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Research Article

RESEARCH ON SYNTHETIC METHODS FOR ACTIVATED CARBON MATERIALS FROM DURIAN PEELS TO DECOLORIZE REACTIVE BLUE 220 IN TEXTILE DYE WASTEWATER

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ABSTRACT

In this study, coal samples are synthesized from durian peel (the outer protective layer of durian fruit) by drying, mincing, and putting into a sieve with a fine mesh of 1-2 micrometers. Coal samples are activated by 2M NaOH solution with 1:20 (w/v) ratio for 2 hours and then heated at 700 degrees Celsius for 1 hour to create activated carbon. After preparation, samples are analyzed using advanced analytic techniques such as FTIR spectroscopy and SEM. The adsorption of activated carbon on the Reactive Blue 220 dye is investigated. Results show that the adsorption of the material is affected by the concentration of Reactive Blue 220, which, therefore, needs to be controlled in the adsorption process. In addition, optimal parameters are also investigated for the best adsorption condition, particularly at pH=7 with dye concentration at 10 ppm, 20 ppm, 30 pmm, and 40 ppm with the addition of 0.2 grams of coal and exposed for 3 hours and 30 minutes (210 minutes). The color removal efficiency is found to be 92.64% (for 10 ppm concentration of Reactive Blue 220). The Langmuir adsorption model is applied and the maximum adsorption capacity is 21.053 mg/g.

Keywords: activated carbon; Adsorb; durian peels; Reactive Blue 220 dye

1. Introduction

Currently, the process of industrialization-modernization brings benefits to socio-economic development, in which the textile and dyeing industry is not out of the common trend. People's needs in general and clothing, in particular, are increasingly rising. Vietnam is the 15th most populous country in the world and ranked the 3rd in Southeast Asia (after Indonesia and the Philippines), so the demand for clothing is relatively high. Because of that, the textile industry is more and more interesting to investors. With such favorable conditions, a growing number of textile dyeing companies are built across the

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country to meet market needs. The strong development of the textile dyeing industry has created an environmental pollution problem, mainly caused by textile dyeing wastewater.

Reactive Blue 220 dye is capable of dyeing materials such as fabric, paper, plastic, and leather. In addition to the color-carrying groups (quinone, azo, nitro), the dye also contains color-supporting groups such as OH and NH_2, which have the effect of increasing the color and the adhesion of the color to the fiber (Patel, Bhatt, & BBhatt, 2013). Color elevation as well as colors, when entering natural water sources such as rivers and lakes, will interfere with the absorption of oxygen and sunlight, hindering the process of photosynthesis (Patel, Bhatt, & BBhatt, 2013). People exposed to this type of hazardous wastewater often suffer from skin diseases, and polluted air causes respiratory diseases, such as rhinitis, pharyngitis, and digestive problems (Patel, Bhatt, & BBhatt, 2013).

There have been several methods used to treat dye color in textile wastewater, such as physicochemical methods (i.e. adsorption, ion exchange), biological methods, and chemical methods. However, activated carbon adsorption is the most commonly used due to its low cost and ease of use. Activated carbon is a form of carbon that is processed and activated at temperatures above 400^0C in an anaerobic environment, creating a carbon with a very large capillary structure that increases the contact surface area and low density. The mechanism of the activated carbon method includes two stages: coarse filtration and adsorption (Le, Nguyen, & Nguyen, 2007).

Currently, cheap and easy-to-find materials (such as durian peels, bagasse, peanut shell, corn cob, coir, rice husk, straw) are used to make activated carbon to adsorb the color dyes in water. Durian has been grown widely in the western provinces of Vietnam but its peel is not often used, so a large number of durian peels are thrown into the surrounding environment. According to statistics from the Ministry of Agriculture and Rural Development, the area under durian cultivation in Vietnam has increased by 51% from 32,300 hectares in 2016 and may increase to 48,600 hectares in early 2020 (Le & Le, 2016). The production level is over 296,200 tons per year, while on average, only 25-30% of the fruit weight is its flesh. Durian fruit can reach 30 centimeters in length and 15 centimeters in diameter, usually weighing one to three kilograms (Le & Le, 2016). Preliminary estimates show that every year, nearly 214.7 tons of durian peels are discarded, an extremely abundant source of scrap. Durian husk has three basic components: cellulose (30.92%), hemicellulose (17.99%), and lignin (7.69%) (Le & Le, 2016). Researches on activated carbon made from durian peels have been conducted using activated carbon to remove heavy metals or adsorbent materials, yet toxic organic chemicals and impurities of sizes larger than the pore will be trapped (Le & Le, 2016).

Therefore, this study investigates the ability to treat Reactive Blue 220 dye applying activated carbon from durian peel and, hence, contributes to the creation of environmentally friendly activated carbon materials as well as establishes the foundation for further research and development on activated carbon from durian peels.

2. Experimental

2.1. Materials and chemicals

Materials and chemicals used in this study include: durian peels, sodium hydroxide (NaOH), hydrochloric acid (HCl), and Reactive Blue 220 dye (99% purity purchased at Azelis Company at 1489 Nguyen Van Linh Street, Tan Thuan Dong Ward, District 7, Ho Chi Minh City).

2.2. Durian peels preparation

Durian peels (Long Khanh durian) are collected from fruit shops in markets or supermarkets. The peels are washed to remove dust, cut into about five centimeters, and dried under direct sunlight for two and three days. The milled sample was then ground in a blender to a fibrous or powder form and then dried in an oven at 80°C for five hours to remove moisture.

2.3. Carbonization of durian peels

The prepared durian peel is activated with a NaOH solution with a molar concentration of 2M with an impregnating ratio of 1:20 g/ml and stirred at 80^0C for 1 hour. Next, the sample is washed with distilled water, then filtered out and dried in an oven at 80^0C until the sample is dry. Then, it is heated at 700^0C for one hour to carbonize into activated carbon.

2.4. Reactive Blue 220 dye preparation

A total of 200 milligrams of Reactive Blue 220 dye reactive dye in powder form is put–in a 1,000-milliliter volumetric titration flask. Its pH value is adjusted to 11.5. The solution is then heated and magnetically stirred for 1 hour at 80^0C.

