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INVESTIGATING METHYL VIOLET DYE ADSORPTION FROM WATER USING WATER HYACINTH: A STUDY OF ISOTHERMS AND THERMODYNAMICS

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Abstract:
As a function of starting methyl violet concentration, contact time, particle size, pH, and temperature, the adsorption behavior of methyl violet from an aqueous solution onto a water hyacinth was investigated. The equilibrium isotherms were described using the Freundlich and Langmuir adsorption isotherms. Water Hyacinth was shown to have a Langmuir monolayer adsorption capability of 6.67 mg/g. At pH 2, the activation energy, enthalpy, and entropy were 3.197 kJ/mol, 5.269 kJ/mol, and 4.078 kJ/mol, respectively.

Keywords: temperature, pH, contact time, and methyl violet.

Introduction

The majority of polluting industries in terms of wastewater generation and release capacity are the textile sector. A moderately emerging family of man-made organic compounds are dyes, which have aromatic cyclic rings that, when in contact with water, produce a hydrophilic character. Therefore, it is challenging to treat certain types of dyestuff (1). The discharge of wastewater with a lot of color into the environment might be harmful or cause cancer, and it can endanger the health of all living things (2). Before the effluent may be released into the environment, the dye must be eliminated, even at very low concentrations, such as less than 1 mg/L (3).Various physical and chemical techniques like oxidations (4), coagulation and flocculation (5), adsorption (6),ion-exchange (7) etc. were established for dyes removal from wastewater. Adsorption is commonly used to intensify the dyestuffs on an adsorbent before chemical or biological treatment (8). Some of the cost effective adsorbents that are evaluated for the dye adsorption operations are rice husk (9), sawdust (10), coconut husk (11), corncob (12), peat (13), Adsorption is a surface occurrence wherein matter adheres to the surface of the other has been examined for colour removal using immobilized aquatic weeds (14).Water Hyacinth removed nutrients and heavy metals from wastewater (15). Recently, utilization of adsorbent (Water Hyacinth)in the removal of methyl violet dye from wastewater was studied (16). The aim of this study is to analysis the capacity of Water Hyacinth and it revived derivative to adsorbmethyl violet dye. The rate of dye adsorption process was analysed including the influence of the different parameters like contact time, pH, concentration of dye, temperature, sieve size and dosage of the adsorbents. Simple equilibrium data for both Langmuir and Freundlich isotherms and thermodynamics analysis were found.

Experimental

Adsorbent Preparation

In order to eliminate clay and other foreign contaminants from their surroundings, the water hyacinth used in this study was gathered, brought inside the lab, and then sliced into pieces after being rubbed with water. After 15 days of drying in the shade, the slice material was placed in a hot air convection oven set to 80°C for one hour. The material would be ground into a powder and allowed to pass through sieve diameters of 300-150 μ, 150-75 μ, and 75 μ. The material was then placed in desiccators and packed in plastic bags (17).

Materials and methods

Methyl violet is a dye that is mostly found in organic substances. Depending on how many methyl groups are connected, the dye's color can be altered. It is mostly used as a purple textile dye. Additionally, methyl violet is used in medicine. It serves as a pH gauge. The dye is known by its IUPAC name, [4-[bis[4-(dimethyl amino) phenyl][methylidene]2,5-dien-1-ylidene cyclohexadimethylazanium chloride (molecular weight: 407.9788 g/mol; chemical formula: C25H30ClN3) [18] was applied as fig. (1) illustrates.

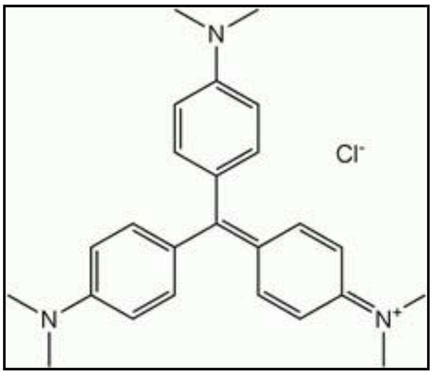

Fig. (1) Methyl violet dye structure

Preparation of dye solution

Methyl violet is used without any purification. A required amount of dye dissolved in 500 ml distilled water solution, this solution is our stock solution.

Effect of Contact Time

The variation in amount percent removal at any time (q_t) of dye with the time is shown in figure 2. The equilibrium concentrations was found in 120 minutes, further that in the adsorption process do not predicted more amount of active sites which do not allow further adsorption to take place[19].

