Physicochemical characterization of tannery effluent and its treatment using Eichhornia crassipes - A Phytoremediation study

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Abstract - **Tannery effluent contains large amount of chemical compounds including toxic substances. So an attempt was made to characterize physicochemical parameters of tannery wastewater and investigated the efficacy and applicability of the biological treatment utilizing aquatic plants. pH of the effluent before the treatment was 6.8 and it was increased to 7.4. An increase in pH value supports the growth of aquatic plant. Physico chemical parameters like BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TDS (Total Dissolved Solids), TSS (Total Suspended Solids) and Total Chromium in the effluent before the treatment was 830, 1765,4640,1560 & 15.96 mg/l respectively. Minerals present in the soil at the discharge of tannery effluent were also analysed using XRF (X-ray Fractionisation). Biological treatment with aquatic plant was found to be effective for the reduction of some physico chemical parameters. E.crassipes was found to be most effective in reducing BOD, COD, TDS, TSS and Total Chromium. E.crassipes was identified as most effective for the removal of chromium in the tannery effluent because of its extensive root system which provides to help the uptake of the pollutants from the industrial effluent.**

keywords - **Tannery effluent, Physico chemical parameters, E.crassipes and XRF.**

INTRODUCTION

Industries can generate a considerable pollution load which in many cases discharges directly into the environment without any pre-treatment. Tanning industry contributes significantly towards export, employment generation and occupies an important role in Indian economy. **Soyalsan and Karaguzel (2007)** reported that tannery wastes are ranked as the highest pollutants among all the industrial wastes. The heavy metal load from the tanning industry **(Nriagu and Pacyna 1988)** ensures that this will be a continuing problem for science and humankind. Chromium(Cr) is one of the heavy metals which is released into the environment is a serious pollution problem affecting water quality, therefore presenting a direct hazard to human health. Chromium which is present in the wastewaters cause chronicle alterations in nervous system, gastrointestinal tract and renal dysfunction and therefore presenting a direct. The chromium is released from a variety of sources such as mining, urban sewage, smelters, tanneries, textile industry and chemical industry. Techniques like reverse osmosis, ion exchange, electro dialysis, adsorption, etc. used for the removal of heavy metals are quite energy intensive, quite costly and metal specific. **Miretzky *et al.* (2004)** & **Singh *et al*. (1996)** reported that phytoremediation offers a promising technology for heavy metal removal from waste water.

Salt *et al*. (1999) reported that plant based bioremediation technologies have been collectively termed as phyto remediation; this refers to the use of green plants and their associated micro biota for the in-situ treatment of contaminated soil, sediments and ground water to remove, immobilize or detoxify environmental contaminants. This process is ecologically friendly and solar energy driven clean up technology. The phytoremediation process is non-destructive and cost effective and can be used for the clean-up of contamination.

Heavy metals are found to contribute to large extent in Environmental pollution all over the world. Extraction of metal from their ores for minerals is mainly responsible for the release of heavy metals into the atmosphere. Processing of these minerals for further use in different industries leads to pollution as the heavy metals are highly mobile in the environment. They are non-biodegradable elements and they tend to accumulate in the environment. When they accumulate in the soil and water bodies have threatening effects on the human health and they are certain to enter the food chain. The heavy metals also have the capacity to bio-accumulate in the tissues of animals and human body. They also have the ability to bio-magnify by reaching into higher trophic level from lower trophic level. A decrease in microbial activity is also seen, this may be the result of toxicological changes in the microbes of soils **(Khan *et al*. 2010)**.

Water hyacinth, an aquatic macrophyte is one of the most commonly used plants for phytoremediation. This is because it has a fast growing rate and exhibit large uptake of nutrients and contaminants **(Rai 1996)**. Water hyacinth (*Eichhornia crassipes*), a wild fern belonging to the family Pontederiaceae, is a submerged aquatic plant, found abundantly throughout the year; it is commonly found in India **(Mohanty et al. 2006 & El-Khaiary 2007)**. The most beneficial aspect of *E. crasppies* is its capacity to remove contaminants from polluted water bodies **(Chen *et al*. 1989)**. Various contaminants such as total suspended solids, dissolved solids, nitrogen, phosphorus, heavy metals, etc. as well as Biochemical Oxygen Demand (BOD), have been minimised using water hyacinth **(Gupta *et al*. 2012)**. Its roots act as natural biosorbent as they possess enormous capacity to absorb heavy metals **(Low *et al*. 1994)**.

