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Effective removal of Methylene Blue dye from water using three different low-cost adsorbents

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ABSTRACT

Water pollution has become an environmental problem worldwide as well as local. Dyes represent the raw material in textile, leather, paper and plastic industries and a pollutant or toxic waste in the untreated effluents discharged out from these industries. The adsorption process is one of the most efficient methods for the removal of dye from waste water. The present laboratory model study was carried out to check the effect of three different low-cost adsorbents (such as banana fibre, coconut fibre and sawdust) and their adsorption capacity of Methylene Blue dye from water. While checking with different initial dye concentration for all the adsorbents, the maximum adsorption was observed in 250 mg l^{-1}, and the same concentration followed for further optimization. For optimization, one parameter at a time method was followed at different pH (3.0, 5.0, 7.0, 9.0, and 11), temperature (25, 30, 35, 40, and 45˚C), adsorbent dosage (1, 3, 5, 7, and 10%) and contact time (30, 60, 90, 120, 150, 180, and 210 min). The pH 7 and temperature 40˚C and contact time 120 min were found to be optimum. From the results, it is concluded that the coconut fibre showed more dye binding ability compared to the other adsorbents and may prove to be an efficient adsorbent to remove the compound dyes present in the effluents on a large scale.

Keywords: Decolourization; Adsorbents; Methylene Blue

1. Introduction

Dyes are intensely coloured complex organic compounds representing an indispensable component of major industries, viz. the textiles, leather, paper, food and other materials product industries. Increased usage of dyes in the industries is sequentially associated with the release of processed dye wastes to the land and water bodies. There are more than 10,000 dyes commercially available worldwide. Over seven hundred tons of dyes are used annually in such industries as textile, leather, paper, cosmetics, printing and plastics [1]. The untreated effluents from these industries may contain chemical deleterious compounds to both land and water bodies. They are the principal

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sources of aqueous contamination and human health afflictions. Textile industries rank first in usage of dyes and they are designed to be chemically and photolytically stable, highly resistant in the natural environment. Dye induced toxological cum pathological problems include cardiovascular, dermatologic, gastrointestinal, genitourinary, hematologic, and CNS damage [2]. The conventional biological treatment process is not very effective in treating dyes from wastewater, due to low biodegradation and bioefficacy. The physical and chemical treatment processes are also very expensive and could not be effectively used to treat the wide range of complex dyes from wastewaters [3].

In recent years, adsorption process is becoming an alternative method in many industries for the removal of toxic chemicals like the dyes. Generally activated carbon is commonly used as an adsorbent for dye removal, but it is also very expensive [4]. There is an urgent need for an alternative adsorption technique which is cheap, non-toxic and locally available for the successful application of wastewater treatment. Already some biodegradable adsorbents like agricultural biomaterials have received significant attention for dye removal from wastewaters with the most economical and effective option. Recently, some adsorbents like bagasse [4], rice husk [5], coconut coir [6], tea leaves and cowdung [7], wool fibre and cotton fibre [8] chitosan [9], mahogany sawdust [10], parthenium hysterophorus [11], neem husk [12], silk cotton hull [13], tuberose sticks [14] and tamarind fruit shell [15] have been found to be cheap and highly effective and safe. The present study aimed to investigate the utilization of commercially available, inexpensive and eco-friendly waste materials as biosorbents for the removal of dyes from waste waters. With this in mind, three different waste materials such as banana fibre, coconut fibre and sawdust were examined as biosorbents, in order to verify their efficiency in Methylene Blue (MB) dye decolourization from water under different optimized conditions in the laboratory.

2. Materials and methods

2.1. Preparation of the adsorbents

The adsorbents used in this study such as coconut fibre, banana fibre, and sawdust were collected from nearby area of Vellore district, Tamil Nadu, India. The above-mentioned fibres were cut into 1 cm length, and they were washed and soaked overnight in water to remove the soluble particles, grinded and dried at 105˚C temperature for 48 h to remove moisture content.

2.2. Preparation of dye solution

The MB dye used in this study was supplied by Merck India private limited. The stock solution of 1,000 mg l^{-1} was prepared. The experimental solution was prepared by diluting the stock solution with distilled water when necessary.

