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Waste Water Treatment with Emphasis on Colour Removal with the Help of Sugar Cane Bagasse

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Abstract- Use of sugarcane bagasse, an agro industry waste, to remove dye (Methylene Blue) from the wastewater is studied in this review. Raw Sugarcane Bagasse (RSB) was chemically activated with different acids (H_2SO_4, HCl, CH_3COOH and H_3PO_4) and carbonized to give Chemically Activated Carbonized Bagasse (CACB). The adsorption capacity of CACB was examined varying various parameters viz. particle size of the adsorbent, pH of the medium, initial dye concentration, adsorbent dosage, contact time, temperature and acids used for chemical activation. Performance of CACB was studied with reference to Powdered Activated Charcoal (PAC). The results from the studies showed that CACB prepared by using H_3PO_4 gave better results than CACB's prepared by other acids, therefore CACB prepared using H_3PO_4 was used for further studies. For CACB, the percentage removal of dye depends on the pH of the medium; it gave better results in neutral to basic pH ranges. Whereas for PAC, it does not depends on the pH of the medium. Both PAC & CACB performed well and gave maximum adsorption results within 10 minutes of contact time for all temperature ranges. It was observed that as dye concentration in the batch increased, adsorption of dye on CACB as well as on PAC decreased. As adsorbent dosage increased, percentage of dye removal increased for both CACB & PAC. Studies showed that as particle size of CACB increased, adsorption of dye on CACB decreased. Data obtained from adsorption experiments fitted well in Freundlich isotherm. Also, it is observed by the experiments that CACB prepared by using H_3PO_4 gave similar results as that of PAC; therefore it can be substituted for PAC and can be used for the colour removal from the waste water.

Index Terms- Sugarcane Bagasse, Adsorption, Dye, Waste Water, Colour

1. INTRODUCTION

Dye is a natural or synthetic substance used to add or to change the colour. The majority of natural dyes are from plant sources. Many thousands of synthetic dyes have been prepared for its use in textile & food industries.

Dyes are lost in waste water during textile processing due to its inefficiencies. Synthetic dyes create hazards and severe environmental problems. Dye effluents are aesthetic pollutants as their colours are concerned and also interferes with light penetration in water thereby disturbing the biological processes. Dye effluents may contain chemicals which can be toxic and / or carcinogenic to receiving bodies. As dyes are hazardous to health and environment, it is necessary to remove dyes from waste water.

Dyes are poor biodegradables and resistant to environmental conditions. It is commonly removed from waste water by Adsorption. Adsorption process is advantageous because of its sludge free operation and completely removed dyes, even from diluted solutions. Activated Carbon is most widely used adsorbent for the removal of dyes from the waste water. Adsorption capacity of activated carbon is on higher side, but it is so much expensive and also regeneration results in loss of adsorbent which is undesirable, also it adds operating cost required for regeneration, therefore a low cost material alternative to activated carbon should be used as an adsorbent. In recent years, many studies have been carried out to find inexpensive adsorbents such as coconut husk, banana pith, rice husk, peanut shell, corn cob, peat, orange peel, wheat straw etc. The experiments has been conducted to study the use of treated sugarcane bagasse as an adsorbent for the removal of dyes from waste water.

In this experiment, a low cost adsorbent is prepared from the agricultural waste i.e. sugarcane bagasse. Attempts were made to analyze the performance of sugarcane bagasse.

2. MATERIALS

2.1. *Chemicals*

Distilled water, dye (Methylene Blue), Powdered Activated Charcoal (PAC)

2.2. *Acids*

H_2SO_4, HCl, CH_3COOH, H_3PO_4

2.3. *Bases*

NaOH

2.4. *Equipments*

Conical flask, Stirrer, Spectrophotometer, pH meter, sieves of different mesh sizes, weighing machine, thermometer, oven, grinder, furnace etc.

3. PROCEDURE

3.1. *Adsorbent preparation*

Raw bagasse was collected from nearby juice centers. Collected raw bagasse was washed to remove dust particles and then boiled in distilled water to remove sugar contents. Boiled bagasse was dried overnight in the oven (50 °C) to remove all moisture contents. Dried raw bagasse was then ground in a micro grinder. The ground bagasse was sieved and the product so obtained was used as Raw Sugarcane Bagasse (RSB) in the experiments.