MATERIALS AND METHODS

Collection of tannery effluent

The tannery effluent was collected from the discharge of tannery effluent located at Nagelkeni, Chennai, Tamilnadu. The effluent was transported to the laboratory to evaluate their physicochemical characteristics such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved solids (TDS) and Total Chromium. **(APHA, 2005)**. The samples were kept in refrigerator at 4°C for arresting any biological activity. The colour, odour and pH of the samples were also recorded.

Figure 1 Collection of tannery effluent and soil sample from Nagelkeni, Chennai, Tamilnadu.

Collection and maintenance of *E.crassipes* plants

Healthy green E.crassipes plants were collected from local unpolluted pond located at Vandavasi, Thiruvannamalai district, Tamilnadu and brought to the laboratory. The plant was identified and authenticated by Prof. Dr.P.Jayaraman, Plant Anatomy Research Centre (PARC), West Tambaram, Chennai, Tamilnadu, India. They were washed in running water to remove adhered sediment, epifauna and epiflora from the root and stem portion of the plants. Uniform sized plants approximately 200g weight of *E.crassipes* with similar shoot area and root length were selected.

Soil sample collection

The soil sample was also collected from the discharge of the tannery effluent and it was analyzed for the characterization of mineral content present in the soil sample through XRF analysis.

Experimental Protocol

The *E.crassipes* healthy plants were assessed for their phytoremediation efficiency against the tannery effluent collected from the discharge site of Nagelkeni. Three different concentrations were prepared so as to contain (0.6, 0.8 and 1.0 mg/l) of chromium and the levels were fixed because preliminary experiments showed that the plant did not grow beyond the level of 1.2 mg/l.

RESULTS AND DISCUSSION

The physicochemical characteristics of the tannery effluent

The physicochemical characteristics of the tannery effluent collected from Nagelkeni was performed. The assay showed that the colour of the sample was greyish black and had offensive odour and pH within the permissible limits. However, tannery wastewater is characterized mainly by measurements of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and Total Chromium. Table 1 shows the characteristics of the tannery effluent and the permissible limits for parameters in the wastewater from an industrial establishment mentioned in the rightmost column as per **CPCB (1995)**.

Table 1 Physico-chemical characteristics of tannery effluent

Parameters	Values for Tannery Effluent	Permissible limit as per CPCB 1995
Colour	Greyish Black	-
Odour	Foul Smell	-
pH	6.8	6.0-9.0
BOD(mg/l)	830	100
COD(mg/l)	1765	250
TDS(mg/l)	4640	2100
TSS(mg/l)	1560	100
Total Chromium(mg/l)	15.96	2

Analysis of Mineral content of soil sample collected from the discharge of tannery effluent using XRF

X-ray Fractionisation is a versatile technique used to identify any crystalline substance, such as most minerals. Most often it is used to quantify the proportion of different minerals and other substances present in the mixture very precisely. Tables 2 enlist the mineral content of the soil samples collected from the site of discharge of the tannery effluent from Nagelkeni. From the table 2, it is very clear that the presence of chromium is extremely high about 25.560 in sample collected from the tannery effluent. These levels indicate the extent of pollution in the soil at the site of tannery effluent discharge. The oxygen concentration is also very high followed by sulphur (7.55), chloride (7.455) and sodium (6.144) in the effluent sample from the discharge site of the present study.

In Table 2 we present the percentage concentrations of some of the compounds present in the soil samples collected at the site of tannery effluent discharge in Nagelkeni. Very high levels of Cr_2O_3 is present. Due to the presence of very high levels of chromium in the discharge site, the present study was continued with chromium and Chromium was removed using Phytoremediation. About 40 – 50% of this compound is present in the effluent studied. This was followed by sulphur oxide 18.85 respectively. Other compounds such SiO_2 and Al_2O_3 are also present in appreciable amounts.

Table 2 Minerals present in the soil sample collected from the discharge of tannery effluent

S. No	Minerals with their Formula	Values
1.	Al_2O_3	7.01
2.	CaO	3.7
3.	Cl	7.46
4.	Cr_2O_3	37.35
5.	CuO	0.03
6.	Eu_2O_3	0.16
7.	Fe_2O_3	1.9
8.	K_2O	0.4
9.	MgO	2.75
10.	Na_2O	8.28
11.	FP_2O_5	1.01
12.	SiO_2	10.48
13.	SO_3	18.85
14.	TiO_2	0.55
15.	ZnO	0.04

