USING RED MUD AS AN ADSORBENT TO REMOVE CRYSTAL VIOLET DYE

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Abstract

Dye is one of the primary concerns in textile manufacturing effluents due to its hazardous nature in aqueous solution. The removal of crystal violet dye from aqueous solution using activated red mud as a low-cost adsorbent was studied at different reaction parameters in this work. The effects of pH, adsorbent dosage, and starting dye concentration on adsorption efficiency characteristics were examined. A UV spectrophotometer with a wave length of 566mm was used to determine the dye concentration. At ideal operation circumstances of pH= 4, contact time = 120 minutes, initial concentration of crystal violet dye=50 ppm, and adsorbent dose of 0.2g/l, higher removal effectiveness of crystal violet dye was found for varied reaction parameters. Three adsorption isotherm models were used to examine equilibrium adsorption data: the Langmuir isotherm model, the freundlich isotherm model, and the temkin isotherm model. Other adsorption isotherm models did not suit the equilibrium data as well as the Freundlich adsorption isotherm model (R2 = 0.828). The pseudo second order kinetic model was shown to be the most prevalent adsorption kinetic model, with a correlation coefficient of 0.999. Based on the findings, we may conclude that employing red mud as a low-cost adsorbent can successfully remove colours from aqueous solutions.

Key words: Adsorbent. Freundlich, colours,Rud mud,Crystal Violet Dye,UV, pH

Introduction

Dyes are organic compounds that are colourful, fragrant, and ionising and can be used to colour other things. The dyes absorb light with a wavelength of 350 to 700 nm in general. The classification or categorization of dye is done into twenty to thirty classes based on its chromophore and chemical structure. Around the world, almost a million dyes are produced each year. The dyes are manufactured at a rate of 0.7 to 1 billion tonnes per year.

Dye compounds can be found in wastewater effluents produced by a variety of industries. The textile sector, out of all the industries that generate dye-containing effluent water, produces a large amount of dye-containing colourful waste water. One of the key industries that generates a high amount of dye compounds in waste water is the textile sector. Reactive dyes are the most often used dyes in the textile industry. Reactive dyes are commonly used to colour wool, strings, polyamide, and fibres, among other things.

Because aromatic benzene compounds are present in the dyes, they remain poisonous and are less biodegradable in nature. If dyes are released into the environment without being treated, they may have negative consequences for the environment. As a result, waste water containing dyes must be treated before being discharged into the environment. Biological approaches, sophisticated oxidation processes, and membrane processes are all options for treating dye-contaminated waste water. The traditional procedure, on the other hand, does not produce effective results and is not ideal for dye removal. Because of the dye's solubility in water (i.e., water solubility), traditional procedures such as precipitation and coagulation will not be able to remove the dyeDue to its better efficiency in the dye removal process, the advanced oxidation method is the most extensively employed process in dye removal investigations. However, there are certain drawbacks to this method. This technique may cause issues due to the creation of by-products and high prices. For the removal of dye from aqueous solutions, adsorption is the most common and commonly utilised approach. The use of activated carbon as an adsorbent for dye removal is common. However, the cost of activated carbon adsorbent is very high, and the adsorption process demands the most experienced person or operator. As a result, it is necessary to investigate the performance characteristics of less expensive and naturally occurring adsorbents as an alternative. Various natural adsorbents are currently being employed as an alternative to remove both organic and inorganic contaminants. Fly ash, charcoal, chitosan, citrus limetta peel waste, calcium hydroxide, and other natural adsorbents have been employed in the past. Red mud is another commonly utilised adsorbent nowadays. Because red mud is a cheap adsorbent, it is commonly utilised in wastewater treatment. Red mud is the most common and widely produced waste in the alumina manufacturing process. In most cases, Bayer's technique is used to produce alumina. Because of its high amount of aluminium hydroxide, bauxite stone is utilised in Bayer's process to produce alumina. The Bayer process involves the interaction of sodium hydroxide with bauxite under the influence of heat and pressure, resulting in the formation of red mud as a waste product. In general, red mud is made up of a variety of hydroxides and ansoxides. The red mud is projected to produce one to two tonnes of alumina for every tonne of alumina produced. Although red mud is widely employed in the construction process, and road building materials are also used in the production of ceramics, a huge amount of red mud is left unused. As a result, the goal of this experiment is to see how effective red mud is at removing crystal violet colour from aqueous solutions.

