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Adsorption of dyes by activated carbon surfaces were prepared from plant residues, A Review

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Abstract

The process of discharging the quantities of dyes resulting from industrial processes with wastewater leads to the occurrence of a serious environmental problem that threatens the environmental health security of humans. Therefore, a number of studies have been addressed that include presenting many physical and chemical treatment methods to get rid or reduce the proportion of pigments such as biological decomposition, ion exchange, and sedimentation. Chemotherapy, reverse osmosis, coagulation, Toxic sludge generation, flocculation. In addition to the above, this review deals with a number of studies that present activated carbon of plant origin, methods of obtaining it, types and advantages of it being cheap and environmentally friendly. And its use in the field of adsorption of dyes. It also included the presentation of studies of adsorption of a certain dye by a number of activated carbon surfaces prepared in different ways and the adsorption of several dyes with a carbon surface prepared in one way. The most prominent influencing factors were also highlighted (primary dye concentration, acidity, surface dose, and temperature) on the process of adsorption of dyes by surface activated carbon.

1- Introduction

In recent years, the pollution of water due to dyes becomes a great threat to the world, spreading critical diseases due to discharge of dyes. Dyes are used to color the products of many industries such as carpets, plastics, cosmetics, paper, food, and textiles [1]. According to the World Bank statistics, it is estimated that approximately 20 percent is the percentage caused by the processes of dyeing textiles and dyes in industrial water pollution, and this leads to serious problems represented by poisoning aquatic life and damaging the aesthetic nature of the environment [2].

2- dye

Dyes are mostly organic chemicals and are in several classes classified according to the application technology used and their chemical composition. So it is found that more than 100,000 commercially available dyes are present. The colored materials may be in the form of a fine powder that is insoluble in water or Thick liquids. The appearance of color in the pigments is due to the possession of active groups called chromophore, which is a radical formation consisting of double conjugate bonds [3]. There is another classification for dyes according to their use in the dyeing process, and dyes are generally classified into several main classes listed in Table 1. Among these varieties, the reactive dye class is a high-colored organic dye that is widely used in the field of textile coloring and was first used to dye cellulose fibers. It continues to be widely used in the textile industry due to its superior pigmentation and stability properties.

Table 1: Classification of pigments.

Dye class	Description
Acid	Water-soluble anionic compound
Basic	Water-soluble, applied in weakly acidic dyebaths; very bright dyes
Direct	Water-soluble, anionic compounds; can be applied directly tocellulosics without mordants (or metals like chromium and copper)
Disperse	Not water-soluble
Sulfur	Organic compounds containing sulfur or sodium sulfide
Vat	Water-insoluble; oldest dyes; more chemically complex

3- Activated carbon

The activated carbon (AC) in general is prepared from carbon of various kinds, such as charcoal, coconut shell and wood and any residues or components of plants and animals, through activating it physically or chemically, it is an ancient adsorbent material known to mankind [4]. The physical and chemical activation processes to which carbon is exposed have advantages and disadvantages. On the one hand, physical activation tends to use a high temperature and long activation time, and on the other hand, chemical activation requires a thorough cleaning and removal process of the substrate due to exposure to chemical reagents and what affects the purity of the product [5].

Activated charcoal has been used in the medical field from the last century as a treatment for toxic ingestion and is most commonly used to cleanse the gastrointestinal tract of a botulism patient [6]. Although commercial activated carbon (CAC) is made from natural materials such as algae, lignite, or charcoal, virtually any carbonaceous material can be used as precursors to prepare carbon adsorbents due to its availability on the market and its inexpensive price, charcoal is the most widely used for the production of charcoal. Activator [7,8]

1 gram of commercially available active carbon has a surface area ranging from 500 square meters to 1,500 square meters. Carbon aerogel has the advantage of having higher surface areas They are more expensive and have specific applications. Highly complex particles exhibit countless types of porosity; But there could be regions where flat planes of a graphite-like material would run parallel to each other, which might be separated by a few nanometers. These fine pores provide excellent conditions for absorption so that the adsorbent materials can interact with different surfaces at the same time [9]. And depending on the characteristics of activated carbon, it is qualified for use in several applications such as (purification (water, gas), pharmaceutical industry, wastewater treatment, petroleum. [10]

4– Classification of activated carbon [11]

Activated carbon is classified according to several considerations such as particle size, preparation methods and industrial applications as follows:

4-1- Powdered Activated Carbon (PAC)

The activated carbon is generally in the form of a powder composed of fine grains with an average diameter ranging from 0.15 to 0.25 mm. These particles are trapped in a 50-mesh sieve (0.297 mm).

