International Research Journal of Pure and Applied Chemistry

Volume 25, Issue 3, Page 90-97, 2024; Article no.IRJPAC.117000
ISSN: 2231-3443, NLM ID: 101647669

Efficient and Inexpensive Bio Adsorbent for the Removal of Safranine: Kinetic and Isotherm Study

Dhanashri Sharad Badhe [a], Pratiksha Vittal Jagtap [a], Jayant Prabhakar Sonar [a] and Sandeep Dilipsing Pardeshi [a*]

[a] Department of Chemistry, Vinayakrao Patil Mahavidyalaya, Vaijapur, Dist. Chhtrapati Sambhajinagar, 423701, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/irjpac/2024/v25i3859

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117000

Original Research Article

Received: 20/03/2024
Accepted: 25/05/2024
Published: 30/05/2024

ABSTRACT

Alstonia Scholaris leaves after treatment with 0.01 M NaOH was used for the adsorptive removal of safranine. As the initial safranine concentration increases from 20 mg/L to 80 mg/L the dye removal increases up to 91 % in 60 min contact time at optimum pH of 8. Pseudo second order model and Freundlich isotherm was followed by the adsorption experimental data.

Keywords: Adsorption; cotton red; saptaparni; basic red.

**Corresponding author: E-mail: sandeeppardeshi007@gmail.com;*

Cite as: *Badhe, D. S., Jagtap, P. V., Sonar, J. P., & Pardeshi, S. D. (2024). Efficient and Inexpensive Bio Adsorbent for the Removal of Safranine: Kinetic and Isotherm Study. International Research Journal of Pure and Applied Chemistry, 25(3), 90–97. https://doi.org/10.9734/irjpac/2024/v25i3859*

1. INTRODUCTION

India is a developing country and with the development in the industrial sector like paper, pulp, leather and textile, the consumption of synthetic dyes were also increases, though at most care were taken by these industries, some of the dyes and pigments residues likely to be present in the effluents. The presence of synthetic dyes in trace amount can affect the aquatic and human life [1]. Most of the synthetic dyes have carcinogenic and mutagenic effects [2]. Various chemical, physical and biological methods were used to remove hazardous material from water. Due to the non-biodegradable nature of some of the dyes, the microbial degradation methods have limitation [3]. The various chemical and physical methods used for the removal of hazardous material from industrial effluents, some of them are adsorption [4], oxidation, ozonolysis, chemical and photochemical destruction [5], coagulation, filtration. From the above methods adsorption method is mostly applied due its cost effective and simplicity [6]. Activated charcoal is the best adsorbent but it is not cost effective so researcher preferably uses low costadsorbent form the waste material like Gmelina Aborea [7], pomegranate peel [8] mango leaf powder [9].

Alstonia Scholaris is commonly called as saptaparni or devil plants grown in different parts of India and easily available. Safranine is cationic dye used to stain natural fibers like wool, cotton, silk etc.[10]. Safranine can cause some serious health hazard like abdominal discomfort, eye and skin irritation, mouth and throat discomfort. [10,11]. Various adsorbent were reported for the removal of safranine such as Snail Shell [12], soybean hull [13], zeolites [14], red mud [15], Citrus reticulata peels[16] etc. Safranine is a cationic dye also known as cotton red, the specification are given in Table 1.

So in the present adsorption study, the effectiveness of leaves powder after treatment with NaOH was investigated. The data was analyzed for kinetic and isotherm model.

