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PHYTOREMEDIATION OF CHROMIUM AND SOME CHEMICAL PARAMETERS FROM TANNERY EFFLUENT BY USING WATER HYACINTH (*Eichhornia craassipes*)

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ABSTRACT

The present study was conducted to explore the efficiency of water hyacinth (*Eichhornia crassipes*) to cleanup of tannery effluent in terms of pH, TDS, EC, BOD and most importantly Cr. The study period was from November, 2013 to April, 2014. After 7 days of treatment by water hyacinth, the removal rates were: 68.15% for BOD, 59.82% for TDS and 46.56% for EC, where the corresponding rates after 15 days were: 81.73% for BOD, 67.15% for TDS and 61.93% for EC. After treatment with water hyacinth, pH of effluent reached to nearly neutral level from alkaline condition. In this study, major focus was on Cr removal and the treatment of tannery effluent using water hyacinth resulted in 32.42% reduction of Cr after 7 days and 54.72% after 15 days. The present results revealed that water hyacinth had the strong capability of absorbing Cr. On the other hand, the reduction rates after 15 days for sedimentation were: 54.23% for BOD, 30.21% for TDS, 22.28% for EC and 14.37% for Cr. After comparing the two treatment processes, it was found that the reduction rate by phytoremediation process was much higher than that of sedimentation process. This result reflected the high efficiency of water hyacinth to reduce pollutant especially Cr from tannery effluent as eco-friendly sustainable technology.

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INTRODUCTION

Water pollution is a worldwide issue; accumulation of different heavy metals in water has become very common phenomena. There has been an increasing concern with regard to accumulation of heavy metals in environment as they pose big threat to both human health and natural environment. In Bangladesh, water pollution with heavy metal is also severe where small industrial units are pouring their untreated effluents in the surface drains, which are degrading both of the surface and ground water quality (Borkar et al., 2013).

Industrial wastes are generated from different processes and the amount and toxicity of waste varies with its own specific industrial processes. Tannery effluents are ranked as the highest pollutants among all industrial wastes (Belay, 2010). The most pollution creating industries of Bangladesh are tanning industries. At present, there are about 170 tannery units in Bangladesh. Among various wastes discharged from tanning industries, heavy metals are the most concerning factor. Among the hazardous heavy metals, chromium is the most noteworthy (Kallol, 2012). Along with heavy metals tannery effluent contains substantial pollution load such as pH, total dissolved solids (TDS), electrical conductivity (EC) and biological oxygen demand (BOD).

One of the major emerging environmental problems in the tanning industry is the disposal of chromium contaminated sludge produced as a by-product of wastewater treatment. Tannery effluents severely affect the mitotic process and reduce seed germination in extensively cultivated pulse crops. According to WHO, the metals of most immediate concern are Cr, Zn, Fe, Hg and Pb and at high concentrations, Cr is toxic, mutagen, carcinogen, and teratogen (Belay, 2010). Since tannery water contains detrimental Cr, which is not biodegradable into non-toxic end products, its concentrations must be reduced to acceptable levels before discharging them into environment. This could pose threats to public health and/or affect the aesthetic quality of potable water if not removed (Mahmood et al*.,* 2005). In order to maintain good quality of water, continuous efforts have been made to develop technologies that are easy to use, sustainable and economically feasible. The use of plant species for cleaning polluted waters named as phytoremediation has gained increasing attention since last decade, as an emerging cheaper technology (Borkar et al., 2013).

The most common aquatic macrophytes being employed in wastewater treatment are water hyacinth, penny wort, water lettuce, water ferns and duck weeds (Mahmood et al., 2005). Among these mycrophytes, water hyacinth (*Eichhornia crassipes*) is a fast growing and floating plant with a well-developed fibrous root system and large biomass. It adapts easily to various aquatic conditions and plays an important role in extracting and accumulating metals from water. Hence, water hyacinth is considered to be an ideal candidate for use in the rhizofiltration of toxic trace elements from wastewater bodies (Liao and Chang, 2004). This study aims to determine the suitability of water hyacinth (*Eichhornia crassipes*) for phytoremediation of Cr and some chemical parameters like pH, TDS, EC and BOD from tannery effluent.

