Phytoremediation of Chromium (Cr) from Tannery Effluent by Using Water Lettuce (*Pistia stratiotes*)

Sonya Akter[*]
Rezuana Afrin*
Md. Younus Mia[**]
Md. Zakir Hossen[***]

Abstract

Chromium is the most widely used chemical in tanning and tanning effluents can cause environmental problems related to the elevated chromium (Cr) concentrations. A time bounded study was conducted at the laboratory from November 2013 to April 2014 which was focused with an objective to explore the possibility of using Water lettuce (Pistia stratiotes) for removing pollutants and to compare its effectiveness with sedimentation process. The reduction rates of Cr concentration in effluent samples were found 36.48 and 58.27% after 7 and 15 days of phytoremediation, respectively. Whereas, reduction rates of Cr concentration were found 7.03 and 14.37% after 7 and 15 days of sedimentation, respectively. Maximum removal of Cr and other parameters (pH, EC, TDS, BOD) were achieved after 15 days of phytoremediaton. The concentrating efficiency of the Water lettuce was evaluated by estimating the Cr concentration in it and the concentration levels were found 80.50 mg/L (initially), 7852.85 mg/L (after 7 days) and 9865.88 mg/L (after 15 days).

Keywords: *Phytoremediation, water lettuce, sedimentation*

Introduction

The reuse of treated wastewater in aquaculture or agriculture practices is encouraged to minimize demand on freshwater resources. A major concern for reuse of wastewater is the bioaccumulation of hazardous wastes especially heavy metals and pesticides in food chain (Teisseire and Guy, 2000). The tanning industry is one of the major consumers of water and chrome tanning is the most common type of tanning where a large amount of basic chromium sulfate is used. Tannery waste water contains a very high value of BOD, COD, total solids, chlorides, sulfates and chromium (Bajza and Vrcek, 2001). At high concentrations chromium is toxic, mutagen, carcinogen, and teratogen (Belay, 2010) to human. Since tannery water contains chromium (Cr) which is not biodegradable, its concentrations must be reduced to acceptable levels before discharging them into environment.

[*]Students of M.S., Department of Environmental Science & Resource Management, Mawlana Bhashani Science & Technology University
[**]Professor, Department of Environmental Science & Resource Management, Mawlana Bhashani Science & Technology University
[***]Professor, Department of Agricultural Chemistry, Bangladesh Agricultural University

Phytoremediation is the use of plants to absorb certain contaminants from soil or water through a plant's root system into the body of the plant where they are stored and ultimately disposed (Huang *et al.*, 2004). Water lettuce is a free-floating aquatic plant. It grows as simple free-floating thalli on or just beneath the water surface. The plant grows by vegetative reproduction and can rapidly colonies new water bodies. This aquatic hydrophyte and its rhizosphere bacteria can bio-accumulate many toxic heavy metals including Cr and it could be used for the bio-remediation process (Prajapati *et al.*, 2012). So, the study was conducted to remediate the tannery effluent by using Water lettuce (*Pistia stratiotes*).

Objectives of the study

1. To explore the possibility of using Water lettuce (*Pistia stratiotes*) for removal of pollutant based on laboratory Studies; and
2. To compare the effectiveness of Water lettuce (*Pistia stratiotes*) in pollutant removal with sedimentation process.

Materials and Methods

Study area

The study area was comprised of Hazaribagh tannery area, Dhaka, Bangladesh and located between 23°45′ to 23°44′ North latitudes and 90°21.85′ to 90°22.15′ East longitudes. About 150 tannery units are located here in only 50 acres of land.

Sample collection

Firstly, 2 to 2.5 liters of effluent samples were collected in plastic bottles from the main disposal point after chrome tanning for initial analysis. Then 28 liters effluent samples were collected again from the same area for treating by phytoremediation and sedimentation processes. Samples of matured Water lettuce (*Pistia stratiotes*) were collected from a natural pond of Santosh region, Tangail, Bangladesh. The pond is generally used for bathing, washing, fish culture and dumping wastes (especially domestic wastes).

Treatment process

For phytoremediation process, 2 separate buckets each with 7 liters of effluents were taken and surface of the effluents of both buckets were covered by Water lettuce (*Pistia stratiotes*). Then one was exposed in open air for 7 days and another for 15 days. Again another 2 buckets with 7 liters of effluents in each were taken and then one was exposed in open air for 7 days and another for 15 days without Water lettuce.

Sample preparation

Each of the effluent samples (100 mL) was filtered with Whatman No. 41 (0.45 μm pore size) filter paper from each bucket. Then 3 samples were taken from each of the filtrated effluent samples and total water samples were 12. They were preserved with 2 mL concentrated HNO_3 to prevent precipitation of Cr and then diluted 20 times with distilled water and subjected to

digestion with 5.0 mL di-acid mixtures. Then the samples were filtered again and diluted 10 times.

