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A novel acorn based adsorbent for the removal of brilliant green

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ABSTRACT

Experiments were carried out to remove brilliant green dye by adsorption technique using a novel adsorbent (activated carbon prepared from acorn). The prepared adsorbent was characterized by BET surface area measurement, FTIR, SEM and elemental analysis. Various parameters such as initial dye concentration, adsorbent dose, initial pH and temperature were studied to observe their effects on the dye adsorption process. At optimum values of the above mentioned parameters, more than 90% removal efficiency was obtained within 30 min at adsorbent dose of 2 g/100 mL for initial dye concentration of 25 mg/L. The percentage of dye removal remains almost constant within the pH range of around 6–10. The adsorption of dye was found to follow a pseudo-second-order rate equation. Intra particle diffusion model was studied in order to determine the rate limiting step of the adsorption process. Langmuir isotherm model was fitted the best for the adsorption system with an adsorption capacity of 2.11 mg/g of adsorbent. The present adsorbent may be considered as an alternative adsorbent for the better performance of the brilliant green dye removal from its aqueous medium.

1. Introduction

Dyes as highly toxic compound can cause permanent injury to the eyes and skin of humans and animals. Dyes and pigments are widely used in various industries to color the final product. They are applied in chemical laboratories for analytical purposes and also in many biomedical and biological laboratories as biological stain. Brilliant green (BG) is one of the most important dyes within the category of dyestuffs, which has been extensively used for dying silk, wool, leather, jute, cotton, biological stain, dermatological agent, veterinary medicine, green ink manufacture, intestinal parasites, fungus textile dying and paper printing, therefore waste water of these industries is highly colored and causes water pollution and needs to be treated before its disposal. Cationic dyes make the brightest class of the known dyes and are water-soluble. Several methods like flocculation, coagulation, and membrane separation have been regularly reported for the treatment of dyestuff wastewaters, but most of these methods are either expensive or pose the problem of sludge disposal. The adsorption process provides an attractive alternative for the treatment of dyestuff wastewaters. This process is easy to handle, requires less maintenance and produces smaller amounts of sludge. In this regard preparation and identification of cost effective ease of availability and efficient adsorbent are the major focus in the current state of art in the field of separation and purification technologies. [1–4].

Activated carbons have shown great potential for dye removal due to properties such as large surface area, microporous structure, and high adsorption capacity. The high cost of activated carbon promotes the search for cheap materials mainly derived from biological origin [5–10]. It has been proved that lignocellulosic agro-waste that arbitrarily either discarded or set on fire is attractive resources for the preparation of carbonaceous materials implemented in adsorption processes. Lignocellulosic materials with unique advantages such as eco-friendly nature, their availability and low cost are suitable precursor for preparation of activated carbon. Current state of art focused on the application of low-cost, reusable, locally available and biodegradable adsorbent made from natural sources like rice husk [1], wheat bran [2], waste apricot [3], bagasse fly ash [4] and powdered peanut hull [5]. Natural and modified clays like sepiolite [6], zeolite [7], perlite [8] and bentonite [9], sugar industry mud [10], palm-fruit bunch [11], Jack fruit peel [12], peat [13], orange peel [14], sugar cane dust [15], peat [16] and neem leaf powder [17], acorns and olive sheds [18] and chemically treated guava leaf powder [19] also have been applied to reduce the pollution of wastewaters at a reasonable cost. Hence, there is a scope for the identification and preparation of more economical and effective agro-waste based adsorbents. Acorn (a tree naturally and commercially available in Yasouj, Iran) generally is dark brown with complex material containing lignin and cellulose as major constituents. The objective of the present work is to prepare an

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efficient adsorbent from acorn and investigate its potential applicability for the adsorption of BG. Due to abundance of acorn tree activated carbon prepared from it is very cheap and it would not be necessary to regenerate spent adsorbent.

In the present study, experiments were carried out to remove BG dye by adsorption technique using activated carbon prepared from acorn. Characterization of prepared adsorbent was carried out by measuring BET surface area measurement, elemental analysis and FTIR analysis. The influences of temperature, solution pH, adsorbent dose and initial BG concentration on the extent of BG adsorption were studied under stirred condition. Thermodynamic parameters were calculated to know the nature of adsorption and the kinetic models of BG adsorption process were investigated using different models. The fitness of equilibrium data to different models such as Langmuir, Freundlich and Tempkin isotherms were examined. This fundamental study will be helpful for further application in designing an adsorber for the treatment of dye containing effluent using a local activated carbon prepared from acorn.

2. Materials and methods

2.1. Reagent and solution

Brilliant green dye (C.I.: 42040, FW: 482.62, Dye content: 85%, λ_{max}: 627 nm), supplied by Titan Biotech Limited, Bhiwadi, Rajasthan, India was used as an adsorbate, while its molecule exists as cation in aqueous medium (Fig. 1a). pH of the solution was maintained by using 0.1 M HCl and 0.1 M NaOH solutions that were obtained from Merck, Dermasdat, Germany. Batch experiments were carried out using a 1.0 L capacity glass beaker. Stock solution of BG (1000 mg/L) was prepared by dissolving an accurately weighed quantity (1.0 g) of BG in 1.0 L of deionized water (pH is 6.9). Experimental solutions of desired concentrations were obtained by successive dilution of the stock solution. Initial dye concentrations were varied from 10 to 50 mg/L. For studying the effect of solution pH on dye adsorption, experiments in different pH (varying from 2 to 10) were conducted. To observe the effect of adsorbent dose on dye adsorption, different amounts of adsorbent (varying from 0.2 to 2.2 g/100 mL) were used for the initial dye concentration of 25 mg/L. Effect of temperature on BG adsorption was studied at different temperatures (10 °C to 60 °C). A common adsorbent dose of 2.0 g/100 mL, stirring speed of 400 rpm and pH 6.0 was used for all the experiments.

