

**Decolourisation of the textile dye Methyl Red from aqueous solution using
Sugarcane Bagasse Pith**

ABSTRACT

The present study investigates the potential of sugarcane bagasse pith, an agro waste as an effective adsorbent for the removal of methyl red. Physicochemical parameters like concentration of dye, amount of adsorbent, temperature, pH and contact time were optimized to develop faster decolourization process. The spectrophotometric technique was adopted for the estimation of the concentration of dye before and after the adsorption. The results showed that the maximum decolourization (86%) of methyl red by sugarcane bagasse pith was found in 10mg/L dye, 500g/L of the adsorbent dose at pH 5 with temperature 30⁰C for 5 days. UV-vis spectral analysis showed a new peak at 781nm which confirms the degradation of methyl red. The surface structure of the adsorbent treated with dye showed a significant difference when compared with control. The earlier results justify the applicability of the bagasse in removal of methyl red from textile wastewaters and their safe disposal.

Key words: Adsorption, sugarcane bagasse pith, methyl red, optimisation parameters

1. INTRODUCTION

The rapid development of industries, population explosion and discharge of pollutants from various industries results in environmental pollution. Among various types of environmental pollution, water pollution is the major distress to the community, because of the existence of dye stuff in the wastewater which are released from the dyeing industries [1].

Almost all the industrial sectors are responsible for the environmental pollution [2]. Among them, textile industry plays a vital role in the release of effluents with a huge amount of additives, surfactants, detergents, suspended solids, carcinogenic amines and dyes that poses environmental threats to aquatic bodies [3]. Without any proper treatment, the bleached wastewaters from textile industries are directly released into water bodies. It makes a severe problem to aquatic life, reduces photosynthetic activity and also has an adverse effect on human health and causes toxicity turbidity problems [4]. Hence most of the dyes are toxic, mutagenic and carcinogenic in nature [5]. Elimination of colour from textile wastewater is one of the major environmental problems and its removal seems to be difficult by treating it with conventional method because the dyes are stable and to heat and oxidizing agents [6].

The physicochemical treatment methods such as adsorption, sedimentation, flocculation, floatation, coagulation, osmosis, neutralization, reduction, oxidation, electrolysis, ion-exchange are employed for dye removal. But, these methods are expensive and in addition, most of them produce the large quantity of sludge which needs further disposal. Therefore, economically and eco friendly techniques are needed for the degradation of dye from textile effluent [7,8,9,10].

Recently, a number of low costs, easily available and effective adsorbents were used for the removal of different dyes from aqueous solution. Many studies have been focused on the use of non-conventional low-cost adsorbents such as sugarcane bagasse, coconut husk, groundnut shell, banana pith, clay, rice husk, maize cob, coir pith, orange peel and wheat straw dust in wastewater treatment. Instead of disposing of the sugarcane bagasse as a waste material, it has been used as an adsorbent for the removal of dyes from the wastewater. It mainly consists of cellulose (45%), hemicellulose (28%) and lignin (18%) and also it has carboxylic and hydroxyl groups, which are responsible for the uptake of dyes from wastewater [11,12,13]. The aim of the present study is to determine the optimum conditions for the removal of methyl red by sugarcane bagasse pith.

2. Material and Methods

2.1 Sugarcane bagasse pith

The adsorbent, sugarcane bagasse pith was collected from a local juice market in Coimbatore, Tamilnadu. The bagasse was washed with water to remove the dirt and then it was dried under shade for 5 days for the removal of moisture. The dried bagasse was ground and sieved to the desired particle size of about 50 μm and used for adsorption studies.

2.2 Methyl red dye

Methyl Red, 2-[4-(dimethylamino)phenylazo] benzoic acid, used as an adsorbate for the study was purchased from the local dye market, Coimbatore, Tamilnadu. It is an azo dye pH indicator a dark red crystalline powder with molecular formula – $\text{C}_{15}\text{H}_{15}\text{N}_3\text{O}_2$, molar mass - 269.3 g mol^{-1} , density - 0.791 g cm^{-3} , Colour Index Number - 13020, EC Number 212-682-9, MDL number MFCD00002426 and melting point - 179-182°C.

