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Research Article

Analysis and Treatment of Tannery Waste Water by using Combined Filtration and Coagulation Treatment Process

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Abstract: Tannery waste water severely effects the quality of water bodies into which it is discharged. Tanning effluent contains organic matter, chromium (Cr) and solid waste such as fleshing, trimmings, shavings and buffing dust. About 60% of the total chromium salts react with hides while 40% of the chromium amount remains in the solid and liquid wastes, which makes it a potential environmental concern. In this research work, tannery waste is processed by the pre-treatment step using a filter media followed by post treatment coagulation process. The later step is analyzed using $FeCl_3$ as a coagulant by varying chemical dose and settling time. These parameters were optimized to maximize the pollutant removal efficiencies measured in terms of reduction in concentration of Cr, total dissolve solids (TDS), total suspended solid (TSS), turbidity, biological oxygen demand (BOD_5) and chemical oxygen demand (COD). It was observed that by using 150 mg/L coagulant dose with 24 hours settling time, maximum removal efficiency of 93 % Cr, 71 % TDS, 95 % TSS, 72 % turbidity, 81 % BOD and 85% COD was achieved. The hybrid treatment process, investigated experimentally, can be employed commercially as a pre-treatment step for tannery waste waters.

Keywords: Tannery waste water treatment, coagulation, filtration, removal of chromium, effluent treatment, treatment process

1. INTRODUCTION

Due to increased population growth there has been an increase in the number of industries to meet the day to day demands of the mankind. Along with the useful products, these industries generate a large amount of toxic materials in various forms of solid, liquid and gaseous contaminations. The quantity and toxicity of these hazardous releases vary and depends on the type of industries. In 1991, Sehn et al. [1] analyzed that among all the industrial wastes, tannery effluents are the top ranked toxic releases. A significant part of the chemicals used in leather processing is not actually absorbed or consumed in the process and hence it is discharged into the environment. Due to industrial enlargement, huge amounts of industrial wastes are accruing in the environment and can't be disposed [2]. Liquid effluents from light leather processing comprises about 10 to 100 mg/L of organic matter, chromium, sulphide, and solid waste including fleshing, trimmings, shavings and, buffing dust [3]. About 60% of the total chromium salts react with the hides and about 40% of the chromium amount remains in the solid and liquid wastes [4]. Bidut et al. [5] investigated that Cr is hazardous to human wellbeing, beasts and the surroundings. Nowadays, all tanneries should thoroughly ascertain their waste watercourses. In Pakistan, there are a large number of tanneries (registered as well as un-registered) and footwear manufacturing units. The increase in the number of tanneries can be attributed to the increased demand of tanned leather in the world markets till the end of the fiscal year 2007-08.

Tanning involves a complex combination of mechanical and chemical processes. The heart of the process is the tanning operation itself in which organic or inorganic materials become chemically bound to the protein structure of the hide and

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preserve it from deterioration. These tanning agents give rise to the two predominant types of tanning operations- chrome and vegetable tanning. The pre and post tanning procedure in both tanning process is nearly the same but the difference is in the actual carrying of the tanning operations. In chrome tanning operation, the skin is treated with substances like chromium salts ($Na_2Cr_2O_7$, $K_2Cr_2O_7$, etc.) while in vegetable tanning extracts from the bark of various trees are used as the tanning agents.

The objective of any tannery waste water treatment is to reduce the organic matter, solids, nutrients and other pollutants such as BOD, COD, TSS, TDS and Cr to adhere the discharge standards limits set by relevant authority as allowable level of pollutants. Waste water treatment methods can be broadly classified as physical- chemical and biological processes [6]. Treatment of tannery effluent is difficult and represents a serious environmental and technological problem due to the presence of a series of chemicals with low biodegradability. So the treatment of tannery effluents is a matter of great concern in the country having leather tanning industry. As a result, a number of researchers have worked on the treatment of tannery effluents using different technologies [6]. Several studies have been carried out for the treatment of industrial effluents through coagulation and flocculation process [7, 8]. Coagulation is typically employed as a pre-treatment process and thus further treatments such as biological (secondary) and advanced (tertiary) treatment are required in the leather industry in order to meet the proposed tannery effluent standards [7]. In 2009, Apaydin et al. [8] introduced the electro-coagulation process that gave removal efficiencies of ~46% COD, 90% sulphide, 97% total chrome and 70% suspended solids. Advanced oxidation processes are effective in oxidation, de-colorization and degradation of organic pollutants but their drawback is of high operating cost compared to the other physico-chemical processes. Tasneem and Virupakash [9] treated the tannery waste water by natural coagulants such as *Cicer arietinum* (Chickpea), *Moringa oleifera* (Drumstick seeds) and Cactus which are relatively cost effective compared to the use of chemical coagulants. They obtained optimum dosage of *Cicer arietinum, Moringa oleifera* and cactus to be 0.1, 0.3 and 0.2 gm/500 mL and maximum reduction in turbidity 81.20%, 82.02% and 78.54% and in COD 90%, 83.33% and 75%, respectively.

