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Research paper

Removal of reactive yellow (RY) AZO dye using activated carbon synthesized from fire stick wood

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Abstract

In the present work we synthesized activated carbon using fire stick wood. For the synthesis chemical activation method is employed using phosphoric acid. Various parameters which influence the adsorption process such as agitation time, adsorbent dosage, initial dye concentration, volume of RY dye solution and pH were studied. Studies showed that 40 mg of adsorbent with 240 micron size was found to remove around 96.76% of dye. Increase in adsorption with the increase in dosage of the adsorbent and decrease in size of the particle, initial concentration and increase in pH of the solution 3 to 6. The obtained results show that activated carbon synthesized from fire wood is effective in the removal of the dye from aqueous solution.

Keywords: *Activated Carbon; Fire Stick; Wood; Reactive Yellow; Dye.*

1. Introduction

An image is a two-dimensional picture, which has a similar Advance in science and technology have bought progress and developments in many spheres of society, but in the process, also contributed and are contributing to the degradation of environment. The significant factor for the continuous degradation of the environment is industrial pollution. Due to continuous increase in deposition of waste material the ecological system was affected significantly.
In any form, there are several health hazards from pollution. Dye is a substance which is applied to the substrate in aqueous solution to change its color. Dyes are not biodegradable materials and through various industrial discharges like refineries, plastic food processing industries and so on they are discharged into the environment. The water pollution caused by these dyes severely affects the aquatic life. Presently more than 1 lakh dyes and more than 700 tons of dye stuff are produced presently.
Dyes are classified as basic dyes, acidic dyes, reactive dyes, mordant dyes, azo dyes, sulfur dyes and so on. The presence of sunlight or water does not fade these dyes. Due to their complex structures they cannot be conveniently treated in the conventional treatment plants for waste waters. Reactive dyes are firstly introduced by ICI in 1956. The largest class of dyes used in the world is referred to as reactive azo dyes. Reactive Azo dyes, characterized by their azo bond (R1-N=N-R2), are more popular group of dye used, basically, in textile industry. It provides a full of brilliant color selection and good fastness property to washing, light, and bleaching. The main characteristic for the reactive dyes is forming covalent bond with fiber, which is used to cellulose protein and polyamide fiber.
The earlier reports on the adsorption of dyes using various adsorbents are reported here. Malachite green is one type of dye for which silver nanoparticles were used for adsorption. Parameters such as adsorbent dosage, pH, temperature were studied and reported along with kinetic and thermodynamic data [1-2]. In another report malachite green was removed using Indian leaf spinach powder as adsorbent [3-4]. The adsorption characteristics for this dye were studied using fourier transform infra-red spectroscopy (FTIR). In another report potato peel (PP) and neem bark (NB), agricultural adsorbents which are chemically modified are used. Three isotherms namely Langmuir, Freundlich and Temkin model are studied to understand the kinetics. While Freundlich isotherm favored PP, Temkin isotherm favored NB [5].
Activated carbon synthesized using rice husk, chemically activated using sulfuric acid and zinc chloride [6], [7], peanut shells [8] walnut shells [9], activated and inactivated banana peel powder [10], Montmorillonite clay [11] are reported to removal more than 95 % of the methylene blue dye. In addition to natural adsorbents multi wall carbon nano tubes (MWCNTs) [12] and graphene carbon nano tubes (G-CNTs) [13] and mesoporous SBA-3 [14] were also reported to adsorb significant amount of methylene blue dye. Parameters studied are adsorbent dosage, adsorbent particle size and initial dye concentration. Equilibrium studies and isotherms were fitted for the given data.
Santhi et al., 2016 [15] reported the removal of two different dyes malachite green (MG) and methylene blue (MB) using Annona Squmosa seed. The results showed a removal of more than 75% for MG and more than 30 % for MB It was reportedbased on the adsorption studies that the removal of the dye is highly dependent on pH and the optimum pH was reported to be around 6.

2. Experimental procedure

Experimental studies were performed batch wise, for the adsorption of RY dye using activated carbon from fire stick wood as adsorbent. The experimental procedure consists of:

1) Preparation of adsorbent,
2) Preparation RY dye stock solution and
3) Studies on various parameters effecting adsorption process.

