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Application of Activated Carbon Prepared from Peach (*Prunus persica*) Seed Stone for the Adsorption of Acid Yellow 17 Dye

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Abstract:
The present study investigates the removal of Acid Yellow 17 Dye from aqueous solution by adsorption on the activated carbon prepared from Peach (Prunus persica) Seed Stone by chemical activation with zinc chloride. The activated carbon was prepared at carbonization temperature 400°C. The activated carbon prepared was analyzed by chemical methods such as Iodine number and Methylene blue number to identify micropore and mesopore content. The activated carbon was also analyzed by instrumental techniques like XRD and SEM.The SEM of the activated carbon exhibited the pores of different diameters while XRD showed two broad diffraction peaks indicating the amorphous nature of the activated carbon. The batch adsorption studies have been carried out to investigate the adsorption of the dye from aqueous solution. The optimum pH, contact time and adsorbent dose for the adsorption process have been found to be 2, 90 minutes and 1g/L respectively. The results showed that the activated carbon prepared from Peach Seed Stone can be utilized as an effective adsorption media for removal of Acid Yellow 17 dye from aqueous solutions.

Keywords: Activated carbon, Adsorption, Peach seed stone, Acid yellow dye, Zinc chloride

1.Introduction

Dye removal from industrial effluents on a continuous industrial scale has been given much attention in the last few years, not only because of its potential toxicity, but also mainly due to its visibility problem. There are various promising techniques for the removal of dyes from water. However, the effectiveness of adsorption for dye removal from water has made it an ideal alternative to other expensive treatment methods. Discharge of dye-containing wastewater into natural streams and rivers poses severe problems to the aquatic life, food web and causes damage to the aesthetic nature of the environment.
Dyes absorb and reflect sunlight entering water and so can interfere with the growth of bacteria and hinder photosynthesis in aquatic plants. The problems become graver due to the fact that the complex aromatic structures of the dyes render them ineffective in the presence of heat, light, microbes, and even oxidizing agents and degradation of the dyes become difficult. The presence of very small amounts of dyes in water even less than 1ppm for some dyes is highly visible and undesirable. The removal of color from waste water is a major environmental problem and they are the first contaminant to be recognized in water.
Hence, they pose a serious threat to human health, aquatic life and water quality, thereby becoming a matter of vital concern. Keeping the essentiality of color removal, concerned industries are required to treat the dye-bearing effluents before dumping into the water bodies. Thus, the scientific community should have responsibility of contributing to the waste water treatment by developing effective dye removal technique. Many treatment processes have been applied for the removal of dye from wastewater such as adsorption, oxidation, nano-filtration, chemical precipitation, ion-exchange, reverse osmosis electrochemical degradation, ultra-filtration etc.
Among treatment technologies, adsorption is rapidly gaining prominence as a method of treating aqueous effluent. Some of the advantages of adsorption

process are possible regeneration at low cost, availability of known process equipment, sludge-free operation and recovery of the adsorbate. Activated carbon is the most widely used adsorbent for dye removal because of its extended surface area, micro-pore structures, high adsorption capacity and high degree of surface reactivity. However, commercially available activated carbon is very expensive and has high regeneration cost while being exhausted. Furthermore, generation using solution produces a small additional effluent while regeneration by refractory technique results in a 10–15 % loss of adsorbent and its uptake capacity. This has led to search for cheaper substances for the preparation of adsorbents. Researchers are always in a hunt for developing more suitable, efficient and cheap and easily available types of adsorbents, particularly from the waste materials.

Peach seed stone is the waste product left after using fleshy parts of Peach fruits. Large amount of peach seed stones has been left as waste products every year and cause problem to the environment. To minimize the problem the waste products can be utilized for the preparation of activated carbon for remediation of water pollution.

The present work is aimed to highlight the use of Peach seed stone for the preparation of activated carbon for the remediation of the dye.

A number of agricultural waste materials such as date stone [1], coconut shell [2], peach stone [3], water hyacinth [4], corn stalk [5], Lapsi seed stone [6], etc. have been utilized for the preparation of activated carbon to remove different dyes from aqueous solutions.

