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Removal of Artificial Dye Solution of Brilliant Green Over a Low-Cost Physically Activated Carbon Prepared from Coconut Shell by Adsorptive Technique

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Abstract

The textile effluents are toxic compounds, has a significant negative consequence on the environment, especially during its discharge in water and soil. The present work, physically activated carbon (PAC) is a low-cost effective adsorbent used to adsorb dyes from waste water because of its high adsorption abilities. The batch experiment was investigated by different variables like contact time, dye concentration, dosage of activated carbon, temperature, pH, agitation speed, activation time and desorption studies. At optimum experimental conditions, maximum removal of Brilliant Green (BG) dye has been observed to be 99%. The different adsorption isotherms were modelled to describe the equilibrium data. The adsorption data were analyzed using kinetic and diffusion models. On the basis of experimental results, the physically activated carbon showed excellent sorption properties with high dye removal capacity.

Keywords: Adsorption; Brilliant green dye; Physically activated carbon; Dye removal

Introduction

Environmental pollution is a major problem throughout the world. Most of the synthetic dyes used for colourisation in different industries like textile, leather, paper, plastic and dyeing, accumulate in the environment and have highly harmful effects causes either to human beings or to aquatic life [1]. Thus, the disposal of dyes and pigments into aqueous environment is a main serious environmental problem, making discharge of highly coloured compounds from wastewater. Various treatment methods available for the removal textile dyes from their effluents. They are broadly classified under three categories: physio-chemical and biological methods. Adsorption is an attractive method for treating textile effluents. Although many alternative adsorbents such as Polymer composites, biomass adsorbents, layered double hydroxide, carbonized materials are available for application dye removal process. Among these PAC is found to have high adsorbing nature due to high surface area, micro-porous tight structure and provide good mechanical strength and hardness. Literature survey shows that only few works regarding the use of PAC from coconut shell, for the removal of dyes from textile effluents. In this study is to evaluate adsorption process of BG dye using PAC.

Materials and Methods

The dye concentrations were measured using ELICO SL 27 VIS Spectrophotometer. Brilliant Green (BG) is used in the adsorptive technique was obtained from HI media laboratory pvt ltd, Mumbai. The coconut shells were received from domestic waste.

Experimental methods

Preparation of Physically Activated Carbon (PAC): The coconut shell was carbonized in Bunsen burner. The carbonized substance was ground, dried at 105°C for 2 hrs and used for all adsorption experiments.

Preparation of stock dye solution: A stock solution was prepared by dissolving the appropriate amount of BG in 100 ml using distilled water.

Adsorption studies: The concentration of BG dye solution was measured by using Elico Spectrophotometer at λ_{max} of 625 nm. Batch mode adsorption experiments were agitated in REMI orbital shaker at 250 rpm using 250 ml pyrex bottles at room temperature for 70 min. The PAC was thoroughly mixed with 100 ml of BG dye solutions.

Adsorption experiments permit convenient evaluation of influence of variables like contact time (0-70 min) (Figure 1), initial dye concentrations (5-15 mg/L) (Figure 2), dosage of physically activated carbon (0.5-1.5 g/L), temperature (34-40°C), pH (4-9 pH), agitation speed (50-250 rpm) (Figure 3), activation time (1 and 2 hrs) and desorption study have been analyzed [2,3].

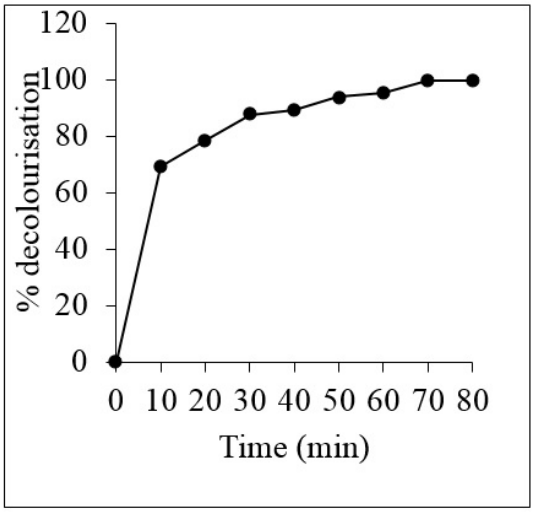

Figure 1: Variation of contact time.

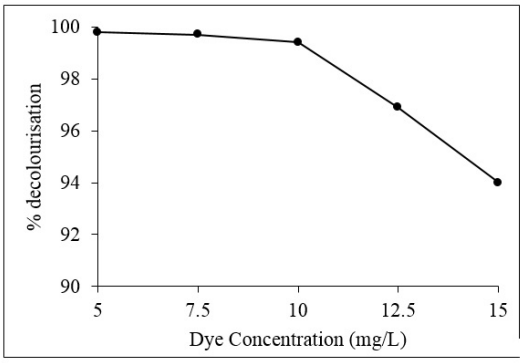

Figure 2: Variation of initial dye concentrations.

