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# Evaluation of the adsorption capacity of sugarcane bagasse, in a fixed bed column, for treating textile dye

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**Abstract**

The industrialization process has economic benefits, such as growth and job creation, but it also results in the production of waste and pollution. Textile industries commonly use precipitation, biodegradation, activated sludge and adsorption as techniques for treating wastewater contaminated with dyes. Fixed bed systems are often more economical, and widely applied in various fields, such as vegetable and mineral oil decolorization, protein purification, and removal of organic pollutants from liquid effluents. In this context, the objective of the present work was to evaluate the influence of operational parameters (bed height and flow rate) on a fixed bed adsorption column, using sugarcane bagasse as an adsorbent, in the treatment of textile dyes. Sugarcane bagasse was characterized through FTIR analysis, water content and pH. Preliminary tests were carried out to identify the influence of the type of dye and concentration on the adsorption capacity of the pomace. The tests in the fixed bed column were conducted with different bed heights (1.5 and 3.0 cm) and different flow rates (3 and 8 $mL.min^{-1}$). FTIR analysis of the bagasse revealed the presence of group characteristic of sucrose. In preliminary adsorption tests, it was found that sugarcane bagasse adsorbs cationic dyes better. Furthermore, it was observed that the adsorption capacity of bagasse increases with the dye concentration. Column tests showed that bagasse is a promising adsorbent for cationic dyes in fixed bed systems, demonstrating great potential for industrial applications.

*Keywords:* adsorption; column; sugar cane bagasse; dyes;

## 1. INTRODUCTION

Industrialization drives economic growth, creates jobs and produces goods, but it also results in waste and effluents. In the textile industry, the dyes used in dyeing are major sources of water pollution, since a significant amount of dyes is discarded due to their incomplete fixation in the fabrics [1,2].

Textile processes generate voluminous and complex effluents, with a high organic load, a high content of inorganic salts and intense coloring due to the presence of dyes that do not fix themselves in the fibers during dyeing. The diversity and complexity of these effluents, together with the legal requirements for efficient treatment, have driven the development of new technologies that seek better and more appropriate solutions, considering cost, time and efficiency in recycling and eliminating toxic substances [3].

The techniques most used by industries in wastewater treatment include precipitation, biodegradation, activated sludge, flotation, and adsorption, among others. However, these conventional procedures are not very effective when applied alone.

Faced with this scenario, there is a growing concern in the development of viable alternatives in order to maintain the biological balance between species in the aquatic environment and for the recovery and maintenance of the environment. Among the techniques available for treating effluents, adsorption stands out due to its low cost, simplicity and efficiency, as well as the possibility of using low-cost materials such as agro-industrial waste, such as sugarcane bagasse, as adsorbents.

Adsorption consists of a physical-chemical mass transfer phenomenon where the spontaneous concentration of certain species occurs on the surface of a material. This process allows the separation of different components in a solution.

The adsorbed material is called adsorbate, and the solid material that effected the adsorption is the adsorbent. As the adsorbed substances are concentrated on the external surface of the adsorbent pores, the larger the contact surface, the greater the adsorption efficiency, therefore, adsorbents are generally finely powdered solids that have characteristics of great porosity in their structure [4,5].

Fixed bed column adsorption is a widely used method for adsorption of solutes from liquids or gases, employing a fixed bed of granular particles. The fluid to be treated is usually passed downward through the packed bed at a constant flow rate. The situation is more complex than the batch process in a stirred tank, in which equilibrium is reached. Mass transfer resistances are important in fixed bed processes and operation occurs in transient mode. The global dynamics of the system determines the efficiency of the process, requiring more than information about the equilibrium [6].

The Brazilian state of Alagoas is a large producer of sugar cane and with each harvest, there is an increase in production, especially due to the expansion of the harvested area, however the processing of this product generates an abundance of bagasse, with around 250 kilograms for each ton of crushed sugarcane. In this sense, studies are carried out to seek a destination that adds value to this residue, in addition to its use for cogeneration of energy by the plants themselves. Adsorptive processes using sugarcane bagasse are promising, both with the use of the natural material or by chemically activating this material or transforming this residue into activated carbon [7,8,9].

