BIOREMEDIATION OF DYEING INDUSTRY EFFLUENT USING MODIFIED CARBON

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Abstract

Pollution control is one of the prime concerns of society today. Untreated or partially treated wastewaters and industrial effluent discharges into natural ecosystems pose a serious problem to the environment. In this study, sulphonated carbon prepared from the bark of *Pongemia glabara* was coated with chitosan gel obtained from crab shells and used for the treatment for dyeing industry effluent.

Keywords : Chitosan, Pongemia glabara, Sulphonated carbon

I. INTRODUCTION

Environmental pollution causes health problems, by affecting human health and lives, economical problems by affecting human property and materials, ecological problems by disturbing a balanced ecosystem, interfering with the conservation of natural resources and threatening the more existence of some species and aesthetic problems by generally affecting human senses (Krishnan Kannan, 1991).

There are a number of chemicals in the environment. Some of these are toxic and the rest non-toxic. The toxic chemicals are discharged mainly from industries into air, water and soil. They get into the human food chain from the environment. Once they enter our biological system they disturb the biological processes leading to some changes even in the genetic level. According to the "International Register of Potentially Toxic Chemicals" of the United Nations Environment Programme, there are four million known chemicals in the world today and another 30,000 new chemicals are added to the list every year. Among these 60,000 to 70,000 chemicals are commonly used and others are potentially toxic (Anil Kumar, 1989).

Pollution is a gift of industrial civilization. India today is one among the top ten industrialized countries of the world. Pesticides, detergents, plastics, solvents, fuels, paints, dyes, food additives etc., are the outcome pollutants of various industries. Due to progress in atomic energy there has also been an increase in radioactivity in the biosphere. Besides these, there are a number of industrial effluents and emissions particularly poisonous gases in the atmosphere. Mining activities also added to this problem particularly as solid waste thus, pollution is a gift of industrial civilization (Sharma, 1999).

On the basis of waste and wastewater (or effluent) generation, the textile mills can be classified (ISPCH, 1995) into two main groups viz., Dry processing mills and Woven fabric finishing mills. In the dry processing mill, mainly solid waste is generated due to the rejects of cotton. In the other group, desizing, scouring, bleaching, mercerising, dyeing, printing, and packing are the main processing stages. These stages consume approximately 2400 to 2700 m^3/day of raw water (ISPCH, 1995). The existing treatment units comprise of neutralization / equalization tank, aeration tank, Reactor-I employing anaerobic biological treatment, Reactor-II employing aerobic biological treatment, and secondary clarifier. In the present investigation an attempt was made to synthesize a biosorbent by coating chitosan on carbon obtained from the barks of *Pongemia glabra* and use the same in the remediation of dyeing industry effluent.

II. MATERIALS AND METHODS

A.Collection of effluent samples

The effluent from various dyeing units of Arni, Tiruvannamalai district was collected from an effluent canal.

B.Preparation of chitosan gel

Chitosan (from crab shells) was obtained from India Sea Foods Cochin, Kerala. About 50 gms of chitosan was slowly added to 1000 ml of 10% acetic acid with constant stirring. The mixture was heated to get a whitish viscous gel of chitosan – acetic acid mixture.

C.Preparations of sulphonated carbon

The bark of the *Pongemia glabara* was cut in to small pieces, ground. This was burnt at very high temperature for 2-3 hours. The surface of carbon obtained was activated by shaking the same with 7% sulphuric acid for 24 hours. The carbon was then washed several times with deionized water till there is no acid in it. The sulphonated carbon was dried in hot air oven for 5 hours at 110°C.

D.Preparation of sulphonated carbon coated with chitosan

About 400 ml of chitosan gel was diluted with water (400 ml) and heated to 40 – 50°C. About 400 gms of activated sulphonated carbon was slowly added and mechanically agitated using a rotary shaker at 150 rpm for 24 hours. This chitosan gel-coated activated carbon was washed with deionised water and dried. This process was repeated to get a thick coating of chitosan on activated carbon. The amount of chitosan coated was determined to be 25% by weight.

