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Adsorption of Nile Blue Dye using Guava Leaf Powder

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***Abstract*– Batch sorption experiments were carried out using two types of adsorbents; guava leaf powder (GLP) and activated carbon (AC) for the removal of Nile blue dye from aqueous solutions (100 ppm). Different adsorbent dosages were applied 0.5, 1, 1.5 and 2g. The concentration of dye solutions was measured with time using ultraviolet spectrophotometer. Adsorption isotherms were applied to the experimental data to test the best fitting. Freundlich isotherm was the best fitting in case of AC and Langmuir isotherm is the best fitting in case of GLP. The maximum uptake of dye for AC was 4.997mg/g with adsorption efficiency 27.65% (0.5 g, 100 rpm, 30 min) and for GLP, 14.85 mg/g with adsorption efficiency 74.25% (0.5g, 100rpm, 30min) which mean the GLP is more efficient than AC. The effect of dye concentration (25, 50, 75, 100 ppm) was studied by fixing all other parameters, it was noticed the improvement in adsorption efficiency with increasing dye concentration. Also the effect of temperature was studied and little improvement was noticed. Two kinetics models were tested and Pseudo first order is the best in case of Ac and Pseudo second order model was the best in case of GLP.**

I. INTRODUCTION

Dyes are the colored materials that applied to textiles and other products, such as leather, cosmetics, pulp and paper, pharmaceuticals, plastics and food to change their appearance [1 - 6]. In the past; they were produced naturally from plants, animals and insects, but the produced amount become inappropriate with the rapid growth of population and their needs, so scientists tried to generate dyes synthetically using chemicals [7]. The generation of synthetic dyes allows the global production to increase up to 700,000 tons/year of 100,000 different types of dyes [1, 3, 4].

On the other hand; dying is a water intensive industry, where huge amount of water is used, so a huge amount of wastewater is produced [8] which contains about 2% of the annual production of dyes [1, 3]. It should be treated before disposal, but the dye is still noticeable even at very low concentrations (less than 1 ppm) which is undesirable [4]. The presence of dyes in wastewater is considered carcinogenic for human [9] besides affecting the aquatic life as dyes prevent penetration of light which damage the biological processes which is performed by the living organisms [1, 3, 10, 11].

The main problem in the disposal of the wastewater from dying process is that dyes are chemicals with complex structure [1], so the ordinary biological treatment is not sufficient for the removal of colors from water [12]. Also the application of the wastewater treatment methods such as flocculation, chemical coagulation, precipitation and membrane filtration is not considered the optimum solution [13], because these methods produce hazardous byproducts and require high cost and energy [4, 14, 15]. So most treatment plants are forced to apply the adsorption technique using various adsorbents to reach their goal. The most commonly used adsorbent is activated carbon due to its high adsorption capacity, availability and non-toxicity, but it is expensive for large scale treatment, so regeneration should be performed [16]. For this reason, the agricultural adsorbents appear as alternatives, as they are available and may be used once through without affecting the environment [12, 16].

In this study different doses of both activated carbon and guava leaf powder (GLP) are applied to calculate their adsorption capacity of Nile blue dye. Different parameters are studied, by changing the dye concentration, residence time and temperature to know the best conditions at which guava leaf powder may be used as an adsorbent for this dye.

II. METHODOLOGY

A. *Materials*

Nile blue dye, activated carbon, guava leaf powder and distillate water.

B. *Apparatus*

Ultraviolet visible spectrophotometer (UV)(EV3122906), dryer, mechanical shaker, digital balance, heater, and mixer.

B. *Method*

The ultraviolet spectrophotometer device is used to determine the adsorption capacity of both activated carbon and guava leaf powder. So a synthetic wastewater mother liquor is formed by dissolving 1 g of Nile blue dye in one liter distillate water. At first; a sample of this wastewater is scanned using UV to determine the maximum wavelength of this dye.

Calibration curve is plotted, by preparation of different concentrations of dye solutions from 1 – 10ppm. The absorbance of light is obtained for each concentration using UV. Then the calibration curve is plotted between the absorbance and concentration.

The effects of dose, concentration, time and temperature are examined, so batch adsorption is performed. As a first step; guava leaf powder is prepared by washing guava leaf using tap water then distillate water. After washing they are dried at 60˚C to get rid of the moisture content, then grinding is performed to increase the adsorption surface area. The powder is used as such without further treatment. Then different doses of activated carbon and guava leaf powder are taken to be able to determine the most effective dose for a constant concentration which is 100 ppm at 100 rpm and 20˚C, so 0.5, 1, 1.5, and 2 g of adsorbents are applied and samples are taken every 10 minutes to check the performance of the adsorbent.