The objective of the present study is to evaluate the adsorptive capacity of sugarcane bagasse in a fixed bed column adsorption system, in the treatment of textile dye.

## 2. MATERIALS AND METHODS

### 2.1. *Collection and preparation of adsorbent material: sugar cane bagasse*

A sugar and alcohol plant in the region of Penedo - Alagoas - Brazil donated sugarcane bagasse, used as adsorbent material. After collection, the material was carefully separated from any accompanying residues, placed on a plastic tray and subjected to an oven drying process at a temperature of 60°C, until it reached a constant mass. Subsequently, the dry material was sieved.

### 2.2. *Physical-chemical characterization of the adsorbent material*

Sugarcane bagasse was characterized through water content analysis and infrared spectroscopy.

### 2.3. *Evaluation of the adsorptive capacity of sugar cane bagasse*

2.5 g of sugarcane bagasse was placed in contact with 250 mL of dye solution, cationic (methylene blue) and anionic (methyl orange), with different concentrations (5, 10 mg.L$^{-1}$). The system (adsorbent + solution) was maintained at room temperature and constant stirring, with the aid of a magnetic stirrer. At pre-established times, 4 mL aliquots of the solution were removed from contact with the bagasse, with the aid of a pipette, and analyzed in a spectrophotometer. The adsorption capacity of the adsorbent, Q (mg of dye/g of adsorbent), was determined using Equation 1.

$$Q = ((C_0 - C_f).V)/m \quad (1)$$

$C_0$ is initial concentration (mg.L$^{-1}$); $C_f$ is final concentration (mg.L-1); V is volume of the solution (L); m is mass of the adsorbent (g).

### 2.4. *Preparation of the adsorption column with fixed bed*

A glass column 30 cm long and 3 cm in diameter was used. Initially, a glass wool support was added to the column so that the adsorbent was not carried away by the effluent flow. The adsorbent was humidified with ultrapure water and carefully placed in the column, with the help of tweezers and a glass rod, in order to avoid the formation of preferential paths and bubbles. Then, the bed was finished with a new glass wool support, avoiding its mobility with the percolation of the effluent through the column. Finally, the system was stabilized with the continuous passage of ultrapure water. After this step, the dye solution was percolated through the column.

Two bed height conditions (1.5 and 3.0 cm) and two effluent flow rates (3.0 and 8.0 mL.min$^{-1}$) were analyzed.

## 3. RESULTS AND DISCUSSIONS

The donated sugar cane bagasse has a water content of 2.75%. This sugarcane bagasse is the result of grinding in the fifth mill, that is, the last stage of sugarcane grinding. After going through the entire grinding set, the resulting bagasse has a humidity of around 50%. The donated bagasse, after milling, was possibly exposed in the plant's yard, considerably reducing its moisture content.

The FTIR spectrum obtained for fresh sugarcane bagasse is observed in Figure 1.

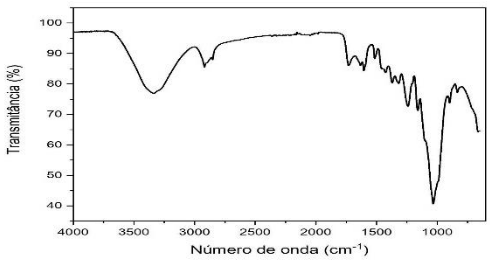


**Figure 1:** Infrared spectrum of raw sugarcane bagasse.

Around 3,450 $cm^{-1}$, a peak associated with the folding of the (OH) bond is observed, while at approximately 3,000 $cm^{-1}$, the presence of the (C-H) bond is identified. The peak around 1600 $cm^{-1}$ is characteristic of the (C=O) bond, and at 1200 $cm^{-1}$, there is the (C-O) bond. Notably, the formation of sucrose in the infrared is evident at 1,110 $cm^{-1}$. Bands between 1000 $cm^{-1}$ and 800 $cm^{-1}$ indicate C bonds with other substances in the sample.

Previously, the adsorptive capacity of sugarcane bagasse was tested against two types of dyes: cationic (methylene blue) and anionic (methyl orange). Both dyes were tested at three different concentrations (5, 10 and 30 $mg.L^{-1}$). Bagasse has a greater adsorption capacity for cationic dyes (methylene blue) and, the higher the dye concentration, the greater the adsorption capacity of the bagasse.