RSB was submerged in the different acids (H_2SO_4, HCl, CH_3COOH and H_3PO_4) to prepare different samples. This acid bath was heated for several hours (5 to 6 hrs) at 150 °C. RSB got carbonized due to acid treatment. After heating, the bagasse was separated from acids and washed with distilled water and then was submerged in base (NaOH) to neutralize free acids. It was then washed with distilled water and dried overnight in the oven (50 °C). This bagasse was termed as Chemically Activated Carbonized bagasse (CACB).

3.2. *Preparation of waste water*

A sample of waste water was prepared in the laboratory. The dye used for this experiment was methylene blue. Stock solution of 1000 ppm was prepared by dissolving 1 gm of methylene blue in 1 litre of distilled water. The test solution required for the experiments were obtained from successive dilutions of the stock solution.

3.3. *Experimental setup*

Fig. 1. Shows the experimental setup. It consists of conical flask (1), stirrer assembly (2), water bath (3), thermometer (4) and electric heater (5) as shown in the figure. A conical flask with stirrer assembly is placed in a water bath. The water bath is maintained at fixed temperature with the help of electric heater.

3.4. *Batch experiments*

To study the removal of dyes from waste water, experiments were conducted batch wise by varying one parameter at a time. For these experiments, water sample of known concentrations of dyes was prepared. This sample was observed under spectrophotometer at 700 nm and absorbance readings were noted down as initial reading. Out of this sample, 10 ml of water sample was kept for adsorption with known amount of CACB under continuous stirring (10 to 15 rpm). pH of the medium was adjusted with the help of HCl and NaOH. After sufficient time interval, stirring was stopped and sample water was filtered to remove CACB. This water was observed under spectrophotometer to get final absorbance reading. The respective concentrations were noted from concentration vs absorbance curve. The difference between initial and final concentration gives the amount of dye removed from the water sample and thus the percentage removal of dye was obtained. Performance of CACB was studied with reference to PAC.

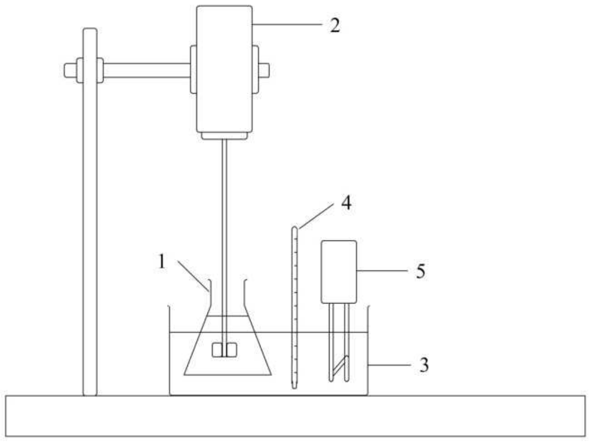

Fig. 1. Experimental Setup

3.5. *Effects of various parameters*

The experiments were performed by varying one parameter at a time to study its effect on adsorption of dye. The parameters varied are acids used to prepare CACB (H_2SO_4, HCl, CH_3COOH & H_3PO_4), pH (1 - 13), particle size of CACB (0 - 1mm), contact time (5 - 25 min), batch temperature (20 - 60°C), initial dye concentration (50 - 1000ppm) and adsorbent dosage (0.5 - 2.5gm)

4. RESULTS & DISCUSSIONS

Adsorption experiments were performed at various parameters and results so obtained are discussed below.

4.1. *Acids used for chemical treatment*

Different CACB were prepared using H_2SO_4, HCl, CH_3COOH and H_3PO_4. Adsorption experiments were performed and samples from batches were studied under spectrophotometer and percentage removal readings were reported in the Table 1. Acid giving best result is used for further experiments.

(Contact time : 10 min, Initial dye concentration : 100 ppm, pH : 7, Adsorbent Dosage : 1 gm, Temperature : 28°C, Batch Volume : 10 ml)

Table 1. % dye removal for various CACB.

