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Dye Removal from Aqueous Solution by using Adsorption on Treated Sugarcane Bagasse

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Abstract: The use of cheap and ecofriendly adsorbents has been studied as an alternative substitution of activated carbon for the removal dyes from wastewater. Adsorbents prepared from sugarcane baggase-an agro industries waste was successfully used to remove the methyl red from an aqueous solution in a batch reactor. This study investigates the potential use of sugarcane baggase, pretreated with formaldehyde (PCSB) and sulphuric acid (PCSBC), for the removal of methyl red from simulated wastewater. Formaldehyde treated and sulphuric acid treated sugarcane bagasse were used to adsorb methyl red at varying dye concentration, adsorbent dosage, pH and contact time. Similar experiment was conducted with commercially available powdered activated carbon (PAC), in order to evaluate the performance of PCSB and PCSBC. The adsorption efficiency of different adsorbents was in the order PAC>PCSBC>PCSB. The initial pH of 6-10 flavors the adsorption of both PCSB and PCSBC. Adsorbents are very efficient in decolorized diluted solution. It is proposed that PCSB and PCSBC, in a batch or stirred tank reactors could be employed as a low cost alternative in wastewater treatment for the dye removal.

Key words: Formaldehyde, sulphuric acid, dyes, adsorption

INTRODUCTION

Dyes production industries and many other industries which used dyes and pigments generated wastewater, characteristically high in color and organic content. Presently, it was estimated about 10,000 of different commercial dyes and pigments exists and over 7 x 10^5 tones are produced annually world wide[1].

Dyes are widely used in industries such as textile, rubber, paper, plastic, cosmetic etc. Among these various industries, textile ranks first in usage of dyes for coloration of fiber.

The convectional wastewater treatment, which rely on aerobic biodegradation have low removal efficiency for reactive and other anionic soluble dyes. Due to low biodegradation of dye, a convectional biological treatment process is not very effective in treating a dye wastewater. It is usually treated with either by physical or chemical processes. However, these processes are very expensive and cannot effectively be used to treat the wide range of dyes waste[2].

The adsorption process is one of the effective methods for removing dyes from the waste effluent. The process of adsorption has an edge over the other methods due to its sludge free clean operation and completely removed dyes, even from the diluted solution. Activated carbon (powdered or granular) is the most widely used adsorbents because it has excellent adsorption efficiency of the organic compound. But, commercially available activated carbon is very expensive. Furthermore, regeneration using solution produced small additional effluent while regeneration by refractory technique results in a 10-15% loss of adsorbents and its uptake capacity [3].

This had led to further studies for cheaper substitutions. Nowadays, there are numerous number of low cost, commercially available adsorbents which had been used for the dye removal (Table 1).

However, as the adsorption capacities of the above adsorbents are not very large, the new adsorbents which more economical, easily available and highly effective are still needed.

MATERIALS AND METHODS

Preparation of adsorbents: Powdered activated carbon was supplied by BDH Laboratory Supplies, Poles England. The adsorbents were used directly without any further grinding and sieving. Following specification are given by the manufacturer: pH value 5-8, loss on drying < 20%, methylene blue adsorption (0.15% solution)>5 mL 0.1 g^{-1}.

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Table 1: Some low cost materials for dye removal from aqueous solution

Adsorbent(s)	Dye(s)	References
Bamboo dust, coconut shell, groundnut shell, rice husk	Methylene blue	[4]
Silk cotton hull, coconut tree sawdust, sago waste, maize cob	Rhodamine-B, Congo red, methylene blue, methyl violet, malachite green	[2, 5]
Parthenium hysterophorus	Methylene blue, malachite green	[6]
Rice husk	Malachite green	[7]
Coir pith	Acid violet, acid brilliant blue, methylene blue, Rhodamine-B	[8, 9]
Orange peel	Acid violet 17	[10]
Indian Rosewood	Malachite green	[11]
Prosopic cineraria	Malachite green	[1]
Banana and orange peels	Methyl orange, methylene blue, Rhodamine-B, congo red, methyl violet, acid black 10B	[12]
Giant duckweed	Methylene blue	[13]
Banana pith	Congo red, Rhodamine-B, acid violet, acid brilliant blue	[14-17]
Orange peel	Congo red, Rhodamine-B, procion orange	[18]
Carbonized coir pith	Acid violet, Rhodamine-B	[19]
Hardwood	Astrozone blue	[20]
Chitosan	Acid blue 25, basic blue 69	[21]
Mahogany sawdust, rice husk	Acid yellow 36	[22]
Biogas residual slurry	Congo Red, Rhodmine-B, acis violet, acid brilliant blue	[23]
Plum kernels	Basic Red 22, acid blue 25	[24]
Rice husk	Safranine, methylene blue	[25]

Table 2: Characteristic of the methyl red

CAS No.	493-52-7
C.I. No.	13020
Chemical Formula	$C_{15}H_{15}N_3O_2$
Molecular weight	269.31
Melting Point	179-182 °C
Dye Content	~ 95 %
Absorption Max (pH 4.5)	523-526 nm
Absorption Max (pH 6.2)	430-434 nm
Absorptivity (1%, 1 cm) pH 4.5	> 1330
Absorptivity (1%, 1 cm) pH 6.2	> 700
Transition Range	pH 4.2-6.2 (Red - Yellow)