Three Water lettuce samples from each bucket were taken and thoroughly washed. Then cut into small pieces, air dried for 2 days and finally dried at 100°C in hot air oven for 4 hours. In warm condition, the samples were finely ground and then subjected to acid digestion (Lokeshwari and Chandrappa, 2006). Another 3 plant samples were taken before grown in the bucket for initial analysis. Total plant samples were 9.

Analytical methods

The concentrations of Cr in water samples and in digested plant samples were analyzed by atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan) (APHA, 1998). The values of pH, EC (Electrical Conductivity) and TDS (Total Dissolved Solids) of water samples were measured using a pH meter (WTW pH 522, Germany), EC meter (WTW CF 521, Germany) and TDS meter, respectively. BOD (Biological Oxygen Demand) of diluted water samples was determined by using incubation method (APHA, 1998). In case of each parameter three samples were analyzed and average values are presented in the Tables.

Results and Discussions

Chemical parameters of the effluent samples

Concentration of Cr and other parameters (pH, EC, TDS and BOD) of the collected effluent samples were determined to know the initial condition of the effluent for conducting further analysis properly. The resulted average values are presented in Table 1.

Table 1: Initial concentrations of Chromium (Cr) and other chemical parameters of effluent samples

Parameters	Initial concentrations	Standard Values According to *ECR (1997)	Standard Values According to * DoE (2003)
Cr (mg/L)	1232.4	2	0.5
pH	8.9	6 - 9	6 - 9
EC (µS/cm)	9230	_	1200
TDS (mg/L)	8746	2100	2100
BOD (mg/L)	920	100	50

*ECR= Environment Conservation Rule; *DoE= Department of Environment.

Chromium (Cr)

After the initial assessment of the effluent, Cr was found 1232.4 mg/L (Table 1) which was much higher than the discharge limit (2 mg/L) (ECR, 1997). The major source of Cr in the effluent from tanneries is chrome sulfate which is an essential chemical used in the tanning process. Cr is

used to convert the skin into leather and only 60-80% of Cr is absorbed by the leather and remaining is discharged as effluent (Ramesh *et al*., 2013). So, it can be assumed that higher Cr concentration was found in the studied samples because of excessive use of chrome sulfate in the tanning process and it would create toxicity to aquatic life.

Other parameters (pH, EC, TDS, BOD)

The initial value of pH of chrome tanning effluent was found 8.9 and it was within the permissible limit (6-9) (ECR, 1997). This alkaline nature is (may be) due to the presence of high concentrations of salts of sodium, potassium and chromium but it would not be detrimental to aquatic life. The initial value of EC was found 9230 µS/cm which was much higher than the permissible discharge limit (1200 µS/cm) (DoE, 2003). The higher conductivity alters the chelating properties of water bodies and creates an imbalance of free metal availability for flora and fauna in the aquatic environment (Akan *et al*., 2008). From the initial assessment of the tannery effluent, the TDS value was found 8746 mg/L which was much higher than the standard discharge limit (2100 mg/L) (ECR, 1997). The value of BOD was found 920 mg/L in the initial assessment of effluent water samples which was quite higher than the discharge limit (100 mg/L) (ECR, 1997) which indicates the presence of huge biodegradable matters in the effluent samples.

Concentrations of chemical parameters of effluent samples after sedimentation

The collected effluent was allowed to be settled down in buckets without any disturbance for 7 days and 15 days time periods. The settling process was carried out to determine how much pollutants can be removed through sedimentation process from the effluent. Here Cr also removed from the effluent samples by settling down with other pollutants. The results of the analysis after sedimentation have been presented in Table 2.

Table 2: Concentrations of chemical parameters after sedimentation of effluent samples

Parameters	Initial values	Values after 7 days of sedimentation	Reduction after 7 days of sedimentation		Values after 15 days of sedimentation	Reduction after 15 days of sedimentation	
			Values	% Removal		Values	% Removal
Cr (mg/L)	1232.4	1145.7	86.7	7.03	1054.9	177.5	14.40
pH	8.9	8.5	0.4	4.49	8.2	0.7	7.87
EC (µS/cm)	9230	8243	987	10.69	7173	2057	22.29
TDS (mg/L)	8746	7152	1594	18.23	6103	2643	30.22
BOD (mg/L)	920	589	331	35.98	421	499	54.24

Reduction of Chromium (Cr) concentration

After 7 days of sedimentation process, the Cr concentration in effluent samples reduced to 1145.7 mg/L whereas the initial value was 1232.4 mg/L and the reduction rate was 7.03% (Table 2). Though the reduction rate was quite low but as the time passed the reduction rate increased to 14.37% after 15 days of sedimentation.

Reduction of pH, EC, TDS and BOD values

The reduction rates of pH, EC, TDS and BOD were 4.49, 10.69, 18.22 and 35.97% and 7.86, 22.28, 30.21 and 54.23%, respectively after 7 and 15 days of sedimentation.

