Linear versusNon-linear Adsorption Kinetics of Methylene Blue on Raw and Chemically Activated Sawdust

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Abstract: The kinetic analysis of Methylene blue adsorption on raw and activated sawdust was studied using pseudo-first, second, arbitrary nth order and intra-particle diffusion models. Comparisonof thekinetic parameters obtained from a linear and non-linear regressionwas performed.The coefficient of determination(R^2) from linear regression was complimented with the sum of squares due to errors (SSE) to choose the best fits.The obtained parameters were used to construct adsorption curves.Interestingly, it was revealednon-linear regressionrenders parameters with lower SSE compared to the ones derived from linear regression.Chemical activation of sawdust improved adsorption capacity of dye. A negative influence of the temperature was revealed on theadsorptioncapacity when raw sawdust was used while activated sawdust was insensitive to the change in temperature. The effect of initial dye concentration, contact time, the temperature has been systematically investigated using response surface methodology.

Keywords: Methylene blue; Sawdust; Adsorption; Kinetics;Response surface methodology

Introduction

The textile industry is one of the biggest consumers of water. Dyeing and finishing are the main operations where a large amount of wastewater containing mainly spent dyes is generated. Most of the dyes used in the textile industries are hazardous to the living beings and hence pose great threats to the plants, humans, animals and marine life if go untreated. Dyes are complex non-degradable chemicals. Waste biomass such as sawdust is a cheap material and owing to its exceptional adsorption properties; it can become a potential candidate for the removal of contaminants from wastewater (Bello et al., 2013; Cardoso et al., 2011; Janoš et al., 2009). In this study, raw and chemically activated sawdust were compared for their ability to remove Methylene blue dye from wastewater.

Materials and Methods

Methylene blue, a basic azo-dyeof analytical grade, with anempirical formula of$C_{16}H_{18}ClN_3$Sand concentratedsulfuric acid used in this study were purchased from Sigma-Aldrich. Sawdust was obtainedfrom the local timber market.The chemical activation was performed by combining 3 parts of sawdust with 4parts of concentrated sulfuric acidby weight and left in an airtightoven at 150 °C for 24 h.The carbonized sawdust was then washed, dried, and grounded for further use as chemically activated sawdust.The otherportion (sawdust)was washed/ treated with distilled water and formaldehyde in series. It was then dried in an oven for 24h at 60°C and then pulverized to obtaina similarparticle size fraction as that of activated sawdust.

Results and Discussions

Pseudo-first order model has been widely used for adsorption kinetics. Linear regression lines fitted on the plot of $\ln(q_e - q)$vstfor raw and activated sawdust are shownin

