# Effectiveness of activated carbon from rubber seed shell as adsorbent of liquid waste of heavy metal

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**ABSTRACT**

Iron or Fe is classified as a metal that has low toxicity, but if the concentration exceeds the quality standard, it can potentially cause pollution to the environment. This study aims to make activated carbon from rubber seed coat shells as an adsorbent for artificial Fe liquid waste using $Fe_2(SO4)_3$. 05 grams of activated carbon was activated using a ratio of 2:1, 3:1, 4:1 (NaOH: charcoal), and then an FTIR test was carried out to see the characteristics of the activated carbon. Measurement of Fe concentration using UV-VIS spectrophotometry, with various concentrations of 1, 1.5, 2, 2.5, 3, 4, 6, and 10 mg/L. After that, an analysis of the effect of contact time with the addition of activated carbon as an adsorbent for heavy metal Fe liquid waste was carried out, using variations of 05, 10, 15, 20, 30, 45, 90, and 120 minutes. An analysis of the effect of Fe concentration, with various concentrations of 10, 20, 30, 40, and 50 mg/L. Obtained from the linear equation of the calibration curve y = 0.0679x - 0.0013 with a correlation coefficient of 0.9996. The results of the third FTIR test showed that the ratio of NaOH and carbon activators did not change significantly. The functional groups that appeared were O-H, C=O carboxylate, C-C-C, aromatic C-H, aromatic C=C, C-O, and Si-O. Activated carbon 2:1, 3:1, and 4:1 have an absorption percentage of 86.72%, 89.45% and 96.37%. The greatest absorption efficiency is at a ratio of 4:1, optimum at 90 minutes. Sample 2:1 has an adsorption capacity of 0.163 mg/g, sample 3:1 of 0.259 mg/g, and 4:1 of 1.340 mg/g. The greatest adsorption capacity of activated carbon is at a ratio of 4:1, adsorption occurs physically (Freundlich) with a multilayer layer.

## 1. Introduction

Liquid waste can be generated from domestic activities, public facilities, industry, laboratories or other places. Some of the waste water produced by human activities contains chemicals that are $B_3$ (Material, Dangerous and Toxic) (Novita & Wahyuningsih, 2018). $B_3$ waste, namely residue or waste containing hazardous and toxic chemical substances, is produced by heavy metal materials such as iron (Fe) and other heavy metal elements (Bempa & Kunusa, 2020). In the laboratory, Fe heavy metal liquid waste is produced from the remains of practicum or research (Anzar, 2018; Yuliastri, 2018). Fe is also produced from industrial activities such as chemical, electrical and electronic factories, metal plating, leather, metallurgy, and the paint or

dye industry (Karim, Juniar, & Ambarsari, 2018). The coal mining industry is also a contributor to liquid waste containing the heavy metal Fe (Suryani, Paramita, Susilo, & Maharsih, 2022).

Iron or Fe is classified as a heavy metal with low toxicity, but if the concentration exceeds the quality standard, it can potentially cause pollution to the environment (Oktasari, 2017). According to the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014 concerning Wastewater Quality Standards, the concentration of Fe in liquid waste is limited to 5 mg/L. Excessive concentration in the waters will cause the living creatures that live in it to die due to reduced oxygen levels. In humans, excess Fe will cause poisoning such as vomiting, intestinal damage, sudden death, easily provoked by emotions, arthritis, birth defects, cancer, skin turning black-black, headaches, liver failure, hepatitis (Indrawati, Ma, & Puspawiningtiyas, 2014). Given the many impacts caused by Fe, it is necessary to take action to overcome Fe pollution.

Many methods have been used to treat heavy metals in the environment, namely flotation, ion exchange, precipitation, reverse osmosis, electrochemistry, adsorption, membrane filtration, evaporation, oxidation, and biosorption (Said, Aly, El-wahab, & Soliman, 2012). The adsorption process is a way of purifying and separating substances either physically, chemically, or a mixture of both. The adsorption process occurs on the surface of the adsorbent, so the greater the surface area, the greater the adsorption capacity (Suryadi et al., 2021).

The material that is often used for the heavy metal adsorption process is activated carbon, there are several studies that have used activated carbon as an adsorbent for heavy metals such as activated carbon from bagasse (Bempa & Kunusa, 2020), pectin (Kurniasari, Riwayati, & Suwardiyono, 2012), natural zeolite (Las, Firdiyono, & Hendrawan, 2011), mussel shells (Dewi, Effendi, Saputro, & Sumada, 2020), bintaro fruit (Rosalina, Tedja, Riani, & Sugiarti, 2016).