Materials and Methods

Dye Characteristics

Crystal violet dye has been chosen for the current study. Crystal violet is an antibacterial, antifungal, and anthelmintic colour that is made up of violet rosanilinis. Crystal violet dye is a violet dye with a beautiful tint.

The crystal violet dye's chemical formula is C25H30N3Cl, with a molecular weight of 407.98g/mol. Crystal violet dye has a freezing (or melting) point of almost 2150 degrees Celsius. At normal temperatures and pressures, the crystal violet dye is chemically stable. Figure 1 shows the chemical structure of crystal violet dyes..

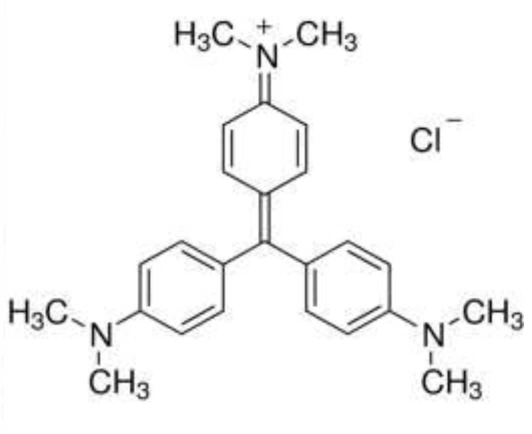


Fig.1. Crystal Violet Dye Structure

Adsorbent Characteristics

Red mud, a waste by-product of the alumina industry, was used as the adsorbent in this investigation. The red mud utilised in this investigation was gathered at the HINDALCO Aluminum plant. In table 1, the various quantities of red dirt are shown.

Parameter	%
Sio2	5.5
Al2o3	18.8
Fe2o3	51.8
Cao	3.3
Na2o	6.8
K2o	0.1
Mno	0.1
Tio2	11.2
So3	0.2
LOI (loss of ignition)	2.2

Preliminary Treatments for Red Mud

The red dirt gathered at Hindalco Aluminium was first cleaned with ion-free water before being dried in an oven at 1030 degrees for 24 hours. The red mud was then steeped for 24 hours in a 1N Nitric acid solution, with the red mud to nitric acid ratio kept at 1:2. The acquired red mud was then baked for further four hours at 1500 degrees Celsius, yielding active red mud. The active red mud is sieved through a 100 mesh sieve after it is obtained.

Analytical Methods

Throughout the research, double distilled water was used. The dye solutions were made by dissolving the powder in appropriate amounts of double distilled water. A UV spectrophotometer with a wavelength of 566nm was used to determine the dye concentration. 1N H2SO4 and 1N NAOH solutions were used to change the pH levels. This technique required the procurement of all chemicals.

Adsorption Experiments

In this investigation, the Batch Adsorption technique was used. pH, adsorbent dose, and dye concentrations are the most effective adsorption efficiency characteristics evaluated in this method. The adsorption study is carried out in a 250mL conical flask. The dye solution is concentrated in the conical flask, and the proportions of red dirt to be treated are known..

The ideal pH condition for removing dye is obtained by keeping other factors such as initial dye concentration and adsorbent dosage constant while altering the pH of the solution in the range of 4 to 10. The combination was then kept in a shaker device with a continuous speed rate of 160 rpm for 2 hours to reach equilibrium. The studies were conducted out at a temperature of 280 degrees Fahrenheit. The optimum adsorbent dosage was obtained in the next step by adjusting the solution's adsorbent dose from 0.05 to 0.25g/l while maintaining other factors like optimum pH and beginning dye concentration constant.