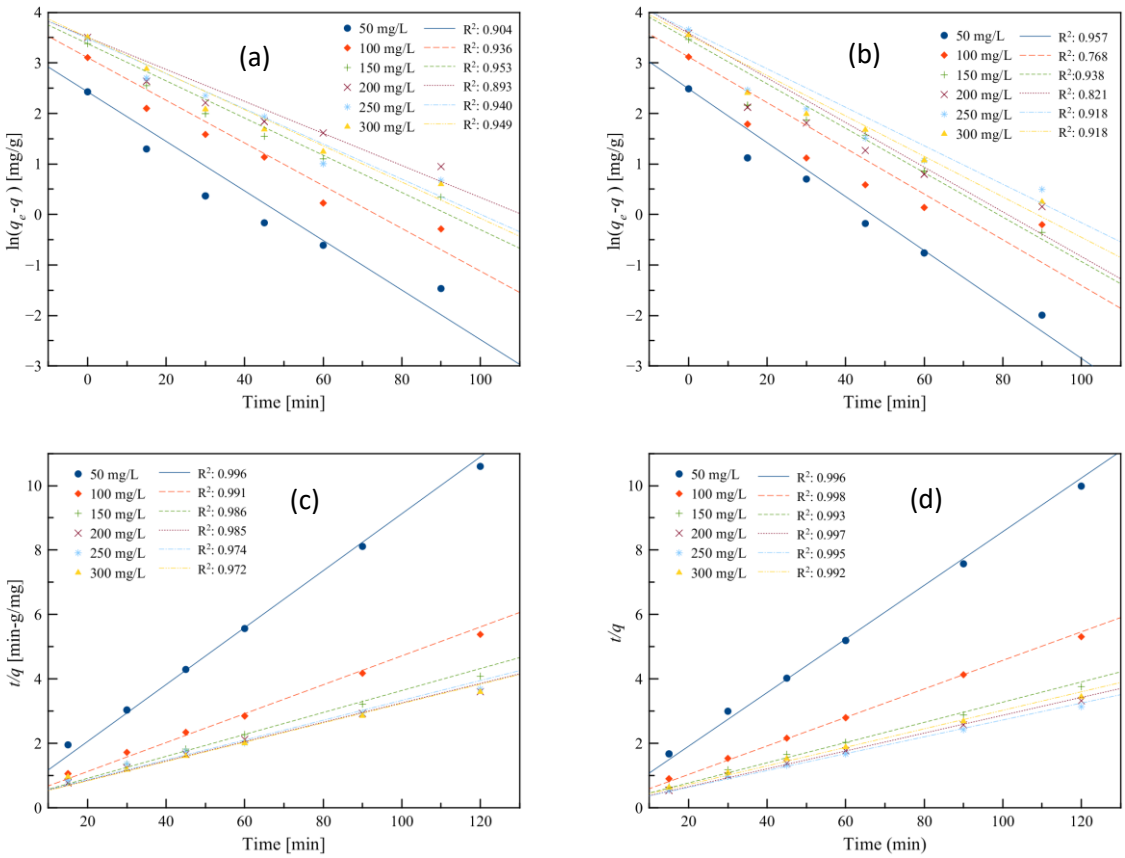

Figure 1 (a & b).The values of pseudo-first-orderrate constants calculated from the slopes of the curves for raw and activated sawdust are given in