Adsorbent		**% Dye Removed**
PAC		100
CACB Prepared Using	**H_3PO_4**	100
	H_2SO_4	98.82
	HCl	96
	CH_3COOH	92

It was observed in the experiment that CACB prepared by using H_3PO_4 gave better results than CACB's prepared by other acids. CACB prepared using H_3PO_4 and PAC removed 100% of the dye from the water sample. Whereas the percentage removal for CACB by H_2SO_4, HCl and CH_3COOH was 98.82, 96 and 92 respectively. As CACB by H_3PO_4 gave better results than other acids, it was used for further experiments. CACB by other acids were then eliminated from the experiments.

4.2. ***Particle size of the adsorbent***

CACB was prepared using H_3PO_4 and sieved in different particle sizes. The batch experiments were conducted to study the effect of particle size on the percentage removal. The samples from these batches were studied under spectrophotometer and percentage removal readings were depicted in Table 2. Size giving best result is used for further experiments.

(Contact time : 10 min, Initial dye concentration : 100 ppm, pH : 7, Adsorbent Dosage : 1 gm, Temperature : 28°C, Batch Volume : 10 ml)

Table 2. % dye removal for various particle sized CACB.

Adsorbent	**Particle size**	**% Dye Removed**
PAC	0 - 0.25 mm	100
CACB	0 - 0.25 mm	100
	0.25 - 0.50 mm	95.49
	0.50 - 0.75 mm	94.81
	0.75 - 1.00 mm	81.60

It was clear from the experiments that as the particle size of CACB increased, adsorption of dye decreased. Maximum percentage adsorption (100%) was observed for the adsorbent particle size of 0 - 0.25 mm. Also for PAC, the percentage removal was noted as 100%. The % removal of 95.49, 94.81 and 81.60 was noted for CACB of size 0.25 - 0.50 mm, 0.50 - 0.75 mm and 0.75 - 1.00 mm respectively. As CACB of size 0 - 0.25 mm gave best result among remaining all sizes, this sized CACB was used in the remaining experiments.

4.3. ***pH of the medium***

pH of the medium was adjusted with the help of HCl & NaOH and the batch experiments were performed at pH 1, 3, 5, 7, 9, 11 and 13. The samples from these batches were studied under spectrophotometer and percent dye removal readings were presented in Table 3.

(Contact time : 10 min, Initial dye concentration : 100 ppm, Adsorbent Dosage : 1 gm, Temperature : 28°C, Batch Volume : 10 ml)

Table 3. % dye removal for various pH.

	pH	**Adsorbent**	
		PAC	**CACB**
% Dye Removed	1	100	92
	3	100	95.76
	5	100	99
	7	100	100
	9	100	100
	11	100	100
	13	100	100

It was seen that, for all pH ranges, percentage removal of the dye was constant i.e. 100 % for PAC. But for CACB, percentage removal goes on increasing as pH increased. Minimum percentage removal of dye i.e. 92% was observed at pH 1. It increased to 95.76, 99 and finally 100 for pH of 3, 5 and 7 respectively. For pH more than 7, the percentage removal of dye remained 100%.

4.4. ***Initial dye concentration***

Water samples with different dye concentrations was prepared by diluting stock solution. Fixed amounts of these samples were adsorbed on CACB. The samples from these batches were studied under spectrophotometer and percentage removal readings were depicted in Table 4.

(Contact time : 10 min, pH : 7, Adsorbent Dosage : 1 gm, Temperature : 28°C, Batch Volume : 10 ml)

Table 4. % dye removal for different initial dye concentrations.

	Dye Concentration (ppm)	Adsorbent	
		PAC	**CACB**
% Dye Removed	50	100	100
	100	100	100
	150	100	100
	200	99.96	99.98
	250	98.87	99.92
	1000	98.83	99.82

It was observed in the experiment that as the concentration of dye decreased, percentage removal of dye increased. And also it was observed that, CACB performed better than PAC at higher concentrations of dye. For both PAC & CACB, maximum percentage removal was 100% for initial dye concentration of 150 ppm and below. For concentration of 1000 ppm, percentage removal was noted for PAC as 98.83 and for CACB as 99.82.

