Adsorptive removal of Eosin yellow dye from aqueous solutions using *Pennisetum glaucum* as a low-cost and green biosorbent

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Abstract

Clean water is essential to both human and environmental survival and has a major positive impact on a nation's rapidly expanding businesses. Nevertheless, the availability of pure water had decreased since contaminants like dyes had a detrimental effect on the primary water sources that were pure and clean. Biomass waste is widely available and has been researched as an inexpensive biosorbent for waste water dye sequestration in recent years. Adsorbents made from biomass waste are environmentally friendly, economically viable, and have a remarkable ability to remove colors. Despite its proven toxicity and carcinogenicity, eosin yellow is widely utilized as a coloring in many different applications. The plant waste *Pennisetum glaucum* were applied as potential adsorbent for the removal of Eosin yellow from aqueous solutions. Different characterization approaches were used to investigate the physicochemical properties of adsorbents. Using artificial aqueous solutions, batch adsorption studies were carried out to examine the effects of initial dye concentration, initial solution pH, initial adsorbent dose, and temperature. With the use of several models, the kinetics, equilibrium, and thermodynamics of the adsorption process were also analyzed.

Introduction

Globally, about 10,000 dyes are available whose annual production is above 7×10^5 tons which are used in textile, paper, food, and pharmaceutical industries to colour their products. Out of the total annual dye consumption in textile industry about 10-15% of them are being discharged as waste into the environment. In India, textile industries have been consuming more than 100 L of water for processing of 1 kg textiles and as a result, they discharge considerable amount of coloured wastewater which is responsible for pollution of surface and ground water resources in many regions of the country. Considering this aspect, different conventional and contemporary techniques such as photocatalysis, electrochemical degradation, coagulation-flocculation, adsorption, ozonation, membrane filtration, oxidation processes etc. have been reported for the elimination of dyes. Among these methods, adsorption with biomass-based green adsorbents is considered as the efficient method for the elimination of dyes from wastewater due to its merits of operational simplicity, cost-effectiveness, ability to adsorb wide pollutants, no secondary-pollution, simple regeneration and environmentally benign nature.

EXPERIMENTAL SET UP

2.1. Preparation of adsorbent

Raw PG adsorbent was prepared via washing, peeling, drying and grinding of PG stems. The stem powder was sieved through 120 BSS mesh and ball milled.

2.2. Characterization of adsorbent

Fourier transform infrared spectroscopy was used to investigate the surface functional groups. Adsorbents morphology was studied with FESEM. The thermal stability of composite was studied by thermo-gravimetric analysis by heating it at 15 °C per minute. X-ray diffraction (XRD) analysis was performed in the 2θ range from 10° to 60°.

2.3. Batch adsorption studies

Batch adsorption studies were performed to evaluate the effect of various factors such as pH, dosage, concentration, temperature and contact time. For kinetic and thermodynamic studies, fixed amount of the adsorbent was added to 10 mL of dye solution having an initial concentration of 75 mg/L, and the residual concentration of the supernatant was evaluated by a UV-visible spectrophotometer(at wavelength 535 nm) at predetermined intervals ranging from 0 to 35 min. Adsorption isotherm was studied with Freundlich, Langmuir, Temkin and D-R models at 30˚C. The quantity of each dye adsorbed by PG was calculated as:

Removal (%)= $(C_o-C_e)/C_o \times 100$

Adsorption capacity at equilibrium, q_e(mg/g)= $((C_o-C_e)\times V)/m$

Adsorption capacity at any time t, q_t(mg/g)= $((C_0-C_t)\times V)/m$

Where, C_e, C_o and C_t are equilibrium, initial and concentration of dye at time, t respectively; m represents the amount of adsorbent in g and V is the volume of solution in L.

