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Removal of dye from aqueous solution by using activated carbon

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Abstract

The present work is aimed at synthesis of efficient adsorbent from coconut shell and comparison with commercial grade activated charcoal (CGAC).The raw material i.e coconut shell powder is first activated with orthophosphoric acid (H_3PO_4) and carbonised in a furnace at temperature range of 450-600^{0}C. The effective surface area of activated carbon is obtained, The coconut shell activated carbon(CSAC) gives us better adsorption in removal of methylene blue dye from aqueous solution as compared to the commercial grade activated charcoal (CGAC).

Keywords: Coconut shell, Activated carbon, phosphoric acid, Methylene blue(MB), Commercial grade Activated carbon(CGAC).

Introduction

Adsorption is an important technique in separation and purification processes. Among many types of adsorbent materials, activated carbons are the most widely used. In this study, Coconut Shell is activated with ortho-phosphoric (H_3PO_4) acid. The purpose of activation is to enlarge the diameters of fine pore and create new pores. Activation can be carried out by chemical or physical means. In chemical activation, the carbonization and activation are accomplished in a single step by carrying out thermal decomposition of the raw material impregnated with certain chemical agents. The advantage of chemical activation is low energy cost due to lower temperature (500-800^{0}C) than those needed for physical activation, and high product yield. Physical activation involves gasification of the char by oxidation with steam, carbon dioxide, air or any mixture of these gases in the temperature range from 800 to 1100^{0}C[1-8].

Activated carbon is a commonly used adsorbent in sugar refining, chemical and pharmaceutical industries, wastewater treatment, and home water filtration systems. Increasing requirements for clearer and more polished effluent from many processes suggest that, barring the development of new technologies, industrial need for activated carbon will only increase in future.

The presence of dyes in effluents is a major concern due to their adverse effect to many forms of life. The discharge of dyes in the environment is worrying for both toxicological and aesthetical reasons. Industries such as textile, leather, paper, plastics, etc., are some of the sources for dye effluents[9-15]. Methylene blue (MB) is the most commonly used substance for dying cotton, wood and silk. Though MB is not strongly hazardous, it can cause some harmful effects where acute exposure to MB will cause increased heart rate, vomiting, shock, Heinz body formation, cyanosis, jaundice, quadriplegia and tissue necrosis in humans. Therefore, the treatment of effluent containing such dye is of interest due to its harmful impacts on the receiving waters. In general, dyes are poorly biodegradable or resistant to environmental conditions. Therefore it is necessary to treat the wastewaters or industrial effluents containing dyes before being discharged into the waterways.

A number of chemical and physical processes such as flocculation, chemical coagulation, precipitation, ozonation and adsorption have been widely used to treat dye bearing wastewaters. However, the adsorption onto activated carbon has been found to be superior compared to other techniques for wastewater treatment in terms of its capability for efficiently adsorbing a broad range of adsorbates and its simplicity of design. However, commercially available activated carbons are still considered expensive. This is due to the use of non-renewable and relatively expensive starting material such as coal, which is unjustified in pollution control applications. Therefore, in recent years, this has prompted a growing research interest in the production of activated carbons from renewable and cheaper precursors which are mainly industrial and agricultural byproducts[3,4,8-10,16].

The objective of this study was to compare the adsorption efficiency of coconut shell activated carbon (CSAC) and that of commercial grade activated carbon (CGAC) for removal of methylene blue from aq. solution. Freundlich adsorption isotherms are generated for comparison of the adsorption efficiencies of the CSAC and CGAC.

Preparation of activated carbon from coconut shell

Broken pieces of coconut shell are procured from a local temple area Ramnagar Nagpur. After washing with water and drying, these are crushed using Hammer Mill. The crushed powder is screened. Avg. particle size between 0.2 to 1mm is used for further treatment. Impregnation of coconut shell powder with orthophosphoric (H_3PO_4) acid solution is carried out using 0.5ml per gram of coconut shell. Impregnated coconut shell powder is then carbonized in a furnace at a temperature range of 450-600°C. The carbonized coconut shell powder is further washed with hot water at a rate of 20ml/gm of powder, filtered and dried at 120°C.