Rubber seed shell is one of the raw materials that can be used as an adsorbent. Rubber seed shells have not been utilized properly and are left as waste in rubber plantations (Zulfadhl & Iriany, 2017). One hectare of rubber plantations can produce rubber shells of 500 kg/ha/year (Astawan, Agustina, & Susi, 2018). When physically observed, the shell of the rubber seed coat has the same texture as hard wood, with a thin thickness and a hard and sturdy construction. The hard shell of the skin is caused by the lignin contained in it so this material can be used as a source of activated carbon (Desi, Suharman, & Vinsiah, 2015). This is in line with the research by Fauziah (2009), which utilizes rubber acacia wood as activated carbon, and Sa'diyah, Suharti, Hendrawati, Pratamasari, and Rahayu (2021), who utilizes sawdust waste.

Activated carbon is the form of granules or powder that is made through a process of carbonization and activation either chemically or physically or a combination of both (Asbhani, 2004; Udyani, Purwaningsih, Setiawan, & Yahya, 2019). Activated carbon can be used as an adsorbent or liquid waste absorbent, decolourizing agent, air pollution control, absorbing metals, and so on (Masrianti & Fatimura, 2018). The quality of activated carbon depends on the characteristics of the raw material and the activation process used. The chemical activation process can use activators such as potassium hydroxide (KOH), sodium hydroxide (NaOH), zinc chloride ($ZnCl_2$), sodium chloride (NaCl), sulfuric acid ($H_2SO_4$), phosphoric acid ($H_3PO_4$), sodium carbonate ($Na_2CO_3$), and others (Patil & dan Kulkarni, 2012).

The absorption capacity of activated carbon can be influenced by several factors, namely adsorbent dose, adsorbate concentration, adsorbate molecular size, adsorbent purity, contact time, stirring speed, surface area and pore volume, temperature, and pH (Asbhani, 2004; Masrianti & Fatimura, 2018; Udyani et al., 2019). The concentration of the adsorbate affects

absorption because the higher the concentration, the absorption efficiency of the adsorbent will decrease. In addition to concentration, contact time also affects it because the longer the contact time, the greater the adsorption (Patil & dan Kulkarni, 2012).

Based on the description above, research will be carried out to make activated carbon from rubber seed coat shells as an adsorbent for liquid waste containing heavy metal Fe; the activated carbon activation process will be carried out with NaOH. It is hoped that this research can be an alternative solution for handling heavy metal liquid waste so that it does not cause pollution when discharged into the environment.

## 2. Theoretical basis

### *2.1. Adsorption method*

Adsorption can be carried out by 02 (two) methods, namely static (batch) and dynamic (column) (Giyatmi, Fallihah, & Swantomo, 2020):

a. Static (batch) is done by pouring the solution into a container containing the adsorbent and then stirring the mixture for a certain period of time. Then, it was filtered to separate the solution and the adsorbent. Components that have been bound are released again by dissolving the adsorbent in a certain solvent, and the volume is smaller than the volume of the initial solution.

b. The dynamic method (column) is carried out by flowing the adsorbate solution into the column containing the adsorbent, then the bound components will be redissolved through a stream of solvent which has a smaller volume.

### *2.2. Rubber seed shell*

The rubber seed shell has a structure similar to wood when physically observed. Rubber plants that live in tropical climates make the shell of the rubber seed coat enter the hardwood shell with a thin thickness, but the structure is hard and sturdy. The strong structure is caused by the lignin content in it; lignin is located in the middle of the lamellae of the wood cells, and the cell walls are composed of phenyl pronan (Astawan et al., 2018). The lignin content in the rubber seed shell makes it potentially used as activated carbon; the material contained in the rubber seed shell can be seen in **Table 1**.

**Table 1**

Ingredients contained in the shell of the rubber seed coat

| Material compound rubber seed shell | Percentage of material compound (%) |
|---|---|
| Cellulose | 48.64 |
| Lignin | 33.54 |
| Pentosan | 16.81 |
| Ash Content | 1.25 |
| Silica Content | 0.52 |

Source: Desi et al. (2015); Pari, Santoso, and Hendra (2006)

## 3. Methodology

### *3.1. Materials*

This study used rubber seed shells, NaOH pellets, potassium thiosanate (KSCN), powdered $Fe_2(SO4)_3$, distilled water, 37% HC1.

### *3.2. Preparation of activated carbon*

The rubber seed shells were cleaned and washed, then dried in the sun for 02 days, weighed as much as 500 grams, then in the oven at a temperature of 110°C for 01 hour to reduce the water content, carbonized the shells of the rubber seed shells using a furnace with a temperature of 500°C for 01 hour. After that, grind using a mortar and sift using a 100 mesh sieve. Charcoal activation with NaOH on a hot plate for 01 hour with a ratio of 2:1, 3:1, 4:1 (NaOH: charcoal), with 05 grams of charcoal for one activation. Rinse the activated carbon to a neutral pH using distilled water and filter using filter paper. Then, dry in the oven at 110°C for 01 hour and finally, 0.3 grams of activated carbon was weighed for the FTIR test.