With this structure achieving the highest ratio of surface to volume and small spreading distance becomes easier.

4-2- Granular Activated Carbon (GAC)

Granular activated carbon, these have relatively large particles compared to the first type, and this leads to them having a smaller outer surface. The GAC is classified according to its dimensions and its scope of use is specified, for example liquid phase and vapor phase applications.

4-3- Bead Activated Carbon (BAC)

Activated carbon is in the form of beads with a diameter of (0.35-0.8) mm and prepared using the petroleum layer. They are in the form of small discs and are low in terms of low pressure change and dust content with high mechanical strength, which makes them highly preferred in life applications such as water purification. The three types of activated carbon listed in Figure 1.

Figure 1. different types of activated carbon A) Granular B) Bead C) Powder

5- Adsorption of Dyes

Several common techniques used to treat pollutants in wastewater streams include: floatation, hydrogen peroxide catalysis, aerobic and anaerobic microbial degradation, coagulation, chemical oxidation, membrane separation, electrochemical treatment, filtration, reverse osmosis and adsorption It has been suggested from time to time [12, 13]. Adsorption is one of the most common methods mentioned above to remove contaminants, including dyes from industrial effluents. The adsorption process involves sticking dye or adsorbent molecules to the surface of the adsorbent. Adsorption is preferred because it is easy to implement and has a low cost, which makes it economically feasible simplicity of design and insensitivity to toxic substances. In this review, we present studies that deal with the use of agricultural waste as cheap natural sources for the production of active carbon in the field of adsorption, making it an economical method and recorded in Table 2. We also list a number of active carbon surfaces from one source (Thevetia peruviana) and prepared in different ways in Table 3.
Adsorption by activated carbon has a greater potential for the removal of dyes without introducing any impurities. However, these processes are effective and economic only in cases where concentrations of solute are relatively high [22]. Despite showing the high efficiency of activated carbon in removing pollutants (textile dyes) by adsorption technology, it is very effective. Emphasis is required on the issue of recirculating the adsorbent surfaces if they are of high production cost, which affects their economic viability, which calls for continuous search for cheap sources for the production of activated carbon [23] From these cheap sources as rice husk [24], bamboo [25], sugarcane stalks [26], tamarind kernel powder [27], palm shell [28] babool wood [29], bagasse fly ash [30], ashoka leaf powder [31], coir pith [32] and banana pith [33] etc.

Table 2. Different sources of activated carbon with their adsorption capacity for different pigments

plant residues / Adsorbent	Dye	Sources	Adsorption capacity (mg/g)
Cordia myxa/ AC	**Disperse Blue 56**	**[14]**	**6.93**
Mahogany sawdust /AC	**Direct dye**	**[15]**	**300**
Coconut shell/AC	**Rhodamine-B**	**[16]**	**600**
almond shell / AC	**malachite green**	**[17]**	**12**
Banana Peel /AC	**methylene blue**	**[18]**	**14**
waste Elaeagnus stone /AC	**malachite green**	**[19]**	**288**
waste Elaeagnus stone /AC	**rhodamine B**	**[19]**	**281**
waste Elaeagnus stone /AC	**methylene blue**	**[19]**	**432**
***Monotheca buxifolia* waste seeds /AC**	**Eriochrome Black T**	**[20]**	**112**
Monotheca buxifolia waste seeds /AC	**Remazol brilliant blue**	**[20]**	**96**
Monotheca buxifolia waste seeds /AC	**Remazol yellow**	**[20]**	**97**
Monotheca buxifolia waste seeds /AC	**methylene blue Remazol brilliant orange**	**[20]**	**90**

