International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 03 - Issue 01 || January 2018 || PP. 01-04

Characterization and Properties of Activated Carbon prepared from Tamarind seeds

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Abstract: Environmental water pollution control has been an issue of major concern in many countries. Rapid urbanization and population growth has enhanced the growth of different industries leading to discharge of pollutants into the water bodies. One of the serious contributor of waste water pollution is discharge of dyes released from textile, food and paper industries. Many researchers worldwide have found Activated Carbon Adsorption technique for dye removal as highly effective. At present, there is a growing interest in using other low cost sorbents for dye removal. In the present study, Activated carbon is derived from a low cost precursor, Tamarind seed using thermal and chemical activation. Proximate analysis, iodine number, methylene blue number, and specific surface area were studied. The results of characterization show that the activated carbon prepared from tamarind seeds has pH = 5.2, moisture content = 1.2 %, Ash content = 8.9 %, bulk density = 0.48 g/cm^3, iodine number = 1000 mg/g, methylene blue number= 248 mg/g, specific surface area = 936 m^2/g. The prepared activated carbon from tamarind seeds shows good adsorbent properties.
Keywords: Adsorption, tamarind seed, activated carbon, characterization, activation

1. Introduction

Many researchers have used adsorption technique for dye removal from waste waters as a superior method than other techniques in terms of cost, simplicity of design, ease of operation, and insensitivity to toxic substances [1]. Researchers have prepared activated carbon from palm-tree cobs [2], cassava peel [3], bagasse [4], jute fibre [5], coconut husk [6], rattan sawdust [7], seed shells [8], and cocoa shell [9]. Tamarind is the fruit of Tamarindus indica popularly used in Indian cuisine. Tamarind fruit consists of pulp and hard-coated seeds containing about 40 % fruit. In this study, activated carbon is prepared from tamarind seeds. The resulting charcoal is activated by chemical and thermal activation to obtain the activated carbon.

2. Materials and Methods

2.1. Preparation of Material

Tamarind seeds (Tamarindus indica) were obtained from Vadodara district, Gujarat, India. The seed were washed throughly by distilled water to remove dirt and other unwanted materials. They were dried in an air-drying oven at 110^{o}C for 24hours. The shell was then removed.

2.2. Preparation of Charcoal

Accurately weighed samples of dried tamarind seed (weighed with analytical balance) were carbonized in a muffle furnace at 500º C for 1 h.

2.3. Preparation of Activated Carbon

The sample was impregnated with 60% weight of orthophosphoric acid at the ratio of 1:2(wt %). Then, the resulting carbons were washed with de-ionized water until the leachate was between a pH of 6- 7. They were then dried in an air-drying oven at 110^{o}C for 6 hours. Also, the sample was crushed and was made to pass through different sieve sizes. Finally, the sample was stored in a tight bottle ready for use.The percent yield of tamarind seed based charcoal is 40 %.The raw tamarind seeds obtained from the market are shown in Fig. 1. The tamarind seeds after carbonization are shown in Fig. 2.

Figure 1. Tamarind seeds obtained from market

Figure 2. Tamarind seeds after carbonization

2.4 Characterization of Tamarind seed activated carbon

2.4.1 Proximate analysis:

The moisture content was determined using ASTM D 2867-04 [10]. The pH of the carbon was determined using standard test ASTM D 3838-80 [11]. The ash content was determined using Laboratory Analytical Procedure.

2.4.2 Methylene blue number

The methylene blue number is defined as the maximum amount of dye adsorbed on 1.0 g of adsorbent. (q_{eq}). In this assay, 10.0 mg of activated carbon are placed in contact with 10.0 mL of a methylene blue solution at different concentrations (10, 25, 50, 100, 250, 500 and 1000 mg L^{-1}) for 24 h at room temperature (approximately 25 °C). The remaining concentration of methylene blue is analysed using a UV/Vis spectrophotometer at 645 nm.

The amount of methylene blue adsorbed from each solution is calculated by the Equation 1:

$$q_e = [(C_o - C_e)\, {}^{V}/_{M}] \quad \text{………………………………………………………….(1)}$$

Where,

C_0(mg/L) is the concentration of the methylene blue solution at starting time (t = 0),

C_e(mg/L) is the concentration of the methylene blue solution at equilibrium time,

V (L) is the volume of the solution treated and

M (g) is the mass of the adsorbent.

To determine the methylene blue number for the Langmuir model, a q_{eq} plot is made in function of C_e.

2.4.3 Iodine Number

The iodine number is determined according to the ASTM D460794 method [12]. The iodine number is defined as the milligrams of iodine adsorbed by 1.0 g of carbon when the iodine concentration of the filtrate is 0.02 N (0.02 mol L^{-1}). This method is based upon a three point isotherm. A standard iodine solution is treated with three different weights of activated carbon under specified conditions. The experiment consists of treating the activated carbon sample with 10.0 mL of 5% HCl. This mixture is boiled for 30 seconds and then cooled. Soon afterwards, 100.0 mL of 0.1 N (0.1 mol L^{-1}) iodine solution is added to the mixture and stirred for 30 seconds. The resulting solution is filtered and 50.0 ml of the filtrate is titrated with 0.1 N (0.1 mol L^{-1}) sodium thiosulfate, using starch as indicator. The iodine amount adsorbed per gram of carbon (X/M) is plotted against the iodine concentration in the filtrate (C), using logarithmic axes.

