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Study of Feasibility of Soil as an Adsorbent for Textile Industry Effluent Treatment

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Abstract :**The control of water pollution has become of increasing importance in recent years. Though the release of dyes into the environment constitutes only a small proportion of water pollution but dyes are visible in small quantities due to their brilliance. Besides aesthetics, tightening government legislation is also forcing textile industries to treat their waste effluents to an increasingly high standard.**

Adsorption as a treatment technique has shown to be highly efficient for the removal of dyes and other organic content from the textile effluent. Normally reported studies are with the use of activated carbon and other low cost adsorbent which are not available abundantly locally making the cost of the treatment prohibitive, especially for MSMEs (Micro small and medium enterprises). Thus, the present scenario requires developing an adsorbent which is economically and commercially feasible.

In the present study, the feasibility of using soil of Indian origin as a low cost adsorbent for treating real textile effluent was studied. Two stage process i.e. coagulation followed by adsorption on modified soil was studied.

Coagulation followed by adsorption on modified soil as a combined unit process has shown encouraging results to treat textile wastewater through this process.

Keywords: Soil, Textile effluent, low cost adsorbents, coagulation.

1. INTRODUCTION

Wastewater generated by the industries which uses dyes and pigments is high in both colour and organic content. It is reported that about 1,00,000 different commercial dyes and pigments exist, and over 7×10^5 tons are produced annually worldwide. It was estimated that about 10-15% of these are released in effluents during dyeing processes [1]. The unexhausted dyes in the effluents are the issue for discharge in the environment because of their high brilliance and oxygen demand that are aesthetically and environmentally unacceptable [2]. They reduce light penetration and photosynthesis thus upsetting biological processes within a stream. In addition, most of dyes are either toxic or mutagenic and carcinogenic [3], [4]. Removal of dyes from effluents is important to regions where water resources might be scarce or sensitive [5]. Wastewater containing dyes is very difficult to treat, since the dyes are recalcitrant organic molecules, resistant to aerobic digestion, and are stable to light, heat and oxidizing agents [6].

Several physical, chemical and biological methods have been reported for colour removal but very few have been accepted by the textile industry. The advantages and disadvantages of some methods of dye removal from industrial effluents are given in Table 1. Amongst the numerous technologies of dye removal, adsorption is the procedure of choice and removes different types of colouring materials to give a high-quality treated effluent [7].

Activated carbon (powdered or granular) is the most widely used adsorbent because it has excellent adsorption efficiency for organic compounds, but its use is usually limited due to its high cost. Also, regeneration using solutions produces a small additional effluent, whereas regeneration by refractory technique results in a 10-15% loss of adsorbent and its uptake capacity [8].

Various low cost adsorbents have been investigated as alternatives to activated carbon such as fly ash [9], saw dust [10], bagasse fly ash [11], rice husk [12], agricultural waste [13], diatomaceous earth [14], clay [15], etc.

In the present study, soil of Indian origin has been used as a low cost adsorbent to treat real textile effluent on a fixed bed column for continuous adsorption. Only a few papers have reported the dye adsorption using continuous flow conditions, which is more useful in large-scale textile wastewater treatment.

The objective of the present study is to evaluate the efficiency of soil of Indian origin to treat the textile effluent. In addition, parameters like chemical oxygen demand and pH are also reported.

Table 1: Advantages and disadvantages of the current methods of dye removal from industrial effluents. [16]

Physical/chemical methods	Advantages	Disadvantages
Fentons reagent	Effective decolourisation of both soluble and insoluble dyes	Sludge generation
Ozonation	Applied in gaseous state: no alteration of volume	Short half-life (20 min), high cost
Photochemical	No sludge production	Formation of by-products
NaOCl	Initiates and accelerates azo-bond cleavage	Release of aromatic amines
Cucurbituril	Good sorption capacity for various dyes	High cost
Electrochemical destruction	Breakdown compounds are non-hazardous	High cost of electricity
Activated carbon	Good removal of wide variety of dyes	Very expensive
Peat	Good adsorbent due to cellular structure	Specific surface areas for adsorption are lower than activated carbon
Wood chips	Good sorption capacity for acid dyes	Requires long retention times
Silica gel	Effective for basic dye removal	Side reactions prevent commercial application
Membrane filtration	Removes all dye types	Concentrated sludge production, membrane fouling
Ion exchange	Regeneration: no adsorbent loss	Not effective for all dyes
Irradiation	Effective oxidation at lab scale	Requires a lot of dissolved O_2
Electrokinetic coagulation	Economically feasible	High sludge production

