristics of Tannery Wastewater:

The characteristics of tannery wastewater vary considerably from tannery to tannery depending upon the size of the tannery, chemicals used for a specific process, amount of water used and type of final product produced by a tannery. Tannery wastewater is characterized mainly by measurements of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids (SS) and Total Dissolved Solids (TDS), chromium and sulfides etc. (Gower, 1980). Typical characteristics of tannery wastewater are given in Table 1. The permissible limits for parameters in the wastewater from an industrial establishment mentioned in the rightmost column are stipulated by World Health Organization (WHO) (Anonymous, 2002). Among the parameters Total Dissolved Solid (TDS) and Total Suspended Solid (TSS) were found 21300 mg/l and 1250 mg/l respectively. pH and temperature of the wastewater were recorded to be 8.3 and 31°C. Dissolved Oxygen (DO) was found 2.72 mg/l.

Table 1: Comparison of the parameters of the collected wastewater sample with the permissible limit stipulated by WHO.

Parameters	Wastewater	Permissible Limit
DO (mg/L)	2.72	4.5
TDS (mg/L)	21300	2100
TSS (mg/L)	1250	600
EC (μS/cm)	42500	1200
BOD (mg/L)	4464	30
COD (mg/L)	12840	250
pH	8.3	5.5-9
PO^{43-} (mg/L)	17.1	5
Cl- (mg/L)	13.8	1000

Parameters	Wastewater	Permissible Limit
Pb (mg/L)	0.1818	0.1
Cu (mg/L)	0.4112	0.1
Fe (mg/L)	14.675	10
Na (mg/L)	12006	nm
Cr (mg/L)	10.348	2
Cd (mg/L)	0.0046	2
Zn (mg/L)	1.5241	1
Ni (mg/L)	0.1513	3

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) was found 12840 mg/l and 4464 mg/l respectively. Electrical Conductivity (EC) was found 42500 µS/cm. Water anions like phosphate, bicarbonate and chloride were found 17.1 mg/l, 207.6 mg/l and 13.8 mg/l respectively which were within the permissible limit. Metals like Na and K were tested in the sample and were found within the permissible limit. However, heavy metals like Cr, Cu, Pb and As were found way beyond the permissible limit in the textile effluent.

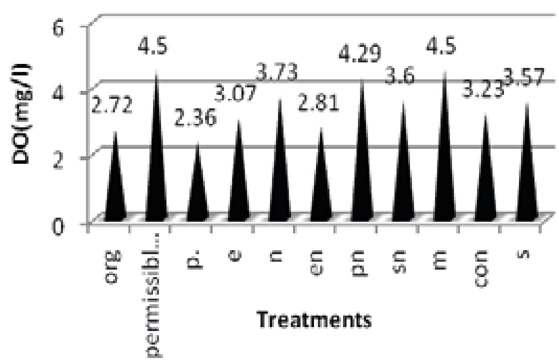

Figure 1: Variation of Dissolved Oxygen (DO) after different treatments.

Effects of different macrophytes and algae on different parameters of effluents were presented in Figures 1-19.

Treatments stands for org: Original Sample, p: Pistia, e: Eichhornia, n: Nostoc, s: Spirodella, en: Eichhornia and Nostoc, pn: Pistia and Nostoc, sn: Spirodella and Nostoc, m: mixed & con: control.

Effect of Treatments on Effluent's Dissolved Oxygen Level:

From Figure 1 it was observed that, DO level was below the standard limit (Brix, 1993) in the original sample. After treatments of Pistia, Eichhornia, Nostoc and Spirodella, DO levels in the effluent were found 2.36, 3.07, 3.73 and 3.57 mg/l respectively. DO levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 2.81, 4.29 and 3.6 mg/l respectively. Mixed treatment changed the DO level of effluent to 4.5 mg/l i e, maximum increase in DO level was effected by mixed treatment on 7th day which is slightly incorporated with Gidhamaari *et al* (2012) findings. He reported that the DO level was increased from 1.34 to 1.75 mg l-1 on 15th day when immobilized bacteria inoculated in the effluent.