The carbon yield (%) of the prepared carbon was calculated using following equation (1)

The quantity of total activated carbon obtained 486gm for 532.2gms of coconut shell powder as a starting raw material. The overall yield is 91.3%.

$$\text{Carbon Yield}(\%) = \frac{\text{Weight after carbonization(gm)}}{\text{Weight before carbonization(gm)}} \times 100 \quad (1)$$

Characterization of coconut shell activated carbon (CSAC)

Specific Surface area: Generally, the larger the specific surface area of the adsorbent, the better its adsorption performance will be. In the present work the specific surface area is determined by BET method. The specific surface area (m^2/g) of Coconut Shell Activated Carbon is 246 (m^2/g) obtained**.**

Standardization: In present work, Digital Photo Colorimeter has been used for analysis of colored solution of Methylene blue in water. For standardization, known concentration of Methylene blue in water solutions have been analyzed using colorimeter. The standard graph is shown in Figure-1 representing concentration of Methylene blue (MB) in water v/s colorimeter reading whereas Table-1 gives reading of constant parameters during the experiment.

Table-1: Constant Parameters.

Quantity of MB solution Initial Concentration Time	100ml 1 gm/lit 24 hr

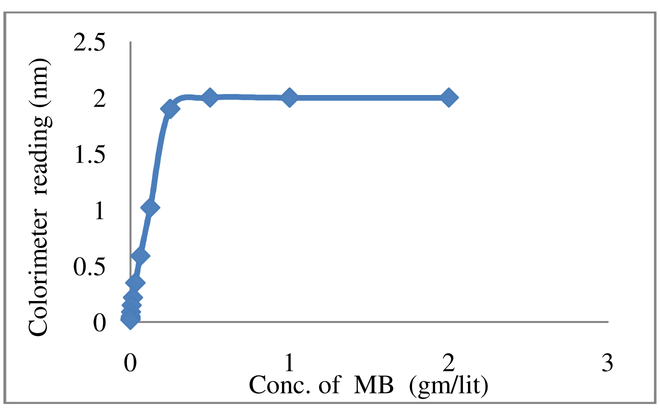

Figure-1: Standardization of MB solution.

Batch Experiments

Effect of adsorbent quantity: Adsorbent samples from 1to 5gm are added in five separate beakers containing 100 ml solution of Methylene blue of concentration 1gm/lit. The mixtures are stirred and after 24hr the solution is separated from adsorbent using filter paper. The concentration of final solution is measured in terms of colorimeter reading. Finally % adsorption is calculated using Equation (2). Effect of adsorbent quantity on % adsorption for CSAC and CGAC given in Figure-2 and 3 respectively and its comparison is given in Figure-4. Table-2, 3 and 4 gives reading of constant parameters during the experiment.

$$\%\,\text{Adsorption} = \frac{(C_0 - C_1)}{C_0} \times 100 \quad (2)$$

C_0=Initial Concentration of MB in water; C_1=Final Concentration of MB in water.

Table-2: Constant Parameters.

Quantity of MB solution Initial Concentration Time	100ml 1 gm/lit 24 hr

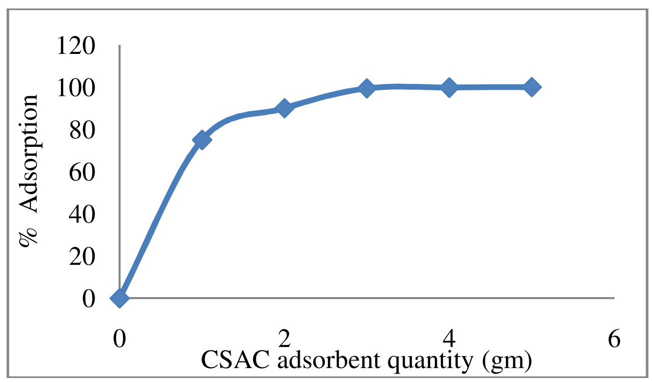

Figure-2: % Adsorption v/s Quantity Adsorbent for CSAC.