2.1. Preparation of adsorbent

Activated carbon is prepared from fire stick plant wood. Initially, Raw material (fire stick plant wood) was washed 2 to 3 times with water to remove mud, dust and any unwanted external materials that are present on the surface. Distilled water is used for second time washing purpose and, then the material is cut into 2-3 cm size and dried under sunlight for 24 h. The dried material was then soaked in 35% phosphoric acid for 1 hour and allowed to cool to room temperature and is kept there for 24 h show in Fig 1. The wood material was then screened, dried and subjected to high temperature in muffle furnace maintained at 550 °C for 1.5 h. After heating, the obtained material is crushed into powder or granular form. The resulting powder is activated at 800 °C for 10 min. The powder is again washed using distilled water until a constant pH was reached. The sample was then dried under sunlight and screened to 120 -300 µ size using a sieve shaker.

Fig. 1: Cutting and Soaking of Fire Stick Wood.

Fig. 2: Stock Solution of RY Dye.

2.2. Preparation of RY dye stock solution

The stock solution of the dye was prepared by dissolving 1g of RY azo dye in 1 L of distilled water shown in Fig 2.
The dyes were without further purification. The chemicals used are analytical reagent (AR) grade category. Different concentrations of synthetic samples of dye solution are prepared from the stock solution. The solution pH is adjusted to the desired value by addition of H_2SO_4 or NaOH. UV spectrophotometer at a fixed wavelength is used to measure the dye concentration in the solution.

2.3. Studies on various parameters of adsorption

2.3.1. Agitation time

To 50 mL of the prepared solution, 0.1 g of adsorbent is added in a 250 mL conical flask. This is further shaken at 160 rpm at room temperature using an orbital shaker for 10 min. The experimental procedure is repeated for different agitation times of 30, 50, 70, 90, 110, 130, 150 and 170 min respectively. These samples are then filtered using Whatman filter papers. The concentration of the filtrates are then analyzed in UV- spectrophotometer
The percentage adsorption of RY dye is calculated as

$$\%\ \text{adsorption of RY Dye} = \frac{(C_0 - C_t)}{C_0} * 100$$

Where, C0= Initial RY dye concentration (mg/L), Ct= Final RY dye concentration (mg/L). To determine the optimum agitation time a graph is plotted between agitation time and % adsorption.

2.3.2. Adsorbent size

To 50 mL of the prepared solution, 0.1 g of adsorbent is added in a 250 mL conical flask. This is further shaken at 160 rpm at room temperature using an orbital shaker for 10 min for optimal agitation time (130 min). The experimental procedure is repeated with various sizes of adsorbent (170, 200 and 240 µm). These samples are then filtered using Whatman filter papers. The concentration of RY dye in the final filtrate is analyzed in UV-spectrophotometer. To determine the optimum adsorbent size a graph is plotted between adsorbent size and % adsorption.

2.3.3. Adsorbent dosage

To 50 mL of the prepared solution, 0.1 g adsorbent of 240 micron size is added in a 250 mL conical flask. This sample is shaken on an orbital shaker at room temperature for optimal agitation time (130 min). The experimental procedure is repeated with various adsorbent dosages (0.2, 0.3 and 0.4 gm). These samples are then filtered using Whatman filter papers. The concentration of RY dye in the final filtrate is analyzed in UV-spectrophotometer. To determine the optimum adsorbent dosage a graph is plotted between adsorbent dosage and % adsorption.

2.3.4. Initial concentration of RY dye in aqueous solution

To 50 mL of the prepared solution, 0.4 g of 240 micron adsorbent size is added in a 250 mL conical flask. This sample is shaken on an orbital shaker at room temperature for optimal agitation time (130 min).These samples are then filtered using Whatman filter papers. The concentration of RY dye in the final filtrate is analyzed in UV-spectrophotometer. The same procedure is repeated for other initial concentrations of RY dye in aqueous solution (50, 75and 100 mg/L).
The effect of initial concentration is studied by plotting a graph between initial concentration and % adsorption.