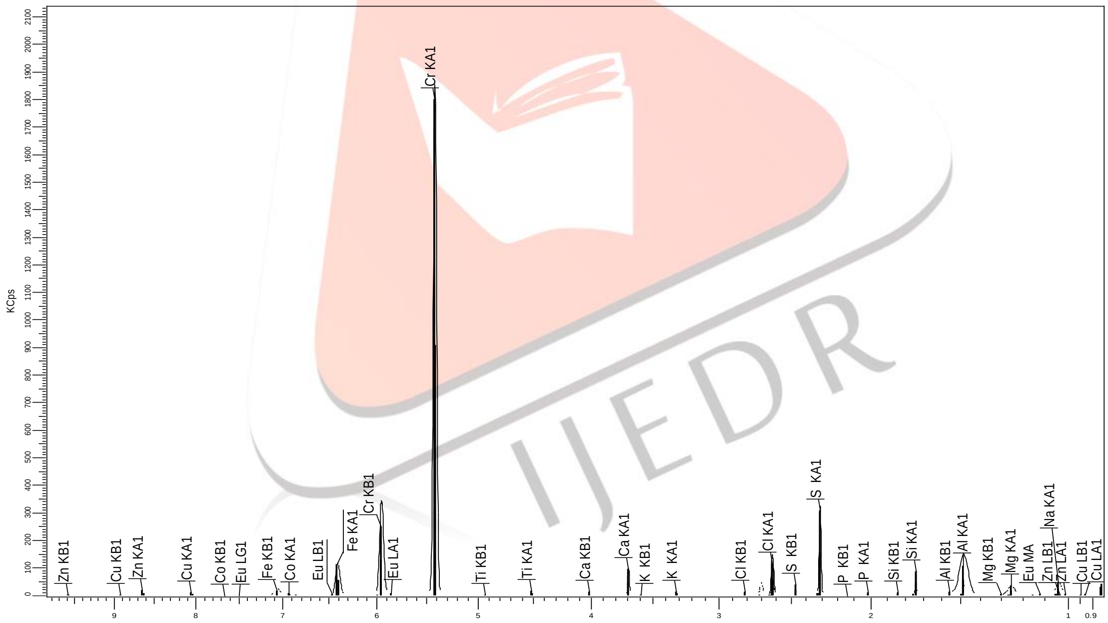

Figure 2 XRF for mineral content of soil sample

Table 3 Physico chemical characters of tannery effluent before and after treatment

Parameters	Values before Treatment	Values after treatment		
		0.6mg/l	**0.8mg/l**	**1.0mg/l**
Colour	Greyish Black	Light Brown	Light Brown	Light Brown
Odour	Foul Smell	Clay soil	Clay soil	Clay soil
pH	6.8 ± 0.01	7.0 ± 0.01*	7.2± 0.01*	7.4± 0.01*
BOD(mg/l)	830 ± 10.1	453 ± 11.2***	251± 8.2***	192± 10.5***
COD(mg/l)	1765 ± 17.2	1436 ± 15.5***	1130± 20.5***	930± 10.8***
TDS(mg/l)	4640 ± 20.5	3542 ± 20.2***	2354± 12.5***	1182± 14.1***
TSS(mg/l)	1560 ± 10.2	344 ± 8.2***	153± 2.2***	067± 1.2***
Total chromium(mg/l)	15.96 ± 1.2	2.32 ± 0.42***	1.42± 0.22***	0.84± 0.02***

Values are means ± SEM (n=6), *P<0.05, ***P<0.001 as compared to control by ANOVA

Physico chemical characters of tannery effluent before and after treatment

The physicochemical parameters were repeated in the tannery effluent collected from Nagelkeni. These tests were carried out after making suitable dilutions (0.6, 0.8 and 1.0 mg/l) based on the presence of chromium.

Colour and Odour

In the present study it was observed that after treatment with *E.crassipes*, the colour of the tannery effluent was changed from dark brown to light brown and foul smell odour was changed to clay soil odour (Table 3). The colour is usually the first contaminant to be recognized in wastewaters that affects the aesthetics, water transparency and gas solubility of water bodies **(Yuxing and Jian, 1999).** Unpleasant odour may be due to a large number of pollutants and microbial decomposition **(Paneerselvam, 1998)**.

pH

The most essential factor in the biosorptive process is pH which affects the metal's solution chemistry, the activity of the functional groups in the biomass and the competition of the metallic ions. pH of the tannery effluent was 6.8±0.01 after treatment with *E.crassipes*, it was increased to 7.4±0.01 (Table 3).The increase in pH could result from the photosynthetic activities of perphyton and phytoplankton communities or algae which depleted dissolved co_2 from the water and raised the water pH. An increase in pH value supports the growth of aquatic plant **(Vermaat and Hanif 1998)**. An optimum pH ranges of 6.5 – 7.5 was reported for *E.crassipes* **(El-Gendy *et al.* 2005)**.