Concentrations of chemical parameters after phytoremediation

After analyzing the collected effluents, *Pistia stratoites* was grown into the effluent over two different time periods to carry out the phytoremediation process. The results of the analysis of the parameters of effluent after the treatment process have been presented in Table 3.

Reduction of Chromium (Cr) concentration

After phytoremediation by Water lettuce, it was observed that Cr reduced efficiently from effluent by *Pistia stratiotes* and the result showed that the initial value of Cr (1232.4 mg/L) was reduced to 782.82 mg/L after 7 days and 514.28 mg/L after 15 days of exposure (Table 3). The reduction rate was 36.48% after 7 days and 58.27% after 15 days of exposure. Water lettuce (*Pistia stratiotes*) was quite efficient in removal of Cr in an experiment conducted under laboratory condition and he observed 30% removal rate of Cr by treatment with *Pistia stratiotes* over 2 days exposure (Prajapati *et al*., 2012).

Table 3: Concentrations of chemical parameters after phytoremediation of effluent samples

Parameters	Initial values	Values after 7 days of phytoremediation	Reduction after 7 days of phytoremediation		Values after 15 days of phytoremediation	Reduction after 15 days of phytoremediation	
			Values	% Removal		Values	% Removal
pH	8.9	7.5	1.4	15.73	6.7	2.2	24.72
EC (µS/cm)	9230	5679.22	3550.78	38.47	3684.61	5545.38	60.08
TDS (mg/L)	8746	3823.75	4922.25	56.28	3262.25	5483.74	62.7
BOD (mg/L)	920	340.03	579.97	63.04	153	767	83.37
Cr (mg/L)	1232.4	449.57	782.82	36.48	514.28	718.12	58.27

Reduction of pH, EC, TDS and BOD

After 7 days of phytoremediation, the reduction rates of pH, EC, TDS and BOD were 15.73, 38.47, 56.28 and 63.04%, respectively and after 15 days, the reduction rates were 24.71, 60.08, 62.7 and 83.37%, respectively.

Comparison between phytoremediation and sedimentation processes

After accomplishment of both phytoremediation and sedimentation process, the results achieved were compared to justify the effectiveness of phytoremdiation process in removal of pollutants from the effluents and the results are presented in Table 4. Here, the reduction rates of Cr, pH, EC, TDS and BOD through phytoremediation process were higher than the sedimentation process in both the time periods. So, it can be said that Phytoremediation process is more effective than sedimentation process in reduction of pH level.

Table 4: Comparing the removal efficiency of sedimentation and phytoremediation

Parameters	7 days removal efficiency (%)		15 days removal efficiency (%)	
	Sedimentation	Phytoremediation	Sedimentation	Phytoremediation
pH	4.49	15.73	7.86	24.71
EC (µS/cm)	10.69	38.47	22.28	60.08
TDS (mg/L)	18.22	56.28	30.21	62.7
BOD (mg/L)	35.97	63.04	54.23	83.37
Cr (mg/L)	7.03	36.48	14.37	58.27

Chromium (Cr) concentration in *Pistia stratoites*

To determine the capacity of *Pistia stratoites* to concentrate Cr, the plant was analyzed and the results have been presented in Table 5.

Table 5: Concentration levels of Chromium (Cr) in Water lettuce (*Pistia stratoites*)

Duration	Concentration of Cr (mg/kg)
Initial value (before grown in bucket water)	80.5
After 7 days	7852.85
After 15 days	9865.88

It can be noticed that the concentration of Cr in Water lettuce was 7852.85 and 9865.88 mg/kg after 7 and 15 days, respectively whereas the initial concentration was found 80.50 mg/kg (Table 5). The result of Cr accumulation indicates that Water lettuce was very much efficient to concentrate Cr.

Conclusion

Tanning industries are one of the main economic activities in Bangladesh. In the chromium tanning process leather consumes 60–80% of the applied chromium salt and the rest is usually discharged into sewage without adequate treatment, causing serious environmental impact. Metals and other inorganic contaminants are among the most prevalent forms of contamination found at waste sites, and their remediation in water is among the most technically difficult. The high cost of existing cleanup technologies led to the search for new cleanup strategies that have the potential to be low-cost, low-impact, visually benign, and environmentally sound. Phytoremediation is an emerging technology for cleaning up of waste water, which is cost effective and has aesthetic advantages and long term applicability. The conducted study was carried out with an aim to minimize the concentration of tannery effluent especially Cr. The initial assessment of the collected effluents were carried out where the concentrations of the parameters found were much higher than the permissible discharge limit which indicated that the effluent needed to be treated before discharged to the environment.

After the initial analyses, phytoremediation and sedimentation processes were carried out and water lettuce (*Pistia stratiotes*) was used as the phytoremediator. The results showed that the pollutant removal through sedimentation process was less effective though the removal of BOD (35.37%) was quite satisfactory. Water lettuce (*Pistia stratiotes*) was proved efficient to reduce the concentration of the pollutant targetedly Cr through phytoremediation process.

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