The inorganic coagulants are compounds that break colloidal suspensions and help the floc formation. The frequently used coagulants in tannery effluent treatment are:

- Alum: industrial aluminum sulphate $\{Al_2(SO_4)_3.18H_2O\}$
- Iron sulphate ($FeSO_4.7H_2O$)
- Iron chloride: industrial ($FeCl_3.6H_2O$)
- Lime: industrial calcium hydroxide $\{Ca(OH)_2\}$

Among the commercially employed coagulants, such as $FeCl_3$, alum, lime, and TiO_2, the coagulant TiO_2 at a dosage of 150 mg/L has been reported to yield a removal efficiency of BOD 78%, COD 90%, TSS 100%, and Cr 94%. However, TiO_2 was reported to be not very economically suitable coagulant [10]. Conversely, $Al_2(SO_4)_3.18H_2O$ and $FeCl_3$ produced the least amount of sludge in comparison to $Ca(OH)_2$. Tannery effluents have also been treated with commercial grade lime [11]. Low values of COD and the removal of chromium, TSS, TDS were observed in this investigation. In this research work, untreated tannery effluent was treated by a combined process of settling, filtration and coagulation with $FeCl_3$ adopted from [12].

2. MATERIALS & METHODS

2.1. Experimental Setup

The experiments were carried out on a lab scale coagulation and flocculation unit with a pre-treatment filtration step. The Fig. 1 and 2 show schematic of the process and equipment that was employed in this work.

2.2. Experimental Procedure

First, 5 liters waste water was passed through the filter media in a pre-treatment step in order to reduce the solid content from the tannery effluent. The filtrate was then passed through the chemical treatment step in a coagulation and flocculation unit. $FeCl_3$ coagulant with a dose of 100 mg/L,

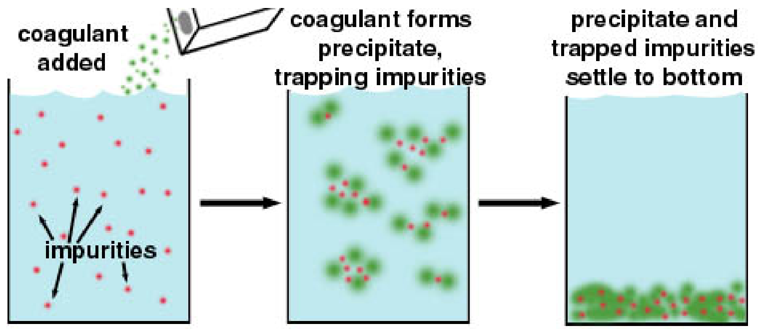

Fig. 1. Schematic of coagulation process [7].

Fig. 2. Experimental setup consisting of coagulation and flocculation unit.

150 mg/L and 200 mg/L was added to the filtered effluent and stirred gently for 20 min at 90 rpm. The effluent was then allowed to settle for 12 hours and 24 hours. After settling the supernatant liquid were then analyzed for various physico-chemical parameters such as concentration of Cr, TDS, TSS, turbidity, BOD_5 and COD.

1.3. Analysis of Physico-Chemical Parameters and its Value for Tannery Effluents

Table 1 shows the standard methods of Water and Wastewater (APHA-AWWA-WPCF, 1998) to analyze the pollutant parameters and their values for tannery effluents, treated in this research work.

2. RESULTS & DISCUSSION

Jar tests were performed by using the $FeCl_3$ coagulant. At the end of each test, the amount of residual pollutant and % removal efficiency of each parameter was measured in order to find out the optimum coagulant dose and settling point.

Table 1. Method of analysis and values of physico-chemical parameters for tannery effluents.

S. No	Parameters	Method of Analysis Used	Values of Tannery Effluent
1	Chromium	Colorimetric Method	725 mg/L
2	TDS	Gravimetric Method	8575 mg/L
3	TSS	Gravimetric Method	2395 mg/L
4	Turbidity	Digital Nephelometer	1500 NTU
5	BOD_5	Microbiological Titration Method	720 mg/L
6	COD	Closed Reflux Colorimetric Method	1150

Table 2. Analysis of coagulant dose and settling time for % removal efficiency of pollutant.

Dose (mg/L)	Settling Time (hr)	% Removal Efficiency of:					
		Cr	TDS	TSS	Turbidity	BOD_5	COD
100	12	69	60	90	50	51	61
100	24	78	62	91	50	55	64
150	12	91	69	94	71	78	83
150	24	93	71	95	72	81	85
200	12	80	62	92	60	59	72
200	24	88	63	93	62	63	74

Table 2 shows the % removal efficiency of the pollutant residues in the tannery effluents by using the coagulant dose of 100 mg/L, 150 mg/L and 200 mg/L for settling time of 12 and 24 hours.

Fig. 3 and Fig. 4 shows the % removal efficiency of the pollutant vs coagulant dose for settling times of 12 hours and 24 hours. From these figures, it can be observed that by increasing the dose, % removal efficiency increases up-to 150 mg/L but after this point dose had an inverse relation on the treatment process. The reduction in treatment efficiency, due to increase in dosage beyond 150 mg/L, may be attributed to increased number of coagulant particles surrounding the hazardous waste particles hindering their combination and of formation flocs that may settle easily [12].