Results and Discussions

3.1. Characterization of adsorbent

FESEM image of PG revealed the porous structure which was mainly responsible for the dye adsorption. FTIR technique was applied to identify the surface states of raw PG as shown in **Figure 3**. A broad peak at 3400 cm^{-1} was observed in the case of raw PG corresponding to the -OH stretching of cellulose and lignin. The presence of a peak at approximately 2915 cm^{-1} was due to the methylene group C-H, the peak at 1733 cm^{-1} was attributed to C=O stretching in ester or acetyl groups of lignin and hemicellulose. The raw PG adsorbent shows two diffraction peaks at 16˚ and 22˚, with the shoulder peak having less intensity and the second peak with a higher intensity which corresponds to the amorphous fraction of the cellulose and crystalline form of cellulose respectively. The DSC curves for PG depicts two exothermic peaks at nearly 283˚C and 360˚C. The isoelectric point of the adsorbent obtained from pH-drift experiment was found to be 6.54.

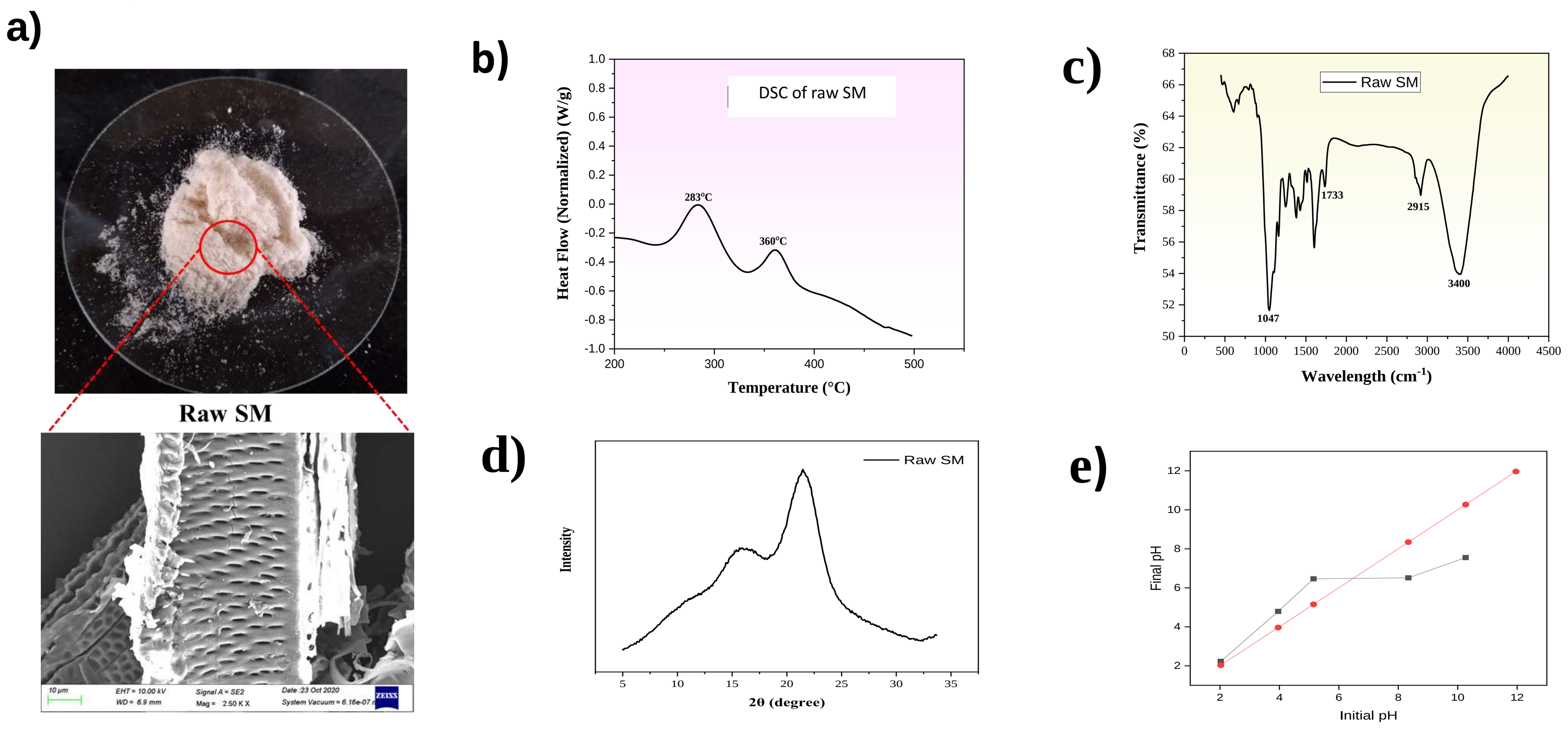

Figure 3- Characterization studies