Different parameters are studied, effect of adsorbent dose (0.5, 1, 1.5, 2) g/100ml of dye solution, effect of dye concentration (25, 50, 75, 100) ppm, effect of temperature 20, 40, and 60˚C. At all parameters the concentration is measured with constant time intervals (10min) up to reaching equilibrium concentration.

After performing the previous experiments, the efficiency of removal of dye should be calculated using equation (1) to determine the optimum conditions for each adsorbent and to determine the most suitable adsorbent among these two adsorbents for removal of Nile blue dye.

$$\text{Removal efficiency} = ((C_o - C_e)/C_o)*100 \quad (1)$$

So two different adsorption isotherms are developed for homogeneous and heterogeneous energy distribution on the adsorption surface which are Langmuir and Freundlich respectively [6]. For Freundlich isotherm the following equation is applied:

$$q_e = K_f.\ (C_e)^{1/n} \quad (2)$$

Where, q_e is the mass of dye adsorbed in mg per one g of adsorbent, C_e is the concentration of dye in the solution at equilibrium in ppm, K_f is the adsorption capacity constant, and n is the adsorption intensity constant. But to get these constants, the pervious form should be linearized to be:

$$\text{Log}(q_e) = \log K_f + (1/n) \log C_e \quad (3)$$

While for Langmuir isotherm the original equation is:

$$q_e = (abC_e)/(1+bC_e) \quad (4)$$

and its linearized form becomes:

$$1/q_e = 1/(abC_e) + 1/a \quad (5)$$

Where, a and b are constants indicate the nature of adsorption. These two isotherms are drawn and the R^2 is determined, so the graph which results higher R^2 is considered the acceptable one and from which the constants are obtained.

The adsorption kinetics is a line or curve describes the rate of adsorption or desorption of a solute from the solid surface of adsorbent. It may follow the pseudo first order or the pseudo second order according to the heterogeneity of the solid surface with respect to the solute [6, 17]. The equations of both pseudo first and second order models are expressed as follows:

The pseudo first order model:

$$\text{Log}(q_e - q_t) = \text{Log}(q_e) - (K.t)/2.303 \quad (6)$$

The pseudo second order model:

$$t/q_t = (1/q_e) \times t + 1/(K.q_e^2) \quad (7)$$

III. RESULTS AND DISCUSSION

It's found that the maximum wavelength of Nile blue dye is 630 nm, so the solutions with concentrations in the range of 1 –10 ppm are exposed to light with that wavelength to be able to plot the calibration curve as illustrated in fig. 1.

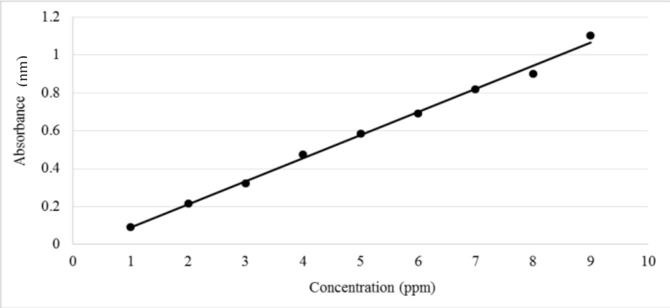

Fig. 1: The calibration curve

The most effective dose at 100 rpm and 20˚C is found to be 0.5g of both activated carbon and guava leaf powder using 100 ml of 100ppm solution. Then the concentration of dye is changed by applying the optimum dose which is 0.5 g adsorbent, at the same conditions (100 rpm and 20˚C) to be 25, 50, 75, and 100 ppm. Samples are taken as time proceeds until reaching the equilibrium to calculate the adsorption capacity at equilibrium. The results from this experiment are represented using the Freundlich and Langmuir models. From these data; the adsorption isotherms are plotted but it is found that activated carbon fits Freundlich isotherm while GLP fits the Langmuir isotherm as shown in fig. 2. From this graph, the value of a and b are 17.6 and 11.852 respectively.

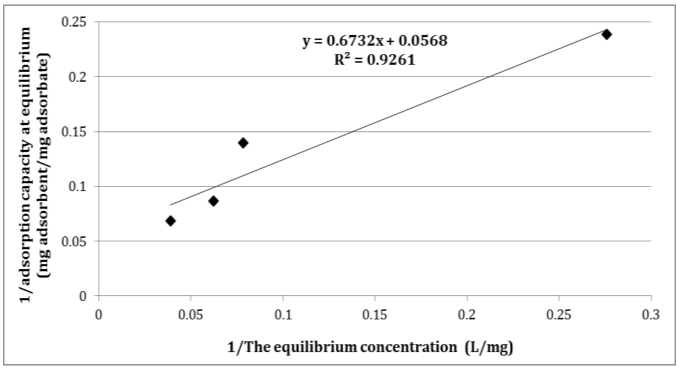

Fig. 2: Langmuir adsorption isotherm for guava leaf powder

To determine the most suitable adsorbent, the maximum adsorption capacity is calculated for both activated carbon and guava leaf powder at equilibrium (after 30min) and found to be 4.997mg/g and 14.85 mg/g respectively. Also the efficiency of removal of dye is calculated in both cases and their values are 27.65% for activated carbon and 74.25% for