Following the determination of the ideal pH and adsorbent dosage, the dye concentrations in the solution were changed while maintaining other variables such as the optimum pH and adsorbent dosage constant. The dye concentration was changed between 50 and 250 parts per million. With regard to the standard curve, the absorption of dye in solution is studied using a spectrophotometer at a wavelength range of 566 nm.

Results and Discussions

Removal of Dye under the consequence of pH

The process was carried out with a 100 ppm concentration of dye solution and adsorbent dose of 0.1g/l, an equilibrium contact duration of 120 minutes, and a pH range of 4 to 10 to identify the best pH conditions due to the effect of pH on dye removal. Figure 2 depicts the outcomes of this procedure..

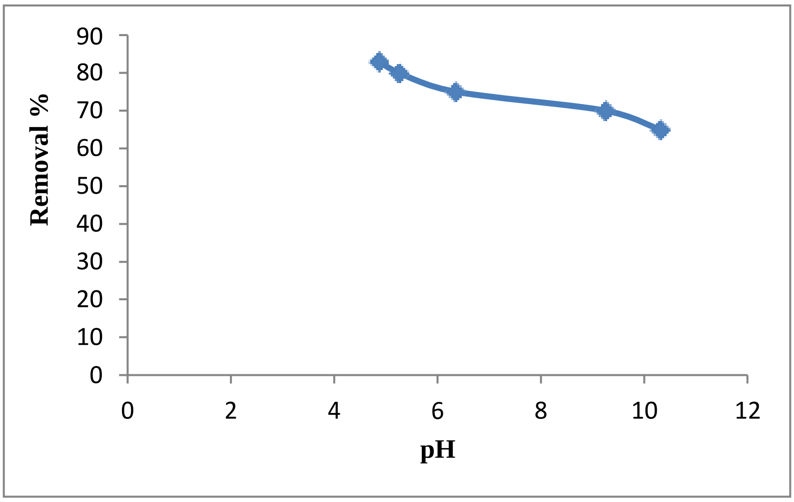


Fig.2. %Dye Removal at Various pH conditions

Figure 2 shows that % dye removal was highest at pH levels below neutral and lowest at pH levels above neutral. At pH=4, a larger percentage of dye removal was seen in this process of removing dye as a result of pH. In the adsorption process, the pH parameter is extremely important. pH has the ability to impact adsorption parameters such as adsorbent surface charge and separation of functional groups present on the activated sites of the adsorbent. It can also affect the chemistry of the solution and the degree of ionisation during the adsorption process. Many investigations have found that pH plays an important role in the electrostatic force that exists between the cells..

Removal of Dye under the Consequence of Adsorbent Dose

The % elimination of dye as a result of adsorbent dose was measured in this method by adjusting the adsorbent dosages from 0.05 to 0.25g/l. The experiment was carried out with the dye concentrations and pH levels kept constant. A constant pH of 7 was maintained, with a dye concentration of 100ppm and a contact period of 120 minutes. Figure 3 depicts the end result of this procedure.

In figure 3, we can observe that by increasing the dosages of adsorbent, the dye removal efficiency has been increased. The maximum dye removal efficiency was obtained at an adsorbent dosage of 0.2g/l. The rate of efficiency of dye removal was kept increasing with adsorbent dose, until it reached to a point of equilibrium in the high doses. It is also observed that even though the percentage removal of dye is high the equilibrium capacity qe was found to be decreased.