3. Results and discussion

3.1. Absorption spectrum and standard curve equation of color RB220

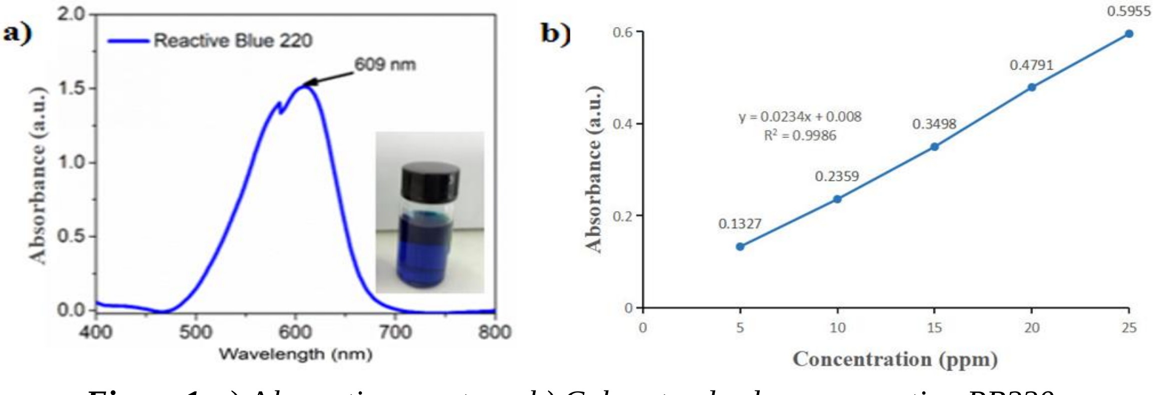

Figure 1. a) *Absorption spectrum b) Color standard curve equation RB220*

Figure 1a shows the characteristic peak of RB220 color at 609 nm. This result is similar to the results of previous studies determining the characteristic absorption peak of the color RB220 (Patel, Bhatt, & BBhatt, 2013).

In addition, Figure 1b shows a linear equation (standard curve): y = 0.0234x + 0.008 (*), R^2 = 0.9986, where y is the absorbance value and x is the concentration of RB220 (ppm). Based on equation (*), the RB220 concentration can be calculated directly from the characteristic absorbance peak value at 608 nm at the initial and processing stages. From there, the decolorization efficiency is determined.

3.2. Surface morphology and structure of activated carbon (AC) material from durian shell

3.2.1. Infrared spectrum FT-IR

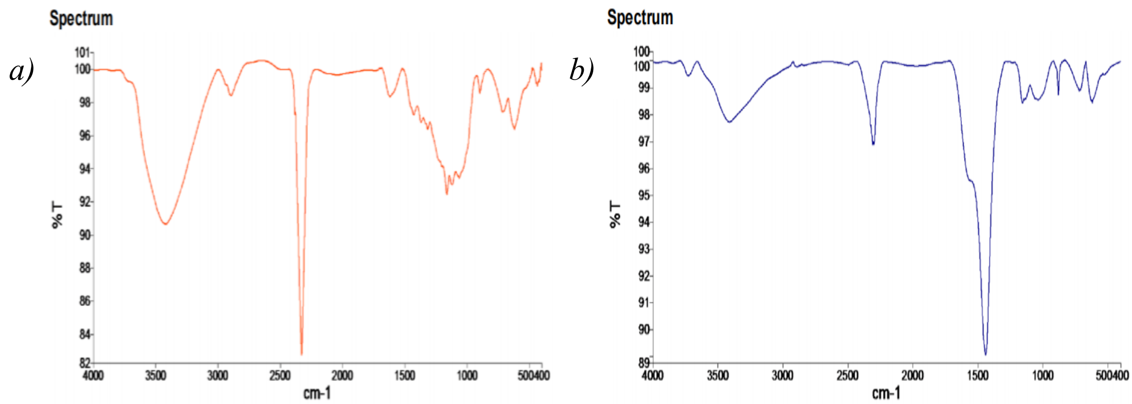

Figure 2. *a) FT-IR of AC before processing. b) FT-IR of AC after processing*

To demonstrate the binding between the stabilizer (OCS) and nano selenium, the infrared spectra of OCS and the SeNPs/OCS solution are measured over the wavelength range from 400 to 4000 cm^{-1} and shown in Figure 2a. The results from the infrared spectrum of OCS show the characteristic absorption peaks for the functional groups as follows: the wide peaks at 3426.72 cm^{-1} represent the valence fluctuations of the -OH group, 2895.24 cm^{-1} and 2883.03 cm^{-1} characterize the asymmetric and symmetric valence vibrations of the $-CH_2$ group, 1619.38 cm^{-1} characterizes the strain vibrations of the CO-NH bond, 1428.71 cm^{-1} is for the vibration of the -NH group, 1316.28 cm^{-1} is for the resonance vibration of the CN and NH bonds, 1161.86 cm^{-1} is for the vibration of the C-OH group of a secondary alcohol, 1062.27 cm^{-1} represents the vibration of the C-OH group of a primary alcohol, and 617.26 cm^{-1} is the oscillation of the glycoside ring.

Figure 2b FT-IR of AC after processing shows the variation of peaks in intensity and position, thereby, proving the presence and impact of dye.

3.2.2. Scanning electron microscopy (SEM)

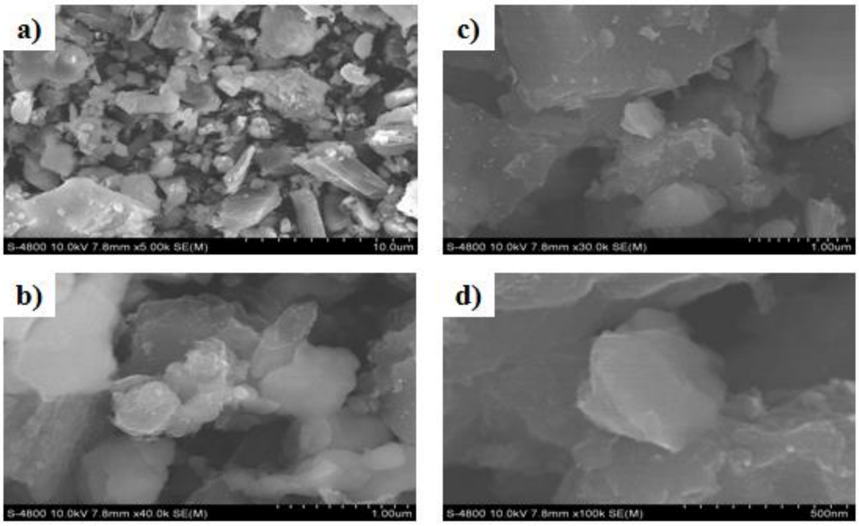

Figure 3. *SEM of activated carbon*

Magnified dimensions in Figure 3 show that the material has many holes with average sizes of the holes vary from 30 to 150 micron. The material has heterogeneous capillaries, porosity, and a rough surface.