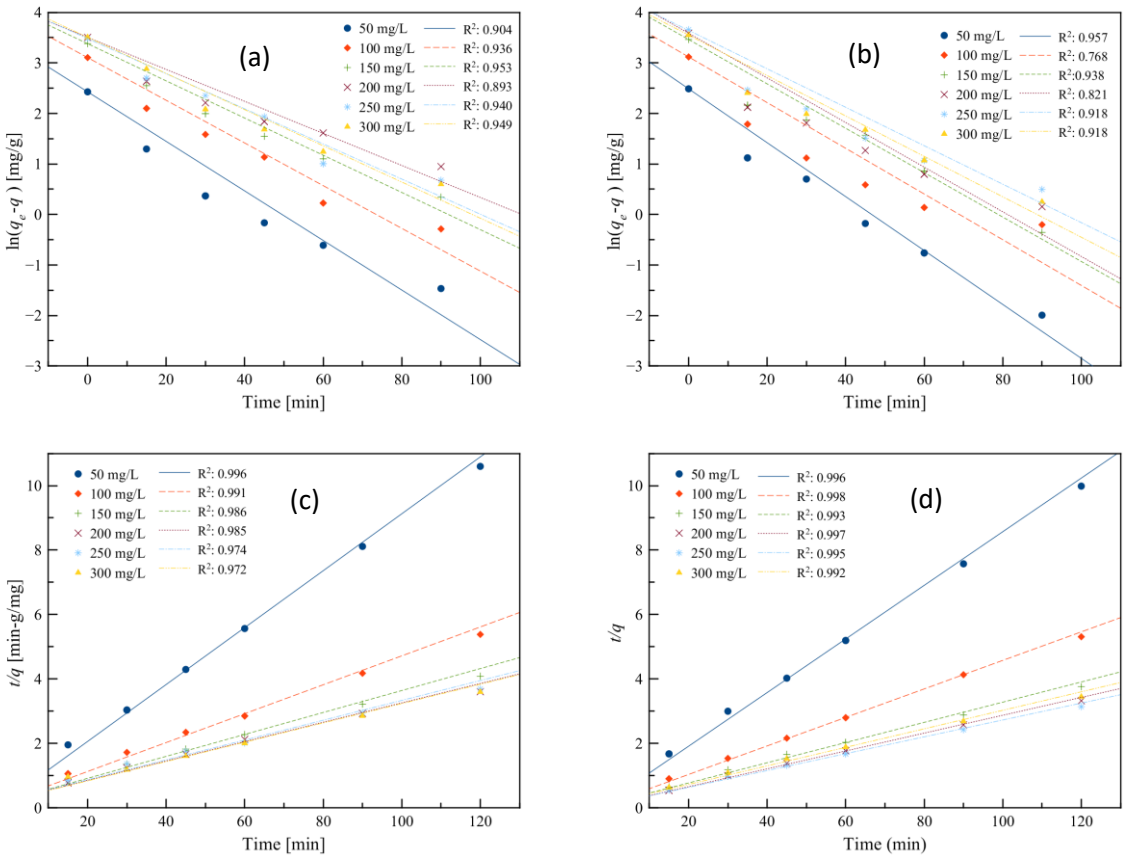

Figure 1 (a & b).Many researchers to study the adsorption kinetics have recently used the pseudo-second-order model. The $\frac{t}{q}$is plotted againstt and fitted with linear regression lines.

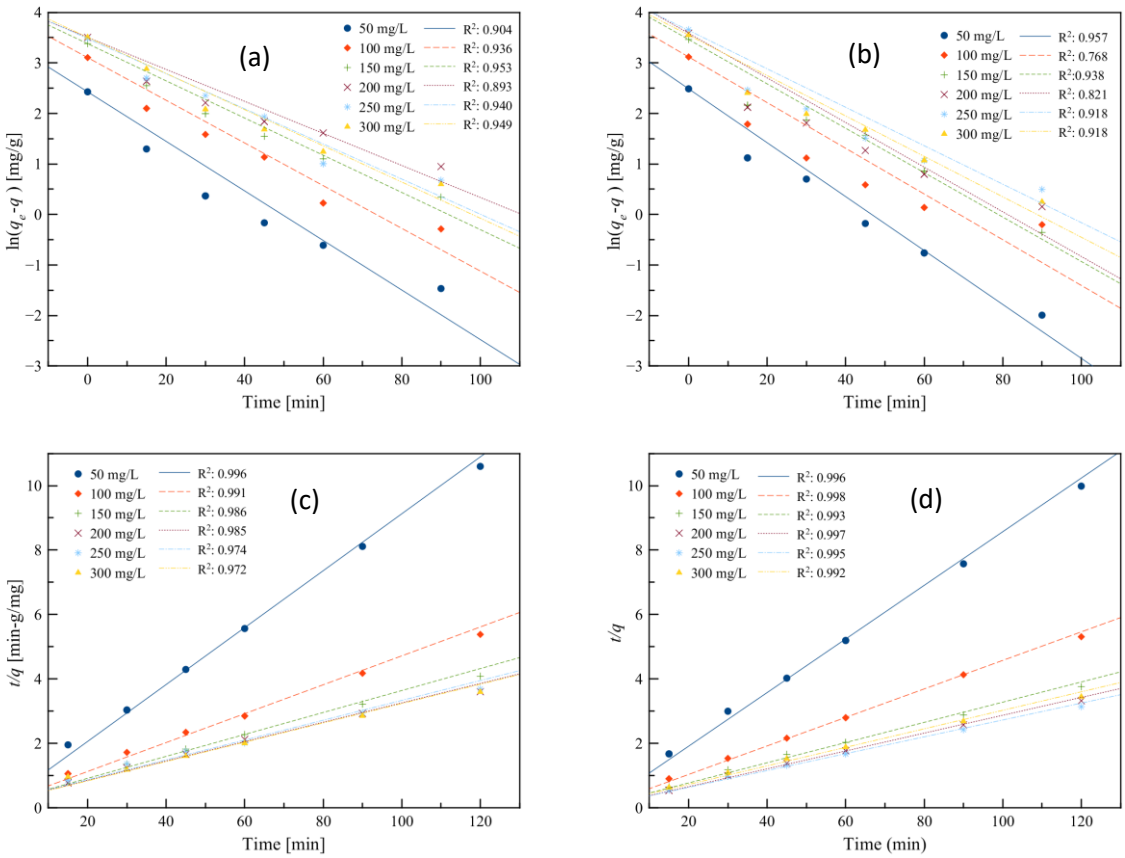

Figure 1 (c & d) represents the pseudo-second order adsorption plots for raw and activated sawdust.