MATERIALS AND METHOD

Study Area

The study area is comprised of tannery area in Hazaribagh Thana situated on the Southwestern part of Dhaka city, Bangladesh. It is located between 23°45′ to 23°44′ north latitudes and 90°21.85′ to 90°22.15′ east longitudes.

Sampling

Firstly, 2.5 L effluent sample was collected in plastic bottles from chrome tanning sector of tannery industry for analyzing initial characteristics. Then, 21 L effluent sample was collected again from the same source for treatment purpose by using water hyacinth (*Eichhornia crassipes*) and sedimentation. Water hyacinth samples were collected in polythene bags from nearby ponds of Mawlana Bhashani Science and Technology University (MBSTU) Campus, Tangail.

Tannery Effluent Treatment

For phytoremediation process, 2 separate buckets each with 7 L of effluent were taken and surface of the effluents in both buckets were covered by water hyacinth. Then, one was exposed in open air for 7 days and another was for 15 days. Again, another bucket with 7 L effluent was taken, and then exposed in open air for 15 days without water hyacinth. Treatment of effluent by using water hyacinth was conducted for two separate time duration: 7 and 15 days. On the other hand, treatment by sedimentation process (without water hyacinth) was conducted for 15 days only.

Phytoremediation of tannery effluent was experimented by water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*). Water samples were collected from the same source at the time for both studies. The initial values of the chemical parameters and Cr were estimated also and already it has been published in Akter et al. (2014). These values were used as initial values here in the present study.

Sample Preparation

Each of the effluent sample (100 mL) was filtered through filter paper (Whatman No. 41; 0.45 µm pore size). Filtrate and the collected effluent samples (100 mL each) were preserved with 2 mL concentrated nitric acid to prevent precipitation of Cr. Then, these effluent samples were diluted 20 times with distilled water and subjected to digestion with 5 mL di-acid mixtures. After digestion, samples were again filtered and diluted 10 times.

Three samples of water hyacinth were collected from each bucket and were thoroughly washed to remove all adhered soil particles. Then, samples were cut into small pieces, air dried for 2 days and finally dried at 100^{O}C in hot air oven for 4 hours. In warm condition, the samples were finely ground. Fine powder of water hyacinth samples were subjected to acid digestion (Lokeshwari and Chandrappa, 2006). Another 3 plant samples were taken before grown in the bucket for initial analysis.

Sample Analysis

The pH of water samples was measured by using a pH meter (WTW pH 522, Germany), Total Dissolved Solids (TDS) was measured by TDS meter, and Electrical Conductivity (EC) was measured by EC meter (HM digital, Germany). Biochemical Oxygen Demand (BOD) was determined by using 5 days incubation method (APHA, 2012). The concentration of Cr in water and plant samples were analyzed by atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan) (APHA, 2012).

RESULTS AND DISCUSSION

Initial Condition of Tannery Effluent before Treatment

Initial concentration of Cr of the sampled tannery effluent was 1232.4 mg L^{-1} (Table 1). This high concentration of Cr was due to the use of chromium salt as a tanning agent in tannery industry. The initial pH level of tannery effluent was 8.9 indicating the alkaline nature (Table 1). Discharge of such effluent into ponds and rivers may be detrimental to aquatic biota such as zooplankton and fishes and also for irrigation. Gupta et al. (2011) found that the pH of tannery effluent was 8.6 and this might be due to the presence of high concentration of salts.

Initial value of electrical conductivity (EC) of the tannery effluent sample was 9230 µS cm^{-1} (Table 1). Noorjahan (2014) found EC ranging from 8344 to 9134 µS cm^{-1} in tannery effluent. This might be due to the presence of organic and inorganic substances and salts that would have increased the conductivity. Initial value of total dissolved solid (TDS) of tannery effluent sample was 8746 mg L^{-1} (Table 1). Noorjahan (2014) reported that TDS in tannery effluent was from 5756 to 6672 mg L^{-1}. This might be due to high salt content, hence further treatment or dilution of the effluents would be required.

Initial value of biological oxygen demand (BOD) of sampled tannery effluents was 920 mg L^{-1} (Table 1). High BOD levels (600 - 1622 mg L^{-1}) have also been reported by Noorjahan (2014), for effluent discharged from tanneries. This might be due to the presence of considerable amount of organic matter reflecting microbial oxygen demand. This leads to depletion of DO, which may cause hypoxia conditions with consequent adverse effects on aquatic biota.

