Adsorption Studies of Activated Carbon Prepared from Coconut Shells

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Abstract: ***A low cost, ecofriendly adsorbent in the form of carbon was derived from waste coconut shells. The carbon was obtained by adapting thermal pyrolysis method of derivation of the same. The derived carbon was characterized using FTIR, XRD and SEM methods of analysis. The behavior of the internal pores with respect to temperature was investigated by analyzing variation in the Iodine number with respect to the temperature taking activation burn off into consideration. Kinetics of adsorption property was checked for the adsorption of Methylene blue dye from the aqueous solution and it was found to follow first order kinetics.***

Keywords: Adsorption, Activated carbon, Methylene blue, First order kinetics

1. Introduction

Water pollution has become one of the major pollution nowadays worldwide. The various sources of water pollution are effluents from the industries, sewage waste fluids; etc.[1] Among these sources the major one is the effluents from the industries mainly from the industries making use of the synthetic dyes, which ultimately; lead to the environmental pollution directly or indirectly affecting the human health. With the advancement of the science and technology in the recent years various methods like solvent extraction, precipitation; etc. are developed to eradicate the major pollutants mainly from the aqueous system.[1,3] The superior method which is being employed nowadays above these all is the adsorption method. Carbon from the oilves stones are also reported to be good adsorbentsfor removal of dye from the aqueous systems.[2] In the adsorption method, an adsorbent is being employed which adsorbs the adsorbent onto it.[3] The advantage of adsorption method over the other methods is that it is eco-friendly, highly effective, cost effective and produces less waste in the form of the biodegradable waste.[3]

Many such adsorbents are being employed for the same. Fly ash which is a by-product from the power plant as a result from the combustion of the coal is reported as an effective adsorbent in order to remove harmful metal ions from the aqueous systems.[3] Fly ash has been reported as an adsorbent of malachite green dye from its aqueous medium.[4] Recently, titanium dioxide synthesized via sol gel method of synthesis has been a hot research topic. Decolourisation of cane juice using TiO_2 pellets have also been reported in order to reduce polyphenols.[5]There are reports I the literature on the adsorption studies of dyes using carbon derived from date stones as well showing a remarkable adsorption.[6] Chlorella based biomass is reported as an adsorbent of malachite green dye from its aqueous solution.[8] Also, removal of Chromium from the industrial effluents using bark biomass[9] and bio sorption of Cr(VI) over rice husk is being studied.[10]

Copper pyrovanadate is found out to show effective photo-fenton catalytic properties for the degradation of methylene blue dye.[11] Araucaria cookie bark has been studied as a low cost, easily available natural bio sorbent for the removal of malachite green from aqueous solution.[7] Recently, tea waste, tamarind seeds carbon is utilized for the removal of dyes from the aqueous solution.[12,16]

Also, activated carbon from the Jute stick char has been reported to have a good adsorption capacity of Benzene and Carbon tetrachloride.[13] Recently activated carbon prepared from the green coconut shells has been reported which was employed for the removal of carbon dioxide from flue gas as well as various inorganic constituents from the waste water and also for the removal efficiency of methylene blue.[14] For the removal of methylene blue, adsorbents like F400 commercial activated carbon, textile sludge Acorn; etc are being employed.[15,17,18,19]

In this present work, we have prepared activated carbon from the coconut shells and characterized viaFTIR, XRD and SEM spectroscopy. Also, Iodine number and activation burn off have been determined. Adsorption studies of methylene blue inorder to investigate the reaction order was carried out.

2. Materials and Methods

Iodine (99.9%), Potassium Iodide (99%), Sodium thiosulfate (99.9%), Methylene blue dye was obtained from SD-fine Chemicals Ltd.

Synthesis of Activated Carbon (AC)

Coconut shells were taken and pyrolysed thermally followed by grounding to fine powder in order to recover small particle size. This recovered fine powder was heated from 100-500^{0}C using Muffle furnace for 2hoursand was labeled as AC (Activated Carbon).It was allowed to cool and was washed with 0.01M HCl to eradicate the unwanted ash particles followed by washings using deionized water to remove the traces of the acid used previously. The obtained sample was reactivated at 102^{0}C.