III. EXPERIMENT

Five grams of Chitosan coated carbon was used for the experiment. The extent of remediation of the effluent was investigated separately changing the adsorbent dose and time of shaking the adsorbent metal solution mixture. The pH of each solution was adjusted with NaOH or HCl. The stoppered bottles were agitated at 30C by orbital shaker at fixed speed, 160 rpm for various time intervals.

The adsorbates were separated using Whattman filter paper and supernatant liquid was analyzed for residual concentration of the metals by atomic absorption spectrometer. Triplicate runs differing by less than 1% of all the tests were achieved assuring the reproducibility of the obtained data.

A. Studies on Physico-chemical parameters

Physico-chemical parameters such as electrical conductivity (EC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), chlorides, sulphate, sodium and potassium were recorded in the laboratory following standard methods (APHA, 1993).

IV. RESULTS AND DISCUSSION

Conventional physico-chemical methods for removing heavy metals from waste streams include chemical reduction, electrochemical treatment, ion exchange, precipitation and evaporative recovers. These processes have significant disadvantages, such as incomplete metal removal, high reagent and energy requirements, generation of toxic sludge or other waste products and are very expensive when the contaminant concentrations are in the range of 10-100 mg/l (Sao Kutsal, 1995; Bhide *et al*., 1996; Ozer *et al*., 1997).

The specific difficulty with industrial effluents is that they are very persistent and may be transported considerable distances by air, water, or the food chain, where they tend to accumulate, reaching concentrations in the upper trophic levels that are several orders of magnitude higher than those that originally existed, thus representing a continuous threat to the biota (Edmund *et al*., 1976).

These and other constituents degrade water quality, endanger aquatic life and human health. They also corrode equipment, generate hazardous gases, cause treatment plant malfunctions, and make the sludge disposal more difficult.

A new development in recent years for heavy metal removal is to use chitosan (CS) as the adsorptive material. Chitosan is a natural biopolymer with a high content of the amine ($-NH_2$) functional group and is inexpensive and abundant, widely available from seafood-processing wastes (Li and Bai, 2005).

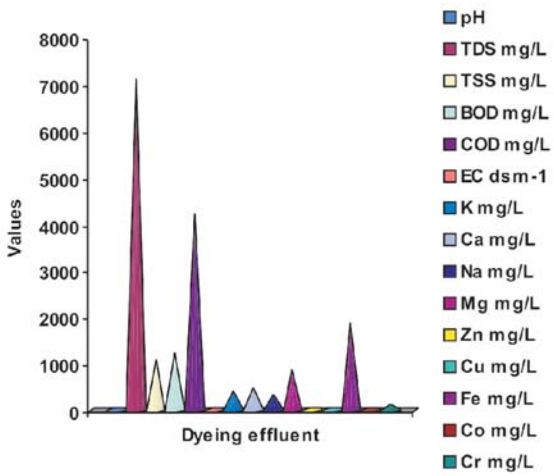
CS has been found to have high binding capacities, normally greater than 1mM metal/g CS, for many heavy metal ions, including Cd, Hg, Pb, Cu, etc., and the capacities have been reported to be even greater than polyaminostyrene, the constituent of expensive ion exchange resins (Bailey, *et al*., 1999). The good performance of chitosan in adsorbing heavy metal ions has been attributed to the capability of the amine group of chitosan to form surface complexes with many heavy metal ions in aqueous solutions (Guibal , 2004; Li and Bai 2005).

Chitosan has ionic edges, which are capable of chelating metals. Hence in the present investigation a study was undertaken to find out the efficacy of chitosan coated carbon of *Pongemia glabara* in remediating the dyeing industry effluent.

