Adsorption of Acetone from Polluted air by Activated Carbon derived from low cost materials

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Abstract: In this investigation, adsorption of acetone from air on the activated carbon derived from agricultural solid waste was studied. The best of our knowledge is to find the best activated carbons from low cost material to remove hazardous compound. The effect of adsorption temperature, initial concentration and effect of raw materials were reported. It is clear that the adsorption temperatures have the negative effect on the adsorption capacity. The adsorption capacity increases with increasing the initial concentration. Three activated carbons were prepared, one (Norit) was purchased and apricot and walnut shell were prepared by physical method and carbon dioxide and water vapor as chemical agent, respectively.

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1. Introduction

Many VOCs (Volatile Organic Compounds) are hazardous to human health and the environment. Acetone is widely used as coolants, solvents, blowing agents in the foam production, and propellants. It can be said that much of the modern lifestyle of the second half of the 20th century had been made possible by the use of VOCs [1].

Emission in gas phase is more difficult to be controlled. Many technologies for gas-phase pollutant control have been developed during the last years [2- 5]. Methods such as condensation, absorption, adsorption, catalytic oxidation, and incineration have been employed for abatement of VOCs. Adsorption is an important alternative technology to provide realistic solutions to many environmental issues in which the concentrations of organic pollutants are low or trace [5-9].

Based on Wikipedia definition, "Activated carbon, also called activated charcoal, activated coal, or carbo activatus, is a form ofcarbon processed to be riddled with small, low-volume pores that increase the surface area available foradsorption or chemical reactions. Activated is sometimes substituted with active. Due to its high degree of microporosity, just one gram of activated carbon has a surface area in excess of 500 m2, as determined by gas adsorption. An activation level sufficient for useful application may be attained solely from high surface area; however, further chemical treatment often enhances adsorption properties". Figure 1 shows the active carbon material that is used for industrial applications.

Activated carbons are widely used as an adsorbent for the removal of a wide range of pollutants from various matrices, because of their high adsorption capacity, fast adsorption kinetics and ease of regeneration. Information about the adsorption of organic pollutants [9] for environmental purposes has been recently published. It is important for this application to understand the extent to which modifications in the surface chemistry, surface area and pore volumes of activated carbon caused by exposure to ozone affect the adsorption of VOCs. This new-type high efficiency adsorbent has many intrinsic characteristics such as large number of micropores, high specific surface areas, fast adsorption rates, low bed pressure drops, ease of handling and manufacturing into various forms.

Based on the Wikipedia website, "A gram of activated carbon can have a surface area in excess of 500 m2, with 1500 m2 being readily achievable. Carbon aerogels, while more expensive, have even higher surface areas, and are used in special applications.

The high surface-area structures of activated carbon are revealed. Individual particles are intensely convoluted and display various kinds of porosity; there may be many areas where flat surfaces of graphite-like material run parallel to each other, separated by only a few nanometers or so. These micropores provide superb conditions for adsorption to occur, since adsorbing material can interact with many surfaces simultaneously. Tests of adsorption behaviour are usually done with nitrogen gas at 77 K under high vacuum, but in everyday terms activated carbon is perfectly capable of producing the equivalent, by adsorption from its environment, liquid water from steam at 100 °C and a pressure of 1/10,000 of anatmosphere".

In this paper, the main scope is to find the suitable raw material for preparing the appropriate adsorbent for removal of acetone from air. The effect of raw material, adsorption temperature and initial concentration of acetone were investigated in this work. The characterizations of activated carbons (surface area) were reported too.

Fig.1 Activated carbon for adsorption of the materials

2.Materials and Methods:

The activated carbons were Norit (NORIT Americas Inc), walnut shell (prepared by physical method and water vapor) and apricot (prepared by physical method and carbon dioxide). They were ground and sieved to 1.5 mm with standard testing sieve.

Purification was carried out and they were dried for overnight and stored in glass vials. Micromeritics ASAP 2010 according to the Brunauer-Emmett- Teller (BET) method was used to measure the physical properties, such as surface area, average pore diameter. Acetone is one of the precursors form Merck Company Table 1.

Procedures for adsorption experiments and related adsorption conditions were as follows. The given amounts (0.1 g) of adsorbents were placed in an electrical balance that was connected to a data-acquisition system.

The influent concentration of Acetone was set at a range from 100 to700 ppm. The inflow rate of VOC vapor was set at 100 ml/min, the adsorption temperature ranged from 20 to 70 ∘C, and the temperature variation was less than 0.1 ∘C. The kinetic adsorption runs were repeated five times for all experimental concentrations.

Table 1. BET Results for Activated Carbons

Sample	Surface Area (m2/g)	Average Pore Size (nm)	Average Pore Volume (cm3/g)
Norit Activated Carbon	1000	1.7	0.532
Walnut Activated Carbon	800	2.1	0.479
Apricot Activated Carbon	750	2.2	0.456

3. Experimental Results:

3-1- Effect of raw material on the removal efficiency of Acetone:

One of the most important effects is raw material which is used for preparing the activated carbons. Many researchers have focused on this field but it is clear that all reports in this matter are not sufficient.

In this work we have prepared three activated carbons. Norit was purchased from one company and two walnut and apricot activated carbons were synthesized in the laboratory. Fig 1 shows that Norit activated carbon has the best removal efficiency among the others. In these results, it can be found that the diffusion step is determining reaction.

$$R = \frac{(C_0 - C)}{C} \times 100 \quad (1)$$

Where R is the removal efficiency of adsorbent, C_0 and C are the initial and equilibrium concentrations of metal ion (ppm) in the aqueous solution.