4.5. *Adsorbent dosage*

Adsorption experiments were performed with fixed dye concentrations and different CACB amounts i.e. 0.5gm, 1gm, 1.5gm, 2gm & 2.5gm etc. The samples from these batches were studied under spectrophotometer and percentage removal readings were noted in Table 5.

(Contact time : 10 min, Initial dye concentration : 100 ppm, pH : 7, Temperature : 28°C, Batch Volume : 10 ml)

Table 5. % dye removal for various adsorbent dosage.

	Adsorbent Dosage (gm)	Adsorbent	
		PAC	**CACB**
% Dye Removed	0.5	98.42	99.38
	1	100	100
	1.5	100	100
	2	100	100
	2.5	100	100

It was seen that, as adsorbent dosage increased, percentage dye removal increased. In this experiment, CACB performed better than PAC. For the adsorbent dosage of 0.5 gm, percentage dye removal for PAC was 98.42 and that for CACB was noted as 99.38%. For adsorbent dosage of 1 gm onwards, percentage dye removal for both, PAC & CACB was noted as 100%.

4.6. *Contact time*

Several batch experiments were performed for different contact times i.e. 5min, 10min, 15min, 20min, 25min etc. The samples from these batches were studied under spectrophotometer and percentage removal readings were tabulated in Table 6.

(Initial dye concentration : 100 ppm, pH : 7, Adsorbent Dosage : 1 gm, Temperature : 28°C, Batch Volume : 10 ml)

It was observed that, PAC gave better result than CACB for contact time of 5 min. The % dye removal noted was 99.26 & 96.11 for PAC & CACB respectively. For contact time of 10 min onwards, both achieved 100% of dye removal from the sample.

Table 6. % dye removal for various contact time.

	Contact Time (min)	Adsorbent	
		PAC	**CACB**
% Dye Removed	5	99.26	96.11
	10	100	100
	15	100	100
	20	100	100
	25	100	100
	30	100	100

4.7. *Temperature*

Experiments were conducted at various batch temperatures viz. 20°C, 30°C, 40°C, 50°C, 60°C etc. The samples from these batches were studied under spectrophotometer and percentage removal readings were presented in Table 7.

(Contact time : 10 min, Initial dye concentration : 100 ppm, pH : 7, Adsorbent Dosage : 1 gm, Batch Volume : 50 ml)

Table 7. % dye removal for different batch temperatures.

	Batch Temperature (°C)	Adsorbent	
		PAC	**CACB**
% Dye Removed	20	99.92	99.98
	30	99.95	99.98
	40	99.95	99.98
	50	99.95	99.98
	60	99.95	99.98

It was observed in the experiment that, both PAC & CACB were independent of temperature of the batch. For all temperature ranges, % dye removal was observed to be constant and nearly 100%.

5. ADSORPTION ISOTHERM STUDIES

To study the adsorption isotherm for the prepared adsorbent, adsorption experiments were carried out with the adsorbent dosage of 0.1 - 0.5 gm (W) per 10 ml of water sample (V) having initial dye concentration of 100 ppm (Co). The amount of dye adsorbed per unit weight of the adsorbent (Qe) is calculated using Co, Ce, V & W.

$$Qe = ((Co-Ce)/1000).(V/W) \quad (1)$$

Where,
Qe = amount of dye adsorbed per unit weight of the adsorbent, mg/gm.
Co = initial dye concentration, mg/lit.
Ce = equilibrium dye concentration, mg/lit.
V = volume of water sample, ml.
W = amount of adsorbent taken, gm.

The values of W, Ce & Qe are noted in Table 8.

Table 8. Data obtained for isotherm studies.

W (gm)	Ce (ppm)	Qe (mg/gm)
0.1	0.74	9.926
0.2	0.698	4.9651
0.3	0.663	3.3112
0.4	0.635	2.4841
0.5	0.623	1.9875

Freundlich & Langmuir isotherm equations are used to find the isotherm constants.

5.1. *Freundlich Isotherm*

Freundlich Isotherm equation is given as,

$$Qe = k.Ce^{1/n} \quad (2)$$

$$\ln Qe = \ln k + (1/n).\ln Ce \quad (3)$$

Fig. 2. shows a graph of *ln Qe* vs *ln Ce*. The slope of curve gives *1/n* and intercept gives *ln k*, which gives the isotherm constants for Freundlich Isotherm.