### *3.3. Preparation of 4M HCl solution*

Pipette 33.5mL of 37% HCl, add distilled water into a 100mL volumetric flask until it reaches the mark, and homogenize.

### *3.4. Preparation of Fe stock and standard solutions*

In this stage, a stock solution was prepared at a concentration of 1,000 mg/L (01 gram of Fe in 1L of distilled water), by homogenizing 3.27 grams of $Fe_2(SO_4)_3$ with the distilled water in a volumetric flask. The stock solution was used as a sample of Fe heavy metal liquid waste.

### *3.5. Preparation standard calibration curve*

Fe solution was prepared with a concentration of 100 mg/L from the mother liquor. Then it was diluted to a concentration of 1; 1.5; 2; 2.5; 3; 4; 6; 10 mg/L, after which the standard solution was added 2mL HCl and 5mL 2M KSCN then mixed and rested for 15 minutes (Suryani et al., 2022). Scanning wavelength of the highest standard solution with a wavelength of 400 - 600nm (Handayani, Mushlih, & Lestari, 2018). After obtaining the maximum wave value, a calibration curve is made, then a table and a combined curve of absorbance and concentration are made to see the relationship.

### *3.6. Adsorption time effect test*

As much as 20 mg/L of Fe solution was added to 0.5 gram of adsorbent. Homogenized using a magnetic stirrer with variations in stirring time for 05, 10, 15, 20, 30, 45, 90, and 120 minutes at room temperature. After homogenization, the mixture is precipitated. The adsorption solution was taken using a pipette and then put into a cuvette and then analyzed using a UV-Vis spectrophotometer with a wavelength of 478nm, using the KSCN method (Suryani et al., 2022).

### *3.7. Concentration effect test*

0.5 gram of activated carbon was added to 100mL of Fe solution with concentrations of 10, 20, 30, 40, and 50 mg/L. The mixture was stirred using a magnetic stirrer for the optimum time of the time effect test and carried out at room temperature. Allowed to settle, tested at maximum wavelength using UV-VIS spectrophotometer.

### *3.8. Data analysis technique*

1. Adsorben carachterization

Using FTIR (Fourier Transform Infra Red) to show functional grups in activated carbon.

2. Standard calibration curve

To analyzed the relation between Fe concentration and absorbance. The calibration curve is acceptable if the linear regression value is $R^2 > 0.995$ (National standardization body, 1995).

3. Activated carbon efficiency

To determine the adsorption efficiency of activated carbon, it was carried out by calculating the percentage of adsorption at various contact times of 10, 15, 20, 30, 45, 90 and 120 minutes. The formula used to calculate the percentage of adsorption can be seen below.

$$PA=[\left(\frac{Co-C}{Co}\right) x\ 100\%] \quad (1)$$

Information:

PA : Adsorption Percentage (%);

Co : Adsorbate concentration at t = 0 (mg/L);

C : Adsorbate concentration at t = t (mg/L) (Giyatmi et al., 2020).

4. Heavy metal adsorption

Adsorption of heavy metals by adsorbents will be seen based on the adsorption capacity and isotherms of activated carbon for various concentrations of 10, 20, 30, 40, and 50 mg/L.

$$qe=\frac{V(Co-Cs)}{W} \quad (2)$$

Information:

qe : Adsorption capacity per weight of adsorbent (mg/g);

V : Volume of solution (L);

Co : Initial concentration of solution (mg/L);

Cs : Concentration of final solution (mg/L);

W : Mass of adsorbent (gr) (Nursia, Syahbanu, & Shofiyani, 2018).

The Langmuir adsorption equation can be seen in Eq:

$$\frac{Ce}{qe}=\frac{Ce}{qmax}+\frac{1}{b.qmax} \quad (3)$$

Information :

qe : Amount of absorbed adsorbate (mg/g);

Ce : Concentration at equilibrium (mg/L);

qmax : Adsorption capacity of the adsorbent monolayer;

b : Langmuir adsorption constant (Christmann, 2010).

The Freundlich adsorption equation can be seen in the equation below:

$$\ln qe = \ln Kf+\frac{1}{n}\ln Ce \quad (4)$$

Information :

qe : Amount of absorbed adsorbate (mg/g);

Ce : Concentration at equilibrium (mg/L);

Kf : Freundlich's constant;

n : Freundlich exponential (Christmann, 2010).

