Removal of Basic Dye in Water Matrix Using Activated Carbon from Sugarcane Bagasse

Mark Bryan Fabon, Gerald John Legaspi, Kenneth Leyesa, and Maria Cristina Macawile

Abstract**—** Activated Carbon (AC) from Sugarcane Bagasse was successfully produced through chemical activation process using zinc chloride as activating agents. The effectiveness of activated carbon in different concentrations of wastewater dye and wastewater from Saffron Textile Dyeing was studied.

To determine the effect of dye concentration in adsorption process, three different concentrations (1%, 3% and 5%) of 200 mL basic dye were prepared and added with 15 grams of activated carbon. The effect of varying AC concentration was performed using a 200mL of 1% wastewater dye solution added with 15 g , 20g and 25g AC. Using different concentrations of AC and dye solutions, the optimum amount of activated carbon use to adsorb the color from simulated wastewater was determined.

The color removal from dye solution was measured using UV-VIS spectrophotometer. It was noted that the result of absorbance decreases significantly in each sample taken every hour for 10 hours. Experimental results shows that 99.35 % of color was removed in 5% dye wastewater using 15 g of AC. While 99.5% of color was removed in 1% basic dye solution using 25 g of AC.

This study reveals that activated carbon from sugarcane bagasse is more effective in a higher concentration. This study shows that bagasse activated with $ZnCl_2$ is an effective adsorb. The activated carbon from sugarcane bagasse can decolorize the different concentration of basic dye in wastewater.

Keywords**—**activated carbon, adsorption and sugarcane bagasse

I. Introduction

ONE of the greatest contributors of water pollutant after agriculture is the textile industry [1]. Textile Industry is among the chemical industries involved in water pollution wherein degree of pollution is characterized by its high water consumption and chemical usage [2]. Many textile manufacturers are using basic dye to give color to their products. Dyes even in low concentrations affect the aquatic life and human being causing its removal from wastewater effluents necessary.

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According to the Environmental Hazards of Textile Industries (2005), many textile manufacturers use dyes that release aromatic amines. Dye bath effluents may contain heavy metals, ammonia, alkali salts, toxic solids and large amounts of pigments many of which are toxic. About 40 % of globally used colorants contain organically bound chlorine, a known carcinogen. Natural dyes are rarely low impact, depending on specific dye and mordant used. Mordants such as chromium are very toxic and high impact. The large quantities of natural dyestuffs required for dyeing, typically equal to or double that of the fibers on weight, make natural dyes prepared from wild plants and lichens very high impact [3].

Several advanced wastewater treatment methods were used to improve the removal of textile dye in wastewater. Among these are the studies conducted using methods of electrocoagulation [4], photocatalysis [5] and nanomembrane filtration [6]. While these methods are effective in color removal, another method that gains popularity in removal of dissolved and suspended solids in wastewater is adsorption process. Adsorption is the process by which activated carbon removes substances from water which refers to the diffusion of a gas or compound into the porous network where a chemical reaction or physical entrapment takes place. Activated carbon is an effective adsorbent material due to its large number of cavernous pores. Principally, activated carbon adsorption proceeds through 3 basic steps which are substances adsorb to the exterior of the carbon granules, substances move into the carbon pores, and substances adsorb to the interior walls of the carbon [7].

Activated carbon is most widely used as adsorbent. There are three main forms of activated carbon commercially available in market (a) granular activated carbon, (b) powder activated carbon and (c) pelleted activated carbon. These can be produced from any carbonaceous material rich in elemental carbon. These materials are used in environmental application for protecting our water, for treating our wastewater and as gas filter. The production of activated carbon involves two processes which are the physical and chemical activation process.

While commercially activated carbon remains very expensive, many studies had been conducted to develop activated carbon from residual waste and agricultural products to eliminate various pollutants such as rice husk to remove dibenzothiophenes in kerosene [8] , nut shell [9] and coconut husk used in Cyanosine [10]. Due to the large degree of organics present from dyes, conventional, physiochemical and biological treatment methods are ineffective for their removal.

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The adsorption process is one of the efficient methods to remove dyes from effluent due to its sludge free clean operation and complete removal of dyes even from dilute solutions [11].

