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Alkali treated Foumanat tea waste as an efficient adsorbent for methylene blue adsorption from aqueous solution

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ABSTRACT

The adsorption of methylene blue (MB) from aqueous solution by alkali treated Foumanat tea waste (ATFTW) from agriculture biomass was investigated. The adsorbent was characterized by Scanning Electron Microscopy (SEM), Fourier Transform-Infrared Spectroscopy (FT-IR) and nitrogen physisorption. FTIR results showed complexation and ion exchange appear to be the principle mechanism for MB adsorption. The adsorption isotherm data were fitted to Langmuir, Sips, Redlich-Peterson and Freundlich equations, and the Langmuir adsorption capacity, Q_{max} was found to be 461 mgg^{-1}. It was found that the adsorption of MB increases by increasing temperature from 303 to 323 K and the process is endothermic in nature. The removal of MB by ATFTW followed pseudo-second order reaction kinetics based on Lagergren equations. Mechanism studies indicated that the adsorption of MB on the ATFTW was mainly governed by external mass transport where particle diffusion was the rate limiting step.

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1. Introduction

Saving water to save the planet and to make the future of mankind safe is what we need now. With the growth of mankind, society, science, technology our world is reaching to new high horizons but the cost which we are paying or will pay in near future is surely going to be too high. Among the consequences of this rapid growth is environmental disorder with a big pollution problem. Besides other needs the demand for water ("Water for People Water for Life" United Nations World Water Development Report UNESCO) has increased tremendously with agricultural, industrial and domestic sectors consuming 70%, 22% and 8% of the available fresh water, respectively and this has resulted in the generation of large amounts of wastewater [1–3] containing a number of pollutants. One of the important classes of the pollutants is dyes, and once they enter the water it is no longer good and sometimes difficult to treat as the dyes have a synthetic origin and a complex molecular structure which makes them more stable and difficult to be biodegraded [4–5]. Therefore, removal of dyes is an essential procedure of wastewater treatment before discharge. The methods to treat dyeing wastewater can be classified into two types: physical and chemical processes. Among all these methods, adsorption by activated carbon is the most common process for dye removal from wastewater. Although, the process is highly effective, the running costs are high with the need for regeneration after each sorption cycle [6]. This has led to the search for other potentially suitable alternative, that is more economical and equally an effective materials for dye removal by adsorption [7]. A number of investigations have shown that agricultural by-products such as clay [8], durian shell [9], Hevea brasiliensis [10], banana stalk waste [11] and mango seed kernel powder [12] have the potential of being used as low cost adsorbent for the removal of dyes in wastewater. Some of the advantages of using agricultural waste for wastewater treatment include simple technique, requires little processing, good adsorption capacity, selective of adsorption effluent, low cost, free availability and easy regeneration [13]. Besides, the exhausted adsorbents can be disposed of by burning and the heat used for steam generation [14]. However, the application of untreated agricultural or plant waste as adsorbents can also bring several problems such as low adsorption capacity, high chemical oxygen demand (COD) and biological oxygen demand (BOD) as well as total organic carbon (TOC) due to release of soluble organic compounds contained in the plant wastes [15]. Recently, comparative studies of cationic and anionic dye adsorption by agricultural solid wastes and some other low-cost adsorbents were reported [13,16–18]. Therefore, the agricultural wastes need to be treated or modified before being used as adsorbent. Alkali treatment is viewed as one of the widely employed chemical treatment techniques for surface modification of agricultural wastes for the purpose of improving its adsorption properties. Treatment of agricultural wastes with aqueous sodium hydroxide (NaOH) solutions breaks the covalent association between lignocellulose components, hydrolyzing hemicellulose and de-polymerising lignin [19]. This treatment has a substantial influence on morphological, molecular and supramolecular properties of cellulose, causing changes in crystallinity, pore structure, accessibility, stiffness, unit cell structure and orientation of fibrils in cellulosic fibers [20]. NaOH also improves mechanical and chemical properties of cellulose such as structural durability, reactivity and natural ion-exchange capacity. Treatment with NaOH removes natural fats and waxes from the cellulose fiber surfaces thus revealing chemically reactive functional groups like –OH [21]. In our previous work, we examined the use of Foumanat tea waste for methylene blue (MB) removal [22]. The objective of this work was to study the adsorption of methylene blue onto alkali treated Foumant tea waste (ATFTW). Adsorption kinetics, isotherms and thermodynamics were also evaluated and reported.

2. Materials and methods

2.1. Materials

The Foumanat tea waste was collected from Faculty of Fouman Cafeteria. The collected materials were washed several times with boiled water and finally with distilled water to remove any adhering dirt. The washed materials were then dried in the oven at 60 °C for 48 h. The dried tea waste was then