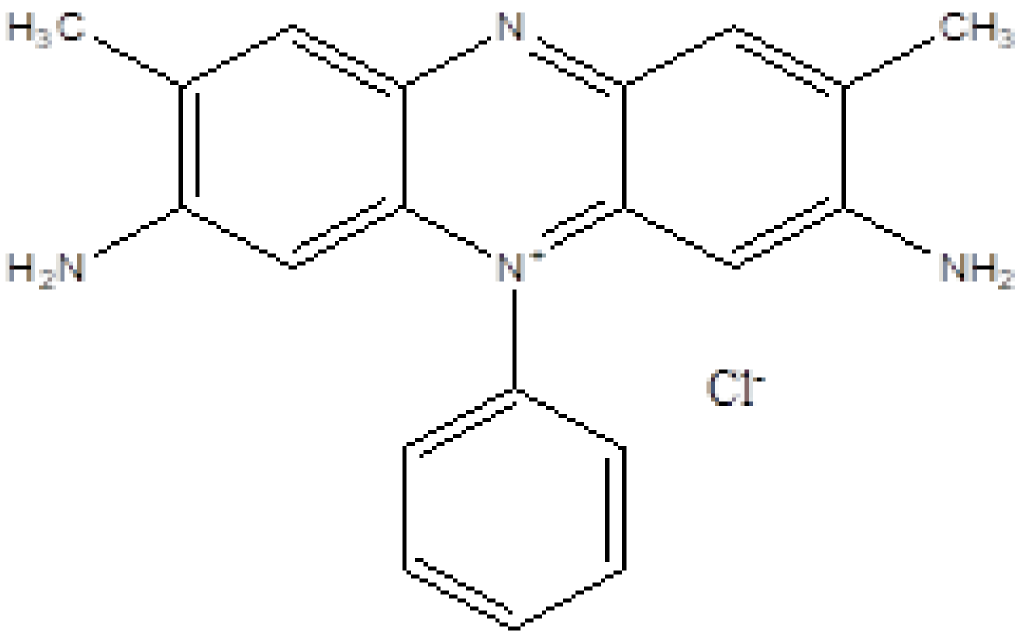

Fig. 1. Chemical structure of safranine

Table 1. Specification of safranine

Molecular Formula	**$C_{20}H_{19}N_4Cl$**
Molecular Weight	350.85
λ max (nm)	521

2. MATERIALS AND METHODS

All chemicals were purchased from Loba Chemie Pvt Ltd. India and were used without further purification. Elico double beam spectrophotometer SL-210 was used to determine the absorbance. Equiptronics pH meter and Remi stirrer was used. 0.1 M NaOH and 0.1M HCl were used to adjust the pH. The dried leaves of Alstonia Scholaris were collected from the institute, grinded and washed with water. The powder was treated with 0.01 M NaOH solution and washed with water till the pH is neutral. The residue was dried in a hot air oven overnight and used for as an adsorbent. By measuring absorption at 521 nm and with the help of standard curve the concentration of Safranine was determined.

The milligram of Safranine dye on adsorbent (q_e) was determined using the following equation:

$$qt = \frac{(C_i - C_t)v}{W}$$

Where C_i and C_t were concentration of Safranine, v is volume of dye solution and w is weight of adsorbent

To determine the optimum condition of adsorption, the adsorption study was performed using batch adsorption method. In this 25 mL dye solution was taken in 100 mL flask and stirred with 0.05 g of adsorbent powder for specific time.

3. RESULTS AND DISCUSSION

3.1 Effect of Initial Amount of Adsorbent

The effect of adsorbent dose was assessed by altering the adsorbent dose from 0.02 to 0.15 g. The result shows that the percentage removal of Safranine increases with increase in the initial amount of adsorbent (77 to 89 %) (as shown in Fig. 2). The increase in the initial adsorbent dose increases the site for adsorption thus increases the percentage removal.

3.2 Effect of Initial pH

The initial H^+ ion concentration (pH) mostly affect the dye adsorption process [17]. It has been observed from experimental result that the increase in pH increases the dye adsorption, this trend is observed up to pH 8, and further increase in pH decreases the removal. (Fig. 3)

3.3 Effect of Initial Dye Concentration and Contact Time

Batch adsorption study was performed by altering initial dye concentration (20 mg/L, 40 mg/L, 60 mg/L and 80 mg/L) and contact time at optimum pH with 0.1 g of adsorbent.

With increase in initial dye concentration and contact time the percentage removal increases up to 91% this may be due to mono layer formation [18].

3.4 Kinetics Studies

The experimental data was studied by applying three kinetic model viz. pseudo first order model, pseudo second order model and Elovich model.