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guava leaf powder. From the previous results; it is clear that guava leaf powder is more effective than activated carbon, so the rest of experiments are done using GLP only.

Effect of Time

Fig. 3 illustrates the equilibrium time, and from which it is obvious that after equilibrium when time increases, desorption occurs, so the concentration increases again.

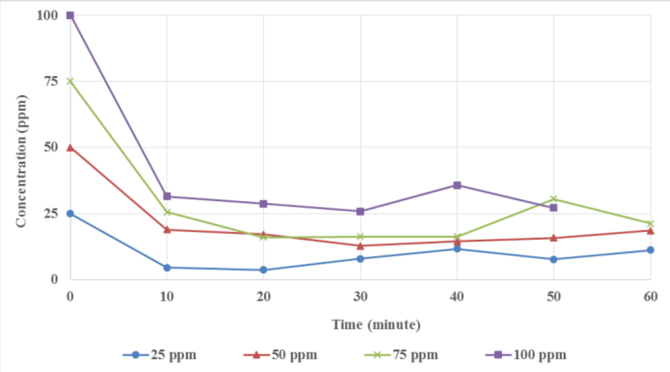

Fig. 3: The change in concentration of dye with time

Effect of Dye concentration

It was noticed that as concentration of dye increased from 25-100 ppm the adsorption capacity (q_e) increased from 4.2mg/g to 14.85 mg/g.

Effect of Temperature

Fig. 4 shows that as temperature increases, the adsorption power of Nile blue dye increases slightly.

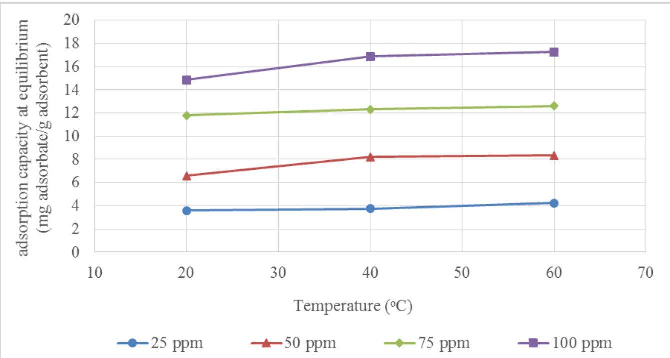

Fig. 4: The effect of temperature on the adsorption power

Adsorption Kinetics

The adsorption kinetics of dye over the surface of guava leaf powder is represented in fig.5; it was found that the adsorption process of Nile blue dye over the surface of guava leaf powder is compatible with the pseudo second order model.

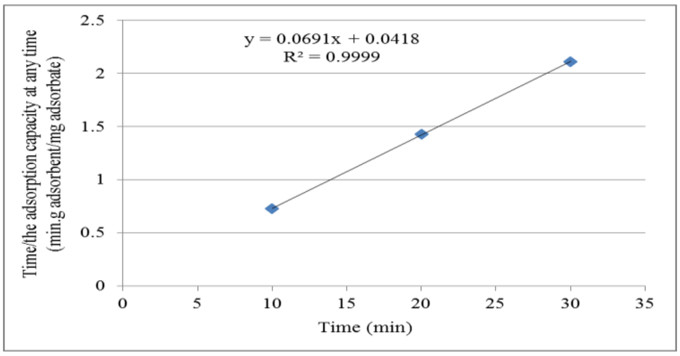

Fig. 5: The pseudo second order model

IV. CONCLUSION

- Guava leaf powder and activated carbon can be used for adsorption of Nile blue dye
- Guava leaf powder is cheaper than activated carbon and more efficient.
- Adsorption efficiency of activated carbon is 27.65 % and 74.25% for guava leaf powder
- Increasing the temperature from 20-60°C slightly improved the adsorption efficiency of guava leaf
- Increasing the concentration of dye from 25-100ppm improved the adsorption capacity of guava leaf from 4.2mg/g to 14.85 mg/g.
- Langmuir adsorption isotherm was the best fitting for guava leaf powder
- The pseudo second order model was the best fitting for kinetics of adsorption using guava leaf powder.

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