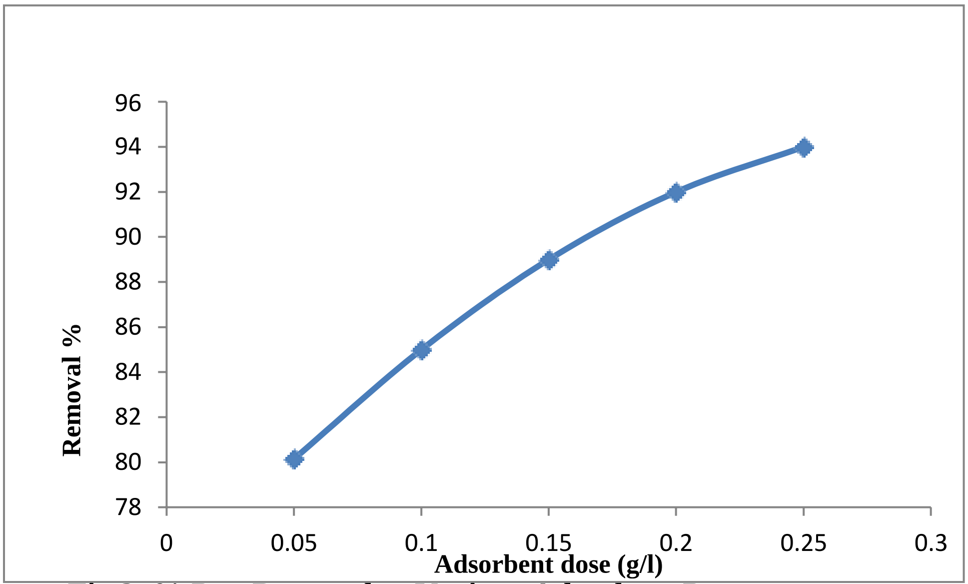


Fig.3. % Dye Removal at Various Adsorbent Dosages

Removal of Dye under consequence of concentrations of Dye

The process of removing dye under the consequence of concentrations of dye was determined by varying the concentrations of dye in the range of 50ppm to 250ppm. This experiment was carried out by maintaining the constant pH and adsorbent dosage. The constant pH was maintained as 4 and the constant adsorbent dosage was maintained as 0.2g/l with an equilibrium contact time of 120 minutes. The outcomes of this process were shown in figure 4.we can observe that dye removal efficiency was higher at the lower dye concentrations and it was lower at higher concentrations. Therefore, the percentage removal of dye was found to be high at lower concentrations of dye.

The dye removal effectiveness was observed to be reduced at increased dye concentrations due to the adsorbent's low active sites. In the case of lower dye concentrations, the adsorbent contains a greater number of active sites. While the demand for active sites on the adsorbent would be significant at increasing dye concentrations, the availability of active sites on the adsorbent will be restricted. The dye removal percentage was decreased because we kept the adsorbent dosage consistent across all dye concentrations.