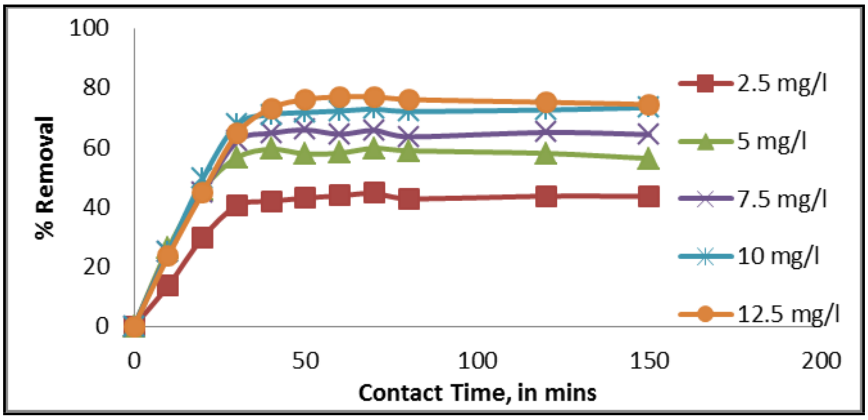

Fig. (2) Effect of Contact Time

Effect of pH

The pH of the wastewater solution is a significant parameter in the adsorption process of dyes. The effect of solution pH on methyl violet dye adsorption was analysed at the pH ranges of 2–12and the results are shown in Fig. 3. The sorption of methyl violet was found to be maximum at the initial pH 2 and it decreased up to pH 12. At alkaline pH, lower adsorption of methyl violet might be due to the presence of excess OH^- ions competing with the cation groups on the dye for adsorption sites. A similar result was reported for methylene blue previously [20].

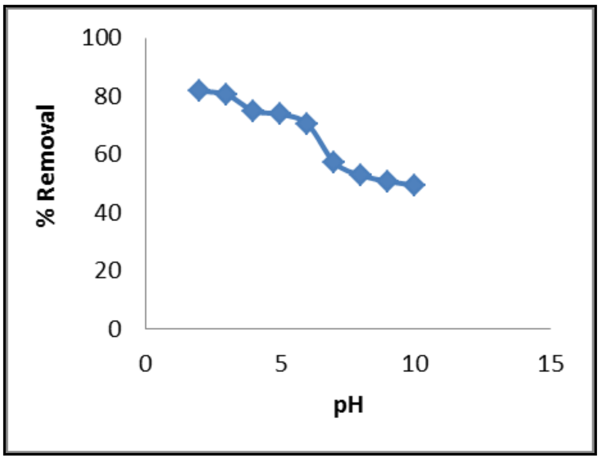

Fig. (3) Effect of pH Adsorption isotherm

Langmuir isotherm(21) is represented by the following equation below:

$$C_e / q_e = 1/q_{max} K_L + (1/q_{max}) C_e$$

Where q_e is the amount of adsorbate in the adsorbent at equilibrium (mg/g), C_e is the equilibrium concentration (mg/l) and q_{max} and K_L are the Langmuir isotherm constants related to free energy. The above equation can be linearised to get the maximum capacity, q_{max} by plotting a graph of C_e / q_e Vs C_e .

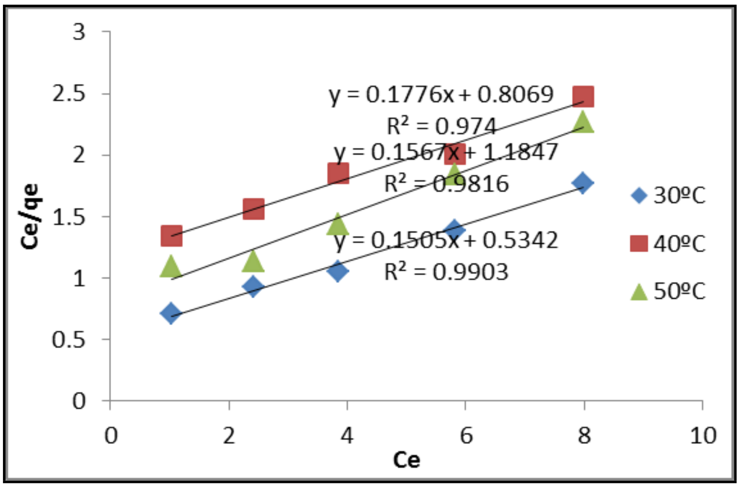

Fig. (4) Langmuir Adsorption Isotherm

The important characteristics of the Langmuir isotherm can be indicated in terms of a unitless equilibrium parameter (R_L), which is expressed by:

$$R_L = 1/ (1 + K_L C_o)$$

where K_L is the Langmuir constant and C_o the initial dye concentration (mg/l). The value of R_L indicates the nature of the isotherm to be either favourable ($0 < R_L < 1$) or irreversible ($R_L = 0$),unfavourable ($R_L > 1$), linear ($R_L = 1$). The value of R_L for temperatures30°C, 40°C and 50°Cwere found to be 0.587, 0.752 and 0.645 respectively, confirmed that the treated water hyacinthis favourable for adsorption of the methyl violet dye under conditions used in this study.