2.3. Optimization of initial dye concentration for adsorption

The MB dye was prepared at different concentrations from 50 to 1,000 mg l^{-1} (between 50 mg l^{-1} concentration intervals), and 1 g of each adsorbent was added in 100 ml of different concentrated dye solution and kept at 25 on a rotary shaker (150 rpm) for 24 h. After 24 h, the OD values were noted at 668 nm in spectrophotometer. The standardized dye concentration was subjected to optimize the pH, temperature, adsorbent dosage and contact time [16].

2.4. Optimization of pH, temperature, adsorbent dosage and contact time for the removal of MB

For optimization, one parameter at one time method was followed; to optimize the removal of MB from water by adsorbents, the concentrated dye was prepared by adjusting different pH (3.0, 5.0, 7.0, 9.0, and 11) using NaOH and HCl, temperature (25, 30, 35, 40, and 45˚C), adsorbent dosage (1, 3, 5, 7, and 10%) and different contact time (30, 60, 90, 120, 150, 180, and 210 min).

2.5. Desorption

The desorption process is carried out by using 1% NaOH solution to desorb the dye MB from the used adsorbents to regenerate the dye for reuse.

In all the experiments the percentage (%) of dye removal was calculated by using the following formula.

$$R = \frac{(C_0 - C_\varepsilon)}{C_0} \times 100\%$$

where C_0 and C_ε are the initial and the final dye concentrations [17].

3. Results and discussions

Removal of dyes using waste material is a novel approach, and it is considered to be relatively superior to other techniques due to its low cost and availability

[18,19]. For the purpose of removing unwanted deleterious compounds from impure water at a low cost, much consideration has been focused on various naturally occurring adsorbents such as chitosan, zeolites, fly ash, coal, paper mill sludge and various clay minerals [20]. Use of commercially available and cheaper waste material as adsorbents for the removal of dyes from wastewater is an emerging trend in bioremediation. The present study investigated the adsorption of MB in different concentrations using three different low-cost adsorbents. Three different adsorbents, viz. banana fibre, coconut fibre, and sawdust taken for the removal of MB from water at various concentrations revealed that the percentage of dye removal was found to be better in 1% of adsorbent in 250 mg l^{-1} concentration. The maximum dye removal was observed in coconut fibre 96%, followed by sawdust 89% and banana fibre 85%. The dye removal rate decreased beyond 250 mg l^{-1} of MB concentration in all the experiments (Fig. 1). The 250 mg l^{-1} concentration of MB solution was preferably chosen for optimization process. Similar reports were made previously; orange peels have lesser efficiency in dye removal compared to tamarind shell [15]. Dehydrated wheat bran has shown to adsorb MB [21].

The pH is one of the most important factors controlling the adsorption of dye on to the adsorbent. The effect of pH can be explained considering the surface charge on the adsorbent material [22]. In this study, the dye solution (250 mg l^{-1}) pH was adjusted to different levels (3.0, 5.0, 7.0, 9.0, and 11), to determine the dye removing capacity of different adsorbents. The maximum dye removal was observed in pH 7, and coconut fibres decolorized 99.5% of dye from the water followed by sawdust (98%) and banana fibre (96%) (Fig. 2). Hameed et al. [23] studied the adsorption of MB dye as a cationic dye by banana stalk and

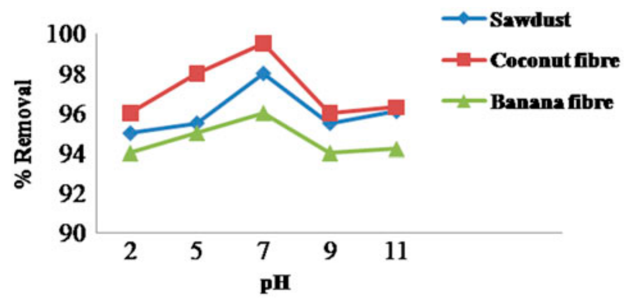

Fig. 2. Decolourization of MB dye at different pH.

they found that the adsorption of MB was at minimum pH 2 and maximum at pH 4.