2. MATERIALS & METHODS

2.1 Adsorbent

In the present study, soil was used as an adsorbent material because of its abundant availability in the local environment. Soil was collected from the premises of Malaviya National Institute of Technology, Jaipur. The collected soil was then washed and oven dried. The dried soil was crushed and sieved. The 300 µm passing and 150 µm retained fraction was used for the present study. This fraction was further processed for the adsorbent preparation. The soil was modified by treating it with sulphuric acid for 30 minutes by very slow vertical stirring. Thus, the soil modified by this procedure was presumed to be activated. Likewise, three types of activated soil were prepared with different normalities of sulphuric acid; 1N, 2N & 6N respectively. After activating, the soil was washed several times to bring down the pH to neutral. This activated soil was then stored for further use.

2.2 Adsorbate

Real textile effluent obtained from Sanganer, Rajasthan was used in the present study. Many small and large scale textile industries are located at Sanganer. Thus, it can be assumed that wastewater brought from this place is composed of varieties of dyes. Effluent was initially treated by coagulation with $FeSO_4$ followed by adsorption on soil in the adsorption column.

2.3 Column studies

A measuring cylinder was devised as column to hold the soil as a fixed-bed adsorber. The bed was supported by gravels and coarse sand. The arrangement of the bed was in three layers such that gravels at the bottom followed by coarse sand in the middle and soil at the top. This was expected to allow uniform and good liquid distribution. The adsorbate was fed to the adsorption column in up-flow mode to avoid channelling of the effluent. A peristaltic pump was used to control the flow rate at the inlet. The flow rate was maintained such that the adsorbate get a 20 minutes contact time with the adsorbent i.e. soil. Samples from the outlet were collected at every 20 minutes interval for 1 hour.

Figure 1. Experimental set up

Figure 2. Untreated textile wastewater

2.4 Instruments

The treated and untreated wastewater were compared for parameters like COD and pH. A standard method based on oxidation of oxidisable components in the sample has been used for chemical oxygen demand (COD) measurements [18]. The reaction is made in the closed ampule and the oxygen quantity is measured colourimetrically on UV-1800 Shimadzu UV-Vis spectrophotometer at 600 nm with standard. pH was measured by pHep®HANNA instruments.

3. RESULTS & DISCUSSION

3.1 XRD Measurements

Adsorption depends on the chemical content of the adsorbent. X-ray diffraction (XRD) data given here provides the chemical content of the unmodified and modified soil. From the XRD data, presence of various aluminosilicates along with other chemical species could be observed. Aluminosilicates likes calcium aluminium silicates, aluminium silicate hydroxide, sodium aluminium silicate, potassium aluminium silicate, etc. are present in the soil. Other chemical species like aluminium oxide, silicon oxide, etc. are also present.