Sugarcane bagasse was also prepared as activated carbon in various studies . This material is the resulting by-product from the milling of sugarcane. Sugarcane bagasse refers to the residues after sugarcane or sorghum stalks are crushed to remove their juice. It contains 46.0% cellulose, 24.5% hemicellulose, 19.95% lignin, fat and 3.5% waxes, 2.4% ash, 2.0% silica and 1.7% other element [12]. The annual global production of 800 million tons of sugarcane results in 240 million tons of bagasse [13]. Instead of disposing it, this will be used as an activated carbon for the removal of dye in wastewater. This study aims to determine the effectiveness of using an agricultural waste such as sugarcane bagasse as activated carbon for treating the basic dye wastewater contamination.

II. Methodology

A. Preparation of activated carbon

Sugarcane bagasse was obtained from Central Azucarera Don Pedro, Inc. located at Central Town of Nasugbu, Batangas, Philippines. It was washed thoroughly with distilled water to remove adhering soil and clay then oven dried at 500 ^{o}C for 60 minutes. The bagasse was weighed and soaked for 1 hour in $ZnCl_2$ (AR grade) solution with impregnation ratio of 1:1. Impregnation ratio is the weight of bagasse to weight of $ZnCl_2$ used in the experiment. The impregnated bagasse was placed in a 500°C furnace for 1 hour. Acid-washing was employed using a 3M HCl (AR grade) solution to eliminate the residual Zn from the char. This char was repeatedly washed with hot distilled water and cold water. Finally, the material was dried in 120^{o}C oven and sieved using 850 μm mesh screen [14].

B. Preparation of wastewater sample

Basic dye was acquired from Philippine Textile Research Institute of the Department of Science and Technology in Bicutan, Taguig, Philippines. Three different dye concentrations of 1%, 3% and 5% in 200 mL of distilled water were prepared. The solution was heated and brought into its boiling point. Two grams of $Na_2SO_4 \cdot 10H_2O$ (AR grade) was added to the solution and finally boiled for another 0.5 hr [15] .

C. Adsorption Process

Batch experiments were carried out by placing 200 mL of 1% basic dye solution with 15 g , 20 g and 25g of activated carbon. Wastewater sample amounting to 200 mL was withdrawn for a specific time interval for each of the three different mass of activated carbon. The effect of varying activated carbon concentration was determined by calculating the amount (%) of basic dye adsorbed as $[(C_o - C_t) / C_o] \times 100$ where C_o and C_t are initial and dye concentration at time t. The absorbance of the sample was measured at standard wavelength of basic dye of 581 nm.

Similarly, batch experiments were conducted to determine the effect of varying the basic dye concentrations in the removal of color. Three different concentrations of 1 % , 3% and 5% were prepared and individually added with 1.5 g of activated carbon. The % of color removal was also determine upon withdrawal of 20 mL of basic dye solution in a specific time interval of 0.5hr, 1 hr , 2 hrs, 3 hrs, 4hrs, 5 hrs, 6 hrs, 7 hrs, 8 hrs, 9 hrs and 10 hrs.

Actual wastewater effluent from Saffron Textile Dyeing company located at Governor's Drive, Bo. Paliparan, Dasmariñas, Cavite, Philippines was collected and used as wastewater effluent in adsorption studies using 15 g of activated sugarcane bagasse. The absorbance of the sample was measured at standard wavelength of actual wastewater of 605 nm.

The schematic diagram of a laboratory scale adsorbent flask is shown in Fig. 1.

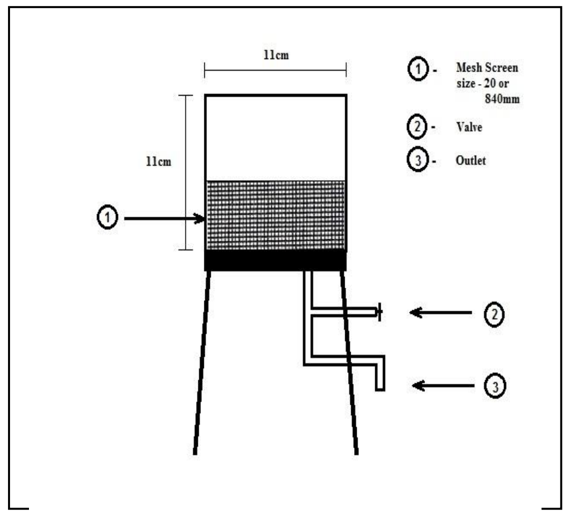


Fig. 1 Laboratory scale adsorption flask
(1) mesh screen (2) valve and (3) outlet

D. Instrumentation

Scanning Electron Microscope (JEOL 5300) was used to display macropores of the sugarcane bagasse activated carbon UV/VIS Spectrophotometer (Hitachi U-2900) was used to determine the adsorption or transmission of UV/VIS light to the sample dye.

