Removal of Dyes from Dye Effluent by Using Sugarcane Bagasse Ash as an Adsorbent

Sachin M.Kanawade and R.W.Gaikwad

Abstract—**Sugar cane bagasse ash, an agricultural by-product, acts as an effective adsorbent for the removal of dyes from aqueous solution. Batch adsorption study was investigated for the removal of Acid Orange-II from aqueous solution. Adsorbents are very efficient in decolorized diluted solution. The effects of bed depth on breakthrough curve, effects of flow rate on breakthrough curve were investigated. The removal of dyes at different flow rate (contact time), bed height, initial dye concentration, column diameter, pH & temperature by Sugarcane Bagasse Ash as an adsorbent has been studied. It is found that percent adsorption of dyes increases by decreasing flow rate from 2 lit/hr to 1 lit/hr, by increasing bed height from 15cm to 45cm, by decreasing initial conc.150mg/lit to 100mg/lit, by increasing column diameter from 2.54cm to 3.5cm,by maintaining neutral pH & at temperature 45ºc than 25ºc & 35ºc.The result shows that, bagasse ash is a good adsorbent for dye effluent treatment.**

Index Terms—**Adsorption, Dye, Effluent treatment, Environment, Sugarcane Bagasse Ash, Industry, India, Textile dye, Water pollution.**

I. Introduction

Dyes production industries and many others industries which used dyes and pigments generated wastewater, characteristically high in colour 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 dyes, a convectional biological treatment process is not very effective in treating a dyes 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 removal of 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 for 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 lead to further studies for cheaper substitutions. Nowadays, there are numerous numbers of low cost, commercially available adsorbents which had been used for the dye removal (Table 1).

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Properties of Acid orange-II

- CAS NO. - 633-96-5
- EINECS NO. - 211-199-0
- Formula -HOC10H6N=NC6H4SO3Na
- Molecular weight - 350.32
- H.S. CODE - 3204.12
- Physical state - Yellow Powder
- Melting point - 1640 C
- Solubility in water - Soluble (116 g/lit)
- FASTNESS - Light (3-4), Washing (4), Rubbing Wet (4-5), Rubbing Dry (3-4)
- NFPA RATINGS - Health: 1; Flammability: 0; Reactivity: 0
- Stability - Stable under ordinary conditions [11].