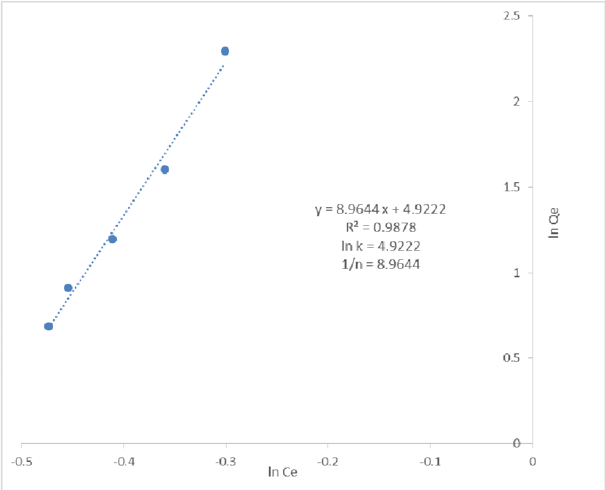

Fig. 2. ln Qe vs ln Ce

We get,

$$\ln k = 4.9222 \quad (4)$$
$$k = 137.3044 \quad (5)$$

&

$$1/n = 8.9644 \quad (6)$$
$$n = 0.111552 \quad (7)$$

5.2. *Langmuir Isotherm*

Langmuir Isotherm equation is given as,

$$Qe = Qm.Kl.Ce / (1 + Kl.Ce) \quad (8)$$

$$1/Qe = (1/Qm.Kl).(1/Ce) + (1/Qm) \quad (9)$$

Fig. 3. shows a graph of *1/Qe* vs *1/Ce*. The slope of curve gives *1/Qm.Kl* and intercept gives *1/Qm*. These values gives isotherm constants for Langmuir Isotherm.

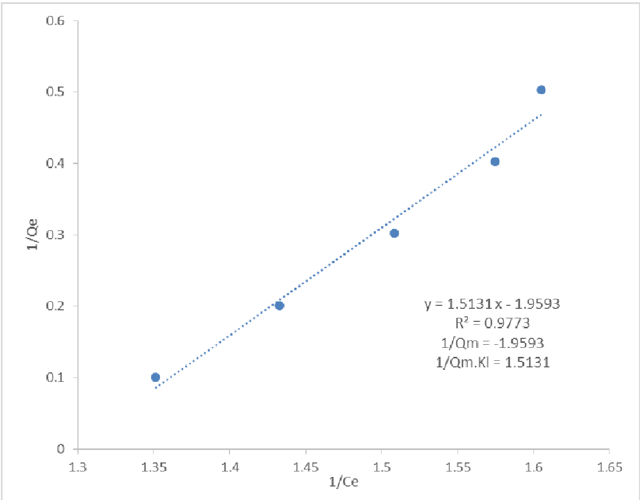

Fig. 3. 1/Qe vs 1/Ce

We get,

1/Qm = -1.9593 (10)
Qm = -0.51039 (11)

&

1/Qm.Kl = 1.5131 (12)
Kl = -1.29488 (13)

As we are getting negative values of isotherm constants for Langmuir isotherm, adsorption of dye on CACB do not follow Langmuir Isotherm. For Freundlich Isotherm, the values for isotherm constants are, *k = 137.3044* & *n = 0.111552*.

6. CONCLUSION

The removal of dye from wastewater using sugarcane bagasse has been investigated under different experimental conditions in batch mode. The present study showed that sugarcane bagasse modified with H_3PO_4 is an effective adsorbent for the removal of methylene blue from aqueous solutions. The effective pH for methylene blue was 7. Equilibrium was achieved within 10 min of contact time. It performed well at all temperature ranges throughout the experiment. Two adsorption isotherm models were tested and studies concludes that adsorption of dye on CACB follows Freundlich Isotherm. The present study concluded that CACB prepared using H_3PO_4 could be employed as a low cost and eco-friendly adsorbent as an alternative to commercially available PAC for the removal of dyes from wastewater.

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