Table 1. Physico-chemical characteristics of the composite dyeing Industry effluent

Parameters	Dyeing effluent*	Optimum levels (MINAS)
pH	8.7	7.0-9.0
TDS mg/L	7120	462
TSS mg/L	1090	111
BOD mg/L	1250.2	400
COD mg/L	4210.0	421
EC dsm^{-1}	10.5	0.68
K mg/L	410	100
Ca mg/L	485	26
Na mg/L	365	200
Mg mg/L	890	84
Zn mg/L	62.4	5.0
Cu mg/L	17.4	3.0
Fe mg/L	1905	3.0
Co mg/L	45	0.2
Cr mg/L	124	2.0

*Values expressed as mean of 6 individual values



ig 1. Physico-chemical factors and the heavy metals present in the dyeing industry effluent

Table.1& Figure - 1 show the physico-chemical factors and the heavy metals present in the dyeing industry effluent. From the values it is evident that all the physico-chemical factors such as the electrical conductivity, the total dissolved solids and total suspended solids were very high when compared to the minimum standard values of this country. The amount of heavy metals such as copper, cobalt, chromium and zinc were found to be many fold higher when compared to the accepted limits. The results thus indicate that the effluent is hazardous to the organisms both aquatic and terrestrial, in which this effluent will be mixed.

An easy and cost effective method is highly necessary to remove the pollutants from the effluent. The chemical methods such as coagulation, precipitation etc., release secondary pollutants, which make the situation still worse. Hence a cost effective method is proposed in the present project work and also an attempt was made to find the efficacy of chitosan-coated carbon in remediating dyeing industry effluent. Initially the adsorbent was taken in different weights, and the level of remediation was measured. The values are presented in Table.2 &Figure – 2.

Table 2. Effect of adsorbent dose on the physico-chemical factors and metals of the dyeing industry effluent

Parameters	Effluent	Chitosan impregnated carbon*			
		1 g	2 g	3 g	4 g
EC dsm^{-1}	10.5	7.2	5.4	3.6	3.6
TDS (mg/L)	7120	4194	2464	1521	1500
TSS (mg/L)	1090	851	540	320	320
BOD (mg/L)	1250.2	734	444.0	202	100
COD (mg/L)	4210.0	1814	910	94	90
K (mg/L)	410	310	140	62	60
Ca (mg/L)	485	356	278	195	135
Na (mg/L)	365	257	196	144	114
Mg (mg/L)	890	711	521	311	315
Zn (mg/L)	62.4	51.0	24.0	8.1	8.0
Cu (mg/L)	17.4	13.4	7.1	2.4	2.4
Fe (mg/L)	19.5	746	379	36.0	35.0
Co (mg/L)	45	32	14.1	4.5	4.5
Cr (mg/L)	124	69	22.1	8.2	8.1

*Values expressed as mean of 6 individual values

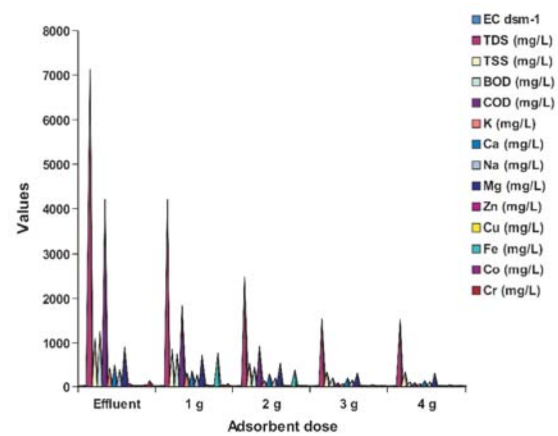


Fig. 2. Effect of adsorbent dose on the physico-chemical factors and metals of the dyeing industry effluent

From the above table it is evident that the removal of pollutants from the wastewater increases with the increase in adsorbent dose. The mechanical properties of chitosan are strongly influenced by the microphase separated morphology which results from an incompatibility between soft flexible aliphatic amino saccharide of chitosan.