Table-3: Constant Parameter.

Colorimeter readings at Blue filter (480nm), Optical density of Water is 0.00

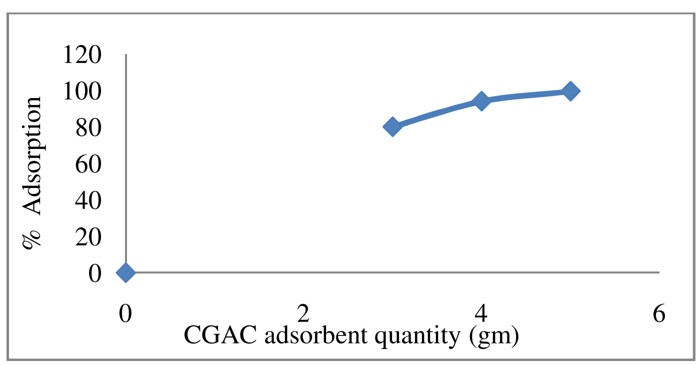

Figure-3: % Adsorption v/s Effect of adsorbent quantity for CGAC.

Table-4: Constant Parameter

Quantity of MB solution	100ml
CSAC quantity	5 gm
Time	24 hr

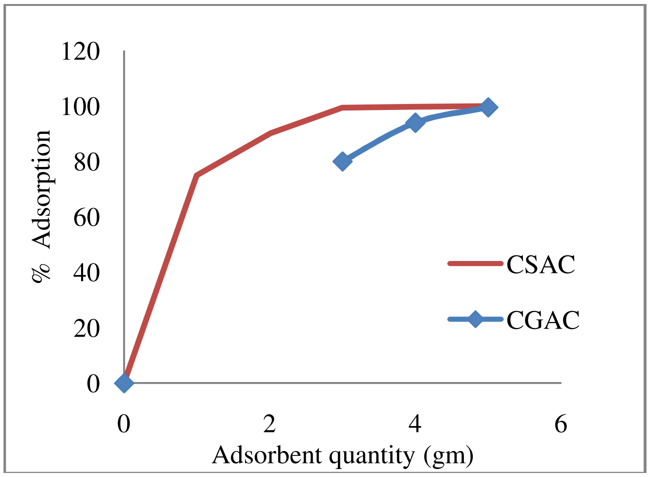

Figure-4: Comparison of % of Adsorption v/s Effect of adsorbent quantity for CSAC and CGAC.

Effect of Initial MB Concentration: The Methylene blue solutions of varied concentrations i.e (1, 1.1, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2 gm/lit) are added with 5gm adsorbent each in separate beakers. The mixture are stirred and after 24hr, the solution is separated from adsorbent with the help of filter paper. The concentrations of final solutions are measured in terms of colorimeter reading. Finally % of adsorption is calculated. Effect of initial concentration of MB on % adsorption for CSAC and CGAC given in Figure-5 and 6 respectively and its comparison is given in Figure-7.

Table-5: Constant Parameter.