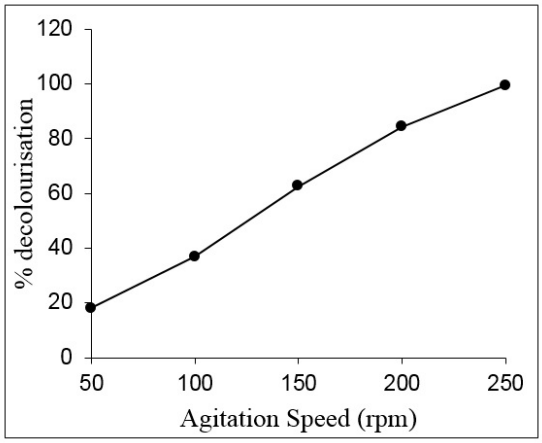

Figure 3: Variation of agitation speed.

Results and Discussion

Adsorption isotherm studies: The experiment was conducted at different contact times (10-70 min) for equilibrium study of adsorption of BG onto PAC. The equilibrium data were analyzed with the Freundlich, Langmuir, Dubinin-Radushkevich, Temkin, Jovanovic, Scatchard and Flory-Huggins adsorption isotherm models.

Freundlich isotherm: The Freundlich isotherm is used to find the interaction between solute (dye molecule) present in the liquid phase and surface of the adsorbent [4].

The linearized expression of Freundlich isotherm as follows:

$\ln q_e = \ln K_f + 1/n \ln C_e$

q_e: amount of dye adsorbed (mg/g); K_f and n: Freundlich constants.

Langmuir isotherm: Langmuir isotherm is explained dye molecules in bind with adsorbent surface at optimum temperature [5] (Figure 4).

The linear equation of Langmuir isotherm is mentioned by:

$C_e/q_e = (1/Q_0 b) + C_e/Q_0$

Q_0 and b are Langmuir constants.

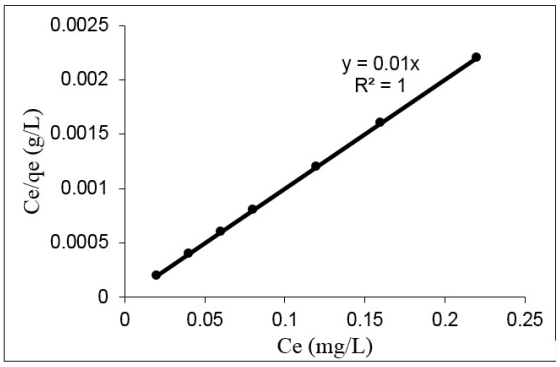

Figure 4: Langmuir isotherm.

Dubinin-Radushkevich model: The Dubinin-Radushkevich model is used to describe the characteristics porosity of the adsorbent and apparent energy of adsorption [5].

The linear of Dubinin-Radushkevich equation is shown below:

$\ln q_e = \ln q_D - 2B_D RT \ln (1+1/C_e)$

B_D: free energy of sorption; q_D: Dubinin – Radushkevich isotherm constant.

Temkin isotherm: Temkin isotherm is assumed by the ratio between the heat of adsorption and adsorbent surface coverage [5].

The Temkin isotherm is mentioned by the following linear equation

$q_e = B_T \ln K_T + B_T \ln C_e$

K_T: equilibrium binding constant(L/mg); B_T: variation of adsorption energy (KJ/mol).

Jovanovic isotherm: Jovanovic model is specified the adsorption behaviour on heterogeneous surfaces [6].

The linear equation of Jovanovic isotherm is

$\ln q_e = \ln q_m - K_J C_e$

q_m and K_J: Jovanovic constants.

Scatchard analysis: Scatchard analysis is employed to analyze the binding isotherm of adsorbate and adsorbent [7].

The Scatchard equation can be represented as

$Q/C = Q_{max}/K_d - Q/K_d$

Q: Equilibrium adsorption amount at each concentration; Q_{max}: maximum adsorption amount; K_d: equilibrium dissociation constant at binding sites.

Flory-Huggins isotherm: Flory-Huggins isotherm is the model describing the quantity of surface coverage of dye molecule onto adsorbent [5].

The linear plot of Flory-Huggins equation as follows

$\log(\theta/C_0) = \log(K_{FH}) + n_{FH} \log(1-\theta)$

K_{FH}: Flory-Huggins equilibrium constant; n_{FH}: model exponent; θ: degree of surface coverage.

The slope and intercept values for all adsorption isotherm models are listed as follows in Table 1.