The following equation were used

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303}$$ pseudo first order equation) [18]

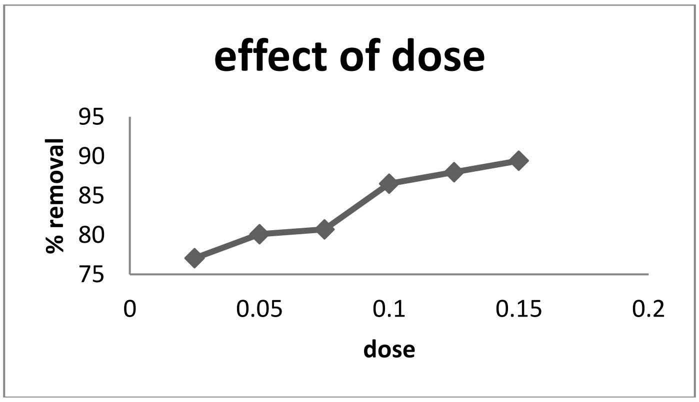

Fig. 2. Effect of amount of adsorbent

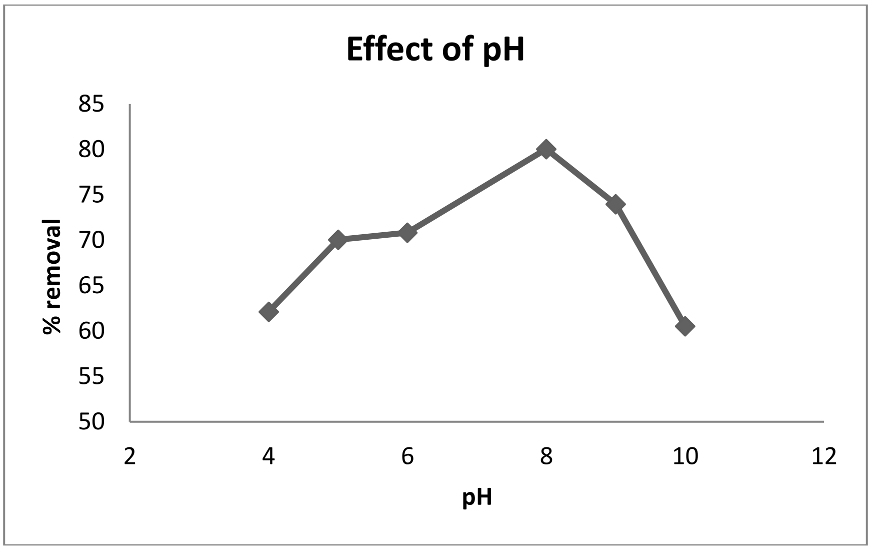

Fig. 3. Effect of initial pH

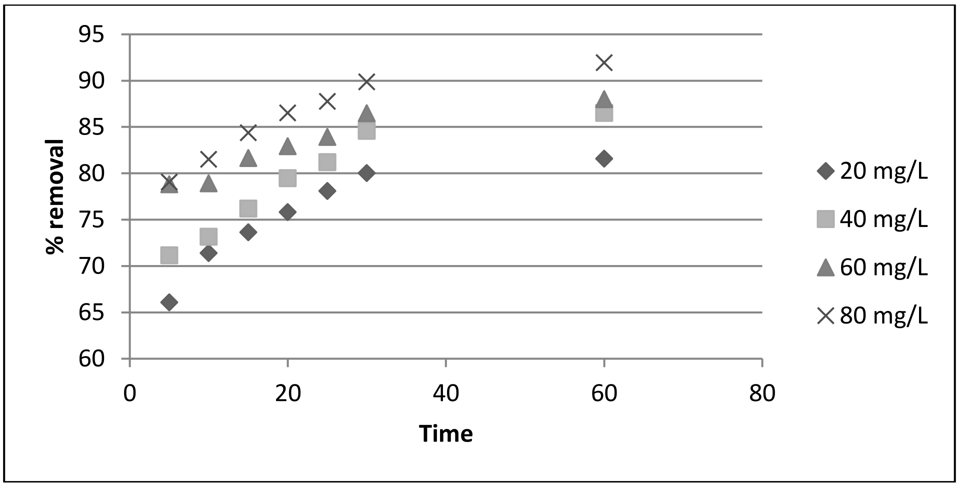

Fig. 4. Effect of initial dye concentration and contact time

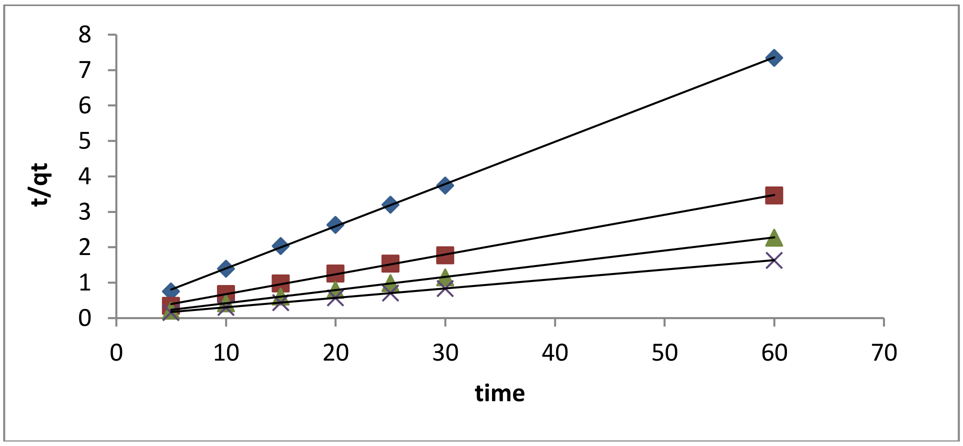

Fig. 5. pseudo second order plot

Table 2. Parameters for pseudo first-order, pseudo second-order adsorption and Elovich model

Dye Conc.	First order				Second order				Elovich model		
(mg L^{-1})	K_1 (min^{-1})	$q_{e(exp)}$ (mg g^{-1})	$q_{e(cal)}$ (mg g^{-1})	R^2	K_2 (min^{-1})	$q_{e(exp)}$ (mg g^{-1})	$q_{e(cal)}$ (mg g^{-1})	R^2	β (mg g^{-1})	α (mg $g/^{-1}$ min^{-1})	R^2
20	0.0859	8.1589	2.6224	0.9565	0.0675	8.1589	8.3892	0.9997	1.5169	4.6775	0.9672
40	0.0773	17.306	5.6636	0.895	0.0268	17.306	17.857	0.9993	0.7212	9.7676	0.9425
60	0.0660	26.409	4.83503	0.8601	0.0288	26.409	26.881	0.9996	0.7965	61.841	0.911
80	0.07001	36.778	8.1583	0.9617	0.0180	36.778	37.593	0.9997	0.4523	40.196	0.9743

Table 3. Adsorption isotherm parameters

Langmuir Isotherm			Freundlich Isotherm			Temkin Isotherm		
b (L mg-1)	q_m (mg g-1)	R^2	n	Kf(mg g^{-1})	R^2	A (L mg-1)	B (J mole-1)	R^2
-11.952	4.9504	0.8926	-2.9403	4.6387	0.9938	4.2975	-35.366	0.9711

Where k_1 is the pseudo first order rate constant and the value is determine from a plot of log (q_e-q_t) versus t.

$$q_t = \frac{1}{\beta}\ln(\propto, \beta) + \frac{1}{\beta}\ln t$$ (Elovich model) [19]

The Elovich parameters were determined from the plot of q_t versus lnt

$$\frac{t}{q_t} = \frac{1}{qe^2 k_2} + \frac{t}{q_t}$$ (pseudo second order equation) [20]