Table 3. The adsorption of dyes by the surface of the prepared activated carbon in different methods [21]

Ways	Adsorbent	Adsorbate
Direct Pyrolysis	Activated Carbon 1	dyes
Na_2SO_4 impregnation	Activated Carbon 2	
H_3PO_4 impregnation	Activated Carbon 3	
$ZnCl_2$ impregnation	Activated Carbon 4	
KOH impregnation	Activated Carbon 5	
HCl process	Activated Carbon 6	
H_2SO_4 process	Activated Carbon 7	
Dolomite process	Activated Carbon 8	
H_2SO_4+H_2O_2 process	Activated Carbon 9	

During the previous period, emphasis was placed on the importance of conducting the adsorption process as a stage of an integrated treatment process (chemically, physically and biologically) of wastewater [34,35], Or at the same time with a biological process [36], The adsorption process for the dye molecules to the adsorbent surface includes four successive stages [37]. The **step1** involves diffusion of the dye particles through the bulk of the dye solution. This is followed by diffusion of the dye particles from the adsorbent surface area. Finally, the dye will adhere to the materials surface through forces interactions. **Step 2** may be influenced by some factors affecting the adsorption process, such as the initial concentration of dye and stir speed. **Step 3** is important because it is the rate-limiting step that controls the rate at which the dye adsorption is applied to the adsorbent surface. Step 4 is based on the nature of the dye and its charge, whether anionic (negative) or cationic (positive). It is necessary to emphasize that **Step 3** can involve two different processes (porous diffusion and surface diffusion) [38]. The adsorption can be divided according to the bonding forces between the adsorbent surface and the adsorbent into chemical adsorption and physical adsorption. Where chemical adsorption is formed through strong chemical bonds (chemical bonds) between atom, molecules or ions of adsorbents through an electronic exchange, which makes it a non-reversible process. Whereas, physical adsorption consists of weak correlations such as weak van der Waals forces making them a reversible process [39].

5- Factors affecting adsorption of dye

The efficiency of the dye adsorption process on the surface of activated carbon is affected by several factors such as pH solutions, initial dye concentration, adsorbent dose, and temperature. A careful study of these factors and determining the optimal conditions will contribute to the development and improvement of the efficiency and success of the process, so we will present something in detail as follows:

5-1- pH solution effect

The pH of the solution is considered a major important factor affecting the efficiency of the dye adsorption process, through its control over the strength of the electrostatic charges present in the solution or carried by the ionized dye particles present in the solution. This leads to changes in the rates of adsorption according to the change in the pH of the solution used. Generally, it was found that the removal ratio for positive dyes decreases and for negative dyes it increases at low pH values, while we observe a different behavior at high pH values where the percentage of removal increases for positive dyes and decreases for negative dyes [40,41]. The pH value is used as a tool to display the pH pzc in systems in which hydrogen and hydroxyl ions are the possible specific ions. Due to the presence of functional or functional groups, cationic dyes are better adsorbed at the pH value> pHpzc, i.e. when the surface is mesh, while the anionic dyes adsorb more at the pH value <pHpzc as the surface becomes positively charged [42]. Acevedo et al. By studying the effect of the pH on the adsorption of a number of dyes (Basic Astrazon Yellow 7GLL and Reactive Rifafix Red 3BN) on activated carbon manufactured reinforcement fibers from tire waste and low grade bituminous coal. The results showed that the adsorption of the reactive dye was more when the pH solution was 2 while the adsorption of the base dye was more when the pH solution was 12. [43]