Table (1): The values of parameters of Langmuir equation

Langmuir Adsorption Isotherms Data				
Temperature, in °C	q_{max}	K_L	R_L	R^2
30°C	6.67	0.281	0.587	0.990
40°C	6.41	0.132	0.752	0.981
50°C	5.65	0.219	0.645	0.974

Freundlich isotherm (22)

$$q_e = K_f C_e^{\frac{1}{n}}$$

On rearranging this equation, we get

log q_e = log K_f +1/n log C_e

A graph between log q_e vs log C_e yields an intercept log K_f and straight line with a slope of 1/n.

where K_f and 1/n are freundlich isotherm constants related to amount of adsorption and intensity of adsorption respectively.

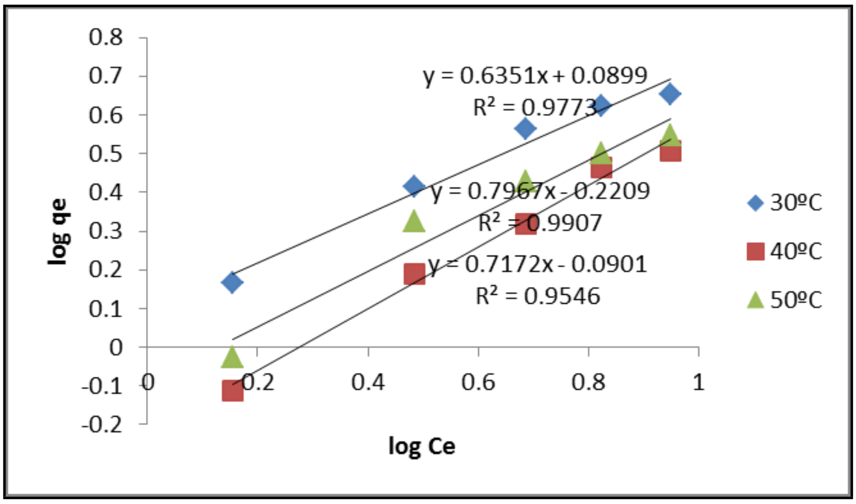

Fig. (5) Freundlich Adsorption Isotherm

Table 2: The values of parameters and correlation coefficient of Freundlich equation

Temperature, in °C	K_f	**1/n**	R^2
30°C	0.089	0.635	0.977
40°C	0.813	0.717	0.954
50°C	0.603	0.796	0.990

The Langmuir and Freundlich adsorption isotherms of methyl violet on water hyacinth are shown in figures4 and 5. Tables1 and 2 give the values of parameters and correlation coefficient of the Langmuir and Freundlich equations. The experimental results indicated that the adsorption isotherms of methyl violet adsorption on water hyacinth followed both Langmuir and Freundlich models.

It can be seen that the Langmuir isotherm fits the yield better than Freundlich isotherm. The homogeneous nature of the treated with water hyacinth, i.e. each dye molecule per water hyacinth adsorption has equal adsorption energy (23).This is also confirmed by the high value of R^2in case of Langmuir.

Thermodynamics of adsorption

The thermodynamic parameters such as alteration in standard free energy (ΔG°), enthalpy (ΔH°) and entropy (ΔS°) of adsorption were found using the following equations (24) :

$$\Delta G^{\circ} = -RT \ln K$$
$$\Delta H^{\circ} = R(T_2 T_1)/(T_2 - T_1) \ln (K_2/K_1)$$
$$\Delta S^{\circ} = (\Delta H^{\circ} - \Delta G^{\circ})/T$$

where R is the gas constant K, K_1 and K_2 the Langmuir constants corresponding to the temperatures 303K, 313K and 323K and T is the solution temperature in Kelvin. The negative values of ΔG° indicate the degree of energy of the adsorption process. The positive values of ΔH° show that the adsorption is endothermic; the explanation for this being displacement of greater than one water molecules separately methyl violet ions for their adsorption, which gives result in the endothermic capacity of the adsorption process. The assured worth of ΔS° suggests reproduced randomness at the solid/solution interface completely the adsorption of water hyacinth towards methyl violet dye. Also the positive ΔS° value corresponds to an increase in the degree of freedom of the adsorbed dye. The values of thermodynamic parameters were given in Table (3).

Table (3): Thermodynamic parameters for the adsorption of methyl violet by water hyacinth

Temperature (K)	- ΔG°(kJ mol^{-1})	ΔH°(kJ mol^{-1})	ΔS°(kJ mol^{-1} K^{-1})
303	3.197		
313	5.269	42.553	0.129
323	4.078		

Conclusion

The methyl violet dye's favorable adsorption on water hyacinth was demonstrated by the Langmuir and Freundlich isotherm parameters. The parameters of thermodynamics were established. An endothermic reaction is confirmed by a positive ΔH° measurement. The degree of energy involved in the methyl violet dye adsorption process on water hyacinth is shown by ΔG°.

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