Structural formula of Acid orange – II

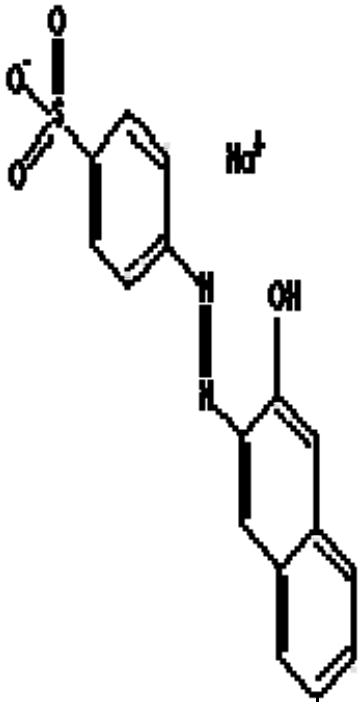

Fig 1.1 Structural formula for Acid orange-II

TABLE 1: SOME LOW COST MATERIALS FOR DYES REMOVAL FROM AQUEOUS SOLUTION

Sr.No	Adsorbent(s)	Dye(s)	References
1.	Bamboo dust, coconut shell groundnut shell, rice husk	Methylene blue	[4]
2.	Silk cotton hull, coconut tree sawdust, sago waste, maize cob	Rhodamine-B, Congo red, methylene blue, methyl violet, malachite green	[2,5]
3.	Parthenium hysterophorus	Methylene blue, malachite green	[7]
4.	Rice husk	Malachite green	[12]
5.	Coir pith	Acid violet, acid brilliant blue, methylene blue, Rhodamine-B	[13,15]
6.	Orange peel	Acid violet 17	[16,20]
7.	Indian Rosewood	Malachite green	[20]
8.	Prosopic cineraria	Malachite green	[11,2]
9.	Banana and orange peels	Methyl orange, methylene blue, Rhodamine-B, congo red, methyl violet, acid black 10B	[19,17]
10.	Giant duckweed	Methylene blue	[21]
11.	Banana pith	Congo red, Rhodamine-B, acid violet, acid brilliant blue	[17]
12.	Orange peel	Congo red, Rhodamine-B, procion orange	[10]
13.	Carbonized coir pith	Acid violet, Rhodamine-B	[4]
14.	Hardwood	Astrozone blue	[2]
15.	Chitosan	Acid blue 25, basic blue 69	[9]
16.	Mahogany sawdust, rice husk	Acid yellow 36	[14]
17.	Biogas residual slurry	Congo Red, Rhodmine-B, acid violet, acid brilliant blue	[3]
18.	Plum kernels	Basic Red 22, acid blue 25	[7]
19.	Rice husk	Safranine, methylene blue	[18]

II. EXPERIMENTAL STUDIES

In the present study, bagasse fly ash (BFA) and wood ash have been utilized for the treatment of acid orange-II bearing aqueous solution. Experimental details of the study have been presented. This details include characterization of adsorbents, column studies etc.

A. Characterization of adsorbent

TABLE 2.1.1 PHYSICAL-CHEMICAL CHARACTERISTICS OF BFA & WA

Surface area(m^2/g)	205.96
Pore volume(cm^2/g)	0.115
Avg pore diameter(A^0)	19.38
Heating value(KJ/g)	7231.50
Bulk density(Kg/m^3)	97.35

TABLE 2.1.2 PARTICLE SIZE ANALYSIS OF (BFA & WA)

Sieve	%wt
>600	0.40
600-500	0.17
500-425	4.65
425-300	2.12
300-212	5.30
212-150	20.50
150-125	3.20
125-90	36.75
90-63	11.25
<63	15.65

Avg particle size = 130.52µm

TABLE 2.1.3 PROXIMATE ANALYSIS OF (BFA & WA)

Characteristics	Value
Moisture (%)	5.10
Volatiles (%)	9.09
Ash (%)	35.58
Fixed carbon (%)	51.23

TABLE 2.1.4 ULTIMATE ANALYSIS OF (BFA & WA)

Element	Value
C (%)	61.560
H (%)	0.093
N (%)	3.235
S (%)	0.132

B. Column study

An acrylic column of 100 cm length and 2.54 cm internal diameter with 0.2cm wall thickness was used to contain the mixture of bagasse fly ash and wood ash as a fixed bed adsorber. A fine mesh was introduced at the bottom of the column over which a layer of ceramic beads was spread to prevent the escape of adsorbent. Acid orange –II was feed to the bed of BFA & Wood ash in up-flow mode to avoid channeling of effluent.

Here we used saline tube to control up-flow motion of solution from tank to column, which is carried out by difference in potential head .Also we provide four outlets at height of 15,30,45cm. A sample of treated effluent was collected periodically and analyzed for (C_t) by colorimeter. The flow through the tested column was continued until the acid orange- II concentration of column effluent approached 0.99, C_t / C_0, which indicate the exhaustion point (C_x). The curve of C_t / C_0 vs. volume treated between concentration at 10% breakthrough (C_b) and the exhaustion (C_x) is called the breakthrough curve.