Name of the isotherm	Slope	Intercept	R2 value
Freundlich	n=121.9512	K_f=20.6777	R^2=0.8903
Langmuir	Q_0=100.0000	b=0.0050	R^2=1.0000
Dubinin-Raduchkevich	B_D=1.5000	q_D=6.7957	R^2=0.8739
Temkin	b=3156.2	A=83.5708	R^2=0.8914
Jovanovic	K_J=0.1016	q_{max}=20.6733	R^2=1.0000
Scatchard	K_d=0.0200	Q_{max}=0.0400	R^2=1.0000
Flory-Huggins	n_{FH}=0.0911	K_{FH}=1.4073	R^2=0.8718

Table 1: The slope and intercept values for all adsorption isotherm models.

Adsorption kinetics:

The kinetics of decolourisation of BG solution over PAC has been analyzed using pseudo-first and pseudo-second order kinetic models [8].

Pseudo-first order kinetic model: Pseudo-first order model is represented by Lagergren as:

$dq_t/dt = k_1 (q_e - q_t)$

q_e: adsorption capacity at equilibrium; q_t: adsorption capacity at time t; k_1: pseudo-first order rate constant.

After integration, the above equation becomes:

$\text{Log}(q_e - q_t) = \log q_e - k_1 t/2.303$

Pseudo-second order model: Pseudo-second order kinetics is derived as

$dq_t/dt = (q_e - q_t)^2$

After integration, the form of rearranged equation (Figure 5) is

$t/q_t = 1/k_2 q_e^2 + t/q_e$

k_2: pseudo-second order rate constant.

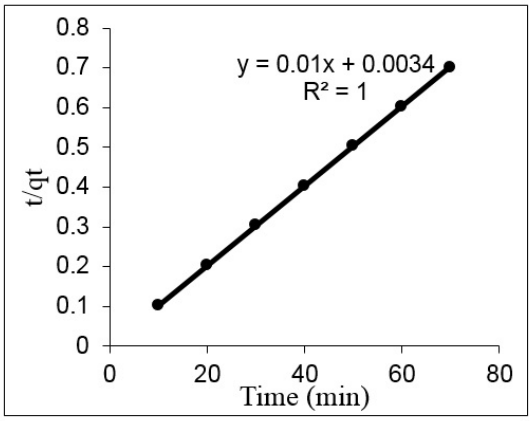

Figure 5: Pseudo-second order kinetic model.

Diffusion studies:

Weber and Morris intra-particle diffusion model: Weber-Morris intra-particle diffusion model is mainly used to explain the diffusion mechanism [9]. The Weber-Morris intra-particle diffusion equation is represented as

$q_t=K_d \sqrt{t}+C$

q_t: amount of sorbate on the surface of the sorbent at time t; K_d: intra-particle diffusion rate constant; C: constant

Adsorption thermodynamics studies: The Van't Hoff equation is derived the relationship between the Gibbs free energy change of adsorption and equilibrium constant [7,10].

The expression is

$\Delta G°=-RT \ln K_L$

K_L: equilibrium constant; T: temperature (Kelvin); R: gas constant (8.314 J/mol/K).

The relationship between the Gibbs free energy change, entropy (ΔS °) and enthalpy (ΔH°) can be represented as follows $\Delta G°=\Delta H°-T\Delta S°$

ΔS° and ΔH° could be calculated from the slope and intercept of the plot respectively. The negative value of ΔG°(-1.7692) and ΔH°(-1.7520) indicate that the process is spontaneous and feasible process and exothermic nature of the adsorption. The negative value of ΔS° (-0.0173) suggests that the process is enthalpy driven.

Conclusion

In this study, PAC was derived by simple process and used for the adsorption of BG from water. Maximum adsorption efficiency of PAC for BG at the equilibrium time of 70 minute was 99.4%. The adsorption rate was increase with increase in contact time, dosage of sago, temperature, agitation speed, activation time and decrease in initial dye concentration. The equilibrium data was better fitted by Langmuir isotherm model than other isotherm models. Equilibrium parameter RL value was calculated as 0.9592 for Brilliant Green. This indicates that adsorption is a favorable process. The adsorption data was follow pseudo-second order kinetics and also fit into Weber-Morris intra-particle diffusion model. In thermodynamics parameters, as the negative value of ΔG° and ΔH° indicate that the adsorption process was spontaneous, feasible process and exothermic in nature. The negative value of ΔS° reveals that the process is enthalpy driven. The present work has proved that PAC prepare from coconut shell could be used as an efficient adsorbent for the removal of BG dye from aqueous solution. Moreover, the use of PAC prepared from coconut shell as adsorbent could contribute not only to solve the environmental pollution but also to decrease the overall cost of wastewater treatment and to minimize the quantity of agricultural byproducts.

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