Biochemical Oxygen Demand (BOD)

BOD is an important parameter indicating the pollution status and it is widely used as an indicator in all water pollution studies **(Subba Rao and Gadgil, 1996)**. It is revealed that high levels of biochemical Oxygen demand in the tannery effluents indicate high organic load. The presence of organic matter will promote anaerobic action leading to the accumulation of toxic compounds in the water bodies. Values obtained for BOD from tannery effluent was 830±10.0 mg/l before treatment and it was decreased to 384±5.2 mg/l after treatment with *E.crassipes* (Table 3). Present result is in agreement with the studies on tannery effluent **(Kulkarni, 1992)**. In the present study, the value of BOD before treatment is greater than the permissible limit of the **CPCB 1995**. Present Study coincides with **Trivedi *et al.* 1986**, in that study it was reported that the high value of BOD could be attributed to the high quantities of heavy metals in organic salts, oil and grease etc., all these components contribute largely towards the high BOD demand.

Chemical Oxygen Demand (COD)

High levels of COD in the tannery effluent indicate that the effluent is not suitable for the existence of the aquatic organisms, due to the reduction in the dissolved oxygen content. Raj *et al*. (1996) also have recorded higher values of COD from the treated tannery effluent of Nagelkeni (Chennai, Tamilnadu, India). Values obtained for COD from tannery effluent was 1765±17.2 mg/l before treatment and it was decreased to 930±10.8 mg/l after treatment with *E.crassipes* (Table 3). The COD values in the present study, decreasing in the effluent from Nagelkeni after phytoremediation with *E.crassipes*. Present study coincides with the similar results obtained by **Pathe *et al.* (1995)**.

Total Dissolved Solids (TDS)

Total dissolved solids are the solids contained in the filtrate that passes through a filter with a normal pore size of 2 micrometer or less. Industrial waste water from tannery effluents contains high fraction of dissolved solids. The size of the colloidal particles in waste water is typically in the range from 0.01 to 1.0 micrometer, **(APHA 2005)**. Values obtained for TDS from Nagelkeni tannery effluent was 4640±20.5 mg/l before treatment and it was decreased to 1182±14.4 mg/l after treatment with *E.crassipes* (Table 3). **Gamage & Yapa (2001)** reported reduction of TDS level after treatment with *E.crassipes*. The reduction of TDS obtained in the present study is similar to the result obtained by **Ghaly *et al.* (2004)** & **Watson & Chaote (1990)**.

Total Suspended Solids (TSS)

TSS is the high removal of solids which could be attributed to the property of proper article sedimentation by the test plant **(Piyush Gupta *et al.* 2012)** or the ability of the root plant to retain both coarse and fine particle and organic materials present in the waste water. TSS plays an important role in water and industrial waste water treatment. Their presence in water samples cause depletion of O_2 level. TSS is an important parameter for designing wastewater treatment plant and the length of the time for which waste water should be retained for primary treatment. Values obtained for TSS from Nagelkeni tannery effluent was 1560±10.2 mg/l before treatment and it was decreased to 067±1.2 mg/l after treatment with *E.crassipes* (Table 3). The reduction of TSS obtained in the present study is similar to the result obtained by **Ghaly *et al.* (2004)**.

Total Chromium

In the present study, the concentration of Chromium in Nagelkeni tannery effluent was reduced from 15 mg/l to 2 mg/l (Table 3) after phytoremediation with *E.crassipes*. Presence of chromium (VI) more than the standard limit in the water bodies causes many adverse effects to human beings, animals, plants etc. Hence stringent regulations have been imposed by various organizations. According to the world Health Organization (WHO) drinking water guidelines, the maximum allowable limit for hexavalent chromium and total chromium are 0.05 and 2 mg/l, respectively **(Gupta and Rastogi 2009)**. High reduction of Cr obtained in the present study is similar to the result obtained by **Mane *et al.* (2011)**; **Zhu *et al.* (1999)**; **Mishra *et al.* (2008)**; and **Valipour *et al.* (2010)**.

Conclusion:

Results obtained indicate that *E.crassipes* plant is suitable for waste water treatment. It has considerable capacity of pollutant reduction from the tannery effluent. Treated effluent is useful for domestic, agricultural and industrial applications. The efficiency of waste watertreatment was expressed in terms of the variation in pH, colour, Odour, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and heavy metals before and after treatment. When the plants were collectively grown, the removal of pollutants from the water is very high. The experimental results have shown that removal of chromium could be achieved by *E.crassipes*. The plants have also got the capacity to convert the accumulated biomass into biogas. This system of treatment was cost effective since cost of installation and maintenance was very low. In conclusion, the present study explained the feasibility of adopting a sustainable and eco friendly approach to tannery waste water treatment using aquatic plant *E.crassipes*.

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