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Thermodynamic and Kinetics Studies on Adsorption of Indigo Carmine From Aqueous Solution by Activated Carbon.

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Abstract

The kinetic and equilibrium parameters of the quantitative adsorption for Indigo Carmine (IC) removed by commercial activated carbon (AC) were studied by UV-visible absorption spectroscopy. AC with a high specific surface area (1250.320 m^2/g) was characterized by the Brunauer–Emmett–Teller (BET) method and point of zero charge (pzc).
The effect of the initial dye concentration (10-60 mg/L), contact time (0-90 min), pH (1-12), agitation speed (0-600 rpm), adsorbent dose (1-10 g/L) and temperature (298-323 K) were determined to find the optimal conditions for a maximum adsorption. The adsorption mechanism of Indigo Carmine onto AC was studied using the first pseudo order, second pseudo order and Elovich kinetics models. The adsorptions kinetic were found to follow a pseudo second order kinetic model with a determination coefficient (R^2) of 0.999. To get an idea on the adsorption mechanism, we applied the Webber-Morris diffusion model. The equilibrium adsorption data for indigo carmine on AC were analyzed by the Langmuir, Freundlich, Elovich, Dubinin and Temkin models. The results indicate that the Langmuir model provides the best correlation at 25 ˚C (q_{max} = 79.49 mg/g) and Dubinin at 40 ˚C (q_{max} = 298.34 mg/g). The adsorption isotherms at different temperatures have been used for the determination of thermodynamic parameters such as free energy (ΔG^o = - 0.071 to -1.050 kJ/mol), enthalpy (ΔH^o = 28.11 kJ/mol), entropy (ΔS^o = 0.093 kJ/mol. K) and activation energy (Ea) of 51.06 kJ/mol of adsorption. The negative ΔG^o and positive ΔH^o values indicate that the overall adsorption is spontaneous and endothermic.

Keywords: Indigo Carmine, Adsorption, isotherm, Kinetics, Thermodynamics, Equilibrium, Modeling

I. Introduction

Carmine indigo (IC) is a water-soluble derivative of the famous indigo disulfonate blue dye which has great applications in many industries as a textile dye **[1]**. It has also been used as additive in pharmaceutical tablets and coloring agent in confectionery, food, beverages and cosmetics. It also serves as a diagnostic aid. (e.g., in renal function tests), an oxidation-reduction indicator in analytical tests, and a micro stain in biology **[2].** IC is an acid dye **[3, 4]** and is therefore used to dye protein fibers, wool and silk **[5],** including the use of alum as a bite in the latter case **[6].** Limited number of studies is reported on the adsorption of IC dyes on silk and wool, in particular with regard to dyeing and the removal of effluents from textile treatments **[7].** The textile industries around the world and the growing demand for textiles, ceramic paper, printing and plastics use a wide variety of dyes as raw materials **[8].** Some dyes are used in medicine, biological strains and plastic staining **[9].** Wastes from these industries, in one way or another, end up in water, thus polluting the environment. In the aquatic medium, unlike other pollutants, coloring pollutants, especially those with benzene rings, even at low concentrations, are visible, reducing the light penetration in water, which has a negative impact on the photosynthesis of aquatic plants and are not degradable **[10].** Similarly, human activities have caused a great damage to the quality of our lifeline, namely water **[11].** IC is also used in the following fields: Cameroon, as an additive in pharmaceutical tablets and capsules as well as for medical diagnostic purposes. However, it is not easily metabolized but is rather freely filterable by the kidneys. Therefore, the dye injection for cystoscopy is a safe technique for detecting compromises in the urinary tract implant **[12].** It is considered as a highly toxic class of IC and its touch can cause skin and eye irritation for humans. It can also produce permanent damage to the cornea and conjunctiva. Consumption of the dye can also be fatal because it is inherently carcinogenic and can lead to a reproduction, development, neurotoxicity and acute toxicity. It has also been established that it causes tumor formation at the application site. Mild effects on hypertension, cardiovascular system and respiration have also been reported. Wastewater containing IC dyes is rich in color and organic content and a large amount of suspended solids whose pH, temperature and chemical oxygen demand (COD) vary considerably **[13].** According to the United Nations Educational, Scientific and Cultural Organization standards, the World Health Organization, the indigo carmine at a concentration above 0.005 mg/L is not acceptable in water **[14]**. IC is not only a nuisance for the aquatic life, but also for the humans. The treatment of this waste before disposal is therefore essential. There are many treatment methods including chemical methods, precipitation, ultra filtration, electrochemical deposition, coagulation-flocculation and adsorption. These methods differ in their effectiveness in removing the IC dye from water **[15].** They have certain disadvantages, including high investment and operating costs and the need for appropriate treatment and elimination of residual dye sludge **[16].** Thus, the adsorption remains one of the most widespread processes because of its simplicity, high efficiency and low cost. The main objective of this work is the elimination of indigo carmine in aqueous solution on activated carbon. This study was carried out with the aim to optimize the initial dye concentration, pH, particle size, contact time, adsorbent dosage, agitation speed and temperature. In addition, the equilibrium adsorption data were fitted to various models for the determination of constants related to the adsorption phenomena. Equilibrium and kinetic analysis were