



## Research Paper

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# Application of bagasse as low cost bio-adsorbent for removal of colour from wastewater of common effluent treatment plant

Accepted 13<sup>th</sup> January 2020

## ABSTRACT

Colour removal from complex effluents is a matter of concern pertaining to the toxicity, visibility problem and its acceptance for reuse. Various physical and chemical methods including adsorption, ion exchange, filtration and coagulation are commonly used for removal of colour from effluent streams. Adsorption is more common because of its easy operation and availability of variety of adsorbing media. The only disadvantage with this process is that once exhausted, the adsorbing media needs replacement which imposes a recurring cost on operator. As a result, applicability of a bio-adsorbent (made from sugarcane bagasse) was tested for removal of colour from effluent which not only appears as a low cost adsorbent but also provides solution to the problem of unmanaged bagasse produced from sugar factories. The adsorption capacity of this bio-adsorbent was checked at various flowrate at a specific column height. The effects of contact time on reduction in colour were also examined at batch scale. The colour removal efficiency in most of the experimental trial was observed as higher than 90% which shows that bagasse from sugar industry can be a potential replacement of conventional adsorbents.

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**Key words:** Color removal, bagasse, low cost adsorbent, characterization, optimization, CETP waste water.

## INTRODUCTION

Rapid industrialization has led to the huge quantities of effluent production which requires low cost and low energy intensive treatment processes so that safe handling of effluent can be achieved round the globe. There are different treatment processes being used at primary, secondary and tertiary levels in any industry and before disposal it is ensured that the effluent contains pollutants' concentration comfortably below than existing norms. Among various waste water characteristics, "colour" is one characteristic which immediately put a question mark on the degree of treatment provided to water/wastewater. It is also a prime parameter which decides the acceptability of water for a particular use. As most of the industrial effluents contain some colour and some specific sectors, such as dyes and pigments, textile and landfills (leachate) that produces an effluent which is highly coloured, they need to install specific units for colour removal because

through other "non-specific units", percent reduction in colour value is not very significant. Adsorption columns are usually deployed in all the effluent treatment plant (ETPs) at the end to provide final polishing to the treated effluent and to ensure colour removal from it. Industries having highly coloured wastewater, commonly faces the issue of color removal as the adsorbent used in tertiary treatment gets exhausted fast and regeneration of adsorbent comes with other operational difficulties.

Development of low cost adsorbent is therefore the need of the hour, especially for the developing countries. A flourishing economy is an asset to every country and in a country such as India where agriculture is the backbone of the economy, myriads of tonnes of agricultural waste is generated having high carbons in it. This waste can be processed to develop bio-adsorbent which not only will help in dealing with high quantities of agricultural waste



**Figure 1:** Heaps of baggase ash dumped.

produced but will also help to treat the effluent from industry. Application of such bio-adsorbent will also reduce the exploitation of natural resources for producing efficient adsorbents.

Bio-adsorbent made from sugarcane baggase has been reported for its applicability to treat wastewater very efficiently (Rodríguez-Díaz et al, 2015; Mubarik et al, 2015). Hence applicability of bio-adsorbent produced from sugarcane baggase (which is an agricultural and industrial waste) has been examined in this study. Baggase is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. This baggase is used as fuel (partially) to run the furnace and the left out "Baggase Ash" is dealt as a waste. Being waste for the respective industry, the sugarcane baggase ash is economical and readily available in huge quantities.

It is reported that per tonne of sugarcane crushed, 140 kg of agricultural residue (baggase) can be obtained with an approximate energy content equivalent to  $15.7 \text{ MJ kg}^{-1}$  (Rodríguez-Díaz et al., 2015). This datum project baggase as a potential energy source and many sugar industries uses it as energy source (Varshney et al., 2019). Once the baggase is combusted for heat recovery, management of combustion product "ash or bottom ash" becomes an unavoidable environmental obligation.