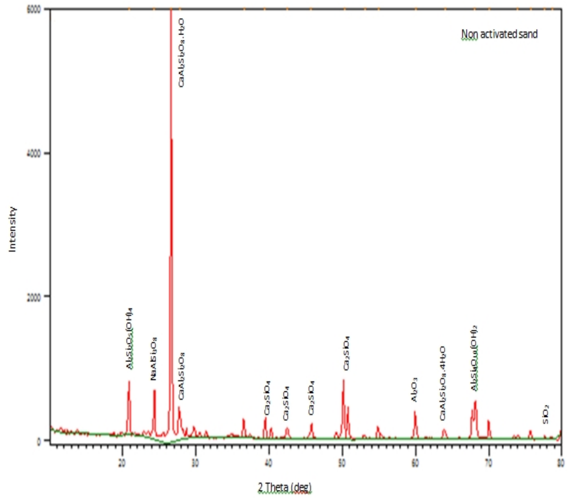


Figure 3. XRD data of Non-activated soil

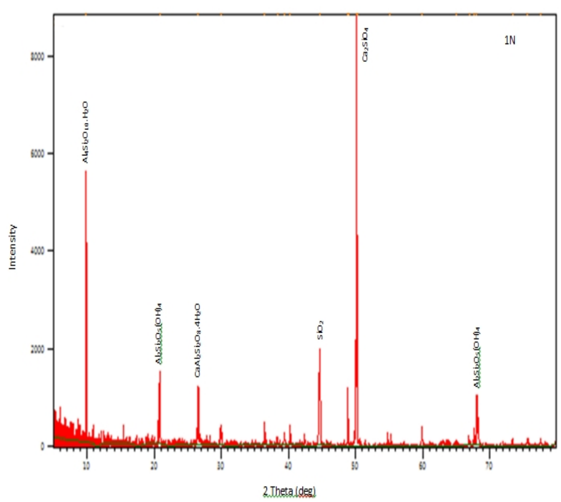


Figure 4. XRD data of 1N activated soil

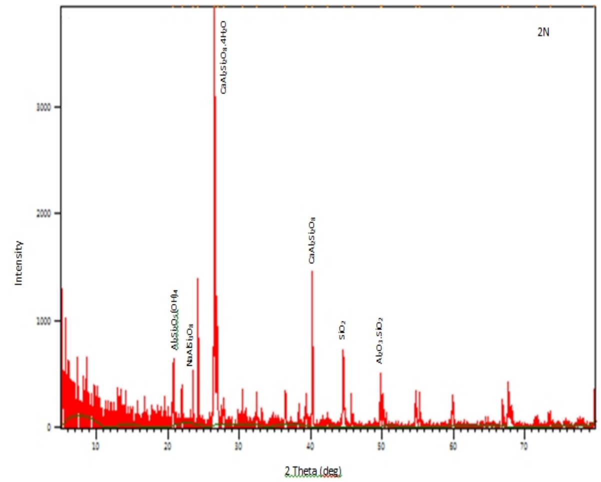


Figure 5. XRD data of 2N activated soil

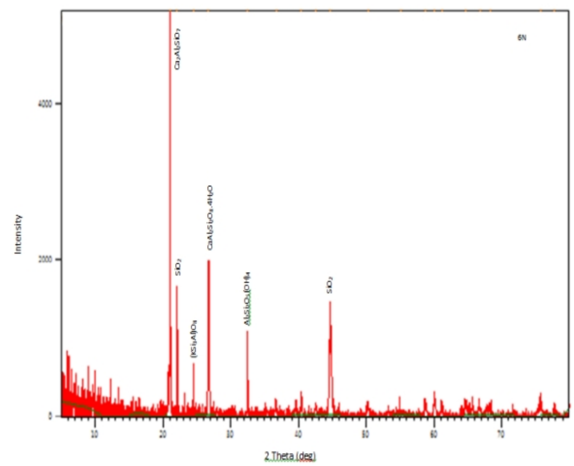
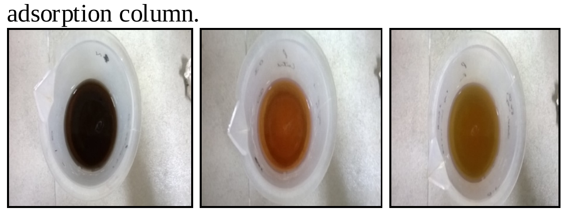


Figure 5. XRD data of 6N activated soil

3.2 Colour Removal through Coagulation with $FeSO_4$

$FeSO_4$ as a coagulant was used to identify its colour removal efficiency. Three different doses of $FeSO_4$ were compared to optimize the dose of the coagulant. After coagulation and flocculation with 0.4 g/L, 1.2 g/L and 2.0 g/L $FeSO_4$, settling time of 30 minutes was provided. Figure 6 shows that the dosage of 2.0 g/L was more effective in removing the colour from the textile wastewater as compared to the other two doses. Coagulation with $FeSO_4$ was helpful in removing partial colour from the textile effluent. Thus, the treated effluent with $FeSO_4$ was then passed through the soil adsorption column.