A least squares fitting regression is applied for the three points. The iodine number is the *X/M* value when the residual concentration (*C*) is 0.02 N (0.02 mol L^{-1}). The *X/M* and *C* values are calculated by the Equations 2 and 3 respectively.

$$\frac{X}{M} = \{\, N1 \times 126.93\ \times V1\,) - \left[\frac{(V_1 + V_{HCL})}{V_F}\right] \times\ (N_{Na\,2S2O3} \times 126.93)\ \times\ V_{Na\,2S2O3}\} / Mc \text{……(2)}$$

$$C = (\,N\, Na_2S_2O_3 \times V\, Na_2S_2O_3\,) \quad \text{……………………….....………………..(3)}$$

Where,

N_I is the normality of iodine solution,

V_I is the added volume of iodine solution, V_{HCl} is the added volume of 5% HCl, V_F is the filtrate volume used in titration, N $Na_2S_2O_3$ is the sodium thiosulfate solution normality, V $Na_2S_2O_3$ is the consumed volume of sodium thiosulfate solution and M_C is the mass of activated carbon.

2.4.4 Specific Surface Area

Specific surface area of the activated carbon is determined by Surface area modelling method carried out by Nunes C. A., Guerreiro M.C., 2011.To describe the behaviour of the methylene blue and iodine numbers in relation to the surface area, a quadratic model was used. The surface fit obtained after the modeling is described by Equation 4 [13].

$$S = 2.28 \times 10^{2} - 1.01 \times 10^{-1} MBN + 3.00 \times 10^{-1} IN + 1.05 \times 10^{-4} MBN + 2.00 \times 10^{-4} IN^{2} + 9.38 \times 10^{-4} (MBN)(IN) \quad \ldots\ldots(4)$$

Where,
S = specific surface area (m^2/g)
IN= Iodine number,
MBN = Methylene blue number

3. Results and Discussion

3.1 Physico-chemical characteristics of Activated carbon prepared from Tamarind seeds

The physico-chemical characteristics of activated carbon prepared from Tamarind seeds is shown in Table 1.

Table 1. Physico-chemical characteristics of Activated Carbon derived from Tamarind seeds

Properties	**Results of Activated carbon derived from Tamarind Seed**
pH	5.2
Moisture Content (%)	1.2
Ash Content (%)	8.9
Bulk Density (g / cm^3)	0.48
Iodine Number (mg/g)	1000
Methylene Blue Number (mg/g)	248
Specific Surface Area (m^2/g)	936

3.1.1 pH

The determined value of pH for the activated carbon prepared from tamarind seed was 5.2 . It in the range of 5-6 pH because of the distilled used from the laboratory for wash having pH range of 5-6.

3.1.2 Moisture Content

Moisture content dilutes the carbon and increases the weight during treatment process. Thus, the lower the moisture contents in activated carbons, the better [14].The moisture content for activated carbon was 1.2 %, indicating that the carbon structure has extensive porosity through the activation process.

3.1.3 Ash Content

The low ash content value for activated carbon (8.9 %) indicates that the activated carbons have low inorganic content and high fixed carbon. This is because ash content can reduce the efficiency of reactivation. Therefore, the lower the ash content, the better the activated carbon [14].

3.1.4 Bulk Density

It can be seen that the bulk density for tamarind seed activated carbon is 0.48 g/cm^3.Bulk density determines the mass of carbon which can be contained in a filter by a given solids capacity. It also determines the amount of treated liquid that can be retained by the filter cake.

3.1.5 Iodine number

Iodine number is a measure of the micropore content of the activated carbon. In addition, the iodine value for tamarind seed activated carbon (1000 mg/g) shows high micropore content in the activated carbon.

3.1.6 Methylene Blue Number

Methylene blue number obtained for tamarind seed activated carbon is 248 mg/g.

3.1.7 Specific Surface area

The specific surface area for tamarind seed activated carbon is 936 m^2/g. The typical range of values for commercial activation reported in literatures is 700-1500 m^2/g. The higher surface area may be due to the restricted pore shrinkage during activation indicating high porosity.

4. Conclusion

There is a growing interest in developing countries for using low cost adsorbents for dye removal from waste waters arising from textile industries. Low cost adsorbents can also be effective to remove organic pollutants from waste waters. The present article describes the conversion of Tamarind seed, a waste product into effective adsorbent by activation processes. Tamarind seed can be used as a low cost precursor from which activated carbon can be derived using cost effective thermal and chemical activation processes. The physico- chemical characterization carried out for the resulting activated carbon shows that the tamarind seed can be used for deriving an efficient adsorbent for the removal of various pollutants from waste water.

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