C. Experimental set-up

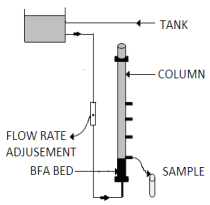

Fig.2.1 Experimental set-up of adsorption column

III. RESULT AND DISCUSSION

A. Effect of bed depth on break through curve

Fig.3.1, 3.2 shows the breakthrough curve for different BFA bed depth between 15 to 45 cm , at a flow rate of 1.0 and 2.0 lit/hr. The time required for the effluent to reach breakthrough concentration, t_b increased with increase in bed depth. This may be attributed to the increase in binding sites on the adsorbent. Although an increasing bed depth increases t_b, Very high bed depth is not useful for single column. The shape and gradient of the breakthrough curves were slightly different with the variable bed depth. As the bed height increases from the 15 cm to 45cm the curve changes their profile steep concave to flatter concave. The breakthrough curve of longer beds tended to be more gradual, meaning that the column was difficult to be completely exhausted. Here, breakthrough time is taken as time of operation at which the ratio of effluent to the inlet Acid orange –II concentration becomes 0.1 i.e. the effluent concentration gives the value of 10 mg/lit.

In the present study, the flow rate of outlet was unstable when the bed depth was too high due to higher flow resistance, resulting from tighter packing of the longer bed containing larger amount of BFA and wide size distribution. Since the treated effluent was not properly drawn of at the top of the packed bed higher than the 45 cm for the diameter of 2.54 cm, the optimum depth to diameter ratio of the column containing BFA should not be higher than 18 (45 cm/2.54 cm). Actually this ratio can be applied for the scale up of the column adsorber [5].

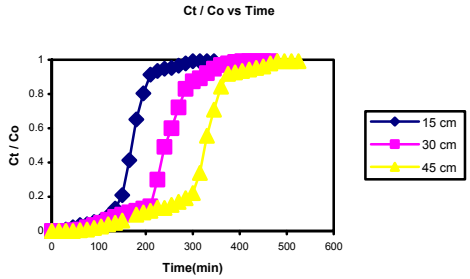

Fig. 3.1 Effect of bed height with respect to time on removal of Acid orange – II by BFA (C0 = 100 mg/lit, flow rate = 1.0 lit/hr)

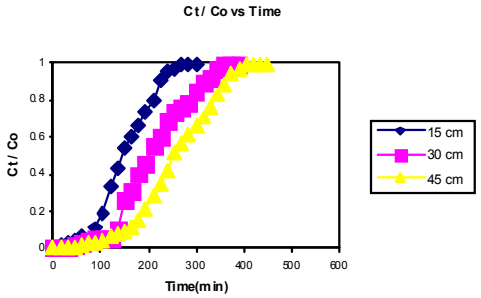

Fig. 3.2 Effect of bed height with respect to time on removal of Acid orange– II by BFA (C0 = 100 mg/lit, flow rate = 2.0 lit/hr

B. Effect of flow rate on breakthrough curve

Fig. 3.3 shows the breakthrough profile for the adsorption of Acid orange –II removal in the continuous flow fixed column of 15cm bed depth with BFA at room temperature. The flow rate was varied from 1.0 to 2.0 lit/hr while the inlet Acid orange –II concentration in the feed was held constant at 100 mg/lit. When the adsorption zone moves upwards and upper edge of this zone reaches the top of the column, the effluent concentration start to rise rapidly. This point is called breakthrough point, which indicate the tb. Result shows that a decrease in the flow rate at constant bed depth increases the tb, and therefore the Vb (volume of solution treated at breakthrough point), due to an increase in empty bed contact time (EBCT). Using a smaller flow rate, the front of the adsorption zone reaches the top of the column later, there by giving higher tb . An increase in the flow rate appears to increase the sharpness of the breakthrough curve. These results indicates that as the flow rate increases the shape of the breakthrough curve drastically changes from S- shaped to

that of downwardly concave shape. The curves exhibit a sharp leading edge and a broad trailing edge. The broadness of the trailing edge is most likely due to slow intra-particle diffusion within the pores of BFA.

As the flow rate through the bed increases, the depth of the adsorption zone increases and the time of the contact of the solution with adsorption zone decreases. In designing a column, the length of the adsorption zone represents the minimum bed depth needed to produced a low effluent Acid orange –II concentration this results suggest that low flow rate or longer contact time may required for Acid orange-II adsorption by column field BFA and Wood ash[5].