## 4. Result and discussion

### *4.1. Characteristics of activated carbon*

The process of synthesizing activated carbon in this study used 250 grams; from this process, a yield of 45% of the initial weight was obtained, namely 137.5 grams of carbon. This is in line with previous research which made bio briquettes from rubber seed shells and hazelnut seed shells; in that study, as much as 3kg of rubber seed shells were carbonized and produced 1.5kg of charcoal (Astawan et al., 2018). This shrinkage is due to the fact that during the carbonization process, there is a change in organic matter in the form of hemicellulose, cellulose, and lignin into carbon by releasing substances other than carbon (Hidayah, Suhendar, Sudiarti, & Maesaroh, 2019).

FTIR (Fourier Transform Infra Red) testing of activated carbon of rubber seed coat shells with NaOH activator with a ratio of 2:1, 3:1, and 4:1 was carried out at UPT OZT Technical Laboratory, Sumatra Institute of Technology. This test was carried out to see the effect of the mass of the activator on the characteristics of activated carbon. Analyzed using wavelengths in the range of 4,000 - 500cm$^{-1}$ which were processed using the origin lab. So that the vibration peaks of the functional groups are obtained, as can be seen in **Figure 1**.

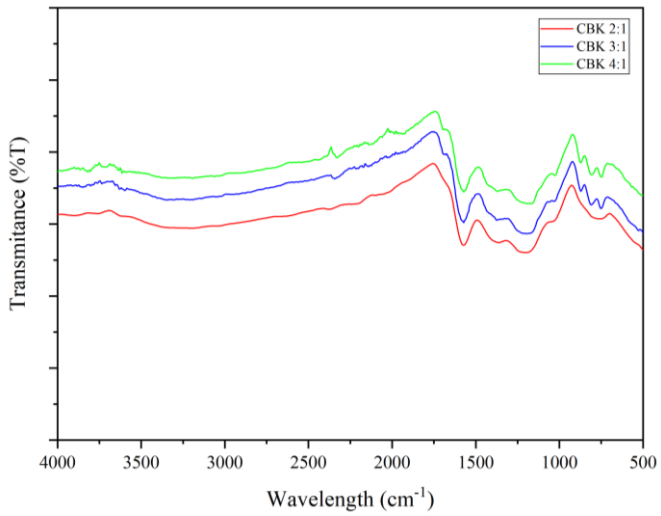


**Figure 1.** FTIR graph of activated carbon of rubber seed shell 2:1, 3:1, 4:1

The FTIR test results for the three samples in **Figure 1**, show no significant difference. The absorption bands at wavelengths of 3,287cm$^{-1}$, 3,602cm$^{-1}$, 3,769cm$^{-1}$, and 3,895cm$^{-1}$ indicate the presence of O-H functional groups, which are hydroxyl groups and water elements. The presence of these functional groups is due to the large number of NaOH activators used. In previous studies, it was stated that the greater the NaOH content, the more NaOH would be left on the activated carbon surface (Refianti, 2018). NaOH concentration that is too high can cause damage to the adsorbent, so it can cause the surface of the adsorbent to become more open, and the pore walls are thin and brittle, which can cause a decrease in the absorption power of the adsorbent (Ganing, 2022). The presence of O-H bonds can also be caused by the cellulose content in the rubber seed shell. The O-H functional group has a negative charge, making it possible to bind positively charged Fe. Supported by previous studies, cellulose has the potential to produce O-H functional groups, which are able to bind positively charged metal ions because of its polar nature (Susilawati & Andriyanie, 2019). The aromatic C-H functional group appears at wave 3,046cm$^{-1}$. In line with the results of previous studies, aromatic C-H was found in a spectrum of 3,055cm$^{-1}$ (Amri, Priyanto, Ramadhan, & Gustantia, 2017).

The carbonyl C=O functional group appears at a wavelength of 2,243cm$^{-1}$. This functional group probably originates from decomposed lignin, and the C=O bond is a sign of the presence of carbon in the adsorbent. In line with previous studies, the C=O carbonyl functional group is present at wave 2,337cm$^{-1}$ (Amri et al., 2017). Absorption with a wavelength of 2,099cm$^{-1}$ shows the alkyne functional group C-C-C. Supported by previous research, this functional group is at a wavelength of 2,090cm$^{-1}$ (Pezoti et al., 2015). The aromatic C=C bands are found at the wavelengths of 1,571cm$^{-1}$ and 1,365cm$^{-1}$. This was confirmed by previous research, which stated that the aromatic C=C bond band was in the range of 1,630 - 1,430cm$^{-1}$ (Refianti, 2018). In addition, in another similar study, the aromatic C=C group was at a wavelength of 1,323.17 - 1,400.32cm$^{-1}$ (Hanum, 2017). This functional group appears because of the high burning temperature of activated carbon, which is 500$^0$C. In line with previous research which stated that, the presence of aromatic C=C groups is because the aromatic C-H bonds are degraded to more stable bonds when the combustion temperature is higher (Muniandy, Adam, Mohamed, & Ng, 2014).