Table 3. Effect of contact time on the physico-chemical factors and metals of the dyeing industry effluent

Parameters	Effluent	Chitosan impregnated carbon*			
		30 min	60 min	90 min	120 min
EC dsm^{-1}	10.5	8.6	5.1	3.6	3.6
TDS (mg/L)	7120	4244	2105	1750	1700
TSS (mg/L)	1090	851	620	320	320
BOD (mg/L)	1250.2	970	550	130	130
COD (mg/L)	4210.0	2210	1140	110	110
K (mg/L)	410	312	150	71	71
Ca (mg/L)	485	375	293	152	125
Na (mg/L)	365	274	202	151	114
Mg (mg/L)	897	722	561	315	313
Zn (mg/L)	62.4	52.6	26.4	9.1	9.0
Cu (mg/L)	17.4	13.6	7.9	2.5	2.5
Fe (mg/L)	19.5	7.68	5.96	4.6	3.3
Co (mg/L)	45	36	20.1	4.5	4.5
Cr (mg/L)	124	69	24.6	8.1	8.1

*Values expressed as mean of 6 individual values

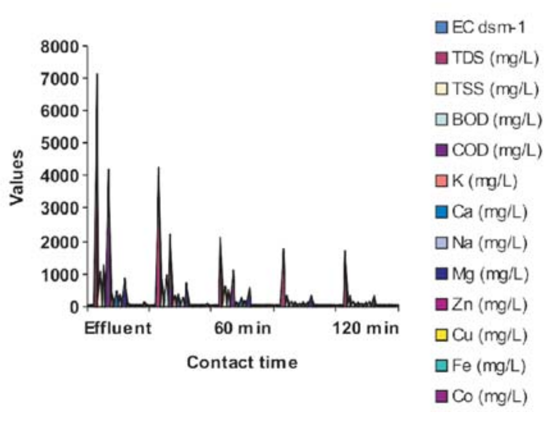


Fig. 3. Effect of contact time on the physico-chemical factors and metals of the dyeing industry effluent

Table.3 and Figure – 3 show the remediation levels of the dyeing industry effluent with respect to the contact time. From the results it is evident that the remediation rate increases with increase in the time of contact of the effluent with the adsorbents. In the case of chitosan-coated carbon, both the materials work synergistically in adsorbing the pollutants and remediating the dyeing industry effluent

Synthetic dyes are extensively used in the textile industry. Due to inefficiencies of the industrial dyeing process, 10– 15% of the dyes are lost in the effluents of textile units, rendering them highly colored (Vaidya and Date 1982; Boer *et al*. 2004). It is estimated that 280,000 tons of textile dyes are discharged in such industrial effluents every year worldwide (Maas and Chaudhari 2005). Direct discharge of these effluents causes formation of toxic aromatic amines under anaerobic conditions in receiving media.

In addition to their visual effect and their adverse impact in terms of chemical oxygen demand, many synthetic dyes are toxic, mutagenic and carcinogenic (Chung and Stevens 1993). The efficient removal of dyes from textile industry effluents is still a major environmental challenge (Baldrian and Gabriel 2003). The frequently high volumetric rate of industrial effluent discharge in combination with increasingly stringent legislation, make the search for appropriate treatment technologies an important priority (O'Neill *et al*. 1999).

Degradation of dyes, especially azo dyes, which comprise about 70% of all dyes used, is difficult due to their complex structure and synthetic nature (Swamy and Ramsay 1999; Maas and Chaudhari 2005). Currently, various chemical, physical and biological treatment methods are used to remove color (Pala and Toket 2002; Zhang *et al*. 2003). Because of the high cost and disposal problems, most of the chemical and physical methods for treating dye wastewater were not widely applied in the textile industries (Robinson *et al*. 2001; Mazmanci and Unyayar 2005). Because synthetic dyestuffs are resistant to biological degradation, color removal by bioprocesses is also difficult (Shaul *et al*., 1991; Willmott *et al*. 1998). Decolorization generally occurs by the adsorption of dyestuffs on bacteria, rather than oxidation in aerobic systems.

V. CONCLUSION

In this work, we have used cost-effective, simple-to-use and environmentally benign treatment technology. A method containing sulphonated carbon coated with chitosan was used for the treatment of dyeing effluents. The results of present investigation shows significant reduction of physico-chemical parameters and heavy metal content after treatment.

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