In order to study the adsorption isotherm, 2.0 g of prepared adsorbent was kept in contact with 100 mL dye solution of different concentrations in the range of 10–50 mg/L at pH 6.0 for 40 min with constant shaking at ambient temperature of 26 ± 2 °C. Then the solution attained equilibrium and the amount of dye adsorbed (mg/g) on the surface of the adsorbent was determined from mass balance. Duplicate experiments were carried out for all the operating variables studied and only the average values are taken into consideration. The average deviation of duplicate results in the units of concentration is found to vary as $\pm 2\%$. Blank experiments were carried out with dye solution and without adsorbent to ensure that no dye was adsorbed onto the walls of the beakers.

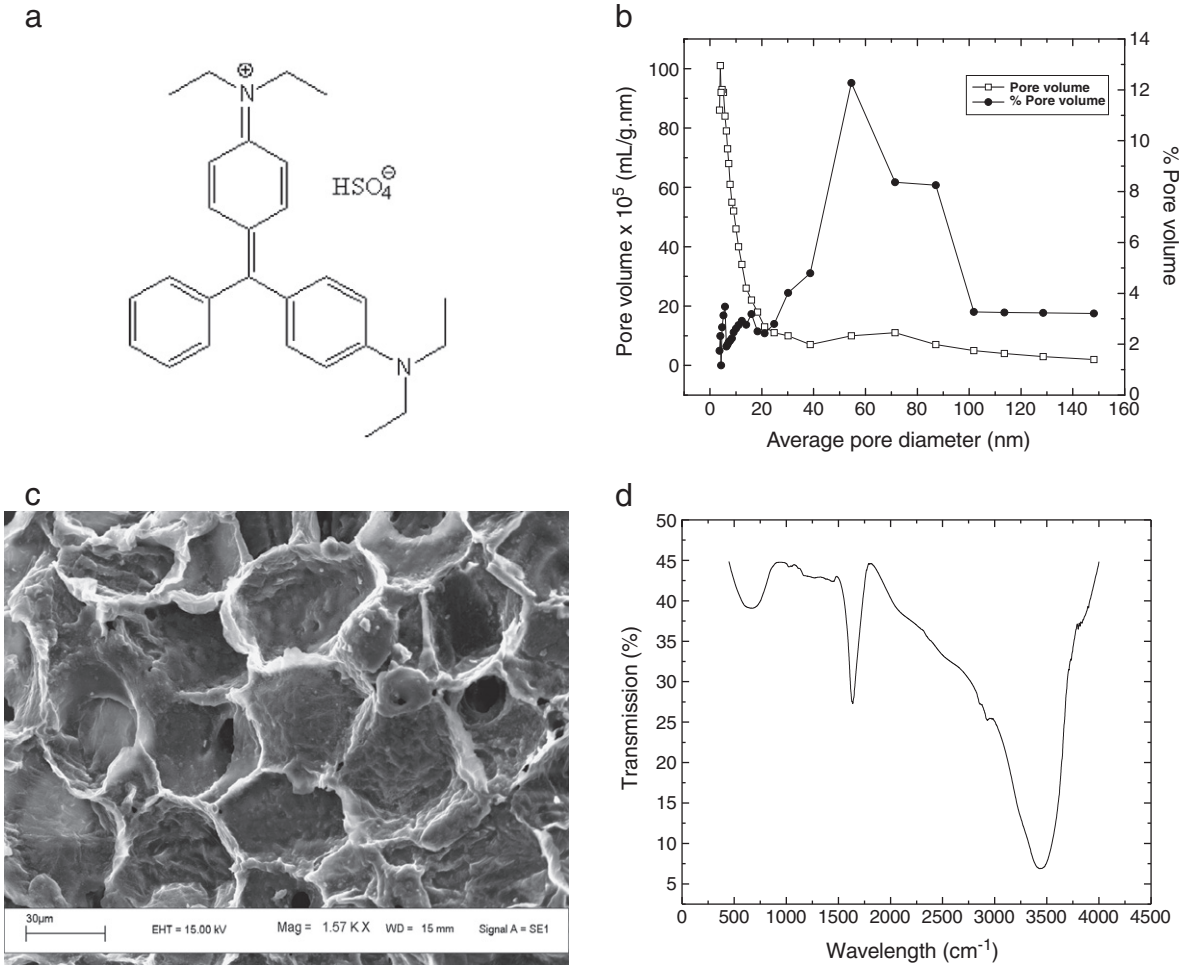

Fig. 1. a) Molecular structure of brilliant green, b) pore size distribution of adsorbent prepared from acorn, c) SEM of adsorbent, and d) FTIR of prepared adsorbent.