The C-O bond appears at a wavelength of 1,199cm$^{-1}$, this functional group is a stretch of ester, phenol, alcohol, or ether. Supported by previous research, the C-O bond is in the wavelength range of 1,300 - 1,000cm$^{-1}$ (Hamad, Noor, & Asri, 2010). The spectrum of 757cm$^{-1}$ indicates the appearance of the Si-O bond, this functional group appears because the shell of the rubber seed coat contains silica. Referring to previous research that the rubber seed shell has 0.52% silica content (Desi et al., 2015; Pari, Santoso, & Hendra, 2006). In addition, other studies also stated that the presence of Si-O in activated carbon was due to the washing process, which was less clean (Riyanto, Kurniawan, & Aminu, 2021).

From the results of the FTIR analysis, the adsorbent that was studied can function as activated carbon or absorbent. This is due to the presence of O-H and C-O functional groups, which give activated carbon a polar nature. This finding is supported by previous studies which stated that activated carbon with functional groups O-H and C-O has polar properties so that it can be used as an absorbent, water purifier, sugar, alcohol, and formaldehyde emitter (Fanani & Ulfindrayani, 2019; Wibowo, Syafi, & Pari, 2011). In addition, the presence of the carbonyl C=O functional group on the activated carbon derived from the rubber seed coat shell indicates the presence of an active substance on the carbon, while the aromatic C=C functional group indicates that there is an increase in the carbon content in the adsorbent. In line with previous research, which stated that the C=O carbonyl functional group is characteristic of activated carbon and is a sign that the adsorbent has been activated, the aromatic C=C functional group shows an increased carbon content (Trina, Supriyanto, Rinawati, & Buhani, 2022). In the presence of the functional groups O-H, C-O, carbonyl C=O, and C=C, the activated carbon used in this study can be used as an adsorbent.

### *4.2. Test the effect of contact time on absorption efficiency*

#### *4.2.1. Standard calibration curve*

To determine the concentration of the Fe solution, a calibration curve is required, which begins with determining the maximum wavelength. At this maximum wave is the area that has the highest absorption capability and the smallest error (Khasanah & Sumarto, 2018). In this study, the maximum wavelength of the Fe solution was obtained at 478nm with an absorbance value of 0.808. In line with previous studies examining the Fe content in acid mines, the maximum wave is located at a wavelength of 481nm (Suryani et al., 2022). In the study of detecting the concentration of Fe in water, the maximum wave of the Fe solution was at a

wavelength of 477nm (Ahriani, Zelviani, Hernawati, & Fitriyanti, 2021). The maximum wavelength scanning results can be seen in **Figure 2**.

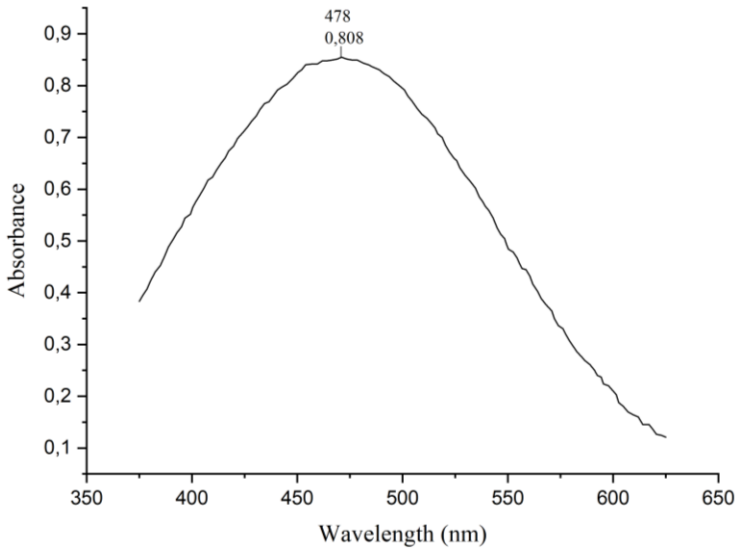


**Figure 2.** The maximum wavelength of the FeSCN solution

In this study, the Fe stock liquor used has a yellow color, when diluted to a smaller concentration, the yellow color of the solution will fade and look clear. In order for Fe concentration measurements to be read by a UV-VIS spectrophotometer, a KSCN complexing solution is required. In line with previous research, KSCN was used as a red and stable color former, and it reacted with HCl in determining the concentration of Fe with the aim of maintaining pH (Hidayah et al., 2019). Other research that added $HNO_3$ stated that the aim of an acidic solution is to maintain the pH and not precipitate iron salt (Bempa & Kunusa, 2020). The reaction formed from a solution of $Fe_2(SO_4)_3$, which is Fe III with KSCN, is as follows (Kurniawati & Sugiarso, 2016):

$$Fe^{3+} + 6SCN^- \longrightarrow [Fe(SCN)_6]^{3-} \quad (5)$$

The addition of KSCN to the varying concentrations of the Fe standard solution makes the color of each resulting solution different, the higher the concentration of the Fe solution, the darker the color. The results of the standard solution absorbance measurements can be seen in **Table 2.**