2.3 Batch adsorption experiment

The effect of dye concentration, adsorbent dosage, pH, temperature and contact time were studied for the effective removal of colour. The batch adsorption studies was conducted at different dye concentration (10-50mg/L), adsorbent dose (100-700g/L), pH (2-10), temperature (20-60°C) and contact time (1-10days). The control experiments were

maintained without adsorbent. The pH of the solution was adjusted using 0.1N NaOH and 0.1N HCl. Under optimised conditions, the untreated and treated dye solutions were filtered and centrifuged at rpm for 10mins. The absorbance of the supernatant was determined by the decolourisation percentage. After the 5th day of contact time, the untreated and treated dye solutions were centrifuged at 5000 rpm/10mins. The absorbance of the supernatant was determined by the decolourisation percentage

$$\text{Decolourisation percentage} = \frac{C_i - C_o}{C_i} \times 100$$

C_i =initial absorbance, C_o = absorbance at 5th day of incubation time

2.4 UV-Vis spectroscopic analysis

Decolourisation was monitored by UV- visible spectroscopic analysis. The spectrum was recorded using Shimadzu UV-1800 at the range of wavelength 200-800 nm. The initial and final absorbance values of untreated and treated peaks of methyl red were used to determine the dye decolourisation.

2.5 Scanning electron microscopic analysis

The surface morphology of treated and untreated sugarcane bagasse pith was investigated using Scanning Electron Microscopy (SEM) Model HITACHIS3400N at an accelerating voltage of 15 kV. Before the examination, the surface of the untreated and treated samples was coated with a thin layer of gold approximately 30 nm using Sputter Coater Polaron SC 515.

3. Results and Discussion

3.1 Physicochemical parameters

The adsorbent dose is an important parameter in adsorption studies because it determines the capacity of the adsorbent for a particular dye concentration. The dye removal from methyl red by sugarcane bagasse pith was studied by varying a amount of adsorbent doses (100-700g/L). The percentage of colour removal was increased from 14% to 87%, as the adsorbent dosage increased from 100 to 500g/L after that the equilibrium was attained (Figure.1).

The experiment was carried out at different concentrations of methyl red (10-50mg/L). Figure 2 shows that the dye removal was reduced from 72% to 19% as concentration was increased from 10 to 50 g/L. It was evident that the percentage of dye adsorption by sugarcane bagasse pith decreased with the increase in initial dye concentration.

pH plays a significant role in decolourisation process and mainly on the adsorption capacity. Variation in solution pH leads to change the degree of ionization and the surface properties of the adsorbent [20]. In this view, the experiments were performed in different pH

100 ranges (2-10) to attain the optimum pH for dye decolourisation. The results showed in the
101 figure 3 reveal that the maximum of 83% decolourisation was found at pH 4 which decreased
102 to 13% at pH (10).

103 A study on the temperature dependence of adsorption reactions gives valuable
104 knowledge about the enthalpy and entropy changes [26]. The effect of temperature on
105 decolourisation methyl red by sugarcane bagasse pith was studied at five different
106 temperatures (20-60⁰C). In figure 4, the maximum decolourisation of methyl red by bagasse
107 pith was noticed at 30⁰C.

108 The effect of contact time on methyl red decolourisation by sugarcane bagasse pith
109 was investigated on different days (1-10 days). A rapid decolourisation was found at the
110 initial stages of the adsorption and equilibrium was attained from 5th day onwards (Figure. 5).
111 Such uptakes specify a high degree of affinity towards the dye molecules through
112 chemisorptions [30]. The minimum colour removal efficiency was obtained at the 10th day
113 which shows that the aggregation of dye molecules decreased with increase in contact time
114 and makes it almost impossible to diffuse deeper into the adsorbent structure at highest
115 energy sites [31]. The results of the present study coincide with Wong *et al.*[32] who stated
116 that 85% of the RO16 dye was removed within 180mins of contact time when treated with
117 sugarcane bagasse.

118 Thus the optimum conditions for removal of methyl red from an aqueous solution by
119 sugarcane bagasse pith were successfully identified (Table. 1). Under the above-optimised
120 conditions, the maximum adsorption (86%) was achieved.