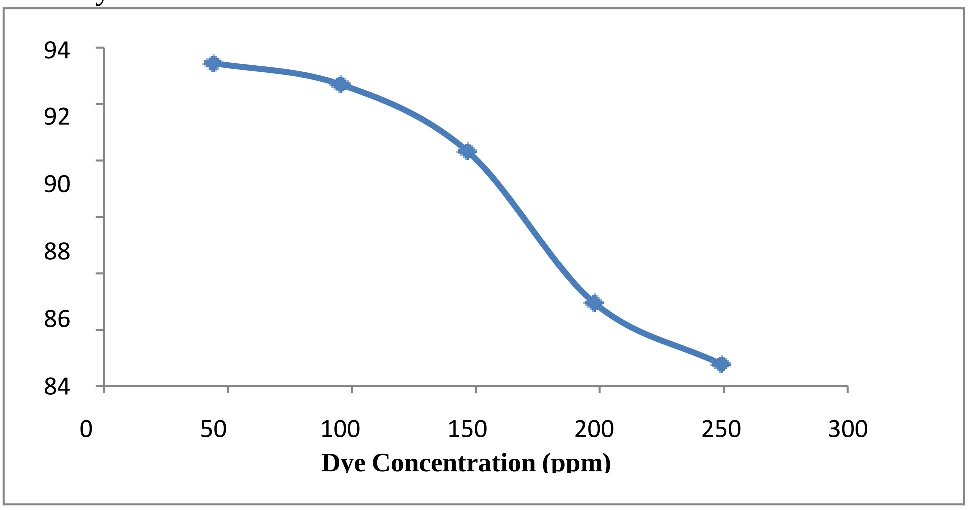


Fig.4. % Dye Removal at various Concentrations of Dye

Adsorption Isotherms

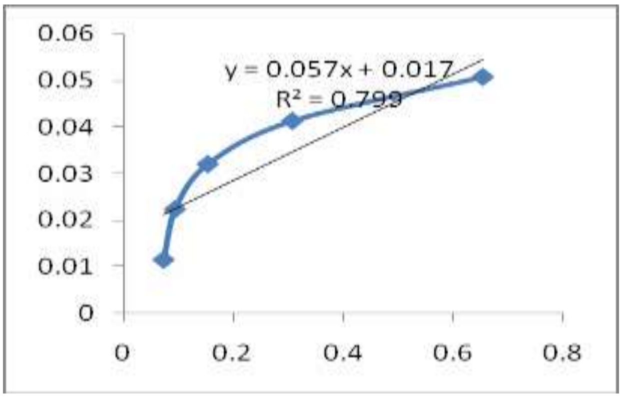
Adsorption isotherms are used to explain the relationship between the amount of dye adsorbed and the dye concentration in the solution. The data from isotherm models is crucial in the design of adsorption systems. There are numerous isotherm equations available in general. However, four of the adsorption models were shown to be significant. Langmuir, Freundlich, and Tekmin isotherms are the three most important adsorption isotherm models. This study focused on these three isotherm models. These three models assist us in estimating the interaction between the solution and the adsorbent.The equation that is used to estimate the adsorption capacity is as follows

$$qe = \frac{c0-ce}{M})V$$

Where; qe = adsorption capacity (mg/gms of adsorption); C0 = initial dye concentration (mg/l);
Ce = equilibrium dye concentration (at any time'tʼ) (mg/l); M= mass of the adsorbent (gms);
V= volume of the sample (l);
Figure 5 illustrates the results of the isotherm equations.

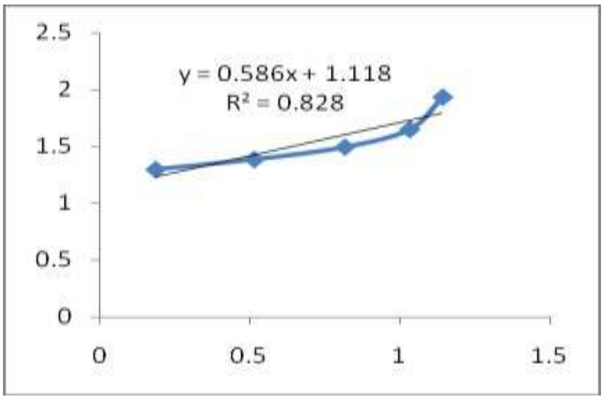
Crystal violet dye on red soil matched the freundlich isotherm model best (R2 = 0.828), according to the adsorption isotherm results. When compared to the other two models, the Langmuir isotherm (R2 = 0.799) performed better than the tekmin isotherm (R2 = 0.658).

Based on the findings, it can be concluded that red mud, a waste product of the

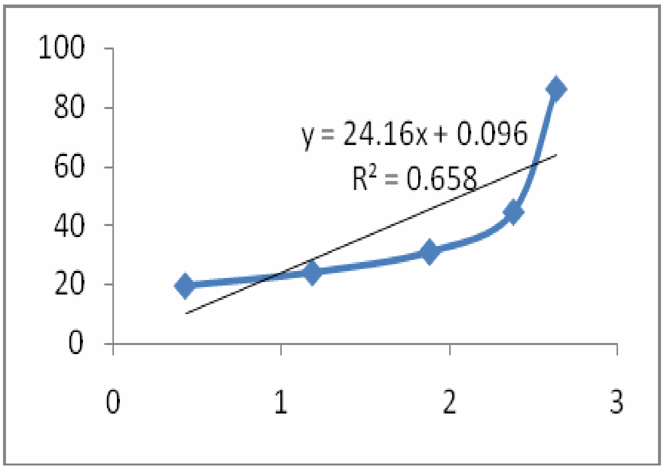


(a)

aluminium sector, can be employed as an adsorbent to successfully extract crystal violet colour from textile effluent. Using red mud as an adsorbent, more than 80% of the crystal violet dye may be extracted from the aqueous solution. Langmuir's isotherm and the freundlich isotherm



