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Effectiveness of Activated Carbon from Nutmeg Shell (*Myristica fragrans*) Waste as Adsorbent for Metal Ions Pb(II) and Cu(II) in Liquid Waste

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ABSTRACT

Various wastes can be utilized to produce activated carbon, one of the wastes that can be utilized is nutmeg shell (*Myristica fragrans*). Activated carbon from nutmeg shells (*Myristica fragrans*) was used in this study to reduce the content of Pb(II) and Cu(II) ions in liquid waste. This research utilized the adsorption method with the batch system to determine the optimum contact time, optimum pH, and adsorption capacity. The characterization of activated carbon was done by Scanning Electron Microscopy (SEM) and Surface Area Analyzers (SAA). The content of Pb(II) and Cu(II) ions in the filtrate after adsorption was analyzed using an atomic absorption spectrophotometer (AAS). The results of SEM analysis showed that the carbon surface was cleaner and had more open pores after the activation process than before activation. The carbon surface area is 19.6243 $m^2.g^{-1}$. From the results of AAS analysis, the optimum time and pH for Pb(II) and Cu(II) ions was 40 min at pH 5 and 70 min at pH 4. With the Freundlich isotherm method, the adsorption capacity of the adsorbent for Pb(II) ions was 9.6028 $mg.g^{-1}$ and Cu(II) ions was 0.035 $mg.g^{-1}$, and the adsorption effectiveness on liquid waste for Pb and Cu metals was 1.9454 $mg.g^{-1}$ and 0.4251 $mg.g^{-1}$, respectively. The results showed that activated carbon from the nutmeg shell (*Myristica fragrans*) was able to reduce the levels of Pb(II) and Cu(II) ions in liquid waste.

INTRODUCTION

Environmental pollution due to the discharge of industrial effluents containing heavy metals into water has led to the need to develop effective adsorbents to reduce