2. Experimental

2.1 Materials

The precursor used in this study is Peach Seed Stone as shown in Figure 1.The precursor was washed with tap water and then with distilled water. The precursor was crushed and sieved to a size range of 300 μm and was mixed with zinc chloride in the ratio of 1:1 .The mixture was dried in the oven at 110°C. Then the mixture was carbonized in tubular furnace under high purity nitrogen flow of 75 ml min^{-1} at temperature 400° C for 180 minutes. Finally, the prepared activated carbon was cooled at room temperature. The prepared activated carbon was cooled at room temperature, treated with dilute HCl and then washed with distilled water until the pH of the filtrate was 7.

Figure 1: Peach fruits and Peach Seed Stones

2.2 Chemical and Equipment

The reagents and chemicals used are of analytical grade (Merck and Qualigens Company). Stock solutions of Acid yellow dye were prepared from Acid yellow -17 dye in distilled water. Digital pH meter was used to adjust pH of solutions The adsorption experiments were carried out by using Shaker (Digital VDRL Rotator RPM-S). The concentration of Acid Yellow Dye -17 after adsorption onto activated carbon was determined by UV-Visible Spectrophotometer (CECIL-100). Working solutions of the dye were prepared by dilution of the stock solutions using distilled water.

2.3 Adsorption Experiments

The adsorption experiments were investigated by batch mode of adsorption. The batch-mode adsorption studies were carried out by using the necessary adsorbents in 50 mL stopper conical flask at a desired pH value, contact time and adsorbent dosage level. The flasks were then stirred well on

Digital VDRL Rotator- RPM-S at 225 rpm. The experiment was run by using 0.05 g of adsorbent in 25 ml adsorbate solution taken in the conical flasks under optimum conditions set out for the experiment. The amount of the dye adsorbed (qe) was calculated by the following equation [7].

$$q_e = \frac{C_o - C_e}{W} \times V \quad \ldots(1)$$

Where q_e is the amount of the dye adsorbed
C_O and C_e are the initial and equilibrium concentrations of the dye in mg L^{-1} respectively
V is the volume of the solution in Liter
W is the mass of adsorbent in gram
The removal of the dye in percentage (Rem %) can be calculated by the following formula [8].

$$Rem(\%) = \frac{C_o - C_e}{C_o} \times 100\% \quad \ldots(2)$$

2.4 Adsorption Experiments

The amount of micropore and mesopore content in activated carbon can be determined by Methylene blue number and Iodine number. Methylene blue number is the amount of the dye adsorbed by one gram of the adsorbent while the iodine number is defined as the amount of iodine adsorbed per gram of activated carbon at an equilibrium concentration. Methylene blue is absorbed into the mesopores whereas Iodine enters into micropores. Methylene blue number (MB_N) can be calculated by the following formula [9].

$$MB_N\left(\frac{mg}{g}\right) = \frac{C_o - C_e}{M} \times V \quad \ldots(3)$$

Where Co and Ce are initial and equilibrium concentration of MB(mg/L) respectively, M is the mass of adsorbent in gram and V is the volume of the solution in liter. Iodine number (IN) can be calculated by the equation given below [10].

$$I_N\left(\frac{mg}{g}\right) = \frac{Amount\ of\ Iodine\ absorbed\ in\ mg\ by\ carbon}{Weight\ of\ carbon\ in\ g} \times V \ldots(4)$$

3. Result and Discussion

3.1 Effect of pH

The pH of solution has been identified as the important parameter that can affect the adsorption capacity of activated carbon. Figure 2 indicates the effect of pH on the removal of the dye onto activated carbon prepared from Peach Seed Stone. The adsorption of the dye was investigated from pH 2 to 9. The percentage of removal of the dye decreased as pH value was increased. When the pH of solution is increased, the amount of negatively charged sites tends to increase while the amount of positively charged sites tends to decrease. A negatively charged surface site on the adsorbent does not favor the adsorption of anionic dye due to electrostatic repulsion and thus the percentage removal of dye is found to decrease as the pH of the solution increases from pH 2 to 9. Hence the optimum pH for the removal of the dye has been found to be 2.

