

Original Research Article

Removal of methyl green dye from water by adsorption onto silicon powder

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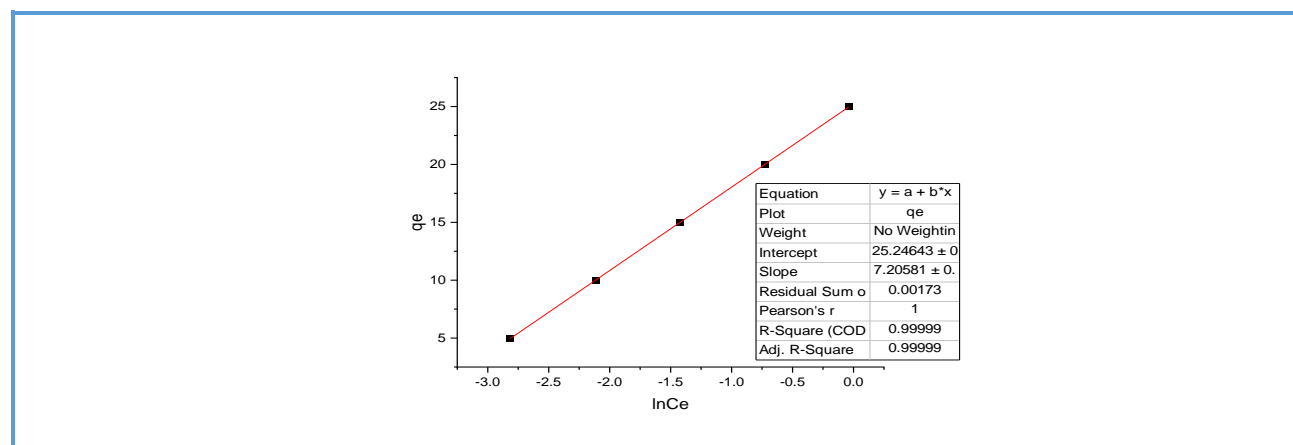
Methyl Green

ABSTRACT

The adsorption process of methyl green on the powder of silicon was investigated, parameters such as pH, time of mixing, dye concentration, temperature were studied. Data were tested for applicability of some isotherms like Langmuir, Freundlich, and Temkin. The adsorption data fitted well to these isotherms. The amount of adsorbate mono layer on silicon was $q_{\max} = 38.63988$ mg/g. Hence, silicon powder could be used as economically and a green adsorbate for methyl green dye from an aqueous solution.

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Graphical Abstract



Introduction

Dyes are used in a textile, polymers industries, food, and many other products [1-3]. Due to its fixed-color properties, high resistance to corrosion, oxidation, and microbial degradation classified as a major pollutant [4]. The existence of dyes in the aquatic environment is one of the biggest problems facing scientists due to the health and environmental problems because of their carcinogenic and toxic properties and their ability to pollute water resources [5]. Tri vinyl methane pigments (methyl green) are widely consumed in various industries for coloring textile, plastic leather, and food products, medicine, gelatin film awareness [6-8], and biology [9, 10], green methyl dye is a basic cation [7]. We treat wastewater in our daily lives and organically contaminated water in several physical and chemical ways including sedimentation, coagulation, adsorption, filtration with clotting, reverse osmosis, ozone, ion exchange, and advanced oxidation process has been used. These methods are limited because they are expensive in terms of money and effort. Therefore, the best effective way to treat and remove organic pollutants in the treatment of medium wastewater is the adsorption method. The good feature used in water purification is clay materials, depending on their properties, including their mechanical and chemical stability, surface area, layer structure, and large ketone exchange capacity [11, 12]. A large number of chemicals used as extractors to adsorb dyes from wastewater such as charcoals, wood, agricultural and natural materials, industrial adsorbent like resins and polymers, etc. The activated carbon is a practical, but the expensive adsorption material due to the high manufacturing costs. It can also be used to treat a large number of effluents due to financial thought [13-15]

during the last decades large number of researches had great interest to use plant wastes such as seeds and roots of different plants as a non-expensive and eco-friendly adsorbent dyes [16-18]. Porous silicon powder was tested as adsorption surface to remove some metal ions from the aqueous solutions with about 82% removal of nickel ions [19]. The aim of this work is to study the availability of using silicon powder as an inexpensive and new method to adsorb and remove methyl green dye from aqueous solution.