Literature reveals that a unit ton of sugarcane processed generates approximately 6 kg of ash, which indicates that an agriculture oriented country such as India deals with tonnes of such ash produced nationwide. This ash being very light in weight becomes airborne very quickly and impacts the local air quality by adding significant concentration of respirable suspended particulate matter (RSPM). Application of baggase ash as adsorbent for colour removal not only provides a "low cost adsorbent" to various industries but also provides solution to "ash management"

issue of sugar industries.

## MATERIALS AND METHODS

### Study area

Ankleshwar is an industrial hub in district Bharuch of Gujarat state. This industrial zone is very rich in numbers of small scale and large scale dyes in pigment industries located in it. Industries, which cannot afford to have their own effluent treatment plant (ETP), send their effluent to common effluent treatment plant (CETP) after neutralizing. For this study, both effluent and adsorbent were taken from Ankleshwar; effluent (treated) was taken from CETP where all the other parameters are within the statutory limits but colour removal is major issue to deal with.

Baggase ash was also collected from a sugar industry located in a village near Ankleshwar. The industry uses the baggase for heat recovery and tones of baggase ash can be seen thrown on the nearby land. Figure 1 shows heaps of baggase ash dumped on nearby grounds.

### Bio-adsorbent from baggase

Literature reveals that sugarcane baggase contains 50% of cellulose, 25% hemicellulose and about 25% lignin. The material is hard in degradation but ash produced after thermal processing is widely used as fertilizers or soil amender in the agricultural sector. The chemical composition is dominated mainly by silicon dioxide which also has pozzolanic property and hence is used in construction sites. It has been reported that the baggase ash has a density approximate of  $0.5 \text{ kg/m}^3$  and specific gravity

**Table 1:** Chemical properties of sugarcane bagasse ash (Patel and Raijiwala 2015).

| Component                      | Mass % | Mass ( Mg/Kg) |
|--------------------------------|--------|---------------|
| SiO <sub>2</sub>               | 68.42  | --            |
| Al <sub>2</sub> O <sub>3</sub> | 5.812  | --            |
| Fe <sub>2</sub> O <sub>3</sub> | 0.218  | --            |
| CaO                            | 2.56   | --            |
| P <sub>2</sub> O <sub>5</sub>  | 1.28   | --            |
| MgO                            | 0.572  | --            |
| SO <sub>3</sub>                | 4.33   | --            |
| Loss of ignition               | 15.90  | --            |
| Na <sub>2</sub> O              | --     | 1621          |
| K <sub>2</sub> O               | --     | 9406          |
| MnO                            | --     | 244           |
| TiO <sub>2</sub>               | --     | 240           |
| BaO                            | --     | 23.73         |

**Table 2:** The proximate analysis of bagasse ash.

| Characteristics | Value |
|-----------------|-------|
| Moisture (%)    | 2.10  |
| Volatile (%)    | 5.26  |
| Ash (%)         | 32.26 |

**Table 3:** The ultimate analysis of bagasse ash.

| Characteristics | Value |
|-----------------|-------|
| C (%)           | 22.3  |
| N (%)           | 8.96  |
| H (%)           | 0.40  |

of 1.8 with specific surface area of 900 m<sup>2</sup>/kg. Table 1 shows chemical properties of bagasse ash as reported by Patel and Raijiwala (2015).

### Experimental study

For this study, the sugarcane bagasse ash was collected from the study area (as shown in figure 1) which is at Sugar factory near Ankleshwar, Gujarat, India and it was processed for further utilization as adsorbent.

### Characterization of bio-adsorbent

The bagasse ash collected was sieved to remove bigger impurities and then characterized for its properties. Tables 2 and 3 show the proximate and ultimate analysis of bagasse ash.

The iodine value shows the adsorbent quality of a chemical substance and it also gives an estimate of its surface area and porosity. The iodine value of bagasse ash

used is 396 which is lesser than that of activated charcoal. The physico-chemical characteristics of bagasse ash make it suitable as adsorbent. Table 4 shows the physical characteristics of bagasse ash.