III. Results And Discussion

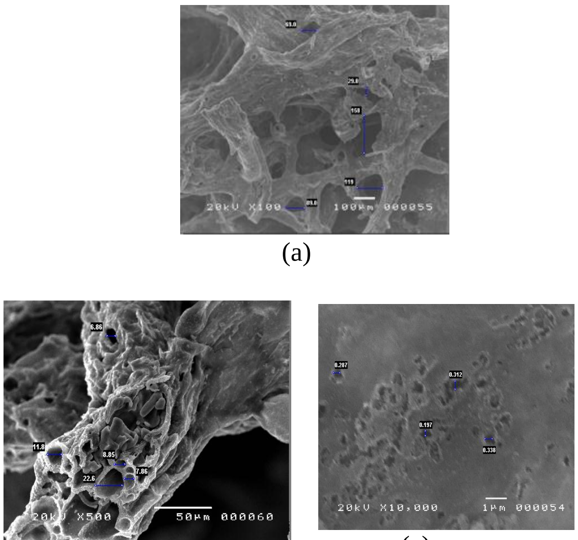
A. Activation process

The use of $ZnCl_2$ as activating agent prevents the formation of tars which blocks the pores of activated carbon. Using impregnation ratio of 1, the chemical activation improves the pore development in a carbon structure of sugarcane bagassse resulting to a yield of 54.22%.

The pore size and structure of activated carbon was compared to a raw sugarcane bagasse. Fig. 2 shows images of granular activated carbon in different magnifications. In a 100μm scale magnification, the largest and smallest surface area of pore recorded were 158μm^2 and 29μm^2 respectively. Likewise using a 50μm scale magnification, the largest and smallest surface area recorded were 22.6μm^2 and 6.86μm^2

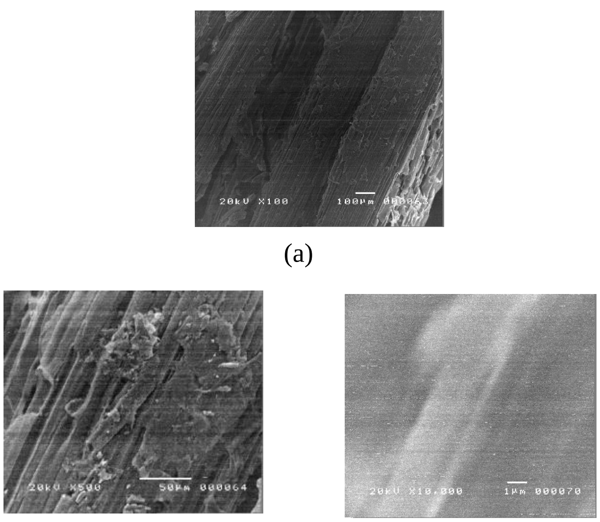
respectively. In a 1µm scale magnification, largest pore surface area obtained was 0.338µm^2 while the smallest pore surface area was 0.197µm^2 .

On the other hand, Fig. 3 shows that no pores were captured in the raw material bagasse which proves that pores can only be obtained if it underwent carbonization process by chemical or physical activation. In general, it can be said that macropores are of little value in their surface area, except for the adsorption of unusually large molecules, thus it is usually considered as an access point to micropores. It is the micropore structure of an activated carbon that is the effective means of adsorption.



(a) (b) (c)

Fig. 2 Surface area of sugarcane bagasse activated carbon in different scale magnifications
(a) 100 µm (b) 50 µm and (c) 1 µm



(a) (b) (c)

Fig. 3 Surface area of sugarcane bagasse in different scale magnifications
(a) 100 µm (b) 50 µm and (c) 1 µm

B. Effect of initial dye concentration

Three different dye concentrations of 1%, 3% and 5% were prepared and added with 15 g of activated carbon . Fig. 4 shows the summary of dye removal from the simulated wastewater solution in three different initial dye concentrations. A sudden increase of % dye removal was observed until 4 hours of treatment. Table 1 shows the corresponding concentration of dye present in each of simulated dye wastewater sample. The highest % removal of dye was obtained after 10 hours for each of the different initial dye concentrations.