(a) (b) (c)

Figure6. Treated wastewater after coagulation: (a) 0.4g/L $FeSO_4$ dose (b) 1.2g/l $FeSO_4$ dose and (c) 2.0g/L dose

3.3 Colour Removal through Adsorption in Soil Column

It was found that the non-activated soil was not much effective in removing the remaining colour from the wastewater which is evident in the figure 7. Therefore, soil modified with sulphuric acid was used for adsorption. It was found that soil activated with 1N H_2SO_4 gave the better colour removal then the soil activated with 2N and 6N H_2SO_4.

(a)

(b)

(c)

(d)

Figure 7. Treated effluent from exit point of soil column (a) Non-activated soil (b) 1N activated soil (c) 2N activated soil (d) 6N activated soil.

In addition to colour removal, COD removal was also identified. And also, pH of the treated wastewater coming out of the soil adsorption column was also checked.

From figure 8, it can be clearly seen that the soil activated with 1N H_2SO_4 gave almost 90% of the of the COD removal. While, the soil activated with 2N H_2SO_4 was slightly lower than the soil activated with 1N H_2SO_4 and gave almost 85% COD removal. A deep dip at 40^{th} minute in COD removal could easily be seen with soil activated with 6N H_2SO_4. It could be presumed that this was due to the leaching out of the organic matter into the treated effluent. Another thing worth noticing is that it took almost an hour in all the three activated soil to provide 80-90% of COD removal.

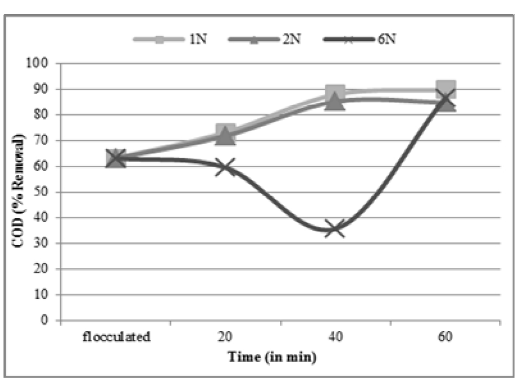


Figure 8. COD removal on different activated soil

The pH of the treated effluent coming out of all the three adsorption columns is almost 7 with a little bit of fluctuations (figure 9).

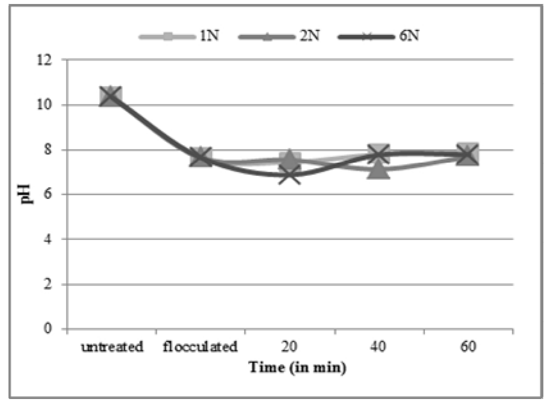


Figure 9. pH of the treated effluent with respect to time

The presence of aluminosilicates along with the oxides of aluminium and silicon are anticipated to play a role in colour and COD removal from the textile wastewater. It has been reported that zeolites have high ion exchange properties due to the presence of the framework of aluminosilicates in their structure [6], [17]. Thus, the expected mechanism of the adsorption in the present study is through ion exchange as the XRD data have shown the presence of aluminosilicates in the soil. However, authors are still investigating to confirm this mechanism. The performance of 1N activated soil was better than 2N and 6N activated soil because of the possibility that the aluminosilicate structure might have been destroyed in the strong acidic conditions of 2N and 6N H_2SO_4 in comparison to 1N H_2SO_4 during the soil modification process [17].

4. CONCLUSIONS

From the preliminary studies, coagulation followed by adsorption on soil has given encouraging results, especially for COD removal though not so encouraging for colour removal. Other methods for the modification of soil must also be investigated to increase the adsorption efficiency. Use of other coagulants instead of $FeSO_4$ must be studied in combination with adsorption on soil for both COD and colour removal, which are a challenge of textile wastewater treatment.

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