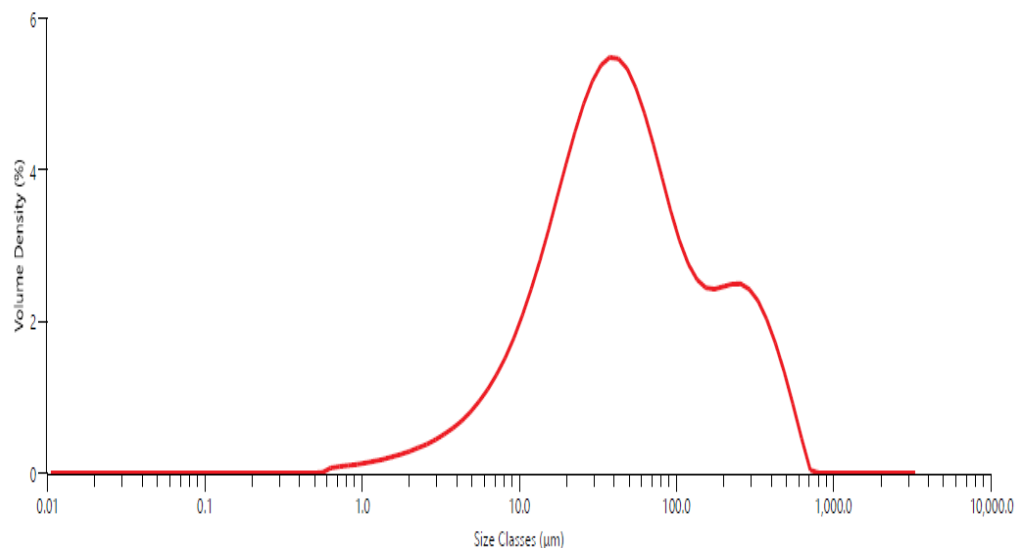
The particle size distribution (PSD) provides information about the range and width of distribution of particle sizes. PSD for the bagasse ash was carried on Mastersizer 3000 (Malvern Instruments Ltd.) and is shown in Figure 2 and particle size distribution in Table 5.

It can be inferred from PSD that bagasse ash can be used as packing in fixed bed absorption columns without critical pressure drops. Moreover, the dimensions of pores allow the medium size molecules to adsorb on internal surface of ash.

The FTIR spectroscopy helps in identifying the composition and structure of functional group in a sample by analyzing the position, the width and absorption intensity. FTIR spectra were measured in a Spectrum One – FT-IR Spectrometer, Perkin Elmer (USA). Spectra were recorded using a diffuse reflectance method, in the range of 4750 to 400 cm<sup>-1</sup>. Pellets for the FTIR were prepared in a

**Table 4:** The physical characteristics of bagasse ash.

| Characteristics           | Value                    |
|---------------------------|--------------------------|
| Bulk density              | 0.238                    |
| Specific surface area     | 305.2 m <sup>2</sup> /kg |
| Particle refractive index | 1.520                    |
| Particle absorption index | 0.1                      |
| Laser Obscuration         | 1.90%                    |
| Uniformity                | 1.582                    |

**Figure 2:** Particle size distribution graph for bagasse ash.**Table 5:** Particle size distribution in bagasse ash.

| D-values | Particle size (μm) |
|----------|--------------------|
| Dv (10)  | 9.87               |
| Dv (50)  | 44.3               |
| Dv (90)  | 261                |
| Dv (95)  | 362                |
| Dv (100) | 665                |

press of using bagasse ash previously grinded, dried and mixed with KBr. Figure 3 shows the FTIR spectra of bagasse ash.

The strong band near 500 and 1100 cm<sup>-1</sup> indicates the presence of symmetric stretching vibration of silicon bonds. The SiO<sub>4</sub> symmetric stretching vibration is at 800 and 620 cm<sup>-1</sup> which is observed clearly. The lowest bending mode of Si-O is noted at 450 cm<sup>-1</sup>. Sharp absorption peaks below 1400 cm<sup>-1</sup> can be related to stretching and bending of Si-O bonds. The broad bands around 3400 cm<sup>-1</sup> is due to symmetric and asymmetric vibration of (O-H) water bounded in ash particles (Srivastava and Mishra, 2007). The peak at 1612 cm<sup>-1</sup> refers to the C=O bonds from

carboxylic acids, normally found in fibrous materials (Krishnani et al., 2008).