121 3.2 UV-visible spectral analysis

122 Adsorption was further confirmed by UV-vis spectra in which the untreated dye
123 showed characteristic absorbance peaks at 586, 393, 315 and 259nm. After adsorption, the
124 decrease of peak intensity at 781nm in treated dye indicates the complete adsorption of the
125 dye by sugarcane bagasse pith (Fig 6). Naveenprasad *et al.*[33] reported that the absorbance
126 peaks of methyl red dye were found to be 530nm before adsorption and after adsorption, the
127 peak intensity decreases which signifies the maximum adsorption of dye.

129 3.3 Scanning Electron Microscopic (SEM) analysis

130 SEM is a primary tool for characterizing the surface morphology and fundamental
131 physical properties of the adsorbent surface and it is also useful for determining the surface
132 shape of particle and the appropriate size distribution of the adsorbent. Figure 7 showed the
133 SEM images of the sugarcane bagasse before and after adsorption. SEM micrograph of

untreated sugarcane bagasse pith formed aggregates whereas the treated bagasse looks like a fiber with flake shape. Pham *et al.* [34] showed that the surface images of sugarcane bagasse had a smooth and less porous texture, after the adsorption of cadmium.

DISCUSSION

Increase in the adsorption with the increase of adsorbent dose can be attributed to the increase in adsorbent surface area and availability of more adsorption sites [14]. Subramanian and Ponnusamy [15] stated that the increase in dye removal with increasing adsorbent dose was due to the split in the concentration gradient between solute concentrations in the surface of the adsorbent. Asoka and Inamdar [16] reported that 76% of methyl red dye was removed by sugarcane bagasse from aqueous solution with 500g/L adsorbent dose which supports the present study. It was also observed by Raymundo *et al.*[17] that 500g/L of sugarcane bagasse removed 80% of congo red dye in aqueous solution.

Natarajan *et al.*[18] stated that, at lower dye concentration, the ratio of dyes to the available surface area is low subsequently the fractional adsorption become independent of initial concentration. However, at high concentration the available sites of adsorption become less and hence the percentage removal of dyes is dependent upon initial concentration. Said *et al.*[19] reported that 100% dye (methylene blue and orange II) removal was achieved in lower dye concentration (100 mg L^{-1}).

This confirms that the alkaline pH was unfavourable for dye decolourisation by sugarcane bagasse pith which was attributed to the anion exchange reaction between the dye and surface-active groups on the adsorbent [21]. Malik [22] and Mohamed [23] reported that at low pH, the active sites of the adsorbent will be largely protonated and the H^+ ion creates an electrostatic attraction between the adsorbent and the dye molecules which leads to maximum colour removal.

At pH above 4, the degree of protonation on the surface sites will be less which result in the decrease in diffusion and adsorption thereby due to electrostatic repulsion [24,25]. Furthermore, lower adsorption of the dyes in an alkaline medium can also be attributed to the competition from excess hydroxide ions (OH^-) with the anionic dye molecules for the adsorption sites. In this study, the adsorption was unfavorable in acidic pH. This is attributed to the increase in H^+ concentration leading to the formation of aqua complexes thereby retarding the dye sorption. A similar finding was reported by Abdullah *et al.*[14] who stated that the 82% of methylene red dye uptake was found at acidic pH (4) by sugarcane bagasse. Adsorption is normally exothermic in nature and the extent and rate of adsorption decrease

with increasing temperature of the system [27]. Similar such removal was observed in textile effluent [28] and Foron blue E-BI [29] at 30⁰C using sugarcane bagasse.

4. CONCLUSION

Sugarcane bagasse is a farming waste material which is easily available at a low cost and also used as a successful adsorbent for the treatment of dyes in the effluent. The optimization study has been investigated under different experimental conditions for the elimination of dyes from the effluent. The decolourisation of methyl red was dependent relative on the solution pH, dye concentration, adsorbent dose, contact time and temperature. The maximum dye removal was achieved using sugarcane bagasse pith, hence it proves that, to be an outstanding low-cost material in the treatment of textile industrial effluent.