Table 1. Initial values of Cr and some chemical parameters of tannery effluents (Akter et al., 2014)

Parameters	***Present study***	***Standard limits (DoE, 2003)***
Cr (mg L^{-1})	1232.4	0.5
pH	8.9	6-9
EC (µS cm^{-1})	9230	1200
TDS (mg L^{-1})	8746	2100
BOD (mg L^{-1})	920	50

Table 2. Changes of Cr and some chemical parameters after sedimentation process in tannery effluent samples

Parameters	**Initial values**	**Values after 7 days**	**Reduction after 7 days**		**Values after 15 days**	**Reduction after 15 days**	
			Value	**% removal**		**'alue**	**% removal**
Cr (mg L^{-1})	1232.4	1145.7	86.7	7.03	1054.9	177.1	14.37
pH	8.9	8.5	0.4	4.49	8.2	0.7	7.86
TDS (mg L^{-1})	8746	7152	1594	18.22	6103	2643	30.21
EC (µS cm^{-1})	9230	8243	987	10.69	7173	2057	22.28
BOD (mg L^{-1})	920	589	331	35.97	421	499	54.23

Table 3. Changes of Cr and some chemical parameters after treatment by water hyacinth

Parameter	**Initial values**	**After 7 days**	**Reduction after 7 days**		**After 15 days**	**Reduction after 15 days**	
			Value	**% removal**		**Value**	**% removal**
Cr (mg L^{-1})	1232.4	832.8	399.6	32.42	558	674.4	54.72
pH	8.9	7.6	1.3	14.60	7.3	1.6	17.97
TDS (mg L^{-1})	8746	3514	5232	59.82	2873	5873	67.15
EC (µS cm^{-1})	9230	4932	4298	46.56	3513	5717	61.93
BOD (mg L^{-1})	920	293	627	68.15	168	752	81.73

Status of Tannery Effluent after Sedimentation Process

After 15 days settlement of the effluent, Cr level was 1054.9 mg L^{-1} where the reduction rate of Cr was 14.37% (Table 2). Akter et al. (2014) reported that after 7 days settlement of tannery effluent, Cr reduction rate was 7.03%. In this study, the reduction of Cr from the effluent might be due to the settling down of chromium salt into settlement bucket.

After 15 days of sedimentation, pH value was 8.2 and the reduction rate was 7.86% (Table 2). Akter et al. (2014) found that the reduction rate of pH was 4.49% after 7 days of sedimentation. The reduction rate of this present study was higher than that of the study report of Akter et al. (2014) indicating that the longer the sedimentation process, the higher the reduction rate of pH.

After 15 days of sedimentation, the value of TDS was 6103 mg L^{-1} and the reduction rate was 30.21% (Table 2). Akter et al. (2014) reported that after 7 days of sedimentation, the reduction rate was 18.22% for TDS. The reduction rate of TDS increased with the passing of time through sedimentation process. After 15 days sedimentation, the value of EC was 7173 µS cm^{-1} and the reduction rate was 22.28% (Table 2). Akter et al. (2014) reported that after 7 days of sedimentation, the reduction rate of EC was 10.69%. The reduction rate of EC increased with the passing of sedimentation time. After 15 days of sedimentation, the value of BOD was 421 mg L^{-1} and the reduction rate was 54.23% (Table 2). Akter et al. (2014) stated that after 7 days of sedimentation, the reduction rate of BOD was 35.97%. The rate of BOD reduction might be affected by time period and with the passing of time, the reduction rate increased. The reduction of BOD in this study might be due to the naturally occurring degradation of organic matter.

Status of Tannery Effluent after Phytoremediation Process

The present study results revealed at tremendous potentiality of water hyacinth to remove Cr from the growth medium. After 7 days phytoremediation, Cr concentration was 832.8 mg L^{-1} having 32.42% reduction rate and after 15 days, it was 558 mg L^{-1} having 54.72% reduction rate (Table 3). Mahmood et al. (2005) reported that treatment of textile wastes with water hyacinth resulted maximum reduction (78.30 - 94.78%) of Cr. According to their study, the extensive removal of Cr by water hyacinth might be due to extensive adventitious root system, which absorbed this toxic element from tannery effluent.