Temperature plays an important role in adsorption process, because change of temperature will change the equilibrium capacity of the adsorbent for particular adsorbate [24]. While optimizing at different temperatures, the decolourization was shown to be high at 40°C by all the adsorbents (Fig. 3). The dye removal increased from 25°C and it was maximum at 40°C. The coconut fibre decolorized 97% of dye while sawdust and banana fibre 95 and 90%, respectively. Similar results were observed by previous authors when they hardened with bamboo-based activated carbon [25]. Temperature effect may be due to an increase in the mobility of the dye molecules and an increase in the number of active sites for the adsorption with increasing temperature for each dye class [26]. It also decreases the adsorption capacity with increasing temperature indicating that the adsorption is exothermic [27].

Three different adsorbents were individually added at different dosages (1, 3, 5, 7 and 10%), and the dye decolourization results were noted. The removal efficiency was increased up to 3.0 g, and there

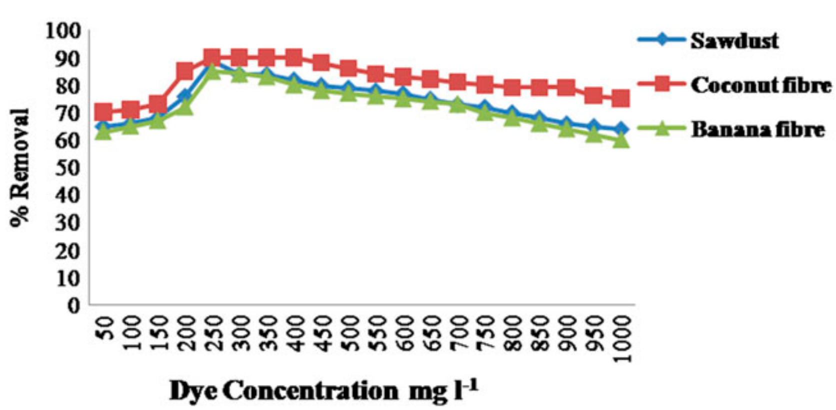

Fig. 1. Decolourization of different concentration of MB dye.

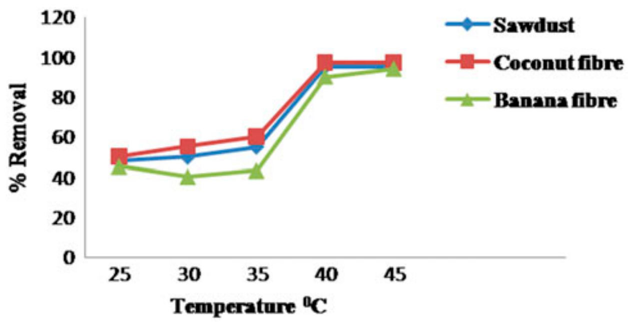

Fig. 3. Decolourization of MB dye at different temperature.

was no change in absorbents activity beyond than 3 g. It infers that 3% is the threshold limit of adsorption and higher saturation of dye beyond that inhibits the process of dye adsorption due to clustering effect of molecules. Among the three adsorbents, the coconut fibre decolourized 97% of dye, sawdust 92% and banana fibre 90% (Fig. 4). The variation in adsorption and adsorbent dosages could be related to the type of surface group responsible for the adsorption of metal ions from solution [19]. Similarly, the previous authors Sonawane and Shrivastava [28] also deliberated that the effect of adsorbent dose on the removal of malachite green by maize cob and they reported that at 20 mg l^{-1} of dye, pH of 8 and a contact time of 25 min, the increase of percentage of dye removal from 90.0 to 98.5% when the adsorbent dose increased from 0.5 to 12 g l^{-1}.