(b)

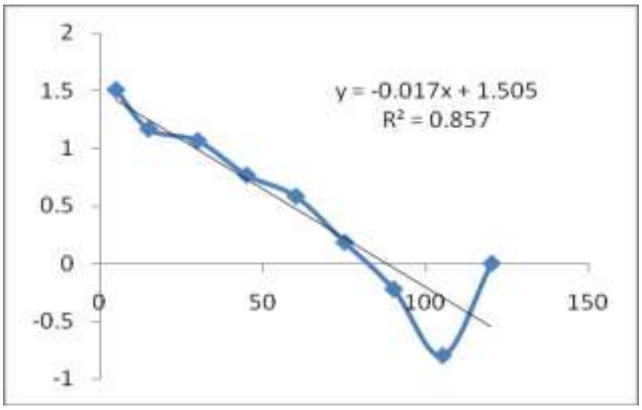


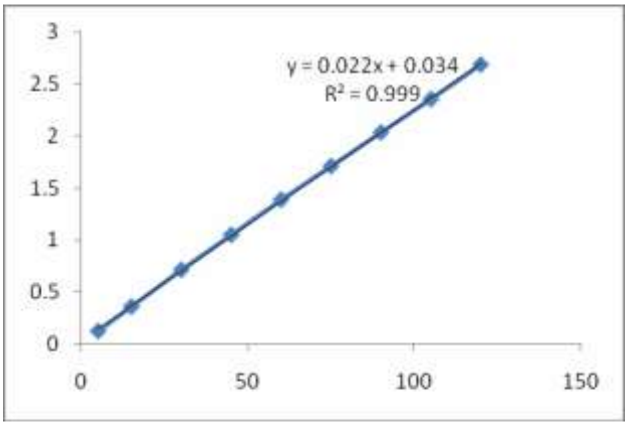
(c)Fig.5. Adsorption Isotherm Models (a: Langmuir, b: Freundlich, c: Tekmin)

AdsorptionKinetics

The effectiveness of the kinetic models in adsorption kinetics was investigated by keeping the contact time between 5 and 120 minutes, with a dye concentration of 100ppm at optimal pH and optimum adsorbent dosage conditions. The variation in biosorption rates and uptakes can be analysed by using Pseudo 1stōrder, Pseudo 2ndorder, Elovich, and Intraparticle diffusion adsorption kinetic models to describe the kinetic data. Table 3 depicted the equations for these four models.

The pseudo 2ndorder model was found to be the most prevalent among the adsorption kinetic models in this process. This model's R_2 is 0.999, implying that the uptake process matches this kinetic model. The correlation coefficient of the pseudo 2ndorder model is larger than 0.995. The Pseudo 1storder and Pseudo 2ndorder outcomes





(a) *(b)*

Fig.6. Adsorption Kinetic Models (a: pseudo 1storder, b: pseudo 2ndorder)

Conculsion

- Due to the effect of pH on dye removal, a pH range of 4 to 10 was used to determine the optimal pH settings.
- The percent dye removal was greatest when the pH was below neutral and lowest when the pH was above neutral. As a result of pH=4, a higher percentage of dye removal was seen in this method of dye removal.
- Adsorbent dosage of 0.2g/l resulted in the highest dye removal efficiency. With increasing adsorbent dose, the rate of dye removal efficiency increased until it reached a point of equilibrium in large doses.

- Dye removal effectiveness was higher at lower dye concentrations and lower at higher dye concentrations, as shown. As a result, the proportion of dye removed was shown to be high at lower dye concentrations.
- According to the adsorption isotherm results, crystal violet dye on red soil best matched the freundlich isotherm model (R_2 = 0.828). The Langmuir isotherm (R_2 = 0.799) outperformed the tekmin isotherm (R2 = 0.658) when compared to the other two models.
- Among the adsorption kinetic models in this process, the pseudo 2ndorder model was determined to be the most common.

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