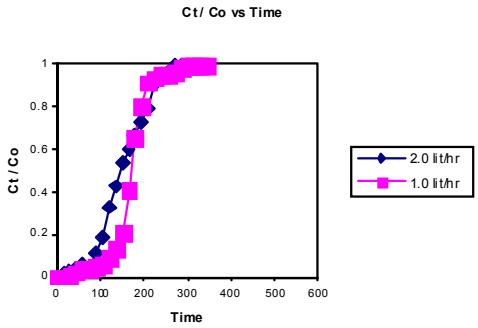

Fig. 3.3 Effect of flow rate with respect to time on removal of Acid orange– II by BFA (C0 = 100 mg/lit, bed height =15 cm)

C. *Effect of Flow rate (contact time) on Dye removal*

From Fig.3.4,3.5 as the flow rate increases from 1 Lit/hr to 2 Lit/hr, the removal of Acid orange –II decreases for the same bed height. It is due to the minimum time of contact between adsorbent and adsorbate.

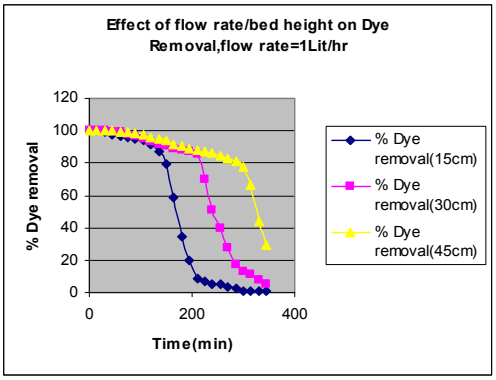

Fig.3.4 Effect of Bed height on Dye removal, flow rate=1lit/hr

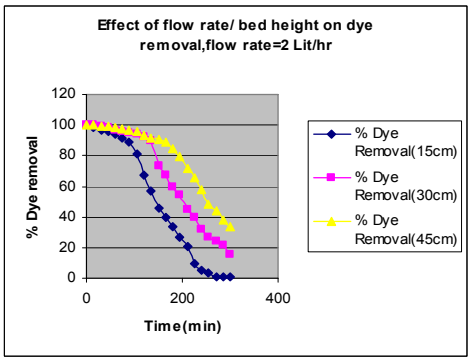

Fig.3.5 Effect of Bed height on Dye removal, flow rate=2lit/hr

D. *Effect of Bed height on Dye removal*

From Fig.3.4,3.5 as the bed height increase from 15cm to 45cm, the removal of Acid orange- II increase for the same flow rate and initial concentration. It is due to the decrease in adsorbate to adsorbent ratio for the same initial concentration.

E. *Effect of Initial Dye concentration on Dye removal*

From Fig. 3.6 as we increase the Initial concentration of Acid orange –II from 100mg/lit to 150mg/lit , the Removal of Acid orange –II decrease for the same flow rate and Bed height . It is due the increase in adsorbate to adsorbent ratio for same flow rate.

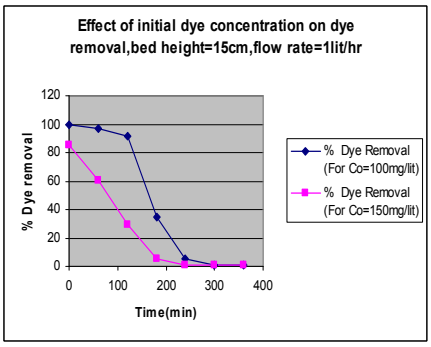

Fig.3.6 Effect of initial Dye conc. on Dye removal, Bed height=15cm,flow rate=1lit/hr

F. *Effect of Column Diameter (For same Contact time) -*

Here we use two types of column of Diameter 2.54 cm and 3.5 cm. In both columns we fill adsorbent up to 15cm and having same initial concentration of 100mg/lit. **From Fig.3.7** the rate of removal of acid orange _II is higher in larger dia.column than smaller Dia.column due to the increase in surface area for same contanct time.

