ASSESSMENT OF ACTIVE CARBON DERIVED FROM MAIZE COBS FOR DECOLOURISING TEXTILE EFLUENTS.

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ABSTRACT

The production of active carbon from maize cobs and its capacity to decolourise textile effluents in comparison with such carbon derived from hard wood is reported. Decreasing uv-visible absorption peak heights of the effluents were monitored as a measure of the changes in their colour as the effluents were passed through columns of the active carbon. Zinc chloride was demonstrated as a superior activating reagent to hydrochloric acid. A limiting adsorptive capacity of the carbon was demonstrated in terms of the decolorizeable volume of effluent passed before the carbon column becomes saturated with the dyes in the effluent. The failure of post-use heat treatment to regenerate the carbon adsorbency was also demonstrated and explained in terms of effluent-carbon matrix interaction.

INTRODUCTION

The application of activated carbon in waste water treatment has been reported[1-12] and such application in environmental pollution schemes has been established[1,11-13]. Applications in this and city water treatment have depended on the high adsorptivity of the carbon for organic solutes that produce colour or objectionable odour and/or taste in effluents or city water sources[14]. The adsorbency of the ultimate activated carbon is improved by rendering it in a particle size that maximises the surface area available for interaction with the solutes that need to be adsorbed out of the treated water. Typical surface areas of about $1000 m^2/g$ have been achieved[11] by reducing the carbon mass to pass a sieve of 180 mesh. Materials that have been successfully carbonized and activated for traditional applications include wood, nutshells, bones, sugars, natural gas and other carbonaceous matter. In certain cases, this application competes with other established needs for these scarce or highly demanded starting materials. In this country in particular, the prevailing consumption pattern imposes great stress on sources of sugar, natural gas and even charcoal or wood. It was this background that suggested the purpose of this article, an examination of maize cobs as a cheap starting material for producing active carbon for effluent and probably city water treatment. Maize cobs are produced in large quantities as a farm waste, a bi-product of the cultivation of maize in most parts but particularly in the Guinea savanah of Nigeria.

EXPERIMENTAL

Hard wood

The dry stems and branches of the acacia tree as used traditionally for firewood were cut into approximately 2.0cm cuboidal pieces.

Maize cobs

The soft woods rejected after the grains are threshed from the ears of maize were selected and cleaned to remove loose flakes. They were investigated without further reduction.

The clay pot

The pot in which the carbonisation process was conducted was purpose-made from clay and burnt after the Hausa pottery tradition, with a wide mouth, 40cm deep, 35cm horizontally across the middle, having a single 5.0cm hole drilled at the bottom and seven 2.0cm holes spaced equally round the middle.

Activation chemicals

The chemicals applied for activation were of analytical grade. Only distilled water was used in all dissolutions and dilutions. Commercial hydrochloric acid was diluted to 2M while 200g of zinc chloride was dissolved in $375 cm^3$ of distilled water.

The effluents

The effluents were collected just as they were discarded from the dye baths into drain without any pretreatment. The effluent from Ahmadu Bello University (ABU) Department of Textile Science was a dark blue colloidal suspension: those from the textile industries, *Kaduna Textiles Limited* and Arewa Textiles Limited, were pink-red and violet-purple solutions, respectively.

Instrumentation

The instruments used in this work included Gallenkamp UV-160 oven, Encrete brass sieve, 180 mesh, 2.0cm diameter glass columns with glass wool, 100cm^3 beakers and a Varian SP 1900 uv-visible spectrophotometer.

Carbonisation process

The same process was adopted to produce charcoal from both the hard wood and the maize cobs. The wood was packed closely in the clay pot and lighted on top with the pot raised off the ground on a tripod. After stirring the content to ensure that the fire had established, the pot was covered with a square piece of asbestos and allowed to burn for about four hours. It was then inverted on the asbestos piece and left for 30 minutes for the bottom pieces to burn. The fire was then quenched with water and the charcoal allowed to cool. It was then collected and washed ash-free with distilled water and spread on the bench to dry in readiness for activation.