### **Experimental set-up and procedure**

The experimental set-up included an analytical column of 50 cm length to contain the bagasse ash. The ash samples were dried in Hot air oven for duration of 2 h at 110°C in order to ensure almost complete moisture removal. Thereafter, the dried bagasse ash was sieved using mechanical sieve shaker to screen out the impurities from bagasse ash. The bagasse ash was tightly filled in the

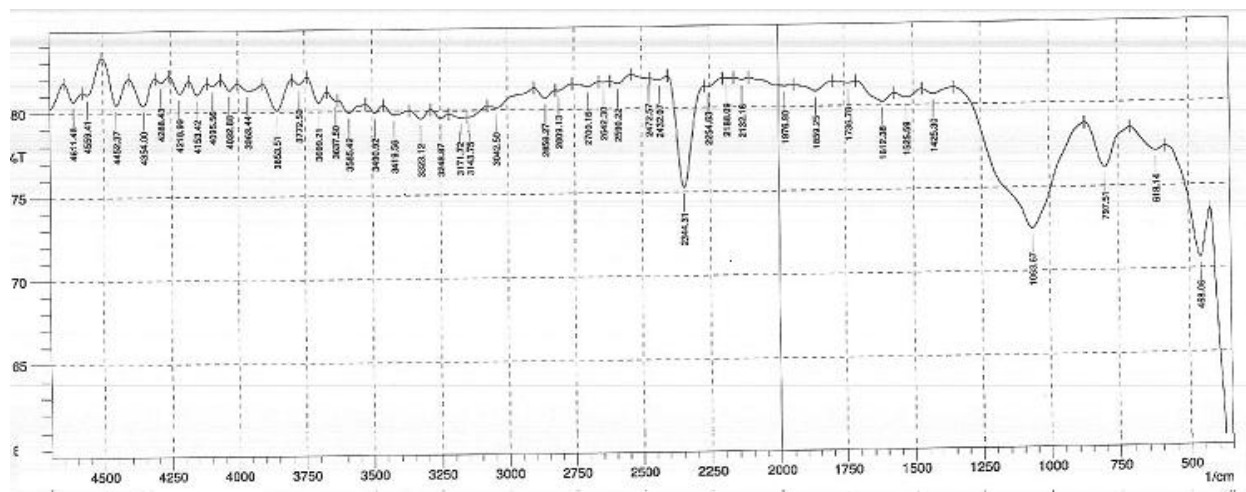


Figure 3: FTIR of bagasse ash.