Quantity of MB solution	100ml
Initial concentration of MB	1 gm/lit
Time	24 hr

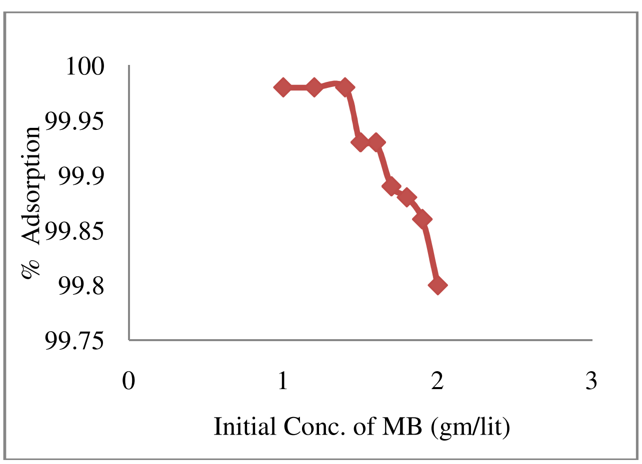

Figure-5: % Adsorption v/s Initial concentration of MB for CSAC.

Table-6: Constant Parameter

Quantity of MB solution	100ml
CGAC quantity	5 gm
Time	24 hr

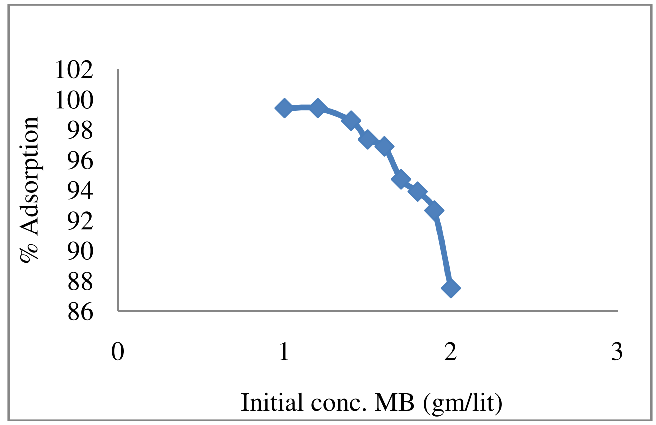

Figure-6: % Adsorption v/s Initial concentration of MB for CGAC.

Table-7: Constant Parameter.

Quantity of MB solution	100ml
Quantity of CSAC and CGAC	5gm
Time	24 hr

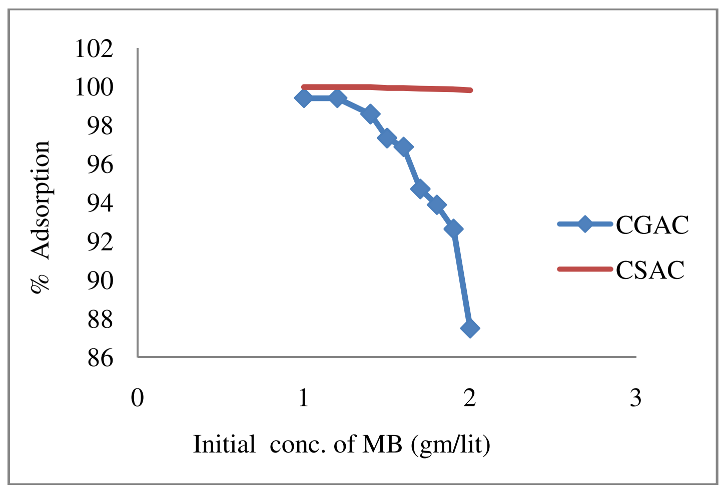

Figure-7: Comparison of % Adsorption v/s Effect of Initial Conc. of MB solution for CSAC and CGAC.

Adsorption isotherm for CSAC and CGAC: The relation between the concentration of Methylene blue adsorbed per unit mass of adsorbent and Methylene blue equilibrium concentration in aqueous solution is given by Freundlich adsorption isotherm:

slog $q_e = \log k + (1/n) \log C_e$

In this equation, q_e is the amount of Methylene blue adsorbed per carbon dosage, C_e is the equilibrium concentration of Methylene blue in water, k and 1/n are empirical constants (Freundlich parameters), the values of which are equal to the intercept and slope of the plot of log x/m versus log C_e. A larger value of k indicates good adsorption efficiency for the particular activated carbon, while a larger value of 1/n indicates a larger change in effectiveness over different equilibrium concentrations.