3.3. Determination of optimal factors in RB220 color treatment with activated carbon.

3.3.1. Optimal pH

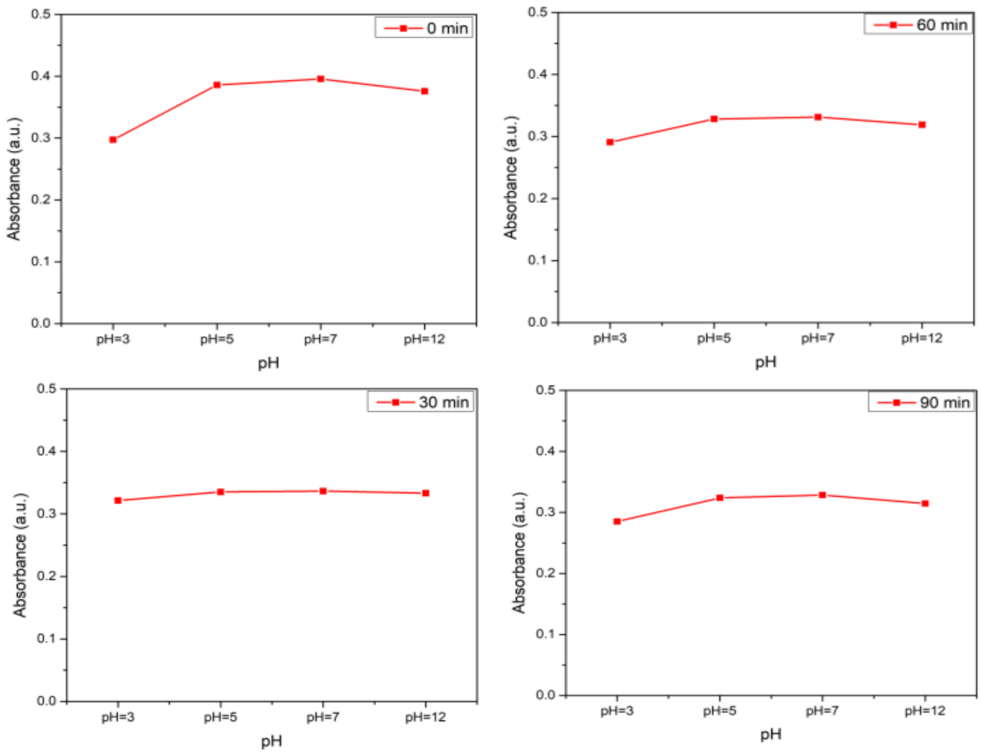

Figure 4. *pH changes with time*

pH is investigated at 3, 5, 7, and 12 to find the optimal pH value. At 20 ppm, pH is adjusted using HCl and NaOH and examined for 90 minutes on a stirrer. According to the efficiency at pH = 7, the adsorption efficiency is higher from 0 to 17.01% compared to the remaining pH points. Therefore, pH = 7 is suggested as optimal for RB 220 dye adsorption.

3.3.2. Optimal time

The optimal adsorption time of coal with RB220 dye is investigated by adding 0.2 g of AC to 250 ml of RB220 solution at a concentration of 10 ppm and adjusting pH = 7, then stirring on a magnetic stirrer for a period of 0 to 210 minutes. The obtained results are displayed on a line graph showing the adsorption capacity with respect of time.

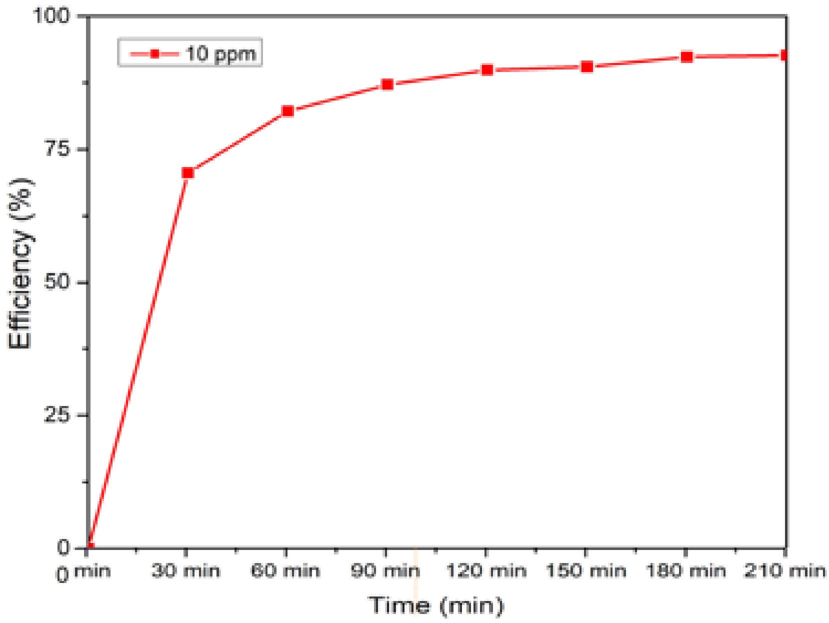

Figure 5. *Adsorption efficiency over time*

The adsorption efficiency increases over time, rapidly from 0 to 90 minutes, then gradually increases over 120 to 210 minutes on the agitator. Peak efficiency is 70.58% after 30 minutes. The performance increases not as much as the first time from 120-210 minutes on the stirrer.

3.3.3. Isothermal line Langmuir

The Langmuir adsorption isotherm refers to a homogeneous adsorption capacity, where each molecule has continuous enthalpies and adsorption activation energies (all sites have equal affinity), the adsorbent does not move in the plane of the surface.

Using the standard curve equation of color RB220: y = 0.0234x + 0.008, the calculation is shown in Table 1.