Furthermore, it was observed that the settling time had a direct relation with the treatment process, i.e. by increasing the settling time the efficiency of the treatment process increased and vice versa. Fig. 5 shows the treated results of different parameters by the proposed process and the value of these parameters outlined by the National Environmental Quality Standards (NEQS) of Pakistan.

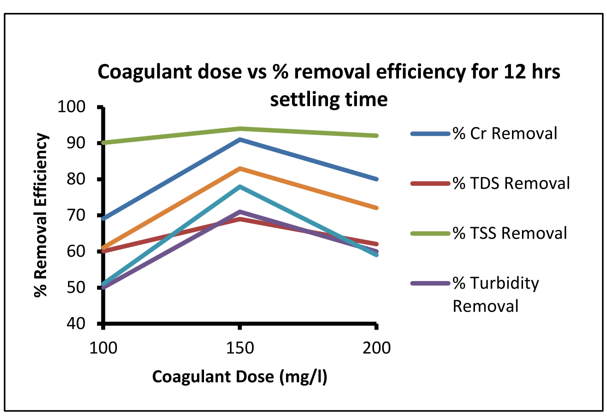

Fig. 3. Effect of coagulant dose on % removal efficiency for 12 hours settling time.

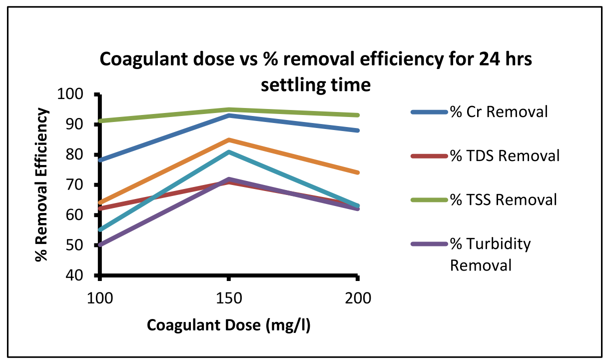

Fig. 4. Effect of coagulant dose on % removal efficiency for 24 hours settling time.

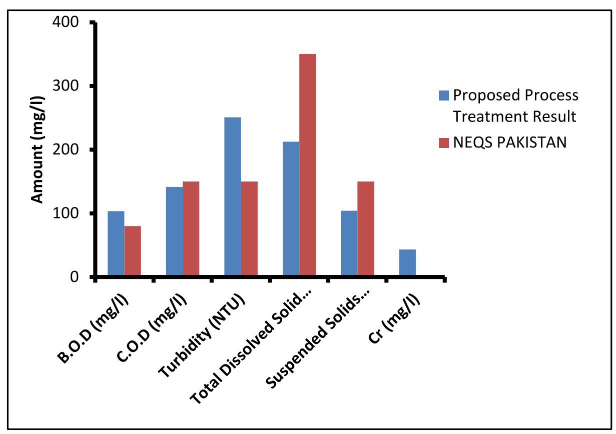

Fig. 5. Comparison of parameters by proposed hybrid treatment process and NEQS.

The treatment results confirmed adherence of most of the parameters for treated waste water, through proposed hybrid treatment process, with the NEQS of Pakistan. However, it is worthwhile to note that BOD_5 after treatment was observed to be slightly higher than the desired level, i.e., 80 mg/L as specified by NEQS of Pakistan. Similarly chromium content of the treated effluent was also higher than the desired 1 mg/L specification. Based on the experimental results it may be concluded that the proposed hybrid treatment process can serve as a suitable and effective pre-treatment step and only additional processing to remove remaining chromium would render the discharge of tannery waste water safe and environmentally more benign.

3. CONCLUSIONS

From this research it is concluded that the proposed hybrid treatment process (filtration and coagulation) can be used as an effective pre-treatment step to treat tannery waste waters. The increased $FeCl_3$ coagulant dose from 100 to 150 mg/L, increased the removal efficiency of the pollutants. However, any increase above the 150 mg/L resulted in decreased removal efficiency due to hindrance in floc formation of waste particles. Hence the 150 mg/L was identified as an optimum value and is thus suggested for the longer settling time of 24 hrs. The results obtained with the use of these identified optimum values suggested that this process was able to achieve the maximum % removal efficiency of 93 % Cr, 71 % TDS, 95 % TSS, 72 % turbidity, 81 % BOD and 85% COD. The results obtained are in good agreement with NEQS except of BOD_5, turbidity, and chromium content. Therefore, post-treatment would be required to reduce chromium content to <1 mg/L as required by NEQS of Pakistan.

Nomenclature:

Cr	Chromium
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
BOD_5	Biological Oxygen Demand on day 5
COD	Chemical Oxygen Demand
NTU	Nephelometric Turbidity Unit
NEQS	National Environmental Quality Standards
mg/L	milligram per liter
rpm	revolution per minute

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