

PRODUCTION AND CHARACTERIZATION OF ACTIVATED CARBON AND ITS APPLICATION IN WATER PURIFICATION

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Abstract - Charcoal has been prepared from coconut shell using two metal containers and activated with steam at a temperature of 900°C -1100°C under controlled atmosphere in a rotary kiln. The average BJH pore size and BET surface area of activated carbon are 1.9645 nm and 850.2342 m²/g respectively. Parameters such as TDS, acidity, chlorides, hardness, and ammonia have been determined before treatment and all the values were above the permitted level, which indicates high level of contamination. These parameters have been determined after treating waste water with activated carbon for periods of 5 minutes, 30 minutes and 60 minutes. Values obtained after treating for 5 minutes were still above the permitted level but the concentration of impurities have been considerably reduced with increase in the time of treatment.

Key Words: Activated Carbon, Adsorption, Pyrolysis, Surface Area, Adsorption isotherm

1. INTRODUCTION

Health and safety are the primary considerations for water purification. Water purification is the process of removing undesirable chemicals, biological contaminants and suspended solids from contaminated water. The methods used include physical processes such as filtration, sedimentation and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light. Purifying water reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi, as well as reducing the amount of dissolved and particulate material derived from the surfaces that come from runoff due to rain.

Water is mainly disinfected for human consumption, but water purification may also be designed for a variety of other purposes, including fulfilling the requirements of medical, pharmacological, chemical and industrial applications. Activated carbon is one of the most effective media for removing a wide range of contaminants from waste water. Activated carbon is used to purify liquids and gases in a variety of applications, including municipal drinking water, food and beverage processing, odor removal, industrial pollution control, and filters for domestic use. Many of these home water filters use activated carbon to reliably remove dissolved impurities and disinfection.

2. MATERIALS AND METHODOLOGY

2.1 Preparation of Carbon (Charcoal)

Charcoal was prepared using two metal containers. The larger container was 30cm high and 25cm diameter and the smaller container was 25cm high and 20cm diameter. The smaller container was filled with firewood and the larger container was placed on the top of the smaller one. A cut was made on the top and bottom of the larger container so that a pipe can be inserted through it. The size of the cut at the bottom of the larger container was smaller than that of the pipe. Then the wooden pieces and coconut shell were filled in the larger barrel after inserting the pipe. The container was closed tightly. The firewood was lighted at a very high temperature. The gases go out through the pipe while the wooden pieces and the coconut shell get converted to carbon due to the high heat. After 2-3 hours the carbon was taken out from the larger container.

2.2 Activation of Carbon (Charcoal)

The coconut shell charcoal was activated by reaction with steam at a temperature of 900°C -1100°C under controlled atmosphere in a rotary kiln. The reaction between steam and charcoal takes place at the internal surface area, creating more sites for adsorption. The temperature factor, in the process of activation was considered very important because below 900°C the reaction becomes too slow and is very uneconomical and above 1100°C the reaction becomes diffusion controlled and therefore takes place on the outer surface of the charcoal resulting in loss of charcoal.

2.3 Surface Area, Pore Volume and Pore Size Analysis

The specific surface area, pore size and pore volume of activated carbon powder were determined by physical adsorption of a gas on the surface of the solid. The amount of adsorbate gas corresponding to a monomolecular layer on the surface was determined. Physical adsorption was mainly due to the relatively weak forces (van der Waals forces) between the adsorbate gas molecules and the adsorbent surface area of the test powder. The determination was carried out at the temperature of liquid nitrogen. The instrument used for the determination of surface area, pore size and pore volume is Micromeritics, Gemini VII Version 3.01.

2.4 Analysis of Waste Water before and after Treatment with Activated Carbon

Waste water was subjected various analysis for the determination of concentration of undesirable impurities. Total dissolved solids (TDS), acidity, chlorides, hardness and ammonia were determined by titration. pH was determined using Systronics pH meter MK-VI.

3. RESULTS AND DISCUSSION

3.1 Surface Area, Pore Volume and Pore Size Analysis

Surface area was determined by BET (Brunauer, Emmett, Teller) analysis. Pore volume and pore size were determined by BJH (Barrett-Joyner-Halenda) analysis.

3.1.1 BET Analysis of Surface Area

BET analysis provides precise specific surface area evaluation of materials by nitrogen multilayer adsorption measured as a function of relative pressure using a fully automated analyser. Single point BET involves determining specific surface area using a single point

on the isotherm and multipoint BET uses minimum three data points.