2.3.5. Volume of the aqueous solution

To 50 mL of the prepared solution, 0.4 g of 240 micron adsorbent size is added in a 250 mL conical flask. This sample is shaken on an orbital shaker at room temperature for optimal agitation time (130 min).These samples are then filtered using Whatman filter papers. The concentration of RY dye in the final filtrate is analyzed in UV-spectrophotometer. The same procedure is repeated for other volumes of the RY dye solution of 100, 150 and 200 mL. The effect of volume on the adsorption of the dye is studied by plotting a graph between Volume and % adsorption.

2.3.6. PH of the solution

To 50 mL of the prepared solution, 0.4 g of 240 micron adsorbent size is added in a 250 mL conical flask. Separate flasks are taken and the pH of the solution varied from 3 to 9 by adding either sulfuric acid or sodium hydroxide. These samples are shaken on an orbital shaker at room temperature for optimal agitation time (130 min).These samples are then filtered using Whatman filter papers. The concentration of RY dye in the final filtrate is analyzed in UV-spectrophotometer. The optimum pH value is obtained by plotting a graph between pH of the RY dye solution and % adsorption.

3. Results and discussion

3.1. Calibration curve

Solutions with different dye concentrations of 10 mg/L, 25mg/L, 50mg/L, 75mg/L and 100mg/L were prepared. Their absorbance values were found using UV spectrophotometer at wavelength of λmax=525. With the obtained absorbance values a standard calibration curve is plotted between concentration and absorbance. This plot is used to determine the concentration of the samples obtained after adsorption.

3.2. Effect of agitation time

Figure 3 shows the graph plotted between agitation time and percentage of adsorption. For 50 mL of the dye solution with an initial concentration of 25 mg/L, the adsorbent dosage is 0.1 g (240 micron size) and pH is 4.5. The experiment is performed for different agitation times of 10 minutes to 170 minutes respectively. The experimental results showed that the percentage adsorption of the dye increased with increase in agitation time up to 130 minutes. Beyond 130 minutes there is no significant increase in the percentage of adsorption.
It is observed that the rate of adsorption is high in the initial stages. This is because of adequate surface area of the adsorbent available for the adsorption of RY dye. With increase in agitation time more amount of dye gets adsorbed onto the surface of the adsorbent and available surface area decreases which decrease the percentage of adsorption. The adsorbate, normally, forms a layer over the surface of the adsorbent. When this ayer covers the entire surface, the capacity of the adsorbent is decreases. The maximum % adsorption is attained at 130 min of agitation. The percentage adsorption of RY dye becomes almost constant after 130 min. Hence all subsequent experiments are conducted at this optimum agitation time.

3.3. Effect of adsorbent dosage

Figure 4 shows the graph plotted between adsorbent dosage and percentage of adsorption. The size of the adsorbent is 240µm. The experimental results show that the percentage of adsorption of RY dye increases with increase in the adsorbent dosage. % adsorption of RY dye increases from 41.68% to 85.04%, for the adsorbent size 240µm, Initial concentration of RY dye, C0=25 mg/L, volume of aqueous solution=50 mL, agitation time= 130 min, pH=4.5, as dosage is increased from 0.1 to 0.4 gm. Such behavior is obvious because the number of active sites available for the adsorption of RY dye would be more as the amount of the adsorbent increases. The change in % adsorption of RY dye is marginal when adsorbent dosage is beyond 0.4 gm. So, all the experiments are conducted at dosage =0.4 gm.

3.4. Effect of adsorbent size

The variations in % adsorption of RY dye with various adsorbent particle size (150, 170, 200 and 240µm) are obtained at adsorbent dosage of 0.1 gm, Initial concentration of RY dye, C0=25 mg/L, Adsorbent dosage=0.4 gm, Volume of aqueous solution=50 mL, Agitation time=130 min, pH=4.5. Figure 5 shows the percentage adsorption of RY dye as a function of adsorbent size. The percentage adsorption of RY dye increased particle size decreases from 240 micron to 150 micron. This phenomenon is expected, as the size of the particle decreases, surface area of the adsorbent increases, thereby the number of active sites on the adsorbent are better exposed to the adsorbate.