Table 1. *Calculation of the adsorption process*

0 min		210 mins			
Absorbance (abs)	**Co: Concentration (ppm)**	**Absorbance (abs)**	**Ce: Concentration (ppm)**	$qe = \frac{(Co - Ce)xV}{m}$	**Efficiency (%)**
0.2370	10	0.0153	0.32	12.10	96.80
0.4680	20	0.1033	4.07	19.91	76.65
0.7080	30	0.2373	9.80	25.25	67.30
0.9360	40	0.3924	16.43	29.46	58.90

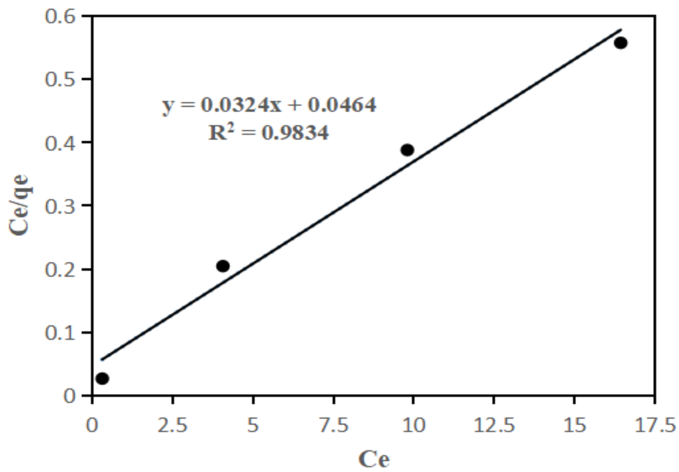

Figure 6. *Isothermal line Langmuir Langmuir*

$$\frac{Ce}{qe} = \frac{1}{K_L \text{ x } Q_{max}} + \frac{Ce}{Q_{max}}, \ \frac{Ce}{qe} = y, Ce = x \Rightarrow y = \frac{1}{K_L \text{ x } Q_{max}} + \frac{1}{Q_{max}}x$$

Table 2. *Mechanical parameters of Langmuir*

Langmuir	Q_{max} (mg/g)	21,053
	K_L	4,204
	R^2	0,9834

3.3.4. Investigate the dosage of NaOH for the modifying process of activated carbon

❖ Modified charcoal

The dye concentrations are evaluated at 10, 20, 30, and 40 ppm, with pH = 7 and 0.2 g inert coal (unmodified coal), stirred on a stirrer in 210 minutes. The obtained results are shown in Figure 7.

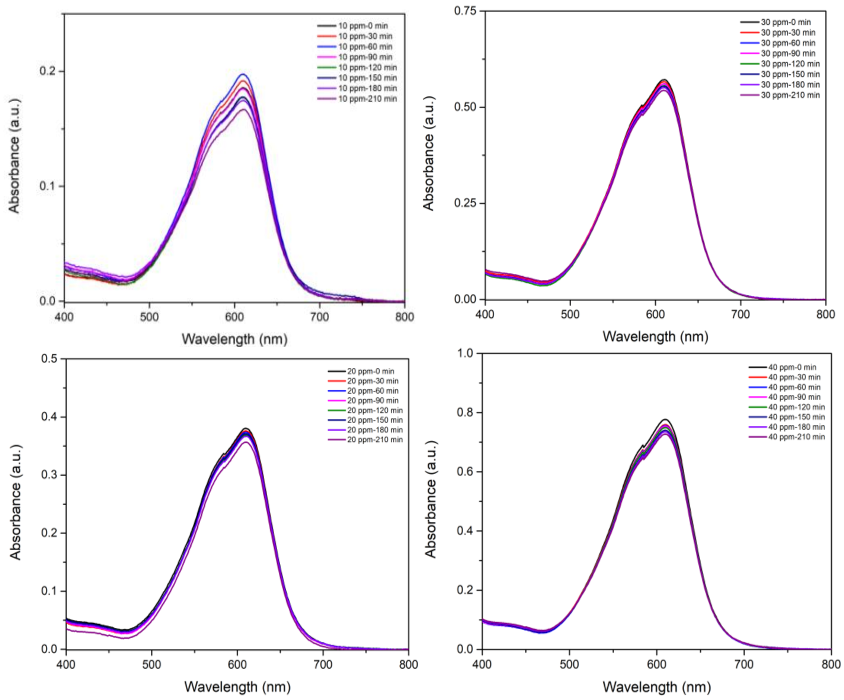

Figure 7. *Absorbance with unmodified charcoal*

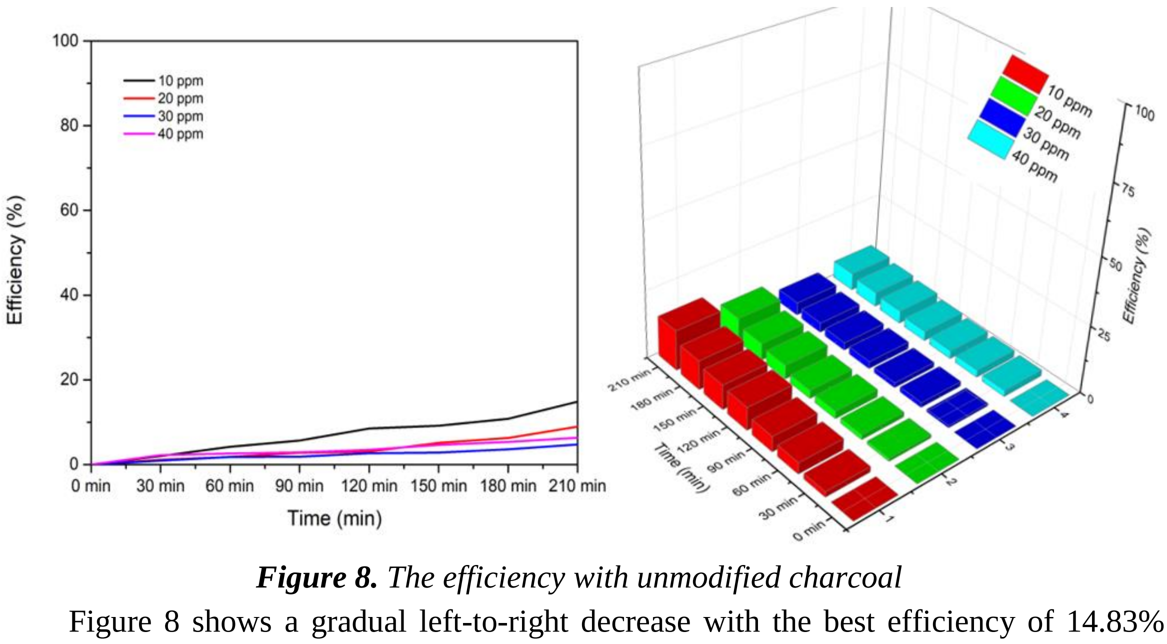

Figure 8. *The efficiency with unmodified charcoal*

Figure 8 shows a gradual left-to-right decrease with the best efficiency of 14.83% seen at 10 ppm concentration and then decreasing. Besides, for unmodified coal, it is not very effective when it comes to dye treatment.