Experimental

Materials and Methods

All Glassware's such as volumetric flasks, beakers, etc. were washed and rinsed with nitric acid 5% and deionized water before using. All of the utilized chemicals were of analytical grade and used directly without further purification.

Effect of dye concentration on adsorption capacity

The effect of amount of dye onto silicon tested at pH 11 solution, with 0.8 g of silicon. The initial concentration ranges of 5 to 25 ppm solutions were prepared from original stock solution, placed on flask shaker for 40 min. Finally, the mixtures were filtered and the absorbance was measured with the aid of spectrophotometers.

Effect of adsorbent mass on adsorption capacity

The extraction process was carried out with sample solution of dye (25 ppm) with shaking time of 40 min. Different doses of silicon (0.2, 0.4, 0.6, 0.8, 1, and 1.5) were introduced to the flasks. The mixtures placed on flask shaker, filtered, and the concentration of dye in filtrate was determined spectrophotometrically.

Effect of contract time on adsorption capacity

The extraction process tested with certain volume of known concentration of the dye with 0.8 mg of silicon powder and left for different time intervals on flask shaker.

Effect of initial pH on adsorption capacity

The properties of adsorption of methyl green at the initial pH values were tested with 25 mL of dye on 0.8 mg of silicon powder changing in pH of solution using sodium hydroxide and citric acid.

Effect of temperature on adsorption capacity

Study of Adsorption capacity

The amount of adsorbed dye q_e onto surface of silicon was determined according to the following Equation:

$$Q = \left(\frac{C_i - C_e}{w}\right)V \quad (1)$$

$$\% \text{Removal} = \frac{C_i - C_e}{C_i} \times 100 \quad (2)$$

Adsorption isotherm model

Langmuir isotherm applies normally to perform the adsorption of adsorbate with monolayer adsorption process as follows [17, 18]:

$$\frac{C_e}{Q_e} = \frac{1}{q_{\max}} C_e + \frac{1}{q_{\max} b} \quad (3)$$

Where, q_{\max} represents capacity of adsorption in mg dye per g of silicon, b is the adsorption energy (L/mg). The value of q and b are estimated from the above Equation (4) as follow:

$$RL = \frac{1}{1 + b + Ci} \quad (4)$$

Freundlich adsorption isotherm

Calculation of adsorption constants were tested using the following Equation [19]:

$$\ln q_e = \ln k_f + \frac{1}{n} \ln C_e \quad (5)$$

$$\ln q_e = \ln K_f + \frac{1}{n} \ln C_e \quad (6)$$

K_f and n are proportional constant refers to the capacity and intensity of adsorption n value ranged from 0.1-10 depending on the adsorption strength [20].

Results and Discussion

Effect of initial dye concentration

Figures 1 displays the effect of the initial concentration of the dye on adsorption 5 to 25 ppm solution were tested. The percent removal increases gradually with the initial concentration up to 15 ppm, and then becomes about 99%, this is because of increasing deriving force with concentration [21, 22].

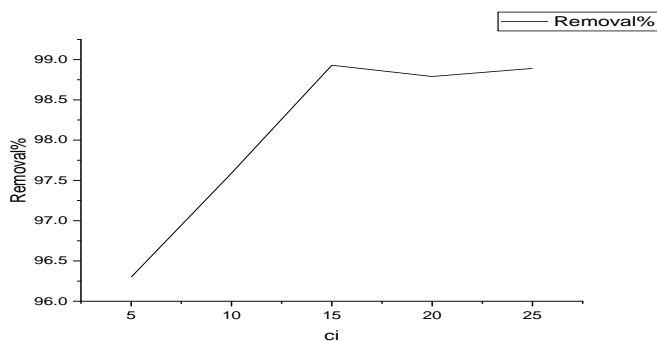


Figure 1. Effect of initial concentration on MG adsorption

Effect time of contact

This study was carried out at different contact time of dye and silicon powder. Three results are depicted in Figure 2. First, increased from 20 to 40 min, and then decreased with

increasing of time. This may be due to the surface saturation and less active sites on silicon available for more adsorption [23, 24]. The adsorption rate becomes slower over time due to the balance situation occurred at 40 minutes.