3.2. Batch adsorption studies

The adsorptive behaviour of the raw PG for the removal of Eosine yellow dye was studied between pH 1 to11 as shown in **Figure 4a**. The adsorption of PG dye was favourable under acidic conditions.

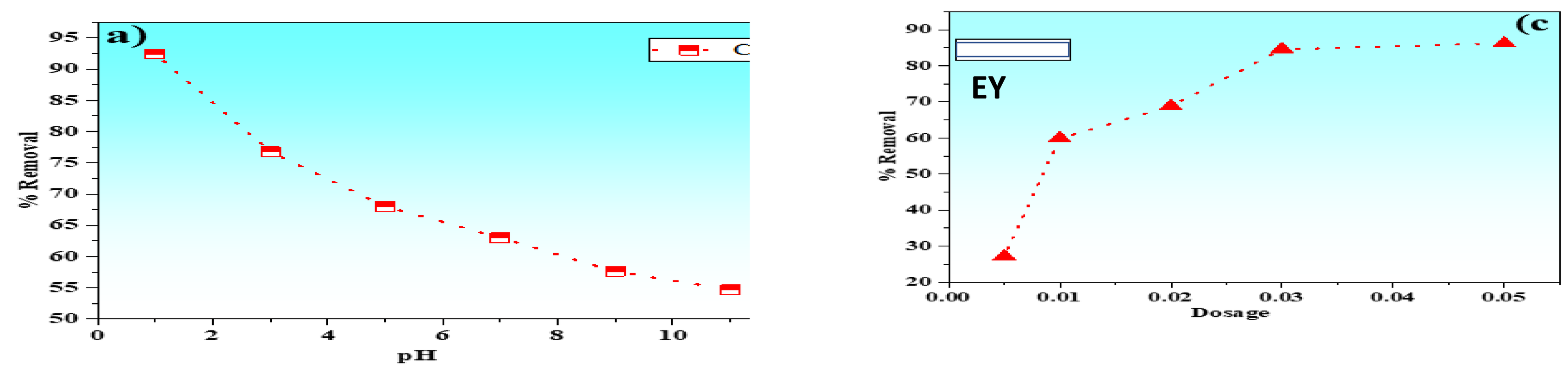

Figure 4 a) Effect of pH on dye adsorption and b) Effect of dosage

Table 1- Thermodynamic and Kinetic studies

Thermodynamic parameters				
ΔG (kJ/mol)			ΔS (J/mol K)	ΔH (kJ/mol)
303K	313K	333K		
-2.987	-2.814	-2.552	-39.367	-20.130
Pseudo-second-order kinetic parameters				
K_2			q_e (mg/g)	
0.063			113.895	

CONCLUSIONS

- ***Pennisetum glaucum*** biosorbent was very effective for the removal of hazardous Eosin yellow dye.
- Experimental data was well fitted with **pseudo-second order kinetics** and thermodynamic studies revealed **spontaneous and exothermic nature** of adsorption.
- PG showed significant adsorption efficacy up to **five adsorption-desorption cycles**, and the desorbed dyes were recovered making the whole process eco-friendly.

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