Activation of carbon

The air-dried charcoal (500g) was soaked in the activating reagent and allowed to stand for 48 hours. It was then washed free from excess reagent, allowed to dry in air, and subsequently dried in the oven at 110°C for 24 hours. The activated carbon was then ground in a mortar and pestle to pass a sieve of 180 mesh. The sieved carbon was washed with distilled water to remove fines and dried at 110°C and then stored in a desiccator at room temperature for use as required.

Effluent characteristics

The uv-visible spectrum of each effluent was scanned to find out the wavelength of maximum absorbance (λ_{max}) of the dyes present in the untreated effluent. Thereafter, the peak height for fixed portions (5cm^3) of the effluent after interaction with a respective activated carbon (1g) was monitored at the λ max and the changes found used to evaluate the effect of the carbon. Typical observations are presented in Table 1 for the ABU Department of Textile Science effluent.

Table 1: Comparison of effects of carbon samples on effluent.

Carbon source	Activating reagent	Reduction in peak ht.at 566 n (chart divisions)
Hard Wood	$ZnCl_2$	17
Hard Wood	HCl	15
Maize Cob	$ZnCl_2$	13
Maize Cob	HCl	10

Comparison of activated carbon samples

The same mass (1g) of activated carbon derived from hard wood and maize cobs were observed on the same volume (5cm^3) of the ABU Textile Science effluent and their effects compared as in Table 1. A similar comparison of the two methods of activation for hard wood and maize cob derived carbon is also presented in Table 1.

Optimisation of carbon mass to effluent volume ratio

Varying volumes of the ABU Textile Science effluent were applied to a fixed (1g or 5g) mass of carbon packed in columns; the volume of residual effluent collected after saturating the carbon was measured and also the uv-peak height at the λ_{max}, 360nm; the results are presented in Table 2.

Table 2: Column characteristics.

C-mass (g)	Effluent presented (cm^3)	Filtrate collected (cm^3)	Void volume (cm^3)	Peak h (chart
1	1	0	-	
1	2	0.3	1.7	14.
1	3	1.3	1.7	14.
1	4	2.3	1.7	14.
5	10	2.8	7.2	14.
5	15	6.7	8.3	14.
5	20	12.0	8.0	14.
5	25	17.5	7.5	14.
5	30	22.0	8.0	14.

Evaluation of decolourisation efficiency

To permit a sufficient effluent volume to be studied, experimental columns were charged with 5g of carbon and 20cm^3 effluent fractions were routinely applied to investigate the decolourising efficiency of the carbon. Four effluent fractions were passed in sequence through the same column and the filtrate collected from each fraction was scanned under uv-visible. The peak heights at 360nm were used as in Table 3 to assess the progress of decolorisation.

Table 3. Decolorisation efficiency of carbon.

Effluent fraction number	Cumulative effluent volume (cm^3)	Peak height (chart divisions)	State of column
1	20	40	active
2	40	34	active
3	60	33	saturated
4	80	31	saturated

Table 4: Progression of decolourisation to saturation of column.

No. of applications	Filtrate peak height (chart divisions)	State of column
1	18	active
2	14	active
3	10	saturated
4	9	saturated

To obtain the same information by a different approach and also estimate the total effluent burden at which the carbon adsorptive capacity is exhausted, the filtrate obtained by passing an effluent fraction through a column is presented again repeatedly at the top of the same column and at each application a fraction of the filtrate is reserved and scanned under uv-visible as before. The results of one such set of observations are presented in Table 4. To study the advantage of continuously presenting fresh carbon matrix to the same filtrate, 50cm^3 of the effluent was passed through a cascade of four columns and a fraction was taken between columns for uv-visible scan. A typical observation from one such operation is presented in Table 5. All uv-visible scans were made using distilled water as blank.

Table 5: Decolourisation with cascade of columns.