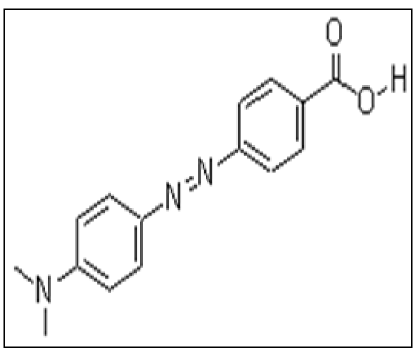

Fig. 1: The structural formula for methyl red

Formaldehyde treated bagasse: The bagasse obtained from the countryside was dried under the sunlight until all of the bagasse evaporated and was ground to a fine powder. The ground bagasse was sieved, so that the size of fiber used was between -80 to +230 mesh size.

In order to polymerize and immobilize the color and water soluble substances, the ground bagasse then was treated with 1% formaldehyde in the weight to volume ratio of 1:5 at 50°C for 4 h. Then, this bagasse was filtered out by using a Buchner funnel. It was washed with distilled water in order to remove free formaldehyde and it was activated at 80°C in the air oven for 24 h. The material was kept in an air tight container for further use.

Sulphuric acid treated bagasse: One part of the bagasse was mixed with one part of sulphuric acid and then heated in a muffle furnace for 24 h at 150 °C. The heated bagasse was washed with distilled water and soaked in 1% sodium bicarbonate solution overnight to remove residue acid.

The material was dried in an oven at 150 °C for 24 h. Then, the material was ground and sieved, until the size between -80 to +230 mesh size was obtained, which will be used for this study.

Dye solution preparation: For this study, methyl red was used and it was obtained from the local supplier. Following Table 2 shows characteristics of the methyl red.

An accurate weighed quantity of the dye was dissolved in double distilled water to the prepared stock solution (500 mg L^{-1}). Experimental solution of the desired concentration was obtained by successive dilutions.

Dye concentration was determined by using absorbance values measured before and after the treatment, at 617 nm with Shimadzu UV Visible Spectrometer (Model No.: UVmini 1240).

An experiment was carried out at initial pH values ranging from 2 to 9, initial pH was controlled by the addition of sodium hydroxide, NaOH or hydrochloric acid, HCl.

Adsorption experiment: In each adsorption experiment, 100 mL of dye solution of known concentration and pH was added to 400 mg of adsorbents in 250 mL round bottom flask at room temperature (26 + 1 °C) and the mixture was stirred on a rotary orbital shaker at 160 rpm.

Table 3: Effect of initial dye concentration on dye removal (adsorbent dosage=0. 4 g 100 mL^{-1}; initial pH=7. 0)

	Percentage of dye removal with time (min)					
Initial Dye concentration (mg L^{-1})	15	30	45	60	90	120
Formaldehyde treated SB						
50	77.0	78.8	80.3	82.3	84.5	85.9
100	66.8	68.0	69.9	70.5	71.8	72.3
150	57.4	58.8	60.5	61.9	62.8	63.5
200	44.6	48.5	50.1	52.8	54.4	60.8
250	24.3	28.4	30.2	32.4	36.8	40.5
Formaldehyde treated SB						
50	90.1	92.5	92.8	93.4	94.0	96.2
100	89.5	90.2	90.8	92.1	93.3	93.9
150	85.2	87.2	89.0	90.0	90.5	90.9
200	78.0	80.9	84.0	87.7	88.5	88.4
250	70.3	73.5	78.4	82.0	85.0	87.3

Table 4: Effect of initial dyes concentration on dye removal (adsorbent dosage=0.4 g 100 mL^{-1}; initial pH=7.0)

	Percentage of dye removal with time (min)					
Adsorbent dose (g 100 mL^{-1})	15	30	45	60	90	120
Formaldehyde treated SB						
0.2	7.8	9.3	11.5	12.2	15.4	17.5
0.4	20.5	29.2	32.5	37.3	42.6	44.8
0.6	38.2	44.4	49.5	52.3	58.5	62.7
0.8	44.3	51.2	54.4	59.6	64.6	68.7
1.0	58.4	62.5	64.7	68.3	73.4	74.5
Formaldehyde treated SB						
0.2	38.4	42.5	48.7	52.5	55.7	59.4
0.4	54.3	63.4	69.0	72.5	75.8	77.6
0.6	74.5	78.9	81.2	83.6	84.5	88.0
0.8	88.4	92.5	93.2	94.5	94.8	95.5
1.0	92.5	93.1	93.7	94.2	95.1	96.3

The sample was withdrawn from the shaker at the pre determined time intervals and absorbents were separated from the solution by centrifugation at 4500 rpm for 5 min. The absorbance of the supernatant solution was estimated to determine the residue of dye concentration.