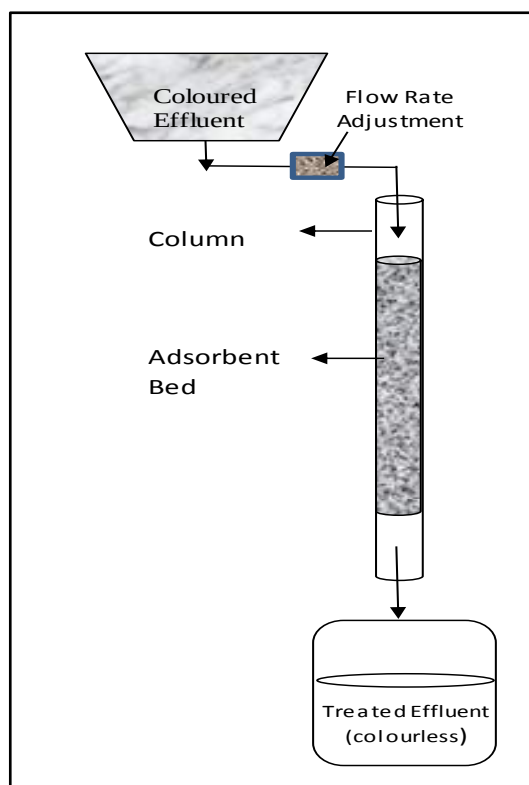


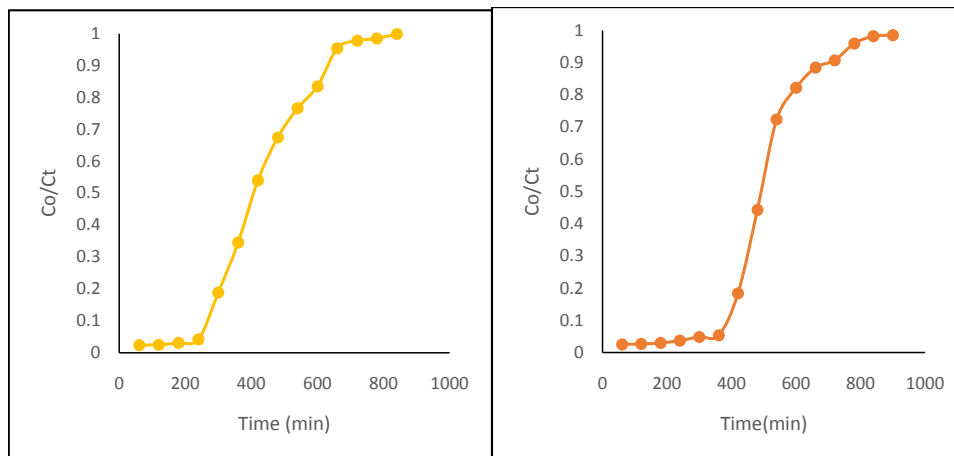
Figure 4: Experimental set up.

column and ceramic beads at the end of the tube did not allow it escape from the column. The highly coloured effluent with  $\lambda_{\text{max}} = 540 \text{ nm}$  was poured into the column at a fix flow rate and the sample collected at the bottom was analysed for reduction in colour. The experiments were repeated by varying column height, flow rates and diameter of the column and results analysed. The batch size for every experiment was 500 ml. The sketch for the set-up is shown

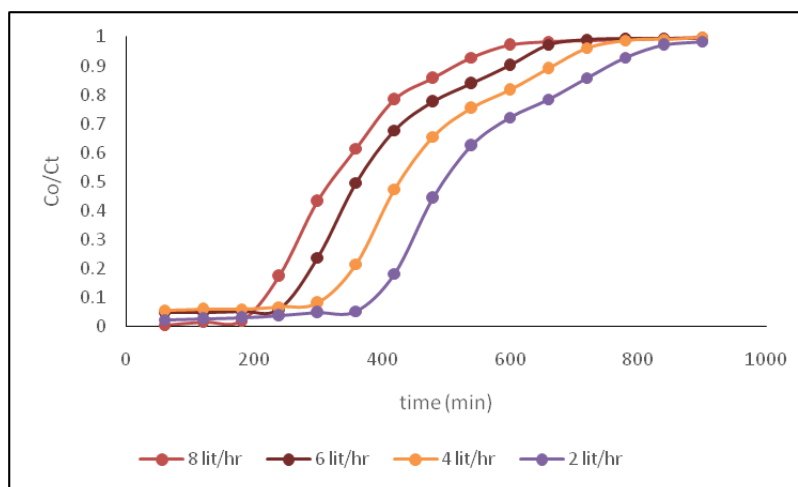
in Figure 4.

## RESULTS AND DISCUSSION

The variable parameters studied for reducing colour from the waste water comprised column height, flow rate and column diameter. The data obtained in respective



**Figure 5:** Effect of bed height on breakthrough curve of adsorption on baggase ash- (5a) 15 cm and (5b) 30 cm.



**Figure 6:** Effect of flow rate on breakthrough curve.

experiments were plotted for breakthrough curves between  $Co/C_t$  and time and the response of the adsorption column was determined by the breakthrough time and shape of breakthrough curve.