After phytoremediation of tannery effluent with water hyacinth, pH has been reduced to significance level. After 7 days of phytoremediation, pH was 7.6 having 14.60% reduction rate and after 15 days, it was 7.3 having 17.97% reduction rate (Table 3). Mahmood et al. (2005) found that after 48 and 96 hours treatment of textile wastewater by water hyacinth, pH was reduced to 7.7 and 7.1, respectively from the initial value of 8.2. They stated that the reduction of pH favored microbial action to degrade BOD in the wastewater.

After phytoremediation of the effluent with water hyacinth, the result showed remarkable reduction in the value of TDS. After 7 days of phytoremediation, TDS value was 3514 mg L^{-1} having 59.82% reduction rate and after 15 days, it was 2873 mg L^{-1} having 67.15% reduction rate (Table 3). Agarwal et al. (2013) reported that TDS value after 10 days of phytoremediation using water hyacinth was 360 mg L^{-1} and after 20 days, it was 245 mg L^{-1}, where the initial value was 2310 mg L^{-1}.

Water hyacinth was also very effective to reduce EC from tannery effluent. After 7 days of phytoremediation, EC value was 4932 µS cm^{-1} having 46.56% reduction rate and after 15 days, it was 3513 µS cm^{-1} having 61.93% reduction rate (Table 3). The evidence of reducing EC by water hyacinth has been documented by different scholars, which was also similar to the present study. Mahmood et al. (2005) noted 55.71% decrease of EC in textile waste samples treated by water hyacinth within 96 hours period.

The result of present study showed that phytoremediation with water hyacinth was very effective to reduce BOD. After 7 days of phytoremediation with water hyacinth, the value of BOD was 293 mg L^{-1} having 68.15% reduction rate and after 15 days, it was 168 mg L^{-1} having 81.73% reduction rate (Table 3). So, time duration had significant effect on the reduction rate of BOD. Mahmood et al. (2005) reported that biological treatment with water hyacinth showed 40-70% reduction of BOD. According to their study, the presence of plants in waste water depleted dissolved CO_2 during the period of high photosynthetic activity. This photosynthetic activity increased the dissolved oxygen of water, thus creating aerobic conditions in wastewater which favored the aerobic bacterial activity to reduce the BOD.

Comparison between Sedimentation and Phytoremediation Processes

The reduction of pH, EC, TDS, BOD and Cr by phytoremediation process using water hyacinth were much higher than sedimentation process. In the present study the highest reduction rates for pH were 17.97% and 7.86% after 15 days of phytoremediation and sedimentation processes, respectively. The highest reduction rates for TDS were 67.15% and 30.81% after 15 days of phytoremediation and sedimentation processes, respectively. For EC, maximum reduction rates were 61.93% and 22.28% after 15 days of phytoremediation and sedimentation processes, respectively. The highest reduction rates for BOD were 81.7% and 54.23% after 15 days of phytoremediation and sedimentation processes, respectively. The highest reduction rates for Cr were 54.73% and 14.37% after 15 days of phytoremediation and sedimentation processes, respectively.

Chromium Accumulation in Water hyacinth

The accumulation of Cr in water hyacinth was estimated after collection from the river after 7 and 15 days of treatment. The accumulation of Cr in water hyacinth after 7 days of application to treat the effluent was 7225.25 mg kg^{-1} and after 15 days, the accumulation was 9642.75 mg kg^{-1}. The accumulation rate of Cr in water hyacinth was increasing with the passing of time. So, it was evident from the study that water hyacinth was highly capable of removing Cr from tannery effluent.

CONCLUSION

The direct discharge of effluents from tanneries into water bodies has become a growing environmental problem as they contain complex mixtures of inorganic and organic compounds with heavy load of toxic Cr. According to the present study, the tannery effluent had alkaline pH, very high levels of EC, TDS, BOD and Cr. The results before and after treatments with water hyacinth showed considerable reduction in the value of each parameter, especially Cr, which reflected the capability of water hyacinth to reduce the pollution of tannery effluent. From these results, it was also found that time duration had significant effects on phytoremediation process, where 15 days of treatment using water hyacinth was more effective than 7 days. Obviously, it can be interpreted that the pollution removal capability of water hyacinth increased with the passing of time.

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