Obtaining the adsorption isotherm for varying concentration of Methylene blue in water for CSAC and CGAC.

Table-8: Constant Parameter.

Quantity of MB solution	100ml
Initial Concentration	1 gm/lit
Time	24 hr

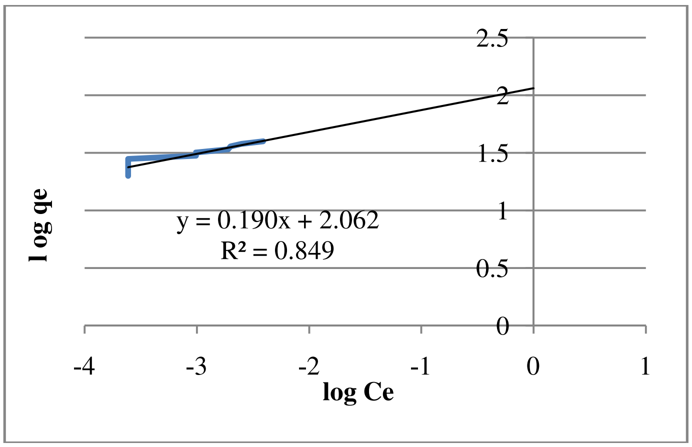

Figure-8: Graph of log q_e v/s log C_e for CSAC.

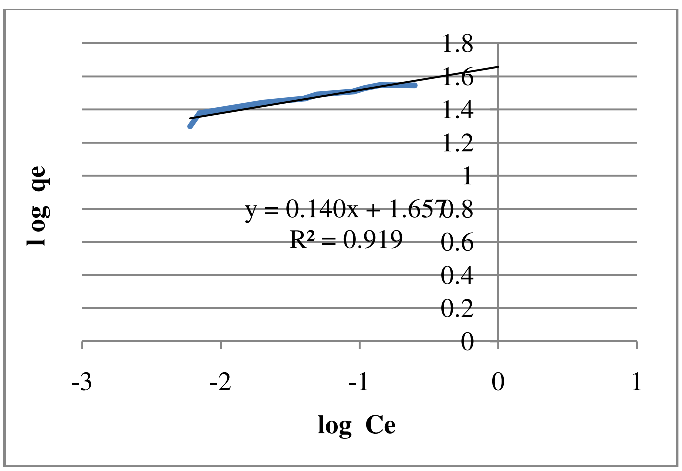

Figure-9: Graph of log q_e v/s log C_e for CGAC.

Table-9: Comparison of Freundlich constants and equations.

Parameters	CSAC	CGAC
Intercept(k)	115.87	45.39
Slope(1/n)	0.190	0.140
Freundlich isotherm Equation	$q_e=115.87C_e^{0.190}$	$q_e=45.39C_e^{0.140}$

Packed bed adsorption studies: Break through curve: Approximately 100gm of coconut shell activated carbon (CSAC) is put into glass column having diameter 4.5cm. upto height 8.5cm. 1gm/lit MB solution is passed through packed column at a volumetric flow rate of 6.6 ml/min. The outgoing solution is collected in beakers over time duration of 1 hr each. The outgoing concentrations of MB are determined by using colorimeter. The process is continued until same concentration of MB as incoming solution is obtained.

Table-10: Constant Parameter.