Effect of Treatments on Effluent's Total Dissolved Solid Level:

From Figure 2 it was found that, TDS level was beyond the permissible limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and Spirodella treatments, TDS levels in the effluent were found 19990, 4830, 23400 and 21100 mg/l respectively. TDS levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 17260, 21400 and 23400 mg/l

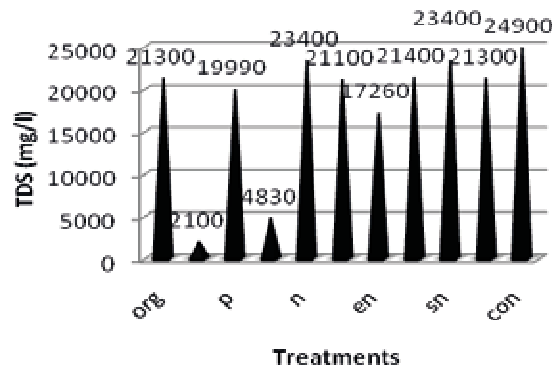

Figure 2: Variation of Total Dissolved Solids (TDS) after different treatments.

respectively. Mixed treatment changed the TDS level of effluent to 21300 mg/l. Maximum decrease in TDS level was effected by Eichhornia treatment. However, Eichhornia crassipes treatment was found most effective in removing TDS reducing up to 77.32% of TDS from the wastewater.

Effect of Treatments on Effluent's Total Suspended Solid Level:

Figure 3, showed the TSS level beyond the permissible limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and Spirodella treatments, TSS levels in the effluent were found 980, 245, 980 and 678 mg/l respectively. TSS levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 765, 1060, and 890 mg/l respectively. Mixed treatment changed the TSS level of effluent to 600 mg/l. Maximum level of TSS was decreased in Eichhornia treatment up to 80.4% .

Effect of Treatments on Effluent's Electrical Conductivity:

In Figure 4, the EC level was beyond the standard limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and

Spirodella treatments, EC levels in the effluent were found 40000, 9660, 46800 and 42200 µS/cm respectively. EC levels in the effluent after the combined treatment of (Eichhornia +

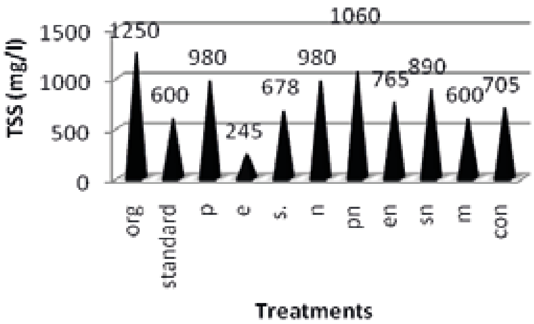

Figure 3: Variation of Total Suspended Solid (TSS) after different treatments.

Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 34500, 42700 and 46700 µS/cm respectively. Mixed treatment changed the EC level of effluent to 42600 µS/cm. Maximum decrease in the EC level was effected by Eichhornia treatment.

Effect of Treatments on Effluent's COD Level:

Figure 5, indicated that the COD level was beyond the standard limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and Spirodella treatments, COD levels in

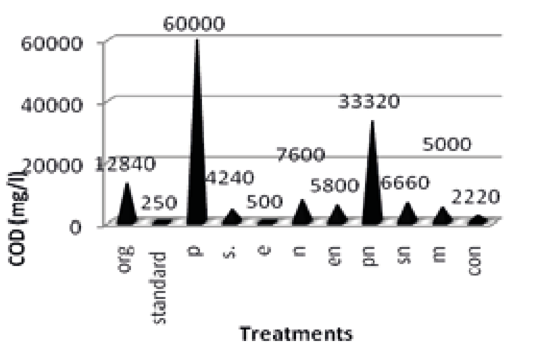

Figure 5: Variation of Chemical Oxygen Demand (COD) after different treatments.

the effluent were found 60000, 500, 7600 and 4240 mg/l respectively. COD levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 5800, 33320, 6660 mg/l respectively. Mixed treatment changed the COD level of effluent to 5000 mg/l. Maximum decrease in the COD level was effected by Eichhornia treatment.

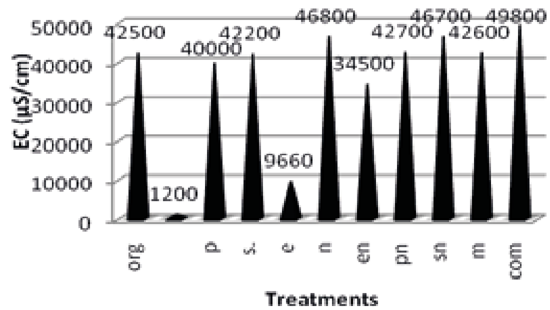

Figure 4: Variation of Electrical Conductivity (EC) after different treatments.