Activation burn-off was calculated as follows:

Activation burn-off (%)= (mass loss (g)/original mass (g)) x 100.[13]

Iodine Number

0.1g of AC was taken in a 250mL conical flask. 10mL of 0.05N Iodine solution in aqueous Potassium Iodide was added to it. After one hour the solid was separated by centrifugation and the recovered residual solution was titrated using 0.1N sodium thiosulfate solution. The iodine number was calculated as 1mg of Iodine adsorbed by one gram of AC.[13]

Adsorption studies

1ppm solution was prepared by dissolving 1mg of Methylene blue dye powder in 1 liter of deionized water. In a 100mL Beaker 60mL of this dye solution was taken and to it 0.1g of AC was added and kept under stirring and after every 5 minutes approximately 5mL of solution was withdrawn and absorbance was recorded at 673nm using Bio-Era visible spectrophotometer. And the kinetic studies were carried out in order to determine the order of the reaction.

3. Results and Discussion

Characterization of Activated Carbon

FT-Infra-Red analysis: FTIR spectrum of AC as shown in figure 1, shows peaks at 1365 is due to the C-O stretch. 1743.65 cm^{-1} is due to the C=O stretch. 2582.68 cm^{-1} is due to the O-H stretch. 1159.22 cm^{-1} and 1217.08 cm^{-1} is again due to C-O stretch.

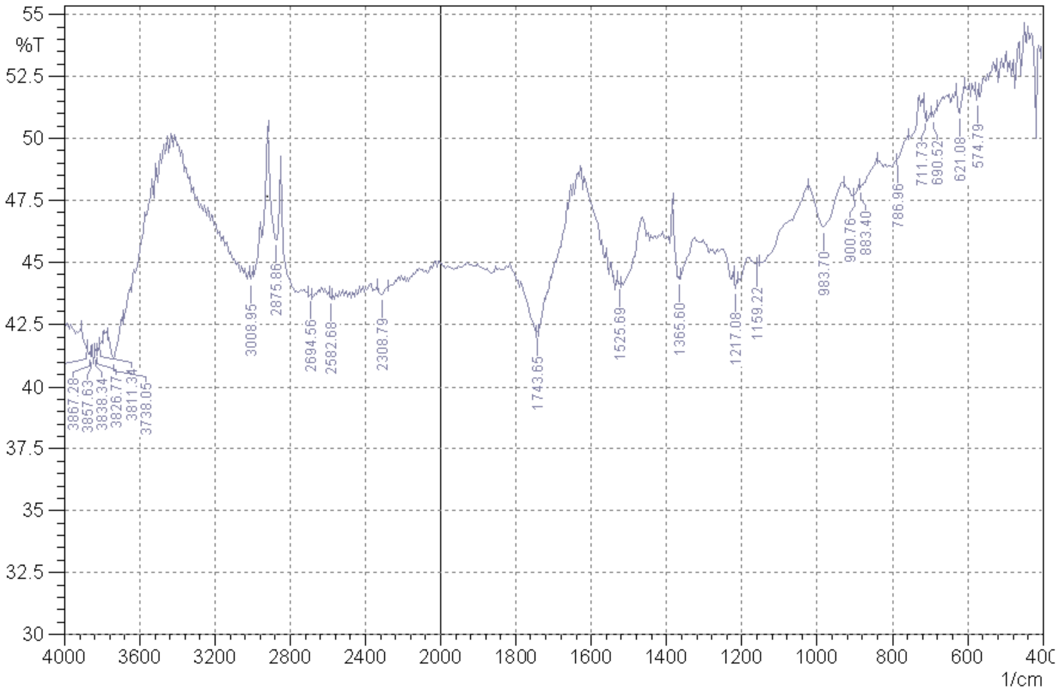

Figure 1: FTIR spectra of AC

X-Ray diffraction studies: XRD spectrum of the AC as depicted in figure 2, shows absence of the sharp peaks indicating the amorphous nature which is an advantageous characteristics of a good adsorbent. Peaks at 26^0, 37^0 and 45^0 indicates some sought of crystalline carbon structure.[14]