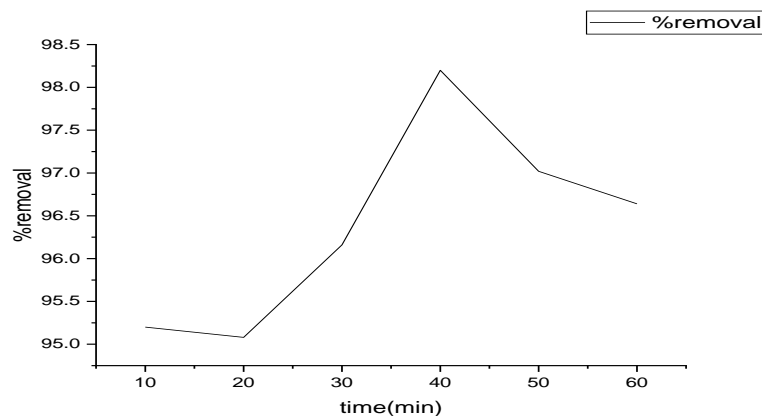


Figure 2. Effect of contact time on MG adsorption

Effect of adsorbent dose

Figure 3 displays the effect of the excreted dose on MG adsorption. With an increased dose of adsorption from 0.2 to 1.5 g, the removal efficiency was increased to 99% and the best dose was at 0.8 g. These results attributed to increase in the availability of

binding sites, and therefore reflected in the adsorption ability [25, 26]. No significant progress has been observed in de-dyeing using more than 0.8 g of the sidenotes dose as molecules are grouped into the active locations that reduce the available surface area.

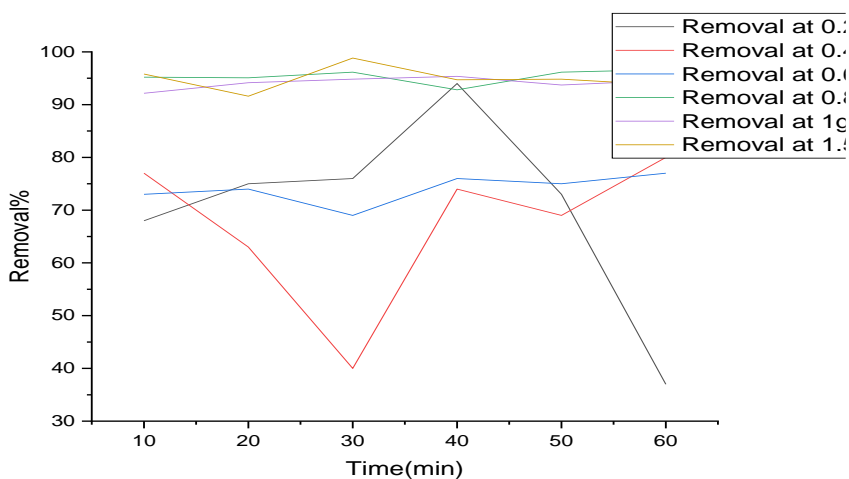


Figure 3. Effect of adsorbent dose on MG adsorption

Effect of pH

The pH effect on MG adsorption was examined in pH variation 2-11. The tests were performed at 25 °C, a combined dose of 0.8 g, and an initial concentration of 25 ppm. [Figure 4](#) demonstrates the pH effects on MG adsorption. The other experiments were conducted under the same conditions to determine the effects of pH change over time and were monitored at 40 minutes, as illustrated in [Figure 5](#). The MG adsorption on silicon increases as the pH value of the solution increases. This may be because of the subsequent effect of dye ions and H⁺ ions, which were competing for the adsorption sites when the pH value of the spoofs declined, as suggested in previous investigations [[27](#), [28](#)]. In contrast, silicon surface area been negatively charged at higher pH, which will increase the number of dye cations on the surface by electrostatic attraction, as indicated in the previous studies [[29](#)].