Effect of Treatments on Effluent's BOD Level:

Figure 6, showed the BOD level which was beyond the standard limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and Spirodella treatments, BOD levels in the effluent were found 4280, 6520, 3280 and 2568 mg/l respectively. BOD levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 4968, 8000 and 7816 mg/l respectively. Mixed treatment changed the BOD level of effluent to 4968 mg/l. In this present study the maximum

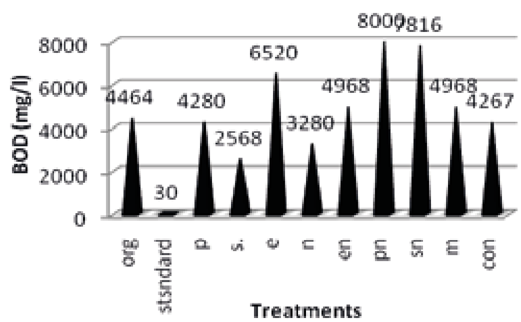

Figure 6: Variation of Biochemical Oxygen Demand (BOD) after different treatments.

decrease of BOD level was observed in Spirodella treatment nearly 42.47% within 7 days whereas Gidhamaari *et al* (2012) reported that the bacterial culture removed BOD almost 75% on two weeks from the date of inoculation in the water samples.

Effect of Treatments on Effluent's PO_4^{3-}, and Cl- Level:

From Figure 7, it was found that the phosphate level was not within the standard limit in the wastewater sample. After

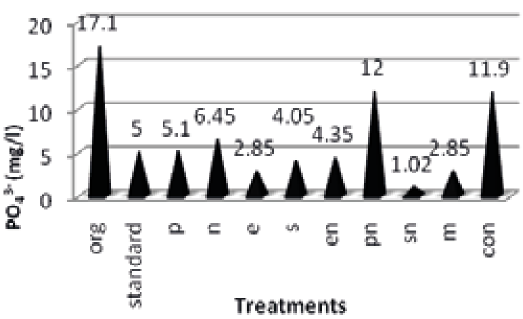

Figure 7: Variation in phosphate concentration after different treatments.

treatments of Pistia, Eichhornia, Nostoc and Spirodella, phosphate levels in the effluent were found 5.1, 2.85, 6.45 and 4.05 mg/l respectively. Phosphate levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 4.35, 12.0 and 1.02 mg/l respectively. Mixed treatment changed the phosphate level of effluent to 2.85 mg/l. Maximum decrease in the PO43- level was effected by Spirodella + Nostoc treatment. (Sekaran and Mariappan, 1994) reported the efficiency of removal of phosphates was more in the immobilized condition than free cells of bacteria. Figure 8, showed the chloride level which was within the standard limit in the wastewater sample. After treatments of Pistia, Eichhornia, Nostoc and Spirodella, chloride levels in the effluent were found 5.2, 2, 8.8 and 9.6 mg/l respectively. Chloride levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 8.0, 8.8 and 9.6 mg/l respectively. Data were not shown. Mixed treatment changed the chloride level of effluent to 9.6 mg/l. Chlorides are generally considered to be

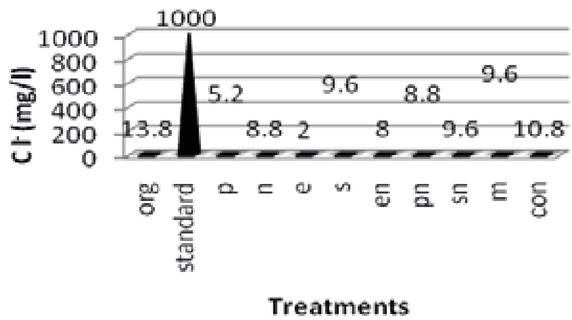

Figure 8: Variation in chloride concentration after different treatments.

one of major pollutant in effluents, which are difficult to be removed by conventional biological methods. Gidhamaari and co-workers (Gidhamaari *et al.* 2012) conducted the study where 24% removal of chloride from the effluent was observed due to the inoculation of bacteria.