The adsorption tests in the fixed bed column were carried out with methylene blue dye with a concentration of 30 $mg.L^{-1}$, as the adsorption capacity of the bagasse was the highest under these conditions. The column, after stabilization and flow adjustment, was filled with the dye solution. The test was carried out until the concentration of the effluent at the column outlet was equal to the concentration of the dye initially inserted, that is, until the column was saturated.

By reading the aliquots collected from the column over time, it was possible to trace the rupture curve for different bed height and flow conditions, as shown in Figure 2 and 3.

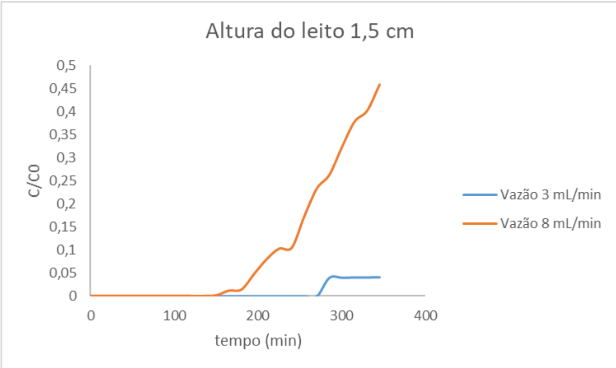


**Figure 2:** Effect of flow on the rupture curve, bed height of 1.5 cm.

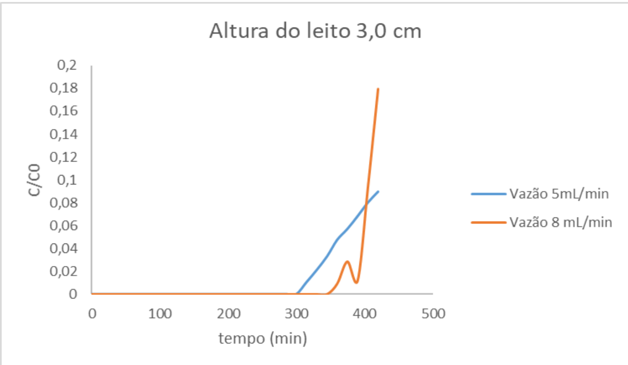


**Figure 3:** Effect of flow on the rupture curve, bed height of 3.0 cm.

It was observed that a greater filling height provides a longer dye retention time, resulting in a longer time for the column to saturate; diffusional resistances are greater.

The effect of the operating flow is closely correlated with the diffusional resistance of the bed. In this way, an increase in flow results in a reduction in resistance to mass transfer in the film, consequently, a reduction in the mass transfer zone [10]. The increase in flow rate is accompanied by a decrease in the column's retention capacity, because the fluid's residence time in the bed is shorter.

## 4. CONCLUSIONS

The physicochemical characterizations revealed that the moisture content of the sugarcane bagasse was approximately (2.75%) and the FTIR analyzes indicate the presence of functional groups, such as hydroxyl and carbonyl, in addition to simple bonds between carbon and oxygen, indicating the presence of sucrose and fructose molecules.

Bagasse adsorptive capacity tests show a greater capacity against cationic dyes and with higher concentrations.

Through the analysis of the effects of modifications to the operational parameters of the fixed bed adsorption column design, for the treatment of methylene blue dye, it was concluded that the increase in flow rate, while fixing the other operational parameters, caused a decrease in the residence time of the effluent in the column, quickly saturating the adsorptive bed. The analysis of the effect of varying the height of the adsorptive bed on the process found that the higher the bed height, the longer the effluent retention time, which is consistent with theory.

In short, it is possible to conclude about the adsorption process in a fixed bed column with sugarcane bagasse, for the treatment of a known sample of dye that the results obtained are consistent with what is shown in the literature, in addition to showing good results in removing the dye from the solution.

In general, it was observed that the treatment of textile dyes through the adsorption process is an attractive alternative, both economically and technically, with a deeper study on the impacts of the raw effluent on the adsorbent being necessary, in order to then improve the characteristics of this adsorbent material.

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