The technique encompasses external area and pore area evaluations to determine the total specific surface area in m²/g yielding important information in studying the effects of surface porosity and particle size in many applications. Hence, micropore/mesopore volume and area cannot be obtained from the BET calculations. The micropore volume and area can be estimated from t-plot method.

The data are treated according to the Brunauer, Emmett and Teller (BET) adsorption isotherm equation:

$$\frac{1}{V_a \left(\frac{P_0}{P} - 1 \right)} = \frac{C-1}{V_m C} \times \frac{P}{P_0} + \frac{1}{V_m C}$$

P = partial vapour pressure of adsorbate gas in equilibrium with the surface at 77.4 K (b.p. of liquid nitrogen), in pascals,

P_0 = saturated pressure of adsorbate gas, in pascals,

V_a = volume of gas adsorbed at standard temperature and pressure (STP) [273.15 K and atmospheric pressure (1.013 × 10⁵ Pa)], in millilitres,

V_m = volume of gas adsorbed at STP to produce an apparent monolayer on the sample surface, in millilitres,

C = dimensionless constant that is related to the enthalpy of adsorption of the adsorbate gas on the powder sample.

Then the BET value:

$$\frac{1}{V_a \left(\frac{P_0}{P} - 1 \right)}$$

is plotted against P/P_0 according to equation (1). This plot should yield a straight line usually in the approximate relative pressure range 0.05 to 0.3. The data are considered acceptable if the correlation coefficient, r , of the linear regression is not less than 0.9975; that is, r^2 is not less than 0.995. From the resulting linear plot, the slope, which is

equal to $(C - 1)/V_m C$, and the intercept, which is equal to $1/V_m C$, are evaluated by linear regression analysis. From these values, V_m is calculated as $1/(\text{slope} + \text{intercept})$, while C is calculated as $(\text{slope}/\text{intercept}) + 1$. From the value of V_m so determined, the specific surface area, S , in $\text{m}^2 \cdot \text{g}^{-1}$, is calculated.

BET data is given in Table.1 and BET surface area plot is given in Fig. 1.

Table-1: BET data

Relative Pressure (P/Po)	Quantity Adsorbed (cm ³ /g STP)	1/[Q(Po/P - 1)]
0.051419979	241.1996	0.000225
0.061837543	244.6442	0.000269
0.072337097	247.4573	0.000315
0.082789265	249.7955	0.000361
0.093306127	251.7647	0.000409
0.103755333	253.4376	0.000457
0.114273572	254.9014	0.000506
0.124770082	256.1535	0.000557
0.135248826	257.2822	0.000608
0.145747679	258.2681	0.000661
0.156396035	259.1631	0.000715
0.166785268	259.9564	0.000770
0.177332441	260.6861	0.000827
0.187908364	261.3467	0.000885
0.198422157	261.9507	0.000945
0.208989561	262.4985	0.001007
0.219448956	263.0219	0.001069
0.229980920	263.5060	0.001133
0.240404290	263.9431	0.001199
0.250937163	264.3575	0.001267

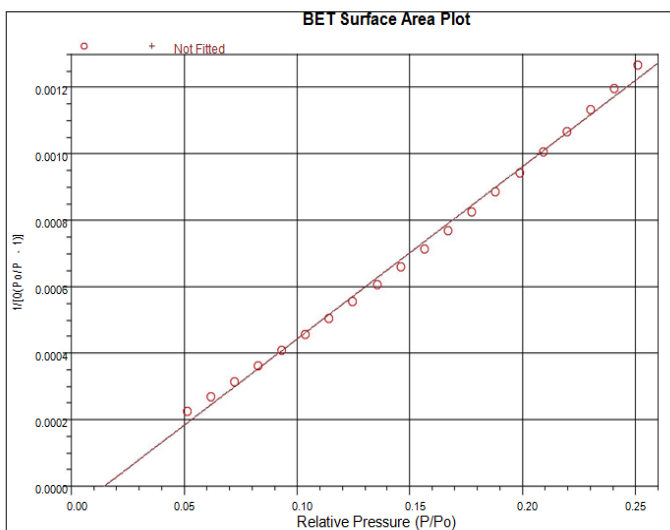


Chart-1: BET Surface Area Plot

3.1.2 BJH (Barrett-Joyner-Halenda) Analysis of Pore Size and Pore Volume

The method of Barrett-Joyner-Halenda (BJH), proposed in 1951, was originally designed for relatively wide-pore adsorbents with a wide pore size distribution. However, it was repeatedly demonstrated that it can be successfully applied to virtually all types of porous materials. The model is based on the assumption that pores have a cylindrical shape and that pore radius is equal to the sum of the Kelvin radius and the thickness of the film adsorbed on the pore wall. BJH analysis can be employed to determine pore area and specific pore volume using adsorption and desorption techniques. This technique characterises pore size distribution independent of external area due to particle size of the sample.