The experiment was done by varying the amount of absorbents (0.2 to 1.0 mg 100 mL^{-1}), concentration of dye solution (50-250 mg L^{-1}) and pH (2-10) at different time intervals.

RESULTS AND DISCUSSION

Effect of initial dye concentration: The study had shown that for the powdered activated carbon (PAC), the percentage of dye removal was very high, nearly 100% for all initial dye concentration and agitation time (Table 3). The lowest dyes removal was were measured for initial dye concentration of 250 mg L^{-1} and 15 min contact time. The efficiency of dye removal was increased as the agitation time increased and lowers initial dye concentration.

For the treated sugarcane bagasse (undergo physical and chemical treatment), it had shown an increment in the percentage of dye removal. Also, it was found that an increasing in the dye concentration had caused the decreasing in the percentage of dye removal, even though the amount of dye being adsorbed is increased. This will suit the finding which had been quotes by the other researchers[1-3].

As a comparison, sugarcane bagasses which undergo the chemical treatment (sulphuric acid treatment) had shown better result in the dye adsorption compared to sugarcane bagasse treated with physical treatment (Table 3). The process was rapid initially and a large fraction of the total amount of dye was removed within a few minutes.

The effect of pH: For the powdered activated carbon, it was found that the percentage of dye removal was not affected by pH variation. The uptake of the dyes was nearly 100% for all pH values.

For the sulphuric acid treated bagasse (PCSB), the dyes adsorption was significantly change over the pH value of 4 to 7. The lowest percentage of dye removal was recorded at pH 2 (52.2%). At the pH range 7 to 10, the percentage of removal was almost remains constant. As the pH of the solution decrease (more acidic), the number of negatively charged adsorbents site increased. This will not flavor the adsorption of the positively charge dyes cation[8]. This, however didn't apply to the PAC, as it was remained almost 100% for all pH values. There might be another mode of adsorption, such as ion exchange[1]. As the pH value increased from 9 to 13, the efficiency of the dye removal is slightly become lessened.

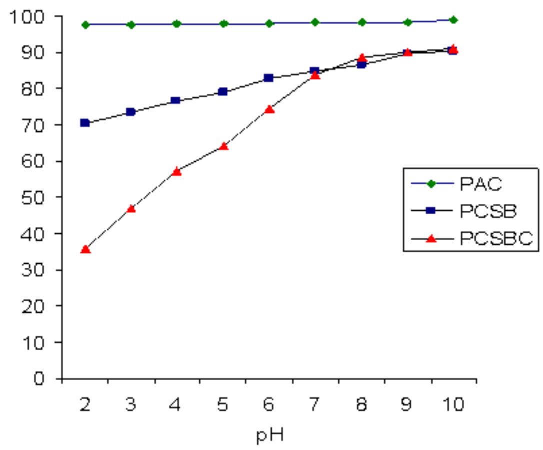

Fig. 2: Effect of pH on methyl red removal by PAC, PCSB and PCSBC (initial dye concentration 250 mg L^{-1}, adsorbent dosage=0.4 g 100 mL^{-1}, temperature 26°C, contact time=120 min

The nearly same pattern was obtained for the formaldehyde treated sugarcane bagasse (PCSBC). The minimum percentages of removal were recorded at pH 2 (78.5) and the highest percentage recorded at pH 10 (98.7%). Figure 2 shows the variation of dye removal for different adsorbents at various pH values.

The effect of adsorbance dosage: For the powdered activated carbon (PAC), it was found that the percentage of dye removal was increased with the increament of adsorbance dosage. For the adsorbent dosage of 1.0 g 100 mL^{-1}, it was found that after 45 min agitation time, the amount of dye being adsorbed was nearly 100% (Table 4).

As for sulphuric acid treated bagasse (PCSBC), the percentage of dye removal was increased from 54.9% to 96.5%, as the adsorbent dosage increased from 0.2 to 1.0 g 100 mL^{-1} after the equilibrium time. Also, the increment from 17.5 to 74.5% was obtained for PCSB for the same increment of adsorbent dosage. This is due to increased in adsorbent dosage attributed to increase in surface area and availability of adsorption site.

CONCLUSION

The removal of methyl red from simulated wastewater by using PAC, PCSB and PCSBC has been investigated for different variables viz contact time, adsorbent dosage pH and initial dye concentration.

From this study, it was found that PCSB and PCSBC has a lower adsorption efficiency compared to powdered activated carbon (PAC) at the any given initial dye concentration. The adsorption efficiency can be arranged in the following order GAC>PCSBC>PCSB.

This study had shown that PCSB and PCSBC had a lower adsorption efficiency compared to GAC at any given pH value. Initial dyes concentration over the range of 2 to 6, decreased the efficiency of the dyes removal. While, the pH range 7 to 10 is optimum for the dye removal for both adsorbents, PCSB and PCSBC.

As sugarcane bagasse is easily available in the countryside, it has potential to be used for the small scale industries which produced dyes as their effluent, after it was being pretreated with formaldehyde and sulphuric acid.

The data may be useful for designing and fabrication of an economically cheap treatment process using a batch or stirred tank flow reactors for the removal of methyl red from diluted industrial effluent.

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