K_2 is pseudo second order rate constant, the values were determined from a plot of t/q_t versus t

The parameters were represented in Table 2.

It has been observed from the R^2 values that the most suitable kinetic model for present study is the pseudo second order kinetic model. Similar trend was observed in the literature [19-21].

3.5 Adsorption Isotherm

The three isotherm model viz. Temkin isotherm, Langmuir isotherm and Freundlich isotherm were applied for the present study.

The following equations were used

$$q_e = B\ln A + B\ln Ce$$ Temkin isotherm [12]

The Temkin parameters A and B were determined from the plot of q_e versus ln C_e

$$\frac{Ce}{q_e} = \frac{Ce}{q_m} + \frac{1}{bq_m}$$ Langmuir isotherm [22]

The Langmuir constant q_m and b were determined from a plot of Ce/qe versus Ce

$$\log q_e = \frac{1}{n}\log Ce + \log k_f$$ Freundlich isotherm [23]

The values of n and k_f were determined from plot of log q_e versus log C_e

As the value of n is less than one (-2.9403) it shows desired correlation of n with Freundlich isotherm [24,25], thus from the values of R^2 and n, it has been observed that the present study follows Freundlich isotherm model [24].

4. CONCLUSION

The 91% removal of Safranine was observed at optimum pH 8, 80 min contact time with 80 mg/L dye concentration. The present experimental data follows pseudo second order kinetic model and Freundlich isotherm model. Alstonia Scholaris leaves powder after alkali treatment can be used as cheap and efficient adsorbent for the removal of safranine.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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