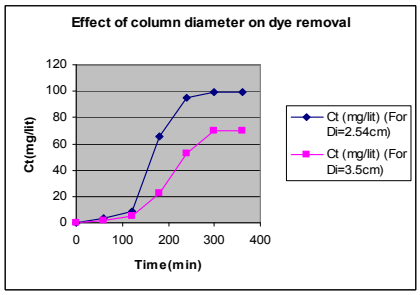

Fig.3.7 Effect of Column Diameter on Dye removal, Flow rate=1lit/hr

G. *Effect of pH on Dye removal*

Here we use three different solution having pH range 3, 7,and 9. From Fig.3.8 the rate of removal of Acid orange –II is very higher at pH- 7 (Neutral), medium at pH-3 (Acidic range), lower at pH- 9 (Basic range)

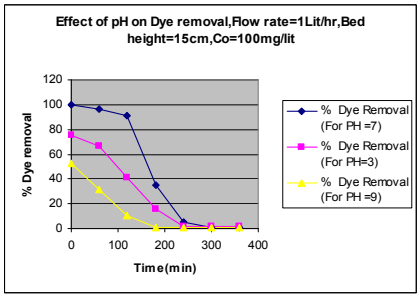

Fig.3.8 Effect of pH on Dye removal, Flow rate=1lit/hr,Bed height=15cm,Co=100mg/lit

H. Effect of Temperature on Dye removal

Temperature is one of the most important controlling parameter in adsorption. Adsorption is normally exothermic in nature and the extent and rate of adsorption in most cases decreases with increasing temperature of the system. Some of the adsorption studies show increased adsorption with increasing temperature.

The effect of temperature was investigated in the temperature range 25 to 45ºC. From Fig. 3.9 the removal of acid orange-II increased from 95.12 to 99.95% by increasing the temperature from 25 to 45 ºC Most of the adsorption processes are reported to be exothermic in nature, but present study has been found to be an example of endothermic adsorption.

This increase in adsorption is mainly due to increase in number of adsorption sites caused by breaking of some of the internal bonds near the edge of the active surface sites of the adsorbents

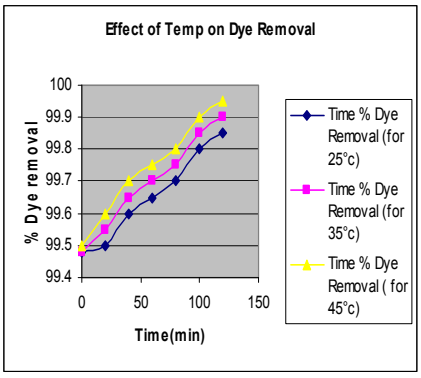

Fig.3.9 Effect of Temperature on Dye removal

IV. Conclusions

Sugar cane bagasse ash, an agricultural by-product, acts as an effective adsorbent for the removal of dyes from aqueous solution. Batch adsorption study was investigated for the removal of Acid Orange-II from aqueous solution. Adsorbents are very efficient in decolorized diluted solution. The effects of bed depth on breakthrough curve, effects of flow rate on breakthrough curve were investigated. The removal of dyes at different flow rate (contact time), bed height, initial dye concentration, column diameter, pH & temperature by Sugarcane Bagasse Ash as an adsorbent has been studied. It is found that percent adsorption of dyes increases by decreasing flow rate from 2 lit/hr to 1 lit/hr, by increasing bed height from 15cm to 45cm, by decreasing initial conc.150mg/lit to 100mg/lit, by increasing column diameter from 2.54cm to 3.5cm,by maintaining neutral pH & at temperature 45^{0C} than 25^{oC} & 35^{oC}.The result shows that, bagasse ash is a good adsorbent for dye effluent treatment.

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