**Table 2**

The results of measurements of the absorbance of the Fe standard curve

| Concentration (Mg/L) | Absorbance |
|---|---|
| **1,000** | 0.064 |
| **1,500** | 0.1 |
| **2,000** | 0.138 |
| **2,500** | 0.161 |
| **3,000** | 0.208 |
| **4,000** | 0.272 |
| **6,000** | 0.407 |
| **10,000** | 0.676 |

Based on the measurement of the calibration curve of the Fe solution, it has a line equation y = 0.0679x - 0.0013 with a correlation coefficient of 0.9996. The value of a = 0.0679 is the intercept value. The value b = 0.0013 is the slope of the linear regression. The calibration curve is acceptable if the linear regression value is $R^2 > 0.995$ (National standardization body, 1995). So the FeSCN calibration curve in this study complied, and can be used as a standard curve. The calibration curve provides information on the relationship between the concentration of Fe solution on the X-axis and its absorbance on the Y-axis, which can be seen in **Figure 3**.

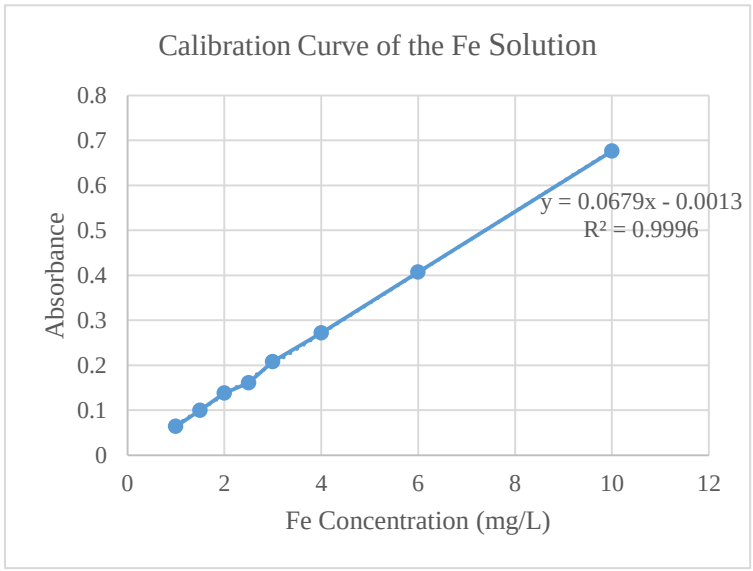


**Figure 3.** FeSCN standard solution calibration curve

*4.2.2. Effect of time variation on absorption efficiency*

Variation of contact time is used to determine how long it takes for the activated carbon of the rubber seed coat shell to reach equilibrium.

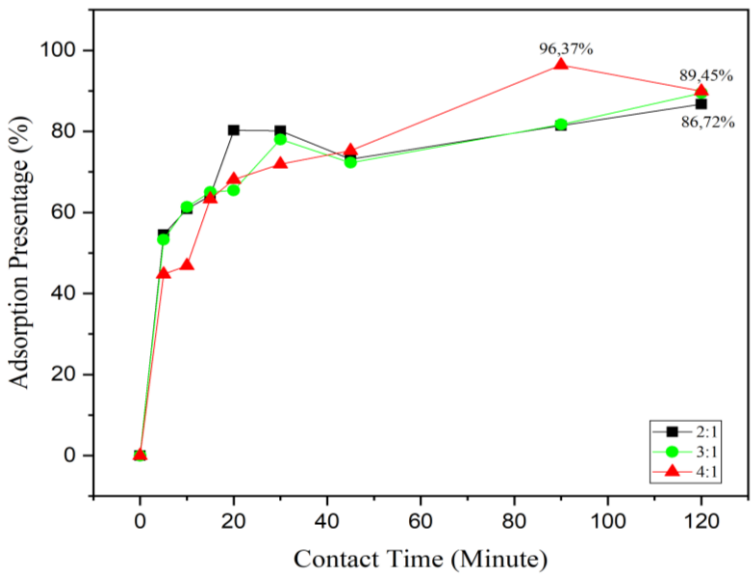


**Figure 4.** Relationship between contact time and adsorption efficiency of $Fe_2(SO_4)_3$

The results of the research in **Figure 4** show that the longer the contact time, the higher the adsorption efficiency of the $Fe_2(SO_4)_3$ solution. In the first minute of activated carbon, the ratio is 2:1 and 3:1; the absorption efficiency tends to increase up to 30 minutes, and then at 45 minutes, the absorption efficiency drops. This is because the activated carbon surface becomes