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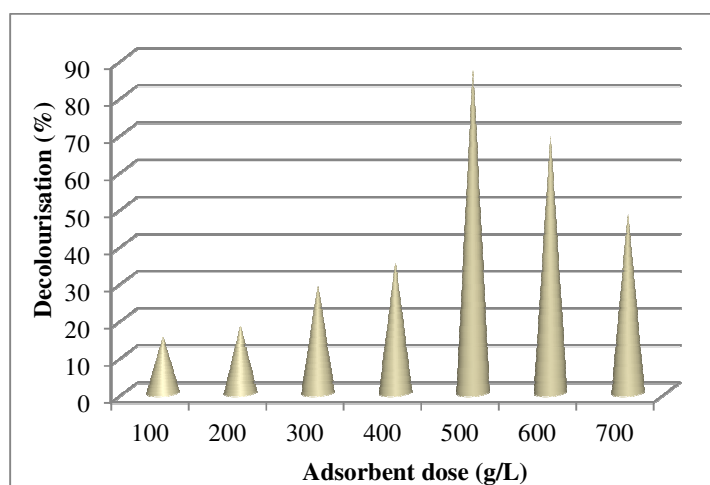
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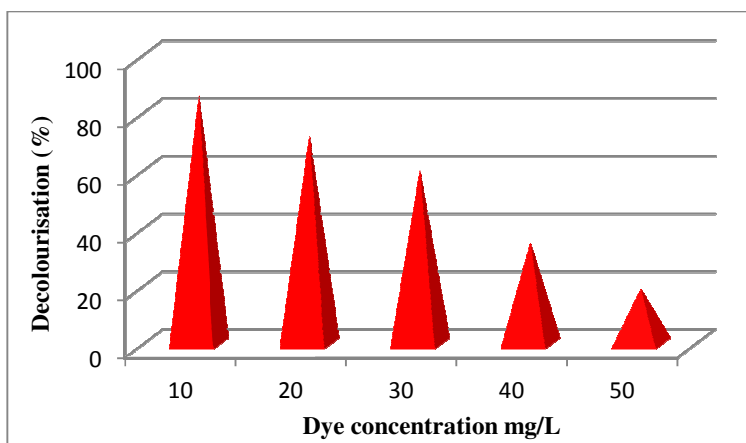
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275 Tables and Figures



276 **Figure-01 Effect of Adsorbent dose**



278 **Figure-02 Effect of Dye concentration**

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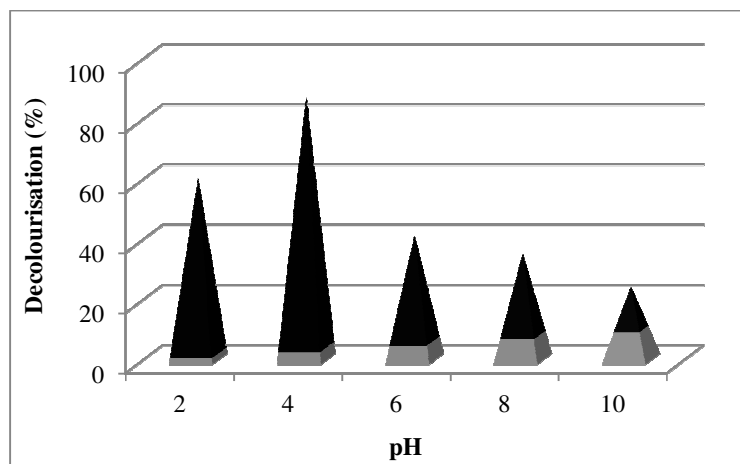


