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Removal of some 4-pyrazolone dyes from aqueous solutions by adsorption onto different types of carbon

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Abstract

A novel group of 4-pyrazolone based dyestuffs, considered as a group of tartrazine dye analogous, was synthesized by the authors [1]. In view of the current interest in utilizing the arylazo-4-pyrazolone dyestuffs for dyeing different types of fibers, this article describes the possibility of using carbon for their removal as organic pollutants from aqueous solutions. The removal of these dyestuffs from their aqueous solutions was carried out by using different adsorbents such materials as granular carbon, carbon soot, and powdered activated carbon (PAC) at different temperatures ranging from room temperature (25°C) to 60°C. Kinetics and mass transfer studies were studied by applying different models such as Lagergren, Weber-Morris, Langmuir, Freundlich and Burnaur Emmette and Teller (BET). Different kinetic parameters (K_{ad}, K_p, a, b, R_L, n, K, A, X_m) were calculated from these models. The thermodynamic parameters (ΔH, ΔS and ΔG) were calculated for the interpretation of the adsorption process.

Keywords: Adsorption; Adsorption dynamics; Thermodynamic functions of adsorption; Langmuir, Freundlich and Burnaur Emmette and Teller (BET); Isotherms; 4-pyrazolone dyestuffs

1. Introduction

In Egypt, the problem of color removal from textile wastewater has been considered in recent years to be of great importance because of the need to satisfy the increasing demand for water. For this reason, a national effort has been launched to deal with this problem using natural, local adsorbents. Investigations have been undertaken to determine whether cheap commercially available materials hold promise in the treatment of wastewater. In spite of the presence of a huge number of dyestuffs which are widely used in dyeing processes, little data is available about the removal of these dyes from textile effluents.

Adsorption is used in industrial wastewater treatment to remove organic materials such as color, phenols, detergents, other toxic or non biodegradables. The most important component of

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the cost of using powdered activated carbon (PAC) is the cost of PAC itself; therefore, searching for inexpensive sources or substitutes for PAC is a must.

Recently many investigators tried to search for some materials as adsorbents to be utilized in water and wastewater treatment. Ahmed et al. [2], Sen [3], Gupta et al. [4] and Kashi Banerjef et al. [5] used coal fly ash which is a solid waste of thermal power plants as adsorbent. Asfour et al. [6,7] used hardwood sawdust for the adsorption of basic dyes. Mckay et al. [8,9] studied the ability of using bagasse pith (a byproduct of the sugar industry remaining after the extraction of juice) as adsorbent for the adsorption of two basic dyes (Basic-blue 69 and Basic-red 22) and two acid dyes (Acid-blue 25 and acid-red 114). El-Gundi [10–11] tested the ability of maize cobe (an agricultural solid waste) to adsorb two basic dyestuffs (Astrazene-blue and Maxilon-red) and two acid dyestuffs (Teflon-blue and Erionyl-red). Korshin et al. [12] studied the adsorption of natural organic matter (NOM) onto iron-oxide-coated sand (IOCS). Rashed et al. [13–15] reported that carbon soot which is a byproduct resulting from partial oxidation of natural gas in Talkha Fertilizers and Chemical Plants (SEMADCO Egypt now named as Delta for Fertilizers Production) is a promising material for various industrial applications as a substitute for commercial powdered activated carbon. Al-Sarawy [16] studied the using of carbon soot as a good adsorbent for the removal of colors of some dyes from their solutions. Jain and Daya Ram [17] studied the removal of lead and zinc on bed sediments collected from the river Kali (in western Uttar Pradesh, India). Attia [18] used carbon soot, powdered activated carbon, and bentonite as adsorbent for the removal of some heavy metals from water. Cheung et al. [19] studied the kinetic analysis for removal of cadmium ions from effluents using bone charcoal; they found that bone charcoal is a suitable adsorbent for the removal of cadmium from wastewater. Since the adsorption capacity is relatively high, they also found that the adsorption process was considered as a first order process. Feng-Chin Wu et al. [20] studied the kinetic modeling of liquid phase adsorption of reactive dyes (RR222, RY 145 and RB222) and metal ions (such as Cu^{++}) on chitosan (chitosan is a partially acetylated glucosamine bipolymer existing in the cell wall of some fungi such as the Mucorales strains); they found that chitosan is a suitable adsorbent for the removal of these reactive dyes and Cu^{++} from their aqueous solutions at 30°C. Shawwa et al. [21] studied the removal of color and chlorinated organics from pulp mills wastewater using activated petroleum coke. They found that the removal efficiency was over 90% and the utilization of petroleum coke for the production of activated carbon can provide an excellent disposal option for oil sand industry and at the same time would provide a cheap and valuable activated carbon.

2. Materials and methods

All chemicals and solvents used in this study were of the highest grade of purity (spectral grade). Sodium salts of five dyes of the hitherto synthesized dyestuffs (listed in Table 1) and considered as 4-pyrazolone dyestuffs or tartrazine dye analogues; their chemical structure shown in Fig. 1 which were previously synthesized by the authors [1] was chosen for studying their adsorption behavior on different types of carbon at different temperatures.

Powdered activated carbon and granulated carbon were obtained from El-Nasr pharmaceutical chemical company. Carbon soot, was produced as a result of partial oxidation of natural gas at SEMADCO (El-Delta for Fertilizers Co.); the existing method of collecting carbon soot in the factory is performed by precipitation using lime, $Ca(OH)_2$, as coagulant agent.

Experimental procedures were carried out to study the adsorption of this dyestuff from their aqueous solutions by using a shaker with water bath controlling temperature. The remaining con-