❖ Modified coal NaOH 1M

The concentration of dye concentration is investigated at 10, 20, 30, and 40 ppm, adjusted with pH = 7 and 0.2 g of modified coal NaOH 1M, stirred on the stirrer for 210 minutes. The results obtained are shown in Figure 9 below.

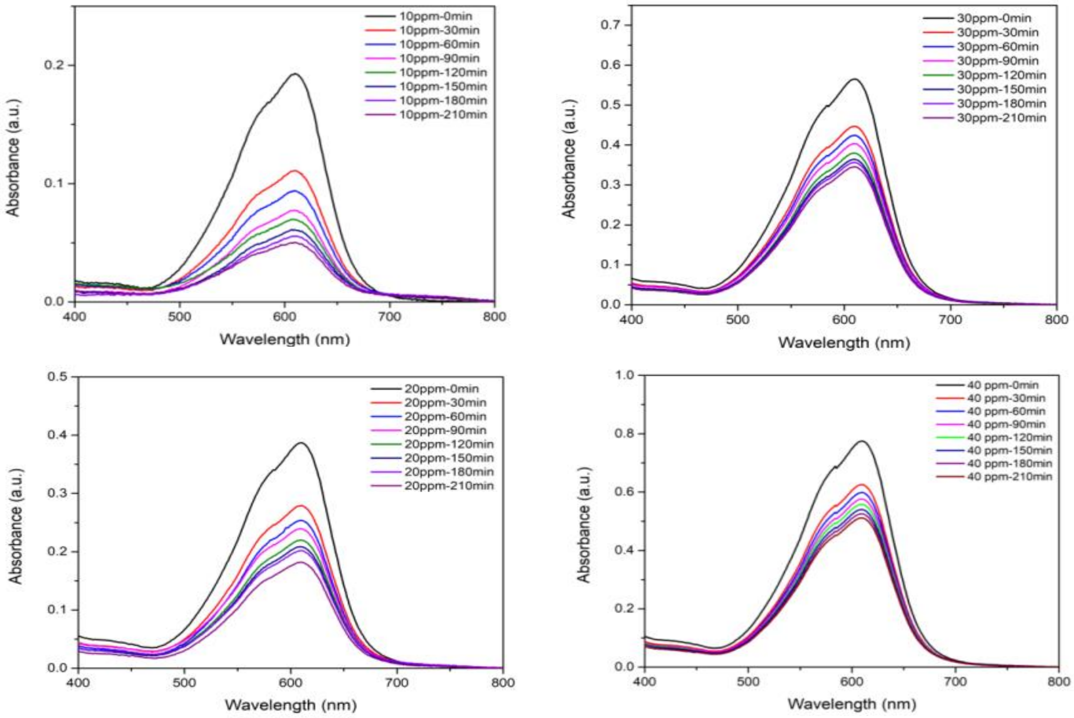

Figure 9. *Absorbance with modified coal NaOH 1M*

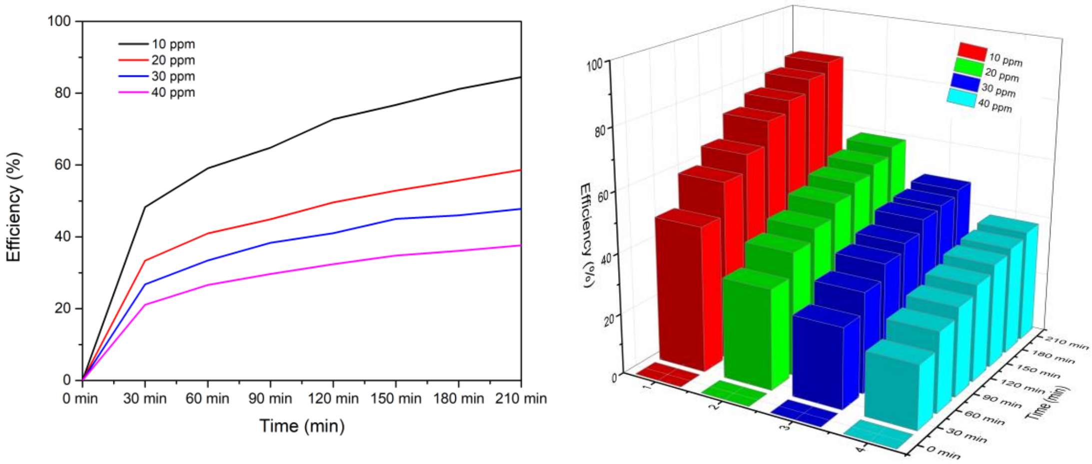

Figure 10. *The efficiency with modified coal NaOH 1M*

Figure 10 shows a left-to-right decrease with the highest efficiency of 84.49% observed at 10 ppm after 210 minutes on an agitator.

❖ Modified coal NaOH 1.5M

The concentration of dye is investigated at 10, 20, 30, and 40 ppm, adjusted with pH = 7 and 0.2 g of modified coal NaOH 1.5M, stirred on the stirrer for 210 minutes. The results obtained are shown in Figure 11 below.