Diameter of column	4.5cm
Height of Column	8.5 cm
Volumetric Flow rate	6.6 ml/min
CSAC quantity	100 gm

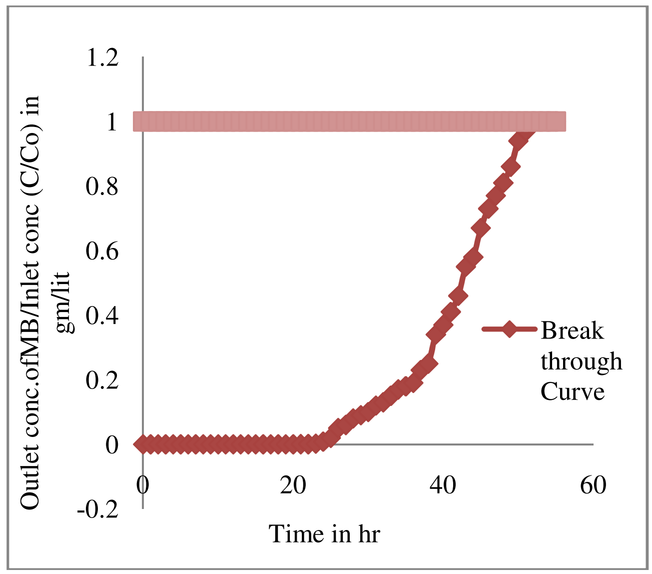

Figure-10: Break through Curve for CSAC.

Results and discussion

The quantity of total activated carbon obtained is 486gm for 532.2gms of coconut shell powder. The overall yield is 91.3%.

As can be seen from Figure-1., there is linear change in colorimeter reading for increasing the concentration MB up to 0.45gm/Lit of MB in water. However beyond this concentration, colorimeter reading is constant.

Figure-2 and 3 show, effect of adsorbent quantity on the percent of MB adsorbed for CSAC and CGAC respectively. Adsorption increases with increasing the adsorbent quantity for given volume of solution. At around 3.5 gm CSAC adsorbent quantity nearly 99% of MB is adsorbed whereas at around 5 gm CGAC adsorbent quantity, nearly 99% MB is adsorbed. Figure-4 shows % adsorption of MB as a function of adsorbent quantity for comparison between CSAC and CGAC. It can be said from the graph that the % of adsorption for CSAC is superior than CGAC.

Figure-5 and 6 show, effect of initial concentration of MB on % adsorption. As can be seen from the graph for the given set of parameters, there is a small drop in the % adsorption from 99.97% to 99.8% for CSAC whereas for CGAC % adsorption is in the range of 99% to 87%. Figure-7 show, comparison of CGAC and CSAC for the effect of initial Concentration of MB. As can be seen and inferred from graph that CSAC is superior as compared to CGAC. The % adsorption of CSAC is more that is 99% where as for CGAC it varies between 88 and 98.

Figure-8 and Figure-9 show the graph plotted between equilibrium conc. of MB in water verses gm of MB adsorbed/gm of CSAC and CGAC respectively on log-log basis. The straight line is further interpreted for its slope(1/n) and intercept(k). The comparison of Freundlich parameters are given in Table-9. In this study, CSAC has highest k and 1/n value as compared to CGAC. Hence it indicates that CSAC has the highest rate of adsorption of MB in the aq. solution followed by CGAC. Therefore Freundlich adsorption isotherm applied is valid for this study.

Figure-10 shows break through curve for CSAC. The graph is plotted between ratio of outlet conc. of MB to its inlet conc. verses time. As can be seen from the graph, up to the operating time of 20-22 hr the C/C_0 ratio almost zero. Further it increases slowly with time and at about 52 hr we get solution of initial concentration (1gm/lit). Hence it can be said that for given parameter, the break through point is around 40 hr.

Conclusion

The objective of present work was to develop economical and efficient adsorbent using coconut shell and compare its performance with commercial grade activated charcoal. Based on the observations, results and discussion it can be concluded that the present study has been successful in developing effective, efficient and low cost adsorbent at laboratory scale. It can also be concluded that the effectiveness of the adsorbent developed in present study (i.e CSAC) is superior as compared to the performance and effectiveness of CGAC. However it is felt necessary to further test and validate CSAC for other adsorbate, to determine experimentally its reusability and also to evaluate economical viability of the product.

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