Column No	Filtrate peak height (chart divisions)	State of column
1	28	active
2	27	active
3	19	active
4	18	active

Table 6: Re-use of the same recovered carbon on fresh effluent fractions.

Effluent fraction No	Cumulative volume passed (cm^3)	Filtrate peak height (chart divisions)	State of column
1	20	15	saturated
2	40	16	saturated
3	60	20	saturated
4	80	21	saturated
5	100	21	saturated

Table 7: Recycling of the same effluent fraction through the same recovered carbon column.

Cycle No.	Filtrate peak height (chart divisions)	State of column
1	16.0	saturated
2	19.5	saturated
3	20.0	saturated
4	21.5	saturated
5	21.5	saturated

Table 8: Same effluent volume through cascade of recovered carbon columns

Column No	Filtrate peak height (chart divisions)	State of column
1	24	saturated
2	27	saturated
3	33	saturated
4	34	saturated
5	34	saturated

Effect of heat on the used carbon

To assess the possibility of regenerating the used carbon, it was collected from the columns that had become saturated in use and dried again at 120°C for five hours and used again as before. The results obtained on such re-use are presented in Tables 6, 7 and 8.

RESULTS AND DISCUSSION

Of the effluents observed in this work, the ABU Textile Science effluent was the most complex in composition and was most appropriate for the arguments of this article. Though the effluent had two prominent bands centred at 360nm and 566nm respectively, the 566nm band got readily removed completely during interaction between the effluent and the active carbon. These two bands probably were associated with two different compounds in the dye mixture present in the effluent. Consequently observations in this work were focussed more on the 360nm band. Compared with a peak height of 70 chart divisions for the untreated effluents, treatment with active carbon reduced the absorbance and peak height of the effluent as shown in Table 1. Although the extent of decoloration effected by the same mass of carbon was superior for the carbon derived from hard wood, that achieved with maize cob derived carbon was comparable and would encourage the exploitation of maize cob for this application. Of the two reagents applied for activation, zinc chloride was superior and was applied for generating the carbon investigated in this work.

The results shown in Table 2 indicate that the active carbon encloses a void volume of about 1.6 - 1.7cm^3/g. Therefore, volumes of effluents for investigation must include an allowance for this; so 20cm^3 was routinely applied to 5g bulk of carbon in order to obtain sufficient filtrate for investigation.

The results of Tables 3-5 indicate progressive retention of the dye on the carbon until it becomes saturated with the dye molecules. An indication is provided of the cummulative effluent volume (about 50cm^3) that has passed through the carbon column by the time it gets saturated with the adsorbed molecules. The spectral scans of subsequent filtrates thereafter coincide with each other. The cummulative effluent volume at this point yields an estimate of the adsorptive capacity of the carbon in use. The effluent gets more dilute and less coloured as it flows through the carbon until the carbon becomes saturated with the dye. Apparently the effluent never gets completely decolourised: a faint residual colour remains even after practically excessive exposure to the adsorbing carbon.

The attempt to regenerate the carbon after exhausting its adsorptive capacity in use was unsuccessful. The carbon appeared to give up again the dyes already adsorbed on it to increase concentrations in the effluent again. Tables 6-8 may suggest that, in use, the carbon holds a loose layer or zone of dye particles; this layer is readily lost back into any influent liquid and its redissolution thereby accounts for the observed increase in uv-visible absorption and peak heights. There must also be a portion of the dye that has become more firmly adsorbed onto the carbon matrix and accounts for the observation that peak heights of filtrates stop increasing at a certain value. This happens when the adsorbed dye is no longer released into the influent liquid fractions by the carbon matrix.

CONCLUSION

Maize cobs are a ready source of charcoal that may be activated for application in the predisposal treatment of textile effluents. Such pretreatment would reduce the colour intesity of effluents to a negligible residue. Carbon derived from maize cobs is comparable in its capacity to decolourise textile effluents with that derived from hard wood. 5g of maize cob derived carbon may clean up about 50cm^3 of a highly concentrated effluent of the kind investigated in this work.

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