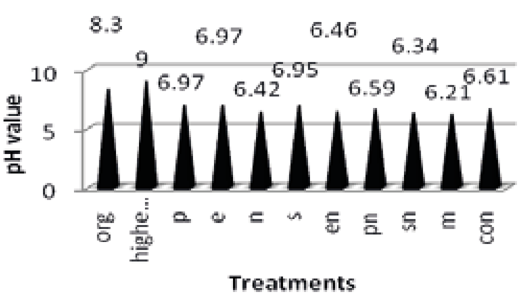

Figure 9: Variation in pH after different treatments.

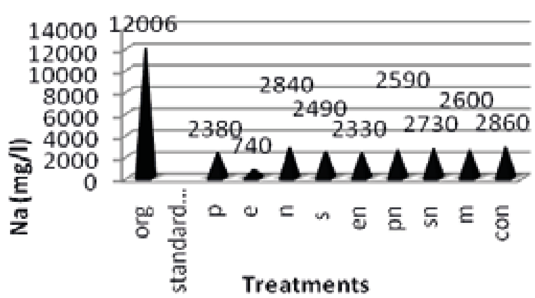

Figure 10: Variation in Na level after different treatments.

Effect of Treatments on Effluent's pH and Na:

The pH level was beyond the standard limit in the wastewater sample, Figure 9. After Pistia, Eichhornia, Nostoc and Spirodella treatments, pH levels of the effluent were found 6.97, 6.97, 6.42 and 6.95 respectively. pH levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 6.46,6.59 and 6.34 respectively. Mixed treatment changed the pH level of effluent to 6.21 mg/l. Maximum decrease of pH level was observed in mixed treatment.

From Figure 10, it was observed that after Pistia, Eichhornia, Nostoc and Spirodella treatments, Na levels of the effluent were found 2380, 740, 2840 and 2490 mg/l respectively. Na levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 2330, 2590 and 2730 mg/l respectively. Mixed treatment changed the Na level of effluent to 2600 mg/l. Maximum decrease in the Na level was effected by Eichhornia treatment. However, the permissible limit of Na is not mentioned in BIS limit.

Effect of Treatments on Effluent's Cu Concentration:

Table 1 & 2, indicated the Cu level which was beyond the standard limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and Spirodella treatments, Cu levels of the effluent were found 0.126, 0.1465, 0.1337 and 0.1300 mg/l respectively. Cu levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were also 0.1433, 0.1833 and 0.1364 mg/l respectively. Mixed treatment also changed the Cu level of effluent to 0.1476 mg/l. Maximum decrease in the Cu level was effected by Pistia treatment.

Table : 2 Effect of different macrophytes and algae on different heavy metal parameters of tannery wastewater effluent.

Heavy metal parameters	Heavy metal concentration in the wastewater after treatment with different macrophytes and algae (mg/l)								
	p	e	n	s	en	pn	sn	m	control
Pb	0.091	0.000	0.091	0.111	0.008	0.111	0.073	0.111	0.111
Cr	1.593	0.791	2.444	1.936	2.493	16.77	3.005	3.106	6.425
Cd	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zn	0 .00	0.043	0.028	0.082	0.054	0.92	0.050	0.141	0.147
Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	6.738	7.143	5.698	7.035	7.805	30.679	6.674	7.325	8.081
Cu	0.126	0.130	0.146	0.133	0.143	0.183	0.136	0.147	0.138

Results are mean of three 3 replications.

Effect of Treatments on Effluent's Cd Level:

No Cd was found in the original sample. After all treatments, Cd levels of the effluent were also found 0, Table 1 & 2.

Effect of Treatments on Effluent's Pb Concentration:

Table 1 & 2, showed the Pb level beyond the standard limit in the wastewater sample. After Pistia, Eichhornia, Nostoc and Spirodella treatments, Pb levels of the effluent were found 0 .091, 0, 0.9 and 0.11 mg/l respectively. Pb levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were also 0.008, 0.111 and 0.073 mg/l respectively. Mixed treatment also changed the Pb level of effluent to 0.111 mg/l. So, all the treatment were found effective to reduce Pb level but Eichhornia treatment was very effective than others.