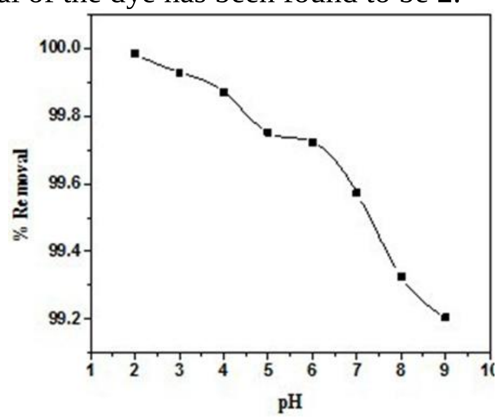

Figure 2: Effect of pH on the dye adsorption

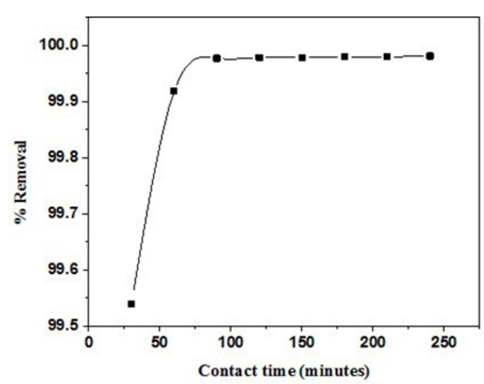

Figure 3: Effect of Contact time on the dye adsorption

3.2 Effect of Contact time

The plot of percentage removal of the dye onto the activated carbon against time is shown in Figure 3. The percentage removal of the increases with increase in time and attains a maximum value at 90 minutes. The adsorption rate is very fast initially up to 60 minutes and then after it attains equilibrium value slowly. The fast adsorption at initial stage may be due to the higher driving force owing to the availability of the large concentration of active sites for adsorption. After 60 minutes the removal percentage increases gradually and attains plateau value at 90 minutes. At equilibrium all the active sites will be covered by the dye and no further adsorption of the adsorbate takes place.

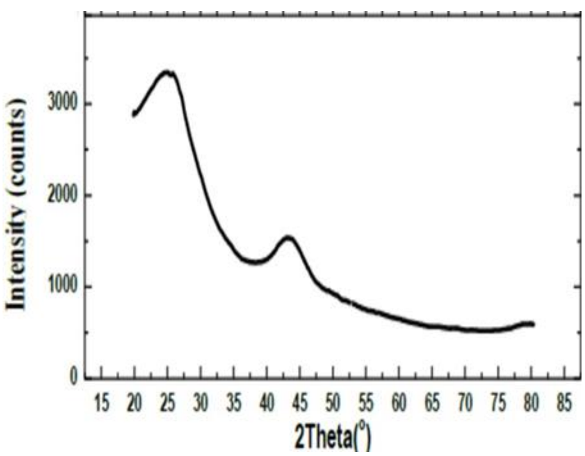

Figure 4: Effect of Adsorbent dose on the dye adsorption

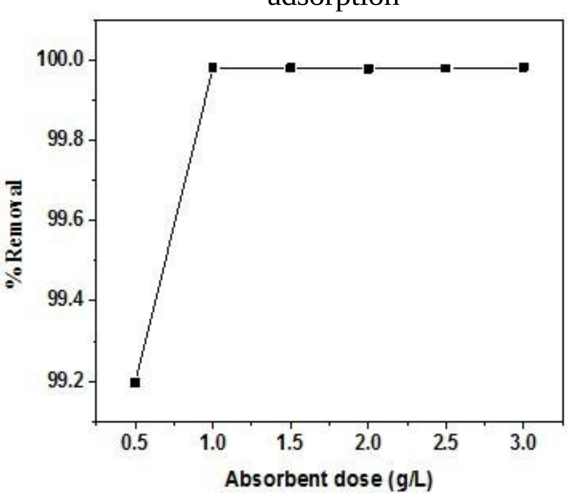

Figure 5: XRD of the Activated Carbon

3.3 Effect of Adsorbent dosage

The effect of adsorbent dosage on the percentage removal of the dye is presented in Figure 4. The removal of the dye increased from 0.5 to 1 g/L and then remained almost constant ahead. This may be due to the availability of more adsorption sites because of increase in adsorbent dosage. Adsorbent dosage of 1 g/ L has been observed as sufficient contact time for effective adsorption of the dye from the aqueous solutions. At the adsorbent dose of 1 g/ L almost all the adsorbate molecules have adsorbed since the adsorbate molecules remains constant in the concentration of the dye used.