3.5. Effect of initial RY dye concentration

The effect of initial RY dye concentration in the aqueous solution on the percentage adsorption of RY dye is shown in Figure 6. The percentage adsorption of RY dye decreased from 85.04% to 63.34% by increasing the initial RY dye concentration from 25 mg/L to 100 mg/L at adsorbent dosage=0.4 gm, adsorbent size= 240 µm, volume of aqueous solution=50 mL, agitation time=130 min, pH=4.5. Such behavior can be attributed to the increase in the amount of adsorbate to the unchanging number of available active sites on the adsorbent (since the amount of adsorbent is kept constant).

3.6. Effect of volume of dye solution

Change in percentage adsorption of RY dye with variation in volume of the aqueous solution from 50 to 200 mL is shown in Figure 7 for an adsorbent dosage of 0.4 gm of 240µm size, optimum agitation time=130 min and pH=4.5. From these plots, it is clear that percentage adsorption of RY dye is gradually decreased with an increase in feed volume. The % adsorption decreased from 85.04% to 55.6 %. As the volume feed solution increases, the amount of RY dye present in the solution also increases. This implies that % dye removal by unaltered adsorbent surface area decreases as the amount of RY dye in the solution is increased.

3.7. Effect of PH

PH influences the surface charge of the adsorbent, the degree of ionization and the species of adsorbate. So pH is an important factor controlling the process of adsorption. In the present investigation, adsorption data are obtained in the pH range of 3 to 9 for RY dye initial concentration of 25mg/L, Volume of aqueous solution=50 mL, Agitation time=130 min and 0.4 gm of 240µm size adsorbent. The influence of pH of aqueous solution on % adsorption of RY dye is shown in Figure 8. The percentage adsorption of dye is increased from 80% to 85.6% as pH is increased from 3 to 6. Increase in % adsorption is marginal for pH values between 6 to 7 (85.6% to 85.2 %). This is due to partial hydrolysis of dye ions. The percentage adsorption is decreased for pH value above 6.

4. Conclusions

In this work, the carbon prepared from fire stick wood is used as a adsorbent for the removal of RY dye from aqueous solution. Adsorption of reactive dye increases with increase in contact time, adsorbent Dosage and decreases with increase in Initial RY dye concentration, Adsorbent size, Volume of solution. Removal of reactive azo dye is found to be pH dependent and the maximum removal occurs in acidic medium (4-6). The pH after 6, percentage adsorption of dye decreases. The optimal parameters obtained in this study are Agitation time= 130 min, Adsorbent size= 240 µm, Adsorbent dosage= 0.4gms, Initial concentration= 25mg/L, Volume of solution= 50 mL and pH value as 6.

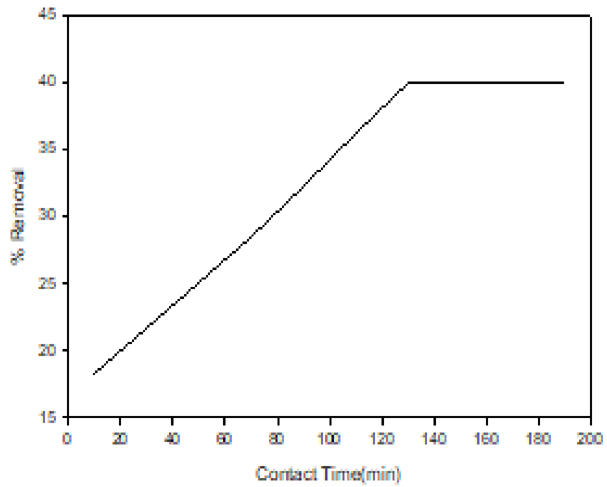

Fig. 4: Effect of Agitation Time.

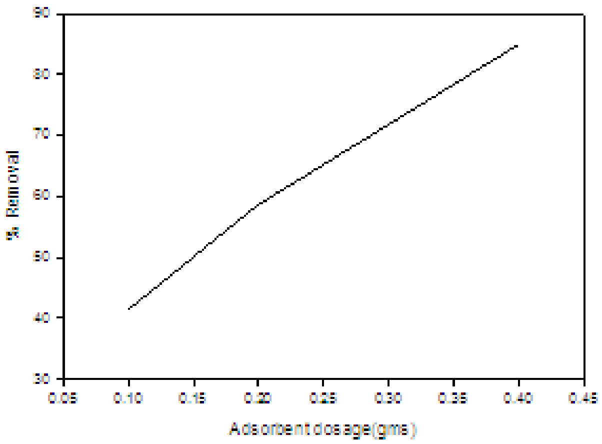

Fig. 5: Effect of Adsorbent Dosage.