Figure-03 Effect of pH

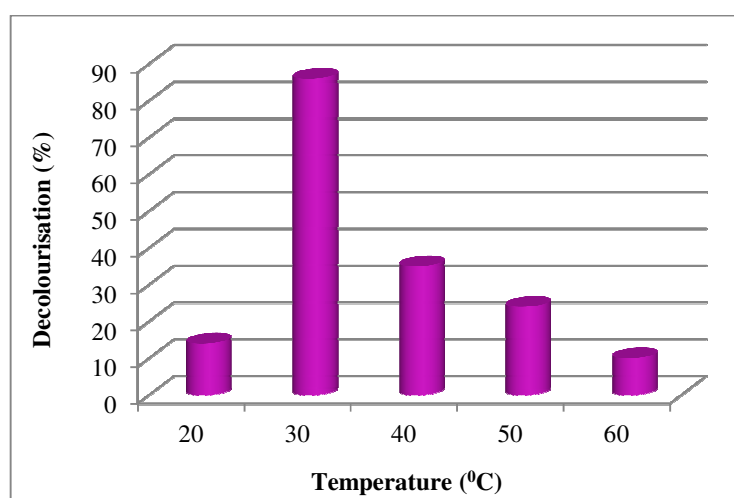


Figure-04 Effect of temperature

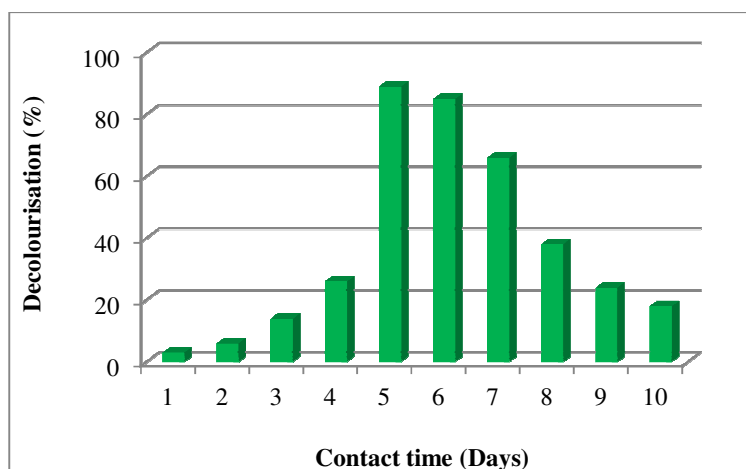


Figure-05 Effect of Contact time

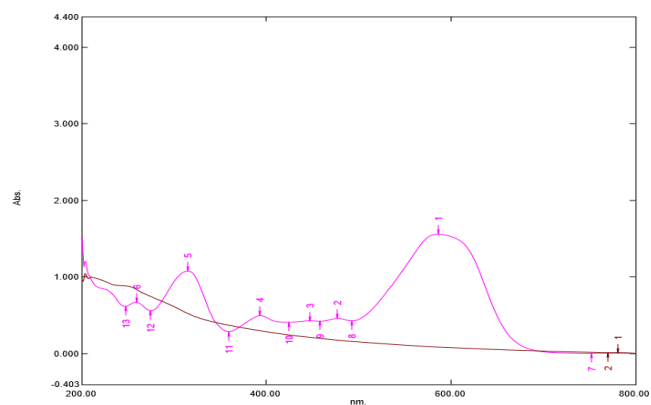


Figure-06 UV-visible spectra of methyl red dye (before and after decolourisation)

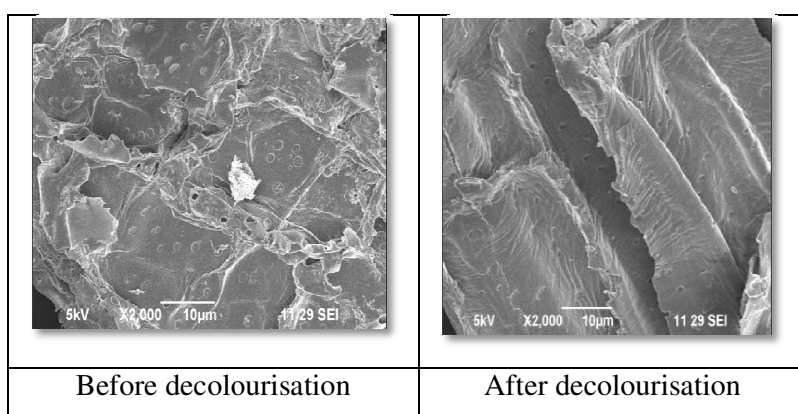


Figure-07 SEM image of sugarcane bagasse pith treated with methyl red

S.No	Parameters	Adsorption condition	% Adsorption
1	Dye concentration	10g/L	85.62
2	Adsorbent dose	500g/L	87.41
3	pH	4	83.15
4	Temperature	30 ⁰ C	86.03
5	Contact time	5 th day	88.79

Table-01 Optimum conditions for maximum methyl red removal