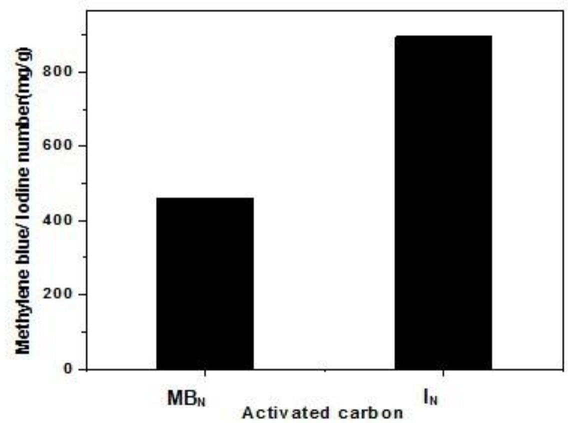

Figure 6: SEM of Activated carbon

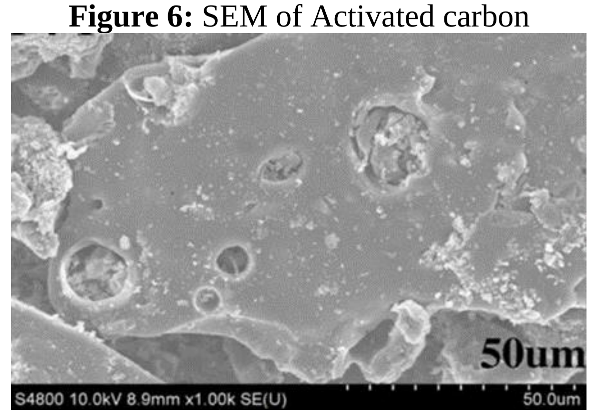

Figure 7: MB_N and I_N of Activated carbon

3.4 XRD (X-ray diffraction)

XRD of the activated carbon shows two broad diffraction peaks located near at $2\theta = 25.5°$ and 43° reflected from 002 and 001 planes as shown in Figure 5. The broad peaks show that the activated carbon is amorphous in nature. The amorphous nature of the activated carbon is one of the good properties of activated carbon for the adsorption since amorphous nature of the activated carbon makes more surface area of the activated carbon. The more the surface area of the activated carbon more will be adsorption.

3.5 SEM (Scanning Electron Microscope)

SEM image as shown in Figure 6 indicates the pores with different diameters. It can be observed that the activated carbon has rough texture with heterogeneous surface and a variety of randomly distributed pore size. During activation process, the interaction between ZnCl2 and carbon occurred, which enhance the pore development thus, the surface area and porosity increased. In addition, almost heterogeneous type of pores structure was distributed on the surface. It is clear from SEM that adsorbents have pores where, there is a good possibility for dye to be trapped and adsorbed into these pores. The development of porous structure may be attributed to the dehydrating action of zinc chloride. Due to this action, it removes oxygen and hydrogen from the precursor as water, and that promotes the development of porous structure.

3.6 Methylene blue number (MBN) and Iodine number (IN)

Methylene blue number and Iodine number of activated carbon are shown in Figure 7. Methylene blue number and Iodine blue number indicate the mesopore and micropore content respectively in activated carbon and found to be 460 mg/g and 895.7 mg/g respectively. The more micropores and mesopores in the activated carbon indicate more approximate surface area which in turn is responsible for adsorption.

4. Conclusion

The activated carbon prepared from Peach Seed Stone by chemical activation with zinc chloride was shown to be effective adsorbent for the removal of Acid Yellow -17 dye from aqueous solutions. The adsorption of the dye is found to be dependent on pH, contact time and adsorbent dose. The results show that the optimum pH, contact time and adsorbent dosage have been found to be 2, 90 minutes and 1 g / L respectively. SEM of activated carbon exhibits the pores of different diameters. XRD analysis indicates two broad diffraction peaks located near at $2\theta = 25.5°$ and $43°$ reflected from 002 and 100 planes. The presence of broad peaks shows that the activated carbon is amorphous and so has more surface area and then more adsorption. Methylene blue number and Iodine number are found to be 460 mg/g and 895.7 mg/g respectively.

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