saturated (Bangun, Zaharah, & Shofiyani, 2016). Because the activated carbon surface is saturated, the absorption efficiency decreases. In the 90th minute, the absorption efficiency increased again; this was due to the adsorbent re-absorbing the adsorbate. At 4:1 activated carbon, absorption efficiency increased constantly until 90 minutes, then decreased again at 120 minutes. This event occurred because there was still a lot of space available in activated carbon that had not been filled by adsorbate (Bangun et al., 2016). The longer the contact time, the absorption of Fe increases until it reaches the optimal limit of 2:1 rubber seed shell activated carbon at 120 minutes with an absorption percentage of 86.72%. For 3:1 activated carbon, it reached its optimum time at 120 minutes with an absorption efficiency of 89.45%, and 4:1 activated carbon reached equilibrium at 90 minutes with an absorption percentage of 96.37%. This is in line with previous research, which stated that the longer the adsorption time affected, the longer the contact time, and the higher the percentage of adsorption (Bangun et al., 2016).

In previous studies also mentioned, the longer the adsorbent binds to the adsorbate, the more adsorbate is captured or occupies the activated carbon space (Yagub, Sen, Afroze, & Ang, 2014). Of the three comparisons, when the activated carbon has reached the optimum time, there is a decrease in absorption efficiency. In previous studies, it was stated that this decrease was caused by the activated carbon space, which was fully filled with adsorbate; the surface of the activated carbon became saturated, and its ability to carry out adsorption decreased (Bangun et al., 2016).

The highest absorption efficiency was found in the activated carbon of the rubber seed coat shell in a ratio of 4:1; this happened because the activator mass used was more than the others. As its function, the use of NaOH activator aims to make the activated carbon surface open and clean from dirt. In previous studies, it was stated that the higher the NaOH concentration, the more pores the activated carbon would have, both large and small (Refianti, 2018). This allows activated carbon to have a 4:1 ratio of more pores than 3:1 and 2:1, so the absorption ability is better.

**Table 3**

Comparison between the absorption efficiency of the rubber seed coat shell adsorbent in this study and the adsorbents of previous studies

| No. | Adsorbent | Adsorbent absorption efficiency (%) | Reference |
|---|---|---|---|
| 1 | Activated carbon from rubber seed shells activated using NaOH in a ratio of 2:1, 3:1, and 4:1 (charcoal:activator) | 96.37 | This research |
| 2 | Activated carbon is made from rubber seed shell shells which are activated using an activator, namely $H_2SO_4$ using various concentrations of 3%, 5% and 7% | 99 | (Bangun et al., 2016) |
| 3 | Kupang putih shell which is activated using NaOH with a ratio of 1:10 (Kupang shell:activator) | 99.98 | (Dewi et al., 2020) |
| 4 | Sugarcane bagasse is carbonized and activated using $ZnCl_2$ with a ratio of 1:10 (charcoal:activator) | 96.76 | (Hadijah, Bempa, & Kunusa, 2020) |

Based on **Table 3**, in this study, the highest efficiency in adsorbing Fe liquid waste was on activated carbon with a ratio of 4:1, which was 96.37%. When compared with adsorbents in previous studies, which used activated carbon from rubber seed shells activator $H_2SO_4$, with an absorption efficiency of 99% (Bangun et al., 2016). In another study using chitosan adsorbent from white Kupang shells, the absorption efficiency of Fe was 99.98% (Dewi et al., 2020). Research has shown that bagasse as an adsorbent has an absorption efficiency of 95.76% (Bempa & Kunusa, 2020). Rubber seed shell shell-activated carbon in this study has a fairly high absorption efficiency. So the activated carbon of rubber seed coat shells has great potential to reduce the contamination of Fe heavy metal liquid waste.

### *4.3. Effect of variation of Fe solution concentration on activated carbon absorption*

**Figure 5**, section A shows that the amount of concentration that can be absorbed by activated carbon continues to increase up to a concentration of 50 mg/L; this means that the rubber seed coat adsorbent has not reached equilibrium and is still able to absorb more than 50 mg/L of Fe. This is in line with the results of previous studies, which stated that the adsorption process would increase if the concentration of the solution was higher (Irawan, 2018).