5-2- Initial day concentration effect

The initial concentration greatly affects the dye removal efficiency through its dependence on the direct relationship between the amount of concentration and the amount available for adsorption on the adsorption surface, which decreases as the adsorption sites reach the level of saturation and the number available for adsorption decreases [44]. When the dye concentration is diluted, this will provide a number of adsorption sites that are not occupied, but with increasing the concentration of the dye and the association of the dye molecules with the adsorption sites, this leads to a decrease in the adsorption sites, which results in a decrease in the adsorption efficiency of the dye [40]. On the other hand, an increase in the initial dye concentration provides high driving forces to transport the highly concentrated dye molecules to the adsorbent surface and this leads to an increase in the dye adsorption [45]. Through study by Garg et al., Which included the adsorption of methylene blue (MB) by means of sawdust treated with sulfuric acid at specific laboratory conditions, they found that the adsorption capacity of the adsorption surface increased from (12.49 to 51.4) mg/g as the (MB) concentration increased from (50 to 250) mg / L, while the dye removal percentage decreased from (99.9 to 82.2) % [46]. Through another study by Garg et al., Which included the adsorption of methylene blue by means of sawdust treated with sulfuric acid at specific laboratory conditions [47].

5-3- Adsorbent dosage effect

The adsorbent dose plays an important role in determining the ability of the adsorbent to adsorb a certain amount of adsorbent at certain laboratory conditions where the ideal weight of the adsorbent surface is determined when the maximum initial concentration of the adsorbent is adsorbed and at the time of equilibrium [40]. In general, as the amount of adsorbent surface increases, the amount of dye adsorbed increases due to the increase in the number of adsorption sites unoccupied on the adsorption surface and as a result, the percentage of dye removal from the solution increases [48]. By studying the effect of the adsorbent dose, we provide information about the dye absorption capacity, and this helps to determine the efficiency of the adsorbent materials, which is important from an economic point of view [40]. Hassani et al. Carried out a study involving the adsorption of dyes (Basic Green 4 and Basic Yellow 28) by chemically modulating nanoclay. This study demonstrated that a relatively high increase in the adsorbent dose led to an increase in the removal efficiency of both dyes at an initial concentration of 30 mg / L and an equilibrium time of 35 minutes. The study also indicated that increasing the adsorbent dose will provide a large surface area and this provides more binding sites for the adsorption of target pollutants on the modified nano layer [49]. Sonawane and Shrivastava conducted a study that analyzed the effect of the adsorbent dose on removing green malachite with a starting concentration of 20 mg / L by a corn cob and a contact time of 25 minutes. 90% to 98.5% [50]. .

5-4- Effect of temperature

Temperature is one of the important factors in determining the nature of the adsorption process, whether it is endothermic. This means that with increasing temperature, the amount of adsorption increases. This may be due to the availability of a greater number of adsorption sites or increased movement of dye molecules and the possibility of reaching the adsorption surface greater at high temperatures [51]. But if the adsorption process is of a heat-emitting nature, then this means that the adsorption capacity decreases with increasing temperature. Here, an increase in temperature reduces the bond forces between the adsorbent and the adsorbate [52].

In a study by Fu *et al.* [50] It includes the application of adsorbent surfaces in the form of polydopamine microspheres (PDA), which were manufactured by facial oxidation polymerization, and were used to adsorb nine pigments (anionic pigments: methyl orange (MO), eosin-Y (EY), and eosin-B (EB), acid blue chromium K (ACBK), neutral pigment: neutral red (NR), cationic dyes: rhodamine B (RHB), malachite green (MG), methylene blue (MB), and saffron T (ST). The results obtained from the study showed that the temperature has an effect on the adsorption process by increasing the adsorption capacity of three dyes (MG, MB and NR) on the PDA microscopic pellets with a temperature rise from (15 to 45) °C, which indicates a preference for adsorption at higher temperatures. This is because the dyes are more adsorbed with higher temperature, and they concluded that an increase in temperature may result in a swelling effect within the internal structure of the carbon, which provides adsorption of more dye molecules into the carbon. In addition to the possibility of increasing the number of unoccupied sites for adsorption with increasing temperature [53,54].

Conclusions

We conclude from this review, which dealt with a number of studies, that the process of adsorption of dyes of all kinds on activated carbon from different plant sources is highly efficient and of great economic feasibility, and this verifies the actual effect of a set of important factors (initial concentration, dose of adsorbent surface) The acidity of the solution, the temperature) through the ideal values that they produce to best represent the dye adsorption process on activated carbon

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