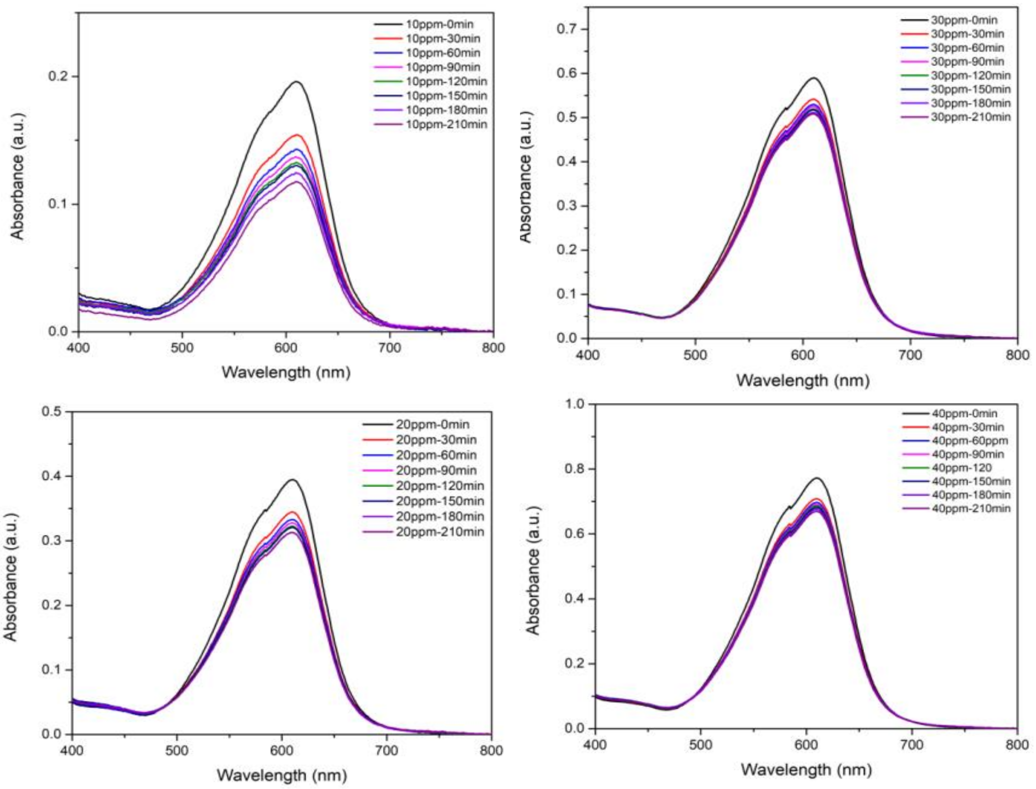

Figure 11. *Absorbance with modified coal NaOH 1.5 M*

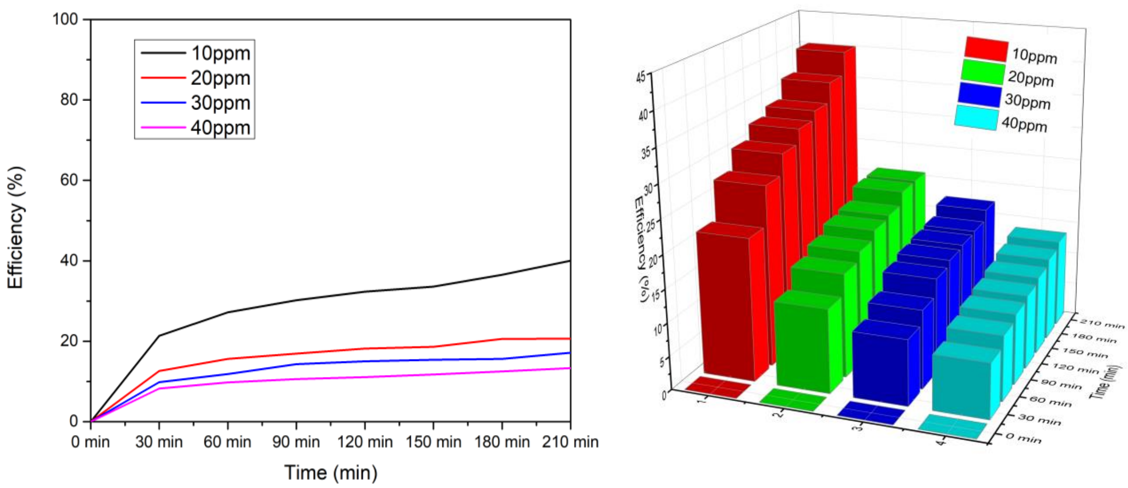

Figure 12. *The efficiency with modified coal NaOH 1.5M*

Figure 12 shows a gradual left-to-right decrease with the highest efficiency of 40.03% observed at 10 ppm at 210 minutes on an agitator.

❖ Modified coal NaOH 2M

The dye concentration is investigated at 10, 20, 30, and 40 ppm, adjusted with pH = 7 and 0.2 g of modified coal NaOH 2M, stirred on the stirrer for 210 minutes. The results obtained are shown in Figure 13 below.