### Effect of column height

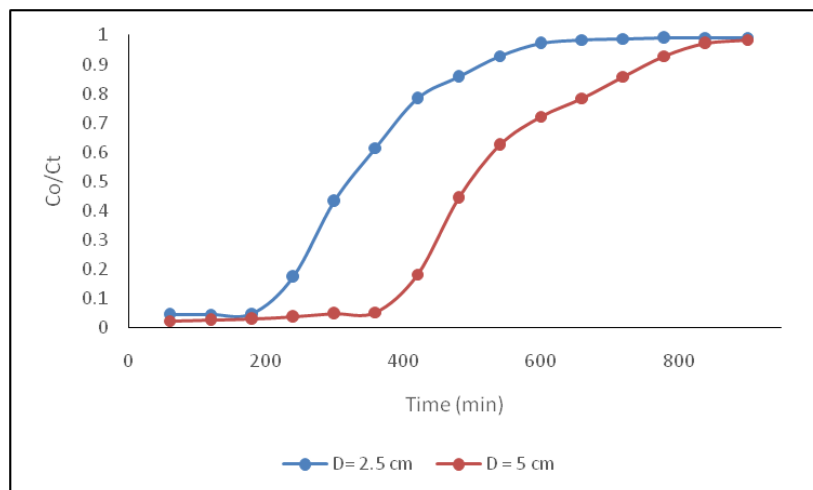
To study the effect of column height, two different columns of 15 and 30 cm height were made by filling the baggase ash up to respective heights in 50 cm glass column. The flow was adjusted to 4 lit/h and 500 ml of effluent was added to the columns at this flow. The breakthrough curves obtained for column with 15 cm height and 30 cm height are shown in Figure 5 (a) and (b), respectively

The curves in Figure 5 (a) and (b) indicate the colour initially adsorbed resulting in almost 99% reduction in colour which gradually rose as adsorption continued.

Initially, when highly colored effluent is introduced in down flow mode from top of bagasse ash containing bed, most of the colour is removed in a narrow band at the top of the column which is referred to as adsorption zone. As column runs continuously, this zone progresses downward as the upper part become saturated. Eventually the adsorption zone reaches bottom of column and concentration of colour starts rising in the effluent. As the height of the column is more, this stage comes later and the efficiency of the adsorption increases.

### Effect of flow rate

In this study the data obtained by varying the flow rates of the waste water and the  $Co/C_t$  are plotted for a bed height of 15 cm which is shown in figure 6. The flow rates which are considered are 2,4,6 and 8 lit/hr. The breakthrough



**Figure 7:** Effect on column diameter on breakthrough curve.

curve clearly indicates that as flow rate increases from 2 to 8 lit/hr, the curve becomes steeper. The breakpoint decreases from 360 min to 180 min. The reason behind this is the residence time of the solute in column is not enough for adsorption equilibrium to be reached at higher flow rate. So at a higher flow rate, the waste water leave the column before equilibrium occurs.

### Effect of column diameter on colour reduction

The diameter of the column used is directly proportional to the percentage reduction of colour from waste water. It is because as the diameter of column increases, more bagasse ash can be filled in up to the required height and thus as the amount of adsorbate increases, the efficiency also increases. Figure 7 shows the breakthrough curve for two columns with diameter of 2.5 and 5 cm and the height of the column is 15 cm and the flow rate of the wastewater introduced is 4 lit/h.

### CONCLUSION

It can be concluded from present study that bagasse ash has potential to be used as a bio-adsorbent and it may replace activated charcoal to remove colour from highly coloured waste water from common effluent treatment plant. The adsorption breakthrough curves obtained during adsorption studies clearly show that more height, lesser flow rate and bigger column diameters results in more reduction in colour from waste water. Higher removal capacities were observed, probably due to the fact that contact times were more and adsorption equilibrium was

developed between adsorbent and adsorbate. The future research has to be focused on scale up of using this agricultural waste as adsorbent in industries and later on its regeneration may also be thought of. Thus, bagasse ash can be one of the best replacement of conventional adsorbents used to remove colour from wastewater in industries.

### ACKNOWLEDGEMENT

The authors are thankful to Shroff S R Rotary institute of chemical Technology for providing necessary equipment and facilities to carry out all the experiments.

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