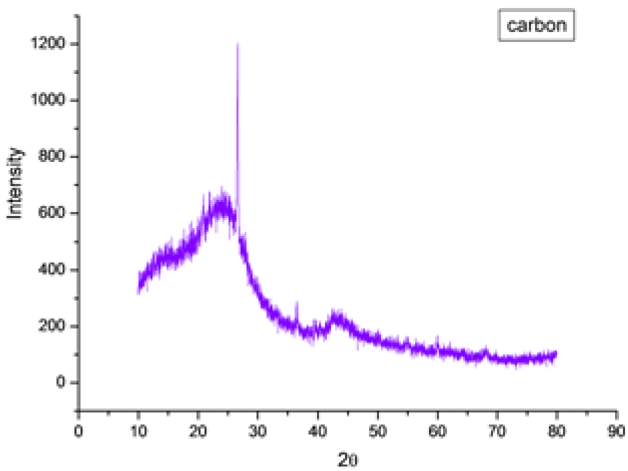

Figure 2: XRD spectra of AC

SEM analysis: SEM analysis of AC as can be observed from image shown in figure 3, shows that there are few pores. Due to carbonation and activation, volatiles are eliminated thereby producing a mass with widening and at some extent breaking of the pores. These microspores contribute towards the methylene blue adsorption.

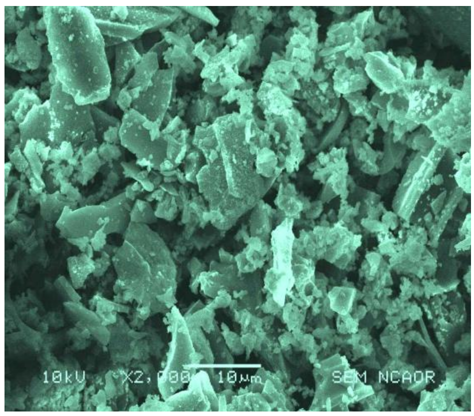

Figure 3: SEM image of AC

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The table 1 represents the effect of temperature on the percentage yield and the properties of the AC under study. The reason for the activation burn-of is the formation of carbon monoxide and hydrogen gas which mostly takes place on the outer surface. It has been found that due to the surface reaction new pores are generated on the surface and an increase in the initial pore size.

Table 1: Effect of temperature on the yield and the Iodine Number of AC

Temperature(^{0}C)	100	200	300	400	500
Activation time (hours)	2	2	2	2	2
Amount of activated carbon produced	0.852	0.985	1.097	0.655	0.587
Activation burn-off (%)	42.60	49.25	54.85	32.75	29.35
Iodine Number	4.8	6.3	9.8	10.5	5.9

From the figure 4, it can be seen that the linear relationship between the activation burn-off and the Iodine number does not exist. On the contrary, it can be observed that initially the activation burn-off goes on increasing with an increase in the iodine number. But, after a particular value of the Iodine number has been reached, the activation burn-off decreases. This can be attributed to the fact that structure is fragile due to which the pore size goes on increasing due to which the activation burn-off also goes on increasing. Due to this the periphery of the pore goes on stretching and ultimately reaches its maximum stretching capacity and then breaks down which, is indicated by decrease in the activation burn-off after attaining a maximum value with an increase in the temperature as depicted in the figure below.

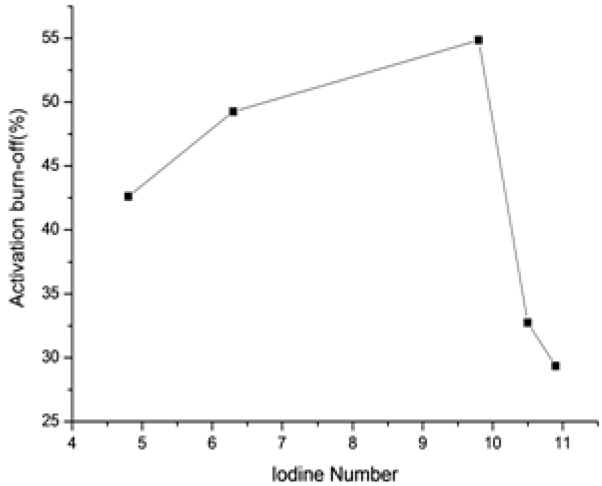

Figure 4: Plot of Activation burn-off versus Iodine number

Effect of Adsorption time: The figure 5, depicts the plot of Absorbance versus time for the adsorption of Methylene blue dye onto AC. Concentration is found out from the absorbance using the expression from the Beer-Lambert's Law i.e. A=εCl. Where, A is the absorbance, ε is molar absorptivity coefficient, C is the concentration in ppm and l is the path length. The %Efficiency is determined using the following expression:[14]