Effect of temperature

To study the temperature effect on adsorption, experiments were conducted at 25,

30, 40, and 50 °C. In these tests, the other parameters such as a sedentary dose and an initial concentration were constant. The temperature effect is depicted in [Figure 5](#). The percentage of de-dyeing decreases as the temperature changes from 25 °C to 50 °C. This scan shows that de-dye decreases with temperature, and thus the system is characterized by low temperature. The increase in temperature reduces the transferability of adsorbate molecules [[30](#), [31](#)].

The thermodynamic data of adsorption process obtained from the temperature studies are presented in [Table 1](#), the lower enthalpy values refers normally to the physical adsorption of methyl green dye on the silicon surface.

Adsorption isotherm models

Adsorption data were plotted for different isotherms, Langmuir, Freundlich, and Timken. The presentation showed linear relations with all isotherms with good correlation coefficients of about 0.94-0.99, as listed in [Table 2](#).

[Figures 6, 7, 8](#) indicated the linear plotting of the adsorption isotherms.

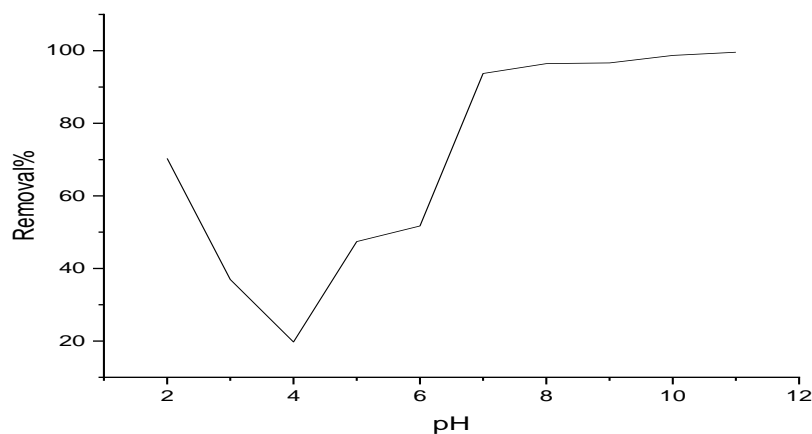


Figure 4. Effect of initial pH on MG adsorption

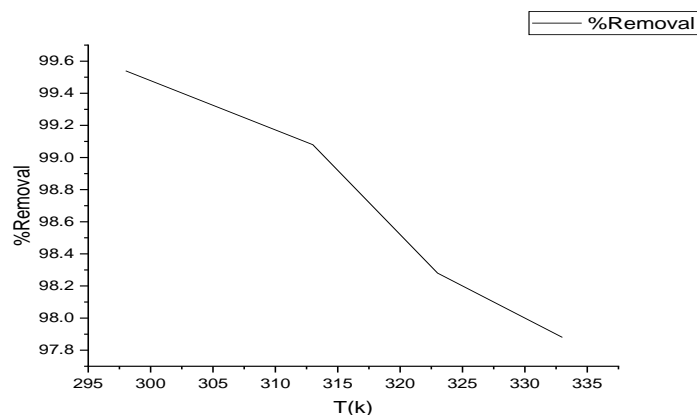


Figure 5. Effect of temperature on MG adsorption

Table 1. Thermodynamic data of adsorption process

T	ΔG KJ/mol	ΔS	ΔH
298	-14.778	16.580 KJ/mol	-48.52 j/mol.K
313	-14.683		
323	-14.624		
333	-14.566		

Table 2. Isotherm parameters and correlation coefficients for the adsorption of methyl green on silicon

Isotherm models	Correlation parameter					
	Intercept	Slope	$q_{\max}(\text{mg/g})$	KL	RL	R^2
Langmuir	0.02588	0.01017	38.63988	2.54473943	0.007798	0.99145
Freundlich	Intercept	Slope	1/n	kf	R2	
	3.37005	0.5646	0.5646	2344.49872	0.94834	
Timken	Intercept	slope	BT (j mol-1)	KT (j mg-1)	R2	
	25.24643	7.20581	7.20581	33.23559311	0.99999	