Moreover, checking the exact contact time for the removal of MB dye (250 mg l^{-1}) from water by three different adsorbents, the experiments were carried out up to 210 min. During the experiments, the water sample from all the experiments were randomly taken at every 30 min time intervals, and the percentage of dye removal was calculated. All the three adsorbents have shown a maximum decolourization at 120 min and the percentage of dye removal was found to be constant in all the experiments after 120 min (Fig. 5). Among the three adsorbents, the coconut fibre decolorized 96% of dye followed by sawdust 93% and banana fibre 89% within 120 min. The results showed comparatively better results from previous studies, because in their studies they observed the adsorption of MB by wheat shells at 130 min and by phoenix trees leaves at 130 min [29,30].

In order to regenerate the adsorbent and recovering the adsorbed dyes, the desorption process is necessary. In general, the desorption rate is proportional to the driving force, and desorption kinetics is very important for the contaminant transport modelling [31–33]. This process is usually done by mixing a suitable solvent with the dye-saturated substrate and shaken together until the dye is absorbed onto substrate and then using filtration the adsorbent is separated. It is dried and the desorbed dye is then determined in Spectrophotometer [34]. In this study, while desorbing the adsorbed dye from all the adsorbents, the maximum dye was desorbed from coconut fibre, sawdust and banana fibre, respectively (Fig. 6). Similarly, Robinson et al. [34] studied desorption of cibacron red from corncob using mixture of methanol, chloroform and water, and they found that the maximum value of desorption was 93%. Won et al. [35] also studied desorption of Reactive black 5 from Corynebacterium and Glutamicum waste biomass, and they reported that the desorption efficiency was lower at almost 80% compared to 100% of adsorption efficiency. Recently, Kumar and Ahmad [36] have studied the desorption of crystal violet dye from ginger waste and they found that NaOH and H2O did not show any desorption while acetic acid desorbed about 35–50% of dye. Similar results were observed by Mahmoodi et al. [37] when desorbing three textile dyes from pinecone and they concluded that the maximum desorption for Acid black 26, Acid green 25, and Acid blue 7 were 93.16, 26.97 and 98%, respectively.

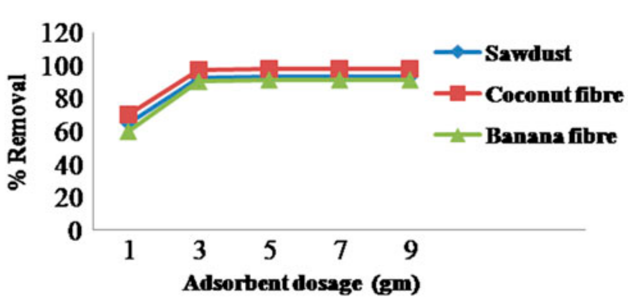

Fig. 4. Decolourization of MB dye by dosages of adsorbents.

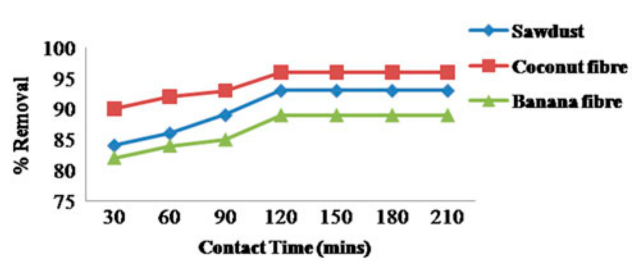

Fig. 5. Decolourization of MB dye at different contact time by adsorbents.

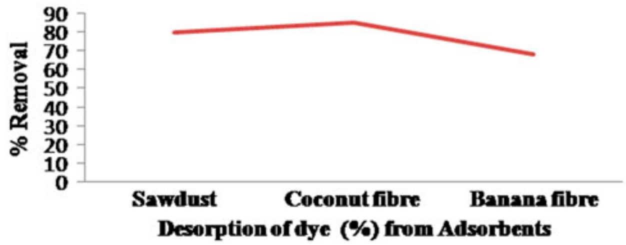

Fig. 6. Desorption of MB dye from the adsorbents.

4. Conclusion

The results of the study concluded that the coconut fibre is more effective in removal of MB from the water and represents commercially available, inexpensive, biodegradable and ecofriendly adsorbent for dye removal in industries. The temperature, pH and concentration of the dye are limiting factors to the adsorbents.

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