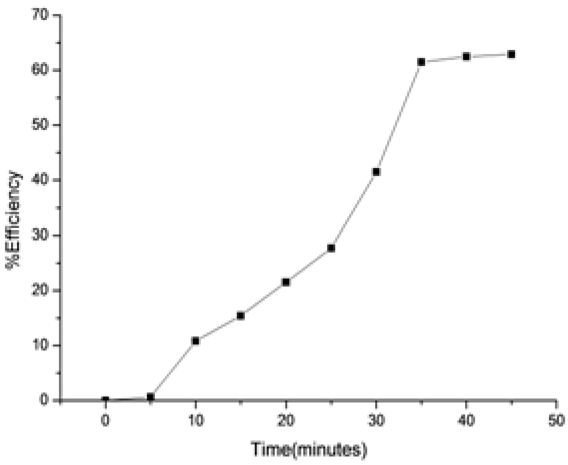

Figure 5: Plot of %Efficiency versus time (minutes)

Kinetic studies of Methylene blue adsorption studies: To study the kinetics of adsorption of the Methylene blue dye plots of ln [Dye concentration] versus time in minutes for first order kinetics and 1/Dye concentration versus time in minutes for second order kinetics were plotted and the correlation coefficients were determined as shown in figure 6.

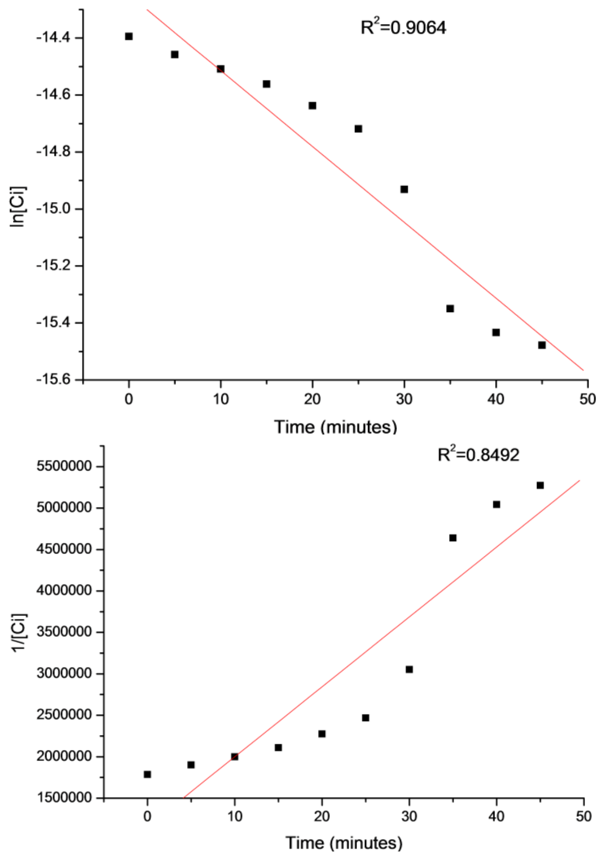

Figure 6: Plots depicting Kinetic studies

From the correlation coefficients it was seen that the best fit was obtained for the first order kinetics plot. And therefore it can be said that the adsorption of methylene blue onto AC follows a first order kinetics.

4. Conclusions

Activated carbon (AC) was successfully prepared by thermal pyrolysis. The activation burn-off was maximum at 300^{0}C.

The effect of activation burn-off over Iodine number was successfully studied which indicated that the pores are fragile in nature. The Adsorption studies were performed using methylene blue dye which showed that AC is a good adsorbent. Kinetic studies suggested that the adsorption of methylene blue dye over AC followed first order kinetics.

So, we can conclude that AC prepared from the coconut shells can act as a good adsorbent material for the adsorption of methylene blue dye and can be used for the waste water treatment.

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