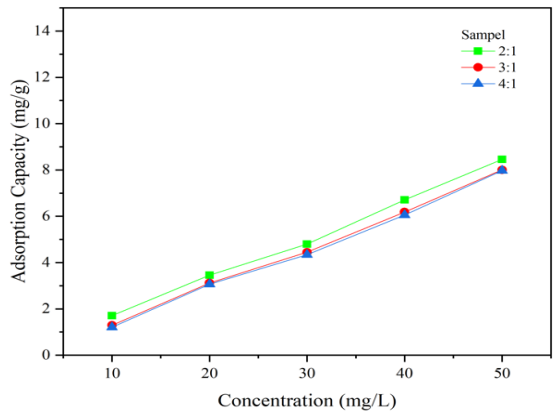


**Figure 5**. Graph adsorption capacity versus concentration

Testing for variations in solution concentration was carried out using the optimum time of contact time variations in ratios of 2:1, 3:1 and 4:1, namely 120 minutes, 30 minutes and 90 minutes. **Figure 5**, hows a comparison between the Langmuir isotherm and the Freundlich isothermal test results for varying the concentrations of the three activated carbon samples. In the Langmuir isotherm, the linear regression values or $R^2$ of the ratios 2:1, 3:1, and 4:1 are: 0.477, 0.466, and 0.529. Meanwhile, the Freundlich isotherm has $R^2$ values, namely: 0.866, 0.907, and 0.958. In previous research, it was stated that the isotherm process was determined from the highest $R^2$ value (Wicaksana & Rachman, 2018). In other studies also stated that the linearity of a curve can be shown from the value of $R^2$, the greater the value, the more representative (Larasati & Notodarmojo, 2014).

**Table 4**

Comparison of Langmuir and Freundlich isotherms of activated carbon of rubber seed coat shells

| Sample | Langmuir | | | Freundlich | | |
|---|---|---|---|---|---|---|
| | qmax (mg/g) | KL (L/mg) | $R^2$ | $K_F$ (mg/g) | 1/n | $R^2$ |
| 2:1 | -4.668 | -0.214 | 0.477 | 0.163 | 1.657 | 0.866 |
| 3:1 | -7.183 | -0.139 | 0.466 | 0.259 | 1.458 | 0.907 |
| 4:1 | 22.401 | 0.0446 | 0.529 | 1.340 | 0.810 | 0.958 |

So that in this study the $R^2$ value that satisfies is on the Freundlich isotherm, with the greatest value being on activated carbon 4:1, which is equal to 0.958. This indicates that the adsorption process of Fe that occurs on the activated carbon of the rubber seed coat shell occurs physically, which means that the adsorption process occurs on the surface of the activated carbon. The presence of Van Der Waals bonds in physical adsorption causes a weak force of attraction between the activated carbon surface and the Fe solution. This problem indicates the possibility of adsorption of more than one layer (multilayer), and has a heterogeneous surface (Larasati & Notodarmojo, 2014). This allows the activated carbon of the rubber seed coat shell to adsorb by forming several layers.

The 1/n value in **Table 4** shows heterogeneity in the adsorbent. The 1/n value for activated carbon was obtained, namely: activated carbon sample 2:1 = 1.657, sample 3:1 = 1.458, and sample 4:1 = 0.810. It can be seen that the one with the smallest 1/n value is the 4:1 activated carbon sample; this shows that in this sample, the adsorbent surface is the most diverse. In line with previous studies, which explained that the smaller the 1/n value, the greater the heterogeneity (Melati, 2023).

The adsorption capacity is determined from the $K_F$ value, the higher the $K_F$ value, the higher the absorption capacity will be. Based on the three comparisons, each of the rubber seed coat shell adsorbents had $K_F$ values of 0.163 mg/g, 0.259 mg/g, and 1.340 mg/g. So it can be concluded that the absorption capacity of activated carbon of rubber seed coat shells for variations in Fe concentrations was the highest in a 4:1 ratio of 1.340 mg/g.

## 5. Conclusions

The activated carbon of rubber seed coat shells with a ratio of 2:1, 3:1, and 4:1 did not have a significant difference; the activated carbon of the three comparisons had functional groups O-H, C=O carboxylate, C-C-C, C-H aromatic, C=C aromatics, C-O, and Si-O. NaOH activated activated carbon with a ratio of 2:1, 3:1, and 4:1 has an absorption percentage of 86.72%, 89.45%, and 96.37%. 4:1 activated carbon was the most effective in adsorbing Fe, with an adsorption effectiveness of 96.37% at 90 minutes of contact time. The higher the concentration of Fe, the absorption capacity of activated carbon will increase; the isotherm process in the three adsorbents occurs freundlich or takes place physically; 2:1 has an adsorption capacity of 0.163 mg/g, 3:1 sample is 0.259 mg/g and 4 :1 of 1.340 mg/g. The greatest adsorption capacity of activated carbon is at a ratio of 4:1.

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