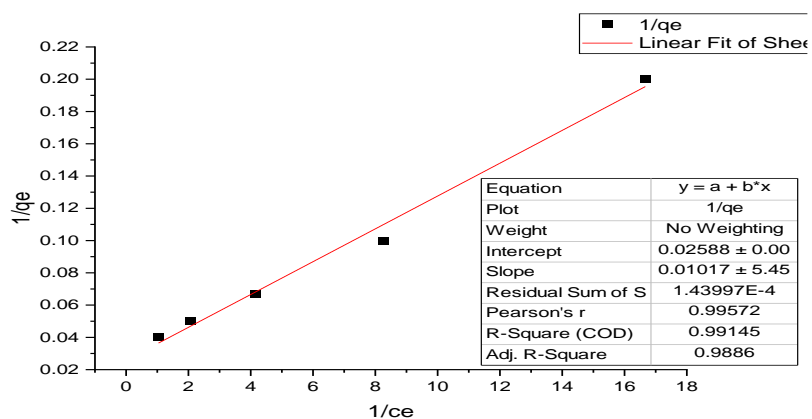


Figure 6. Langmuir adsorption isotherm for MG adsorption onto 0.8 g silicon at 25 °C

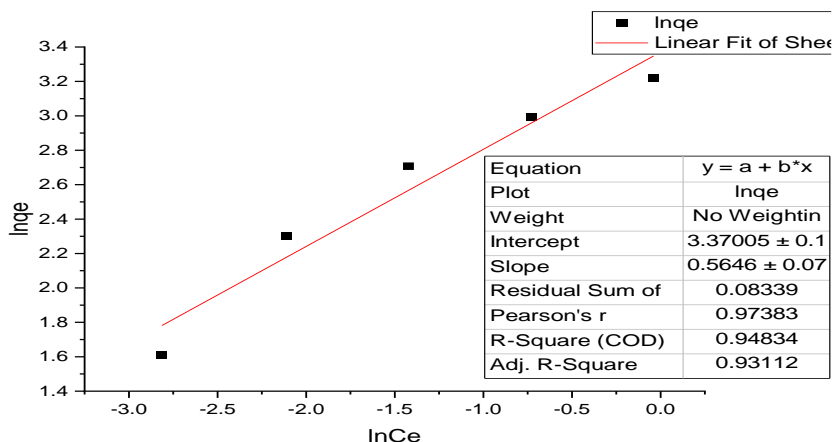


Figure 7. Freundlich adsorption isotherm for MG adsorption onto 0.8 g silicon at 25 °C

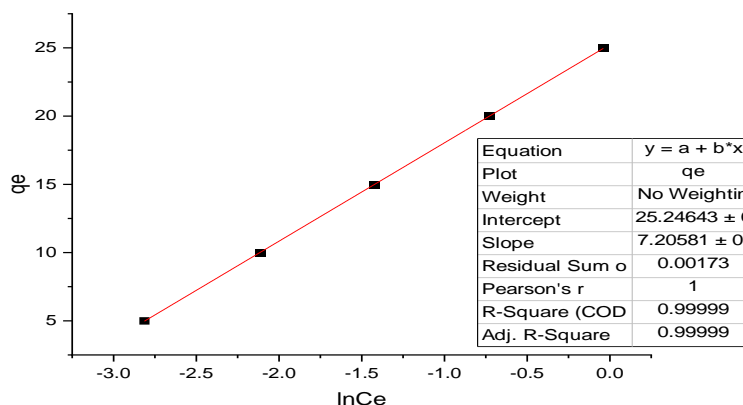


Figure 8. Timken adsorption isotherm for MG adsorption onto 0.8 g silicon at 25 °C

Conclusion

The results improved that silicon is an excellent extractor for methyl green dye. The removal rate reached 99% and the adsorption depends heavily on the concentration of the primary dye and on the time of contact and pH, adsorption was studied using models of Langmuir, Freundlich, and Timken. The results showed matching the results of this study with the three models where the value of $R^2 = 0.99, 0.98,$ and $0.93,$ respectively. The change in heat of the adsorption process with values about 48.0 j/mol.k indicated the physical nature

of the adsorption process of the dye on silicon since silicon is the inert surface.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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