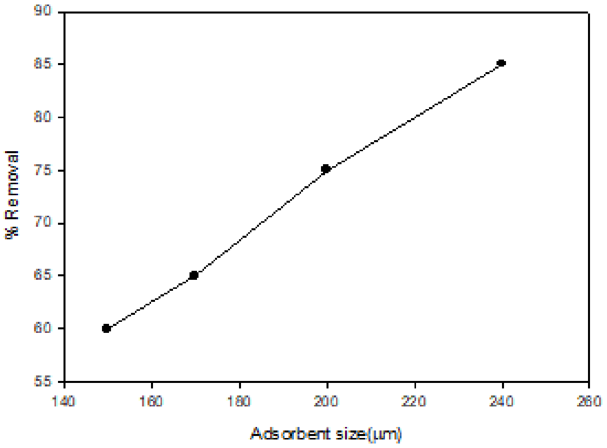

Fig. 6: Effect of Adsorbent Size.

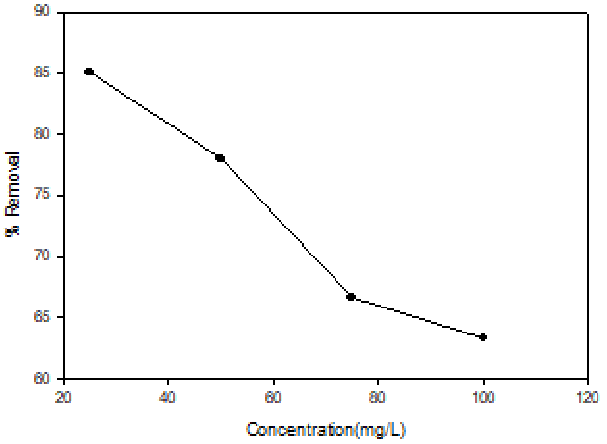

Fig. 7: Effect of Initial Concentration of RY Dye.

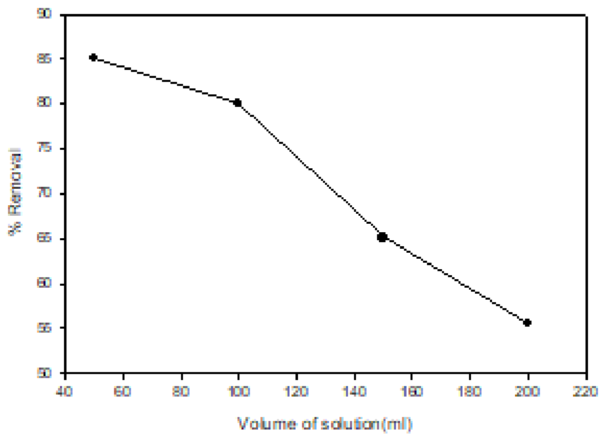

Fig. 8: Effect of Volume of Dye Solution.

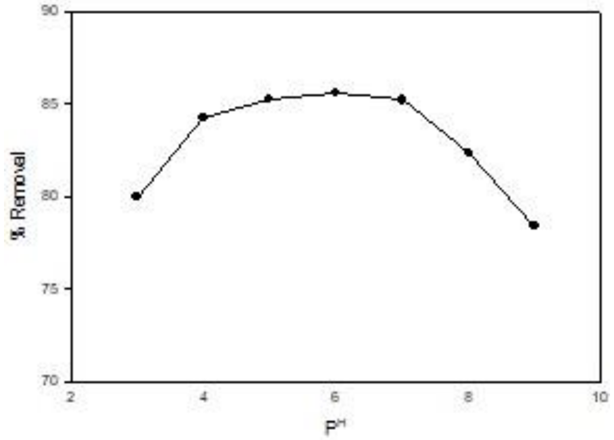

Fig. 9: Effect of PH.

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