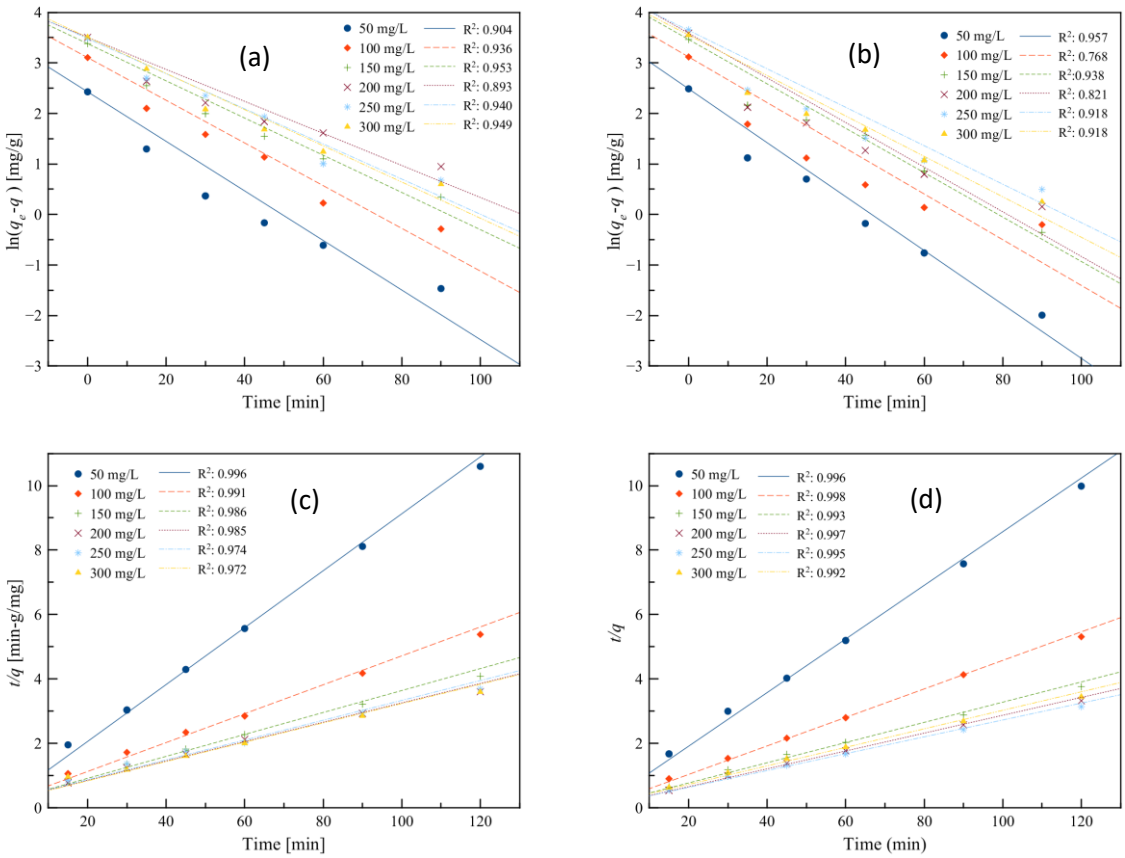

Figure 1: Pseudo-first (a & b) and pseudo-second order (c & d) linear plot for (a& c) raw and (b& d) activated sawdust at various initial Methylene blue concentrations and ambient temperature

The data fits quite well at all concentrations with varying time for both raw and activated sawdust. The pseudo second-order rate constants (k_2) for raw and activated sawdust were used.It is evident from that the value of k_1 decreased from 0.0490 min^{-1} to 0.0317 min^{-1}forraw sawdust when the concentrationwas increased from 50 mg/L to 200 mg/L. Similarly, for activated sawdust, thek_1 value decreased from 0.0534 min^{-1} to 0.0439 min^{-1}as the concentration was increased from 50 mg/L to 150 mg/L. $k_1$values are slighter higher for activated sawdust at the same levels of initial dye concentration. Moreover, R^2 for raw sawdust was higher compared to activated sawdust except at 50 mg/L.

Conclusions

This study shows that sawdust can effectively remove Methylene blue from aqueous solution. Initial dye concentration, contact time, temperature and chemical activation of the sawdust affect the dye adsorption and kinetics. Three-step intra-particle diffusion and arbitrary nth order models show better suitability over pseudo-first and pseudo-second order models. The mechanistic aspect of the kinetic models and comparison of the parameters derived from linear and non-linear regressions is under investigation. The interactions of initial dye concentration, contact time and temperature on the adsorption of the dye with raw and activated sawdust will also be investigated using response surface methodology.

References

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