Effect of Treatments on Effluent's Fe Concentration:

The Fe level was not within the standard limit in the wastewater sample, Table 1 & 2. After Pistia, Eichhornia, Nostoc and Spirodella treatments, Fe levels of the effluent were found 6.738, 7.143, 5.698 and 7.035 mg/l respectively. Fe levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 7.805, 30.67 and 6.974 mg/l respectively. Mixed treatment changed the Fe level of effluent to 7.325 mg/l. Maximum decrease in the Fe level was effected by the Nostoc treatment. Unusual result have been found in the mixed treatment (Pistia + Nostoc), may be due to bio-amplification.

Effect of Treatments on Effluent's Zn Concentration:

The Zn level was beyond the standard limit in the wastewater sample Table 1 & 2. After Pistia, Eichhornia, Nostoc and

Spirodella treatments, Zn levels of the effluent were found 0.00, 0.028, 0.043 and 0.082 mg/l respectively. Zn levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 0.054, 0.925 and 0.05 mg/l respectively. Mixed treatment changed the Zn level of effluent to 0.141 mg/l. Maximum decrease in the Zn level was effected by Pistia treatment.

Effect of Treatments on Effluent's Ni Concentration:

The Ni level was within the standard limit in the wastewater sample Table 1 & 2. After Pistia, Eichhornia, Nostoc and Spirodella treatments, Ni levels of the effluent were found 0, 0,0 and 0 mg/l respectively. Cr levels in the effluent after the combined treatment of (Eichhornia + Nostoc), (Pistia + Nostoc) and (Spirodella + Nostoc) were 0, 0 and 0 mg/l respectively. Mixed treatment also changed the Cr level of effluent to 0 mg/l. So, except (Pistia + Nostoc) treatment, all the treatments were highly effective in reducing Ni & Cr level of the wastewater.

plant of Eichhornia had Pb (0.254), Zn (1.330), Fe (16.91), Cu (0.138) mg/l respectively Table-3.

Spirodella fresh sample had Pb (0.029), Zn (1.570), Fe (4.67), Cu (0.168) mg/l respectively. But when exposed to tannery wastewater effluent, plant of Spirodella showed Pb (0.066), Zn (1.364), Fe (12.84), Cu (0.166) mg/l respectively Table-3.

From table 3, it was found that, the plant Pistia, Eichhornia and Spirodella had no Cr, Cd and very small amount of Pb, Zn, Cu and Fe when fresh and not exposed to the tannery wastewater. But, after the exposure to the tannery wastewater the concentration of the heavy metals specially Cr and Fe in the plants increased drastically. In fact, Pistia Eichhornia, Spirodella were biomagnifying the heavy metals by accumulating them in their body and root systems. This tendency to accumulate heavy metals from the wastewater makes these aquatic macrophytes suitable for heavy metal removal from the industrial effluents.

Table : 3 Heavy metal accumulation by plants (macrophytes)

Type of heavy metals	Heavy metal of fresh plant (average of three replica) (mg/l)			Heavy metal of plant after exposed to tannery wastewater effluent (mg/l)		
	P	E	S	PI	EI	SI
Pb	0.062	0.210	0.029	0.099	0.254	0.066
Cr	0.000	0.000	0.000	9.924	10.95	0.007
Cd	0.000	0.000	0.000	0.001	0.002	0.002
Zn	1.620	1.650	1.570	1.171	1.330	1.364
Ni	0.000	0.000	0.000	0.000	0.000	0.000
Fe	10.24	13.27	4.670	13.75	16.91	12.84
Cu	0.053	0.098	0.168	0.099	0.138	0.166

Results of plant P 1, E1 and S1 exposed to the wastewater are mean of 1st to 4th aftermath cycle.

Heavy Metal Accumulation by Plants:

Table : 3 P, E and S stand for the initial reading of fresh plant of Pistia, Eichhornia, Spirodella and P 1, E1 and S1 stand for plant of Pistia, Eichhornia and Spirodella which was exposed to tannery wastewater effluent respectively. Fresh Pistia had Pb (0.062), Zn (1.620), Fe (10.24), Cu (0.053) mg/l respectively. Whereas the plant of Pistia, exposed to tannery wastewater effluent had Pb (0.099), Zn (1.171), Fe (13.75), Cu (0.099) mg/l respectively.

Eichhornia fresh sample showed Pb (0.210), Zn (1.650), Fe (13.27), Cu (0.098) mg/l respectively. Whereas the exposed

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