Results obtained are summarized below.

Surface Area

Single point surface area at $P/P_o = 0.093958352$: 993.5784 m^2/g

BET Surface Area: 850.2342 m^2/g

BJH Adsorption cumulative surface area of pores between 1.7000 nm and 300.0000 nm diameter: 136.042 m^2/g

Pore Volume

Single point adsorption total pore volume of pores less than 2.0638 nm diameter at $P/P_o = 0.167431898$: 0.402173 cm^3/g

BJH Adsorption cumulative volume of pores between 1.7000 nm and 300.0000 nm diameter: 0.066812 cm^3/g

Pore Size

Adsorption average pore diameter ($4V/A$ by BET): 1.89206 nm

BJH Adsorption average pore diameter ($4V/A$): 1.9645 nm

Micropore volume, micropore area and external surface area obtained from t-plot analysis are 0.323200 cm^3/g , 663.4308 m^2/g , and 186.8033 m^2/g respectively.

3.2 Analysis of Waste Water before and after Treatment with Activated Carbon

The waste water collected was analyzed before and after treatment with activated carbon. Different parameters were observed. The obtained values were compared with the required limits.

Table-2: Parameters

Sl No	Parameter	Obtained value	Required value
1	pH	4.67	6.5-8.5
2	Total Dissolved Solids (TDS)	750 mg/l	500 mg/l
3	Acidity	500 mg/l	-
4	Chlorides	278 mg/l	250 mg/l
5	Hardness	427 mg/l	300 mg/l
6	Ammonia	400 mg/l	50 mg/l

From the different tests conducted it is observed that the waste water collected has high amount of impurities. This water cannot be discharged to any water source without treatment. So this waste water has to be treated with activated carbon for the effective removal of impurities.

3.3. Treatment with Activated Carbon

The waste water sample was treated with the activated carbon prepared. Then various parameters were studied. The waste water sample was taken and activated carbon was added to it. Then it was stirred at a constant rate at different time intervals. Then the sample was tested.

Table-3: Values after 5 minutes

Sl No	Parameter	Before treatment	After treatment
1	pH	4.67	5.1
2	Total Dissolved Solids	750 mg/l	555 mg/l
3	Acidity	500 mg/l	437 mg/l
4	Chlorides	278 mg/l	198 mg/l
5	Hardness	427 mg/l	334 mg/l
6	Ammonia	400 mg/l	280 mg/l

Table-4: Values after 30 minutes

Sl No	Parameter	Before treatment	After treatment
1	pH	4.67	6
2	Total Dissolved Solids	750 mg/l	257 mg/l
3	Acidity	500 mg/l	272 mg/l
4	Chlorides	278 mg/l	98 mg/l
5	Hardness	427 mg/l	258 mg/l
6	Ammonia	400 mg/l	185 mg/l

Table-5: Values after 60 minutes

Sl No	Parameter	Before treatment	After treatment
1	pH	4.67	6.9
2	Total Dissolved Solids	750 mg/l	50 mg/l
3	Acidity	500 mg/l	35 mg/l
4	Chlorides	278 mg/l	11 mg/l
5	Hardness	427 mg/l	37 mg/l
6	Ammonia	400 mg/l	14 mg/l

From the above obtained values it is observed that the treatment of the collected waste water can be done effectively with activated carbon. There is a considerable reduction in the concentration of different impurities present in waste water. As the time increases the amount of impurities removed increases.

The surface area of the activated carbon is much higher than the carbon without activation. Due to this larger amount of impurities can be adsorbed onto the surface. So within short time period the impurities can be removed.

4. CONCLUSIONS

Activated carbon adsorption can be considered as an effective means for reducing various impurities like dissolved particles and colloidal matters and unpleasant tastes and odors in water. The water obtained from this treatment process is more desirable than that obtained from some public supplies. Different types of units can be prepared for purification.

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