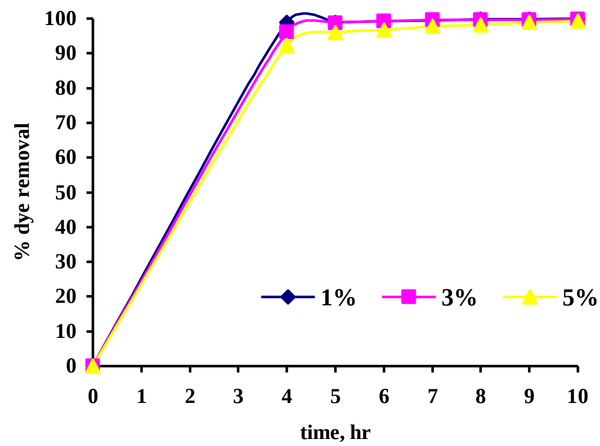


Fig. 4 Effect of initial dye concentration
mass of activated carbon : 15 g

TABLE I
EFFECT OF INITIAL DYE CONCENTRATION :
DYE CONCENTRATION OF SAMPLE (PPM)

Time, hrs	1%	3%	5%
4	4.8	15.7	18.2
5	3.1	10.2	20.2
6	3	3.4	10.8
7	1.9	1.8	8.8
8	1.3	1.2	5.8
9	0.4	1	5
10	0.3	0.8	2.9

C. Effect of initial activated carbon concentration

Three different mass of activated carbon (15g, 20g and 25g) were also used to remove color from a 200 mL, 1% dye concentration. It was noted that 15g, 20g and 25grams of activated carbon placed in a simulated dye wastewater was found effective in the removal of color. Experimental results reveal that mass of activated carbon affects the time of color removal. The higher the mass of activated carbon the faster it can remove color otherwise the higher concentration of dye affects the time of removal of the color. Fig. 5 shows the effect of initial activated carbon concentration on the removal of dye while table II summarize the concentration of dye in each of wastewater sample taken in specified time interval.

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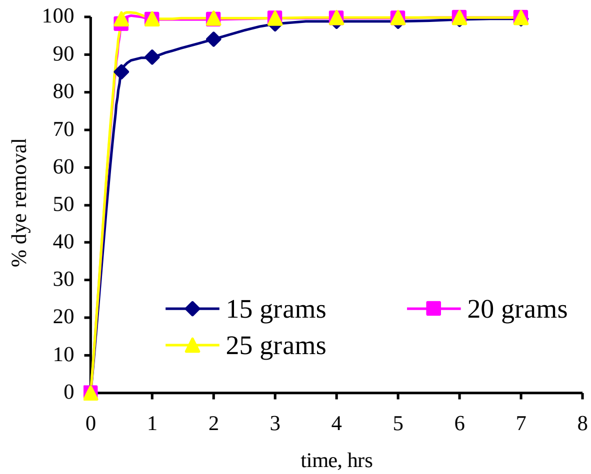

Fig. 5 Effect of initial activated carbon concentration 1% initial dye concentration

D. Carbon adsorption process using actual wastewater sample

The sugarcane bagasse activated carbon was also found effective in the removal of color using actual dye wastewater sample from Saffron Textile Industry. Absorbance reading of wastewater sample reveals that it decreases when subjected to a much longer adsorption process.

TABLE II
EFFECT OF INITIAL ACTIVATED CARBON CONCENTRATION : DYE CONCENTRATION OF SAMPLE (PPM)

Time, hrs	15g	20 g	25 g
0.5	38.4	5	1.4
1	28.3	1.9	1.3
2	15.4	1.7	0.9
3	4.8	1.1	0.8
4	3.1	0.9	0.6
5	3	0.7	0.5
6	1.9	0.5	0.4
7	1.3	0.4	0.3

TABLE III
DYE CONCENTRATION OF SAMPLE USING ACTUAL WASTEWATER SAMPLE INITIAL DYE CONCENTRATION : 1% MASS OF ACTIVATED CARBON : 15 G

Time, hours	Absorbance
0.1	0.075
1	0.069
2	0.056
3	0.044
4	0.035
5	0.029
6	0.027
7	0.025

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