It is obvious, that Norit activated carbon because of large surface area has the high capacity for adsorption of acetone. The removal efficiency has reached the equilibrium after 60 min.

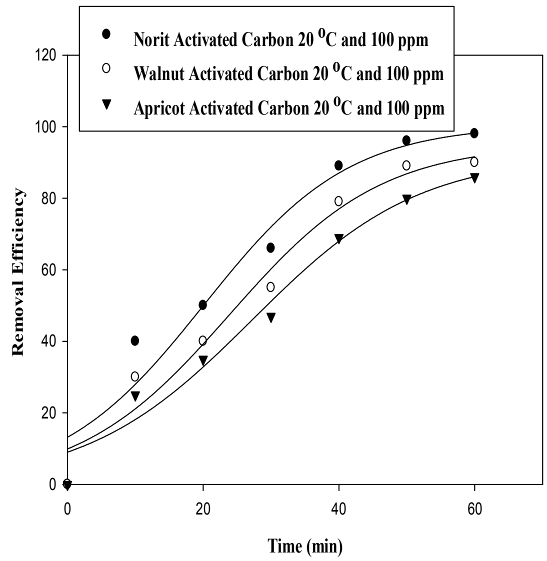

Fig 2. Effect of Raw Material.

3-2- Effect of Temperatures:

Fig. 2 shows the efficiency removal factor (equation1) versus time at different sorption temperatures of 20, 40 50 and 70◦C. Constant parameters of polluted air were: the concentration of acetone=50 mg/l, adsorbent dose of 0.1 g and the flow rate = 100 ml/min.

The experimental data show that the outlet concentration of acetone enhances with increase in the temperature of adsorption indicating an endothermic nature of the sorption processes, while the time required reaching equilibrium remains practically unaffected.

Decrease in the adsorption capacity with temperature suggests that active centers on the surface available for adsorption decrease with temperature. It is clear that this behavior of adsorption can occur for three prepared adsorbents.

3-3 Initial Concentration Effect:

To study the effect of initial concentration on the breakthrough time and adsorption capacity the concentration was varied at 100, 300, and 700 ppm at the flow rate of 100 ml/min and the bed length is 10 cm. The results were shown in Fig 3. Fig. 3 shows adsorption efficiency curves of at different concentrations.

There were good breakthrough curve shapes. However, the concentration of gas stream gradually increases at outlet, because the resistance of mass transfer.

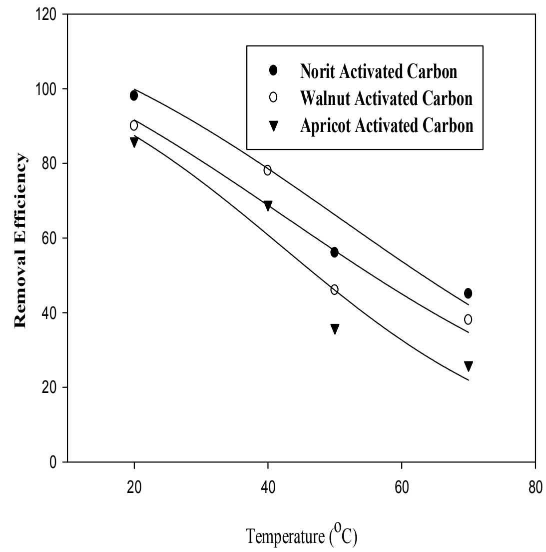

Fig 3. Effect of Adsorption Temperature

It can also be observed from Fig. 4 that at the lowest concentration the percentage removal is above 90% after 1 h also. It is an indication that at low concentration the bed saturates very slowly.

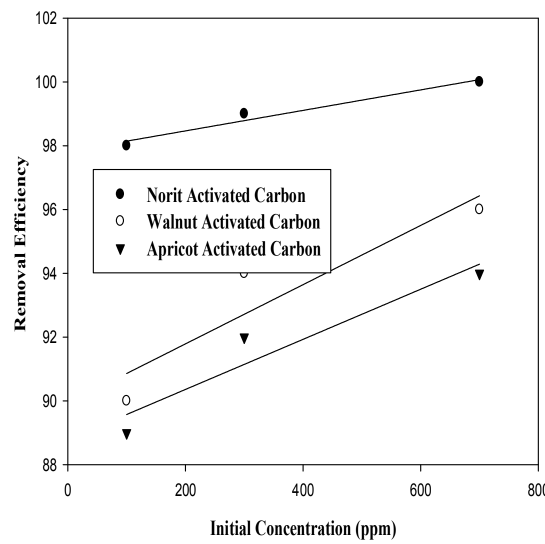

Fig 4. Effect of Initial Concentration.

From the above three curves it was observed that the saturation time of the bed (age of the adsorption column) is more when the concentration is lower; which is very much obvious. At higher concentration the bed saturates very early, the change in behavior is sudden and drastic from 5 to 300 ppm. there is a total change in the trend of the curve itself. But when concentration is changed from 300-700 there is only a shift towards lesser age of filter but not change in trend of the curve.

Conclusion:

The best of our knowledge is to prepare suitable activated carbon from agricultural solid waste. The activated carbons derived from apricot and walnut shell have been investigated for removal of acetone from air. It is clear that commercial activated carbon has the highest capacity versus prepared activated carbons but low cost activated carbons has been placed in the central focus of researches. It is shown that by increasing the adsorption temperature, the adsorption capacity and removal efficiency will decrease. It is also reported that adsorption capacity increases by increase the initial concentration of acetone in the polluted air.

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