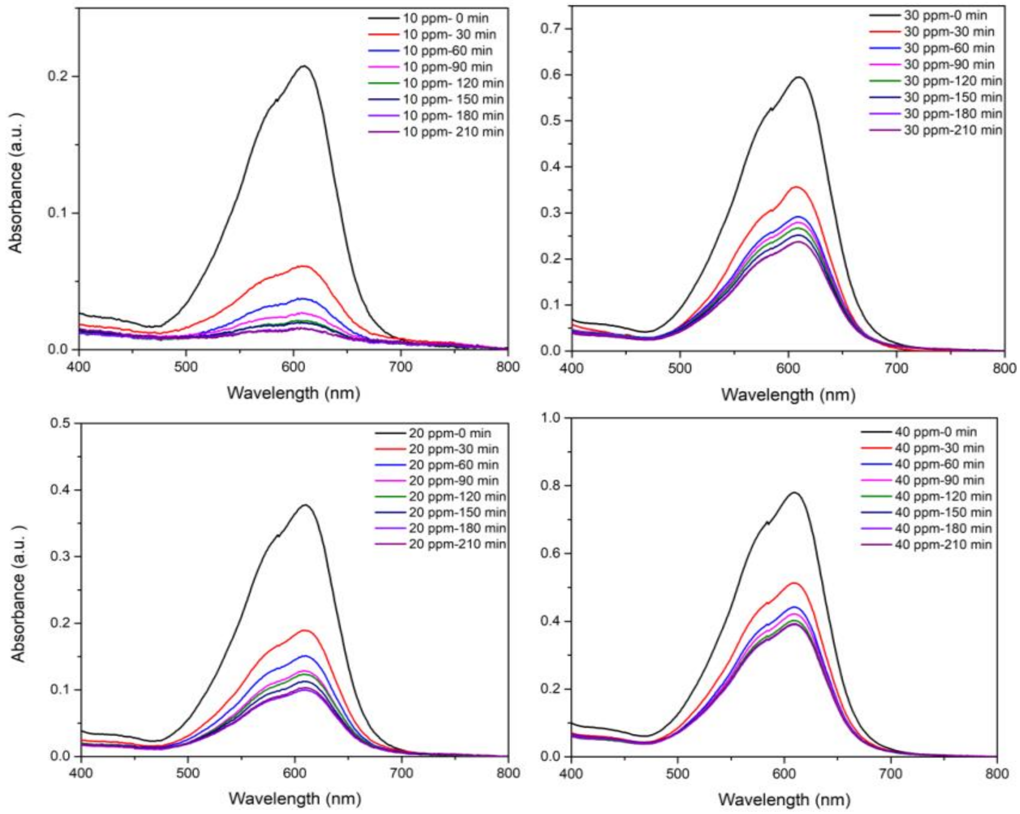

Figure 13. *Absorbance with modified coal NaOH 2 M*

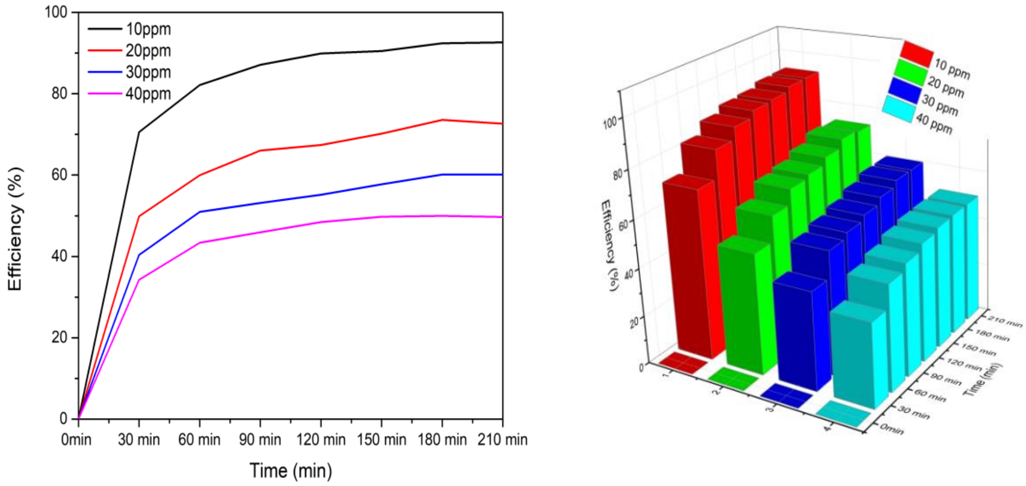

Figure 14. *The efficiency with modified coal NaOH 2M*

Figure 14 shows a left-to-right decrease with the highest efficiency of 92.64% observed at 10 ppm at 210 minutes on an agitator.

3.3.5. Optimal coal mass

The dose of adsorbed coal is investigated at 0.4, 0.6, 0.8, and 1g in 250 ml of dye solution with a concentration of 40 ppm and pH = 7, placed on a magnetic stirrer within 210 minutes. The results obtained are illustrated in Figure 15, showing the adsorption efficiency by dose.

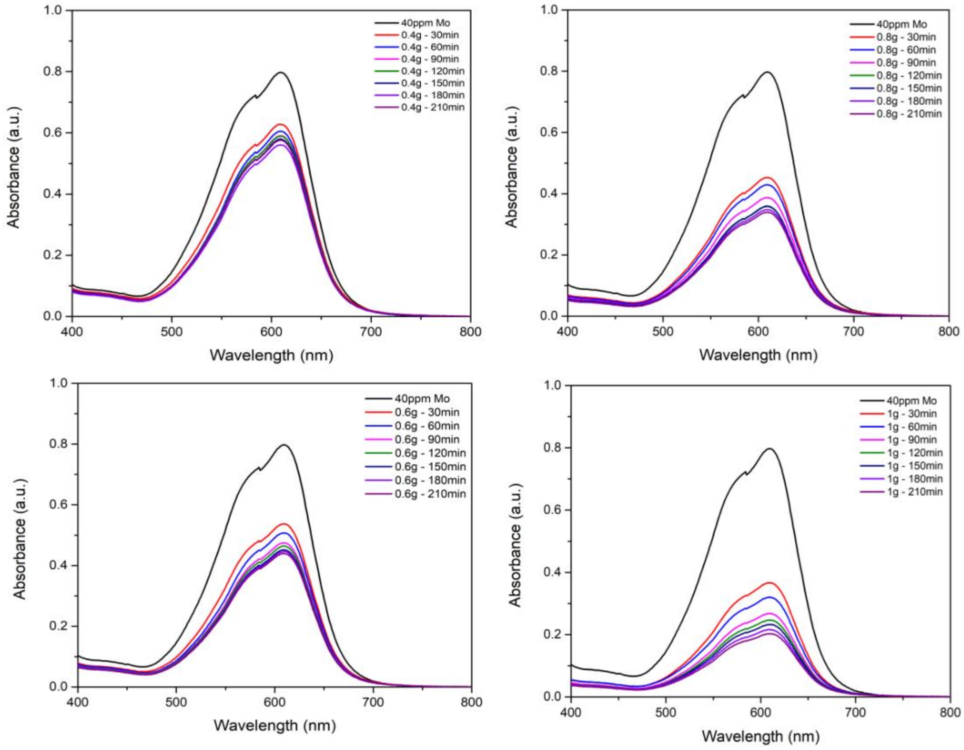

Figure 15. *Absorbance with mass of activated carbon*

For coal mass of 0.4g, results show a small increase efficiency. The highest efficiency is 29% at 180 minutes on the stirrer, while the most increase in efficiency is not significant. For a coal mass of 0.6g, a small increase in efficiency is observed. The highest efficiency is 43.36% at 210 minutes on the stirrer, and a fraction of the efficiency increase is not remarkable over time. For example, the efficiency increases by 6.14% from 90 minutes to 120 minutes, while it increases by 2.0% from 120 minutes to 150 minutes. For the mass of coal of 0.8g, the graph shows the highest efficiency of 55.90% after 210 minutes on the stirrer and a slow increase in efficiency over time. For example, there is an increase by 1.83% between 90 minutes and 120 minutes, or by 0.9% between 120 minutes and 150 minutes. For the mass of coal of 1g, the highest efficiency is 73.75% at 180 minutes on the stirrer, the rest of the efficiency increases is not significant.

3.3.6. Material reusability

The dye concentration is adjusted to 10, 20, 30, and 40 ppm, with pH = 7 and 0.2 g reconstituted and modified 2M coal. The results are illustrated in Figure 16.

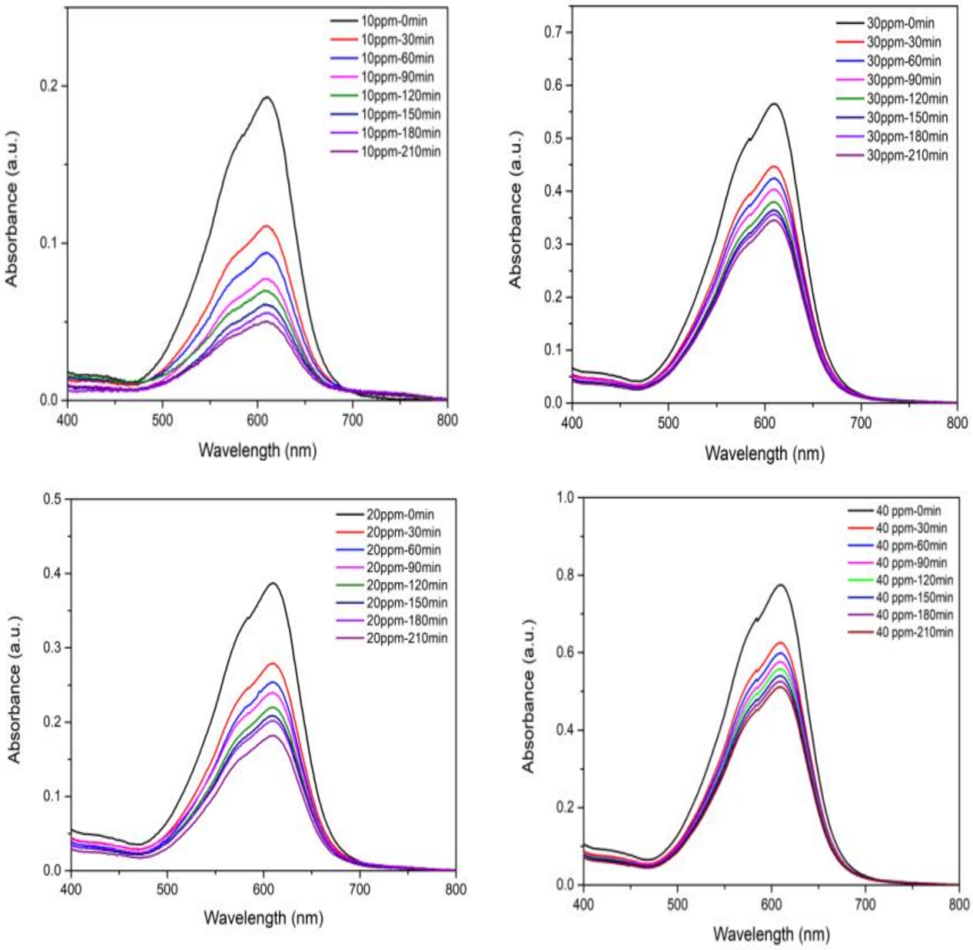

Figure 16. *Absorbance with one-time regenerated activated carbon*

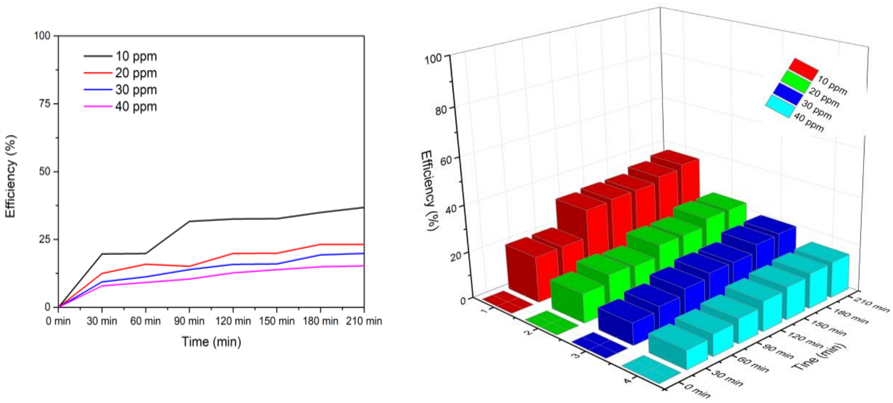

Figure 17. *The efficiency with one-time regenerated activated carbon*

The highest efficiency is 36.79% precisely at 10 ppm concentration at 210 minutes. Besides, the chart shows that the efficiency of one-time regenerated coal is not higher than that of modified coal NaOH 2M. Most color concentrations are not high, and the lowest efficiency is 7.91% at 40 ppm color concentration in the first 30 minutes.

4. Conclusion

Activated carbon materials from durian peel have been successfully fabricated through the process of prototyping and chemically activating with NaOH. Modified NaOH has the highest efficiency of 2M denatured gas with the ratio 1:20 (g/ml). The material is granular with an average size of 1-2 micrometers with porosity.

The adsorption capacity of activated carbon was investigated on RB 220 dye solution, with the criteria of pH, time, denaturation concentration, and dosage. As a result, this study realizes the great influence of the factors on the adsorption process.

The optimal parameters in the investigated adsorption process are:

- pH = 7
- Time: 30 minutes
- Modified coal NaOH 2M
- Mass: 1 gram

The Langmuir isotherm model is applied for the color dose adsorption process of activated carbon and the maximum adsorption capacity is found to be 21.053 mg/g.

❖ ***Conflict of Interest:*** *Authors have no conflict of interest to declare.*

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NGHIÊN CỨU CHẾ TẠO VẬT LIỆU THAN HOẠT TÍNH TỪ VỎ SẦU RIÊNG ĐỂ XỬ LÍ MÀU REACTIVE BLUE 220 TRONG NƯỚC THẢI DỆT NHUỘM

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TÓM TẮT

Trong nghiên cứu này, các mẫu than sẽ được tổng hợp từ vỏ sầu riêng (lớp bảo vệ bên ngoài của quả sầu riêng) bằng cách sấy khô, băm nhỏ và cho vào rây có lưới mịn với kích thước khoảng 1-2 micromet. Hoạt hóa hóa học bằng dung dịch NaOH 2M với tỉ lệ ngâm tẩm là 1:20 (g/ml) trong 2 giờ sau đó nung ở nhiệt độ 700 °C trong 1 giờ để tạo than hoạt tính. Sau quá trình chuẩn bị, mẫu sẽ được phân tích bằng công nghệ phân tích tiên tiến như quang phổ FTIR, SEM. Khảo sát khả năng hấp thụ của than hoạt tính trên thuốc nhuộm RB 220, kết quả cho thấy sự hấp phụ của vật liệu bị ảnh hưởng bởi nồng độ của RB 220, do đó cần phải được kiểm soát trong quá trình hấp phụ. Ngoài ra, một số thông số tối ưu cũng được khảo sát để có điều kiện hấp phụ tốt nhất, đặc biệt là ở các điều kiện như pH = 7 với nồng độ phẩm màu là 10 ppm, 20 ppm, 30 pmm, 40 ppm, 0,2gam than và phơi 3 giờ 30 phút (210 phút), hiệu suất là 92,64% (đối với nồng độ 10 ppm của RB 220). Áp dụng cho mô hình hấp phụ langmuir và ta có dung lượng hấp phụ tối đa là 21,053 mg/g.

Từ khóa: than hoạt tính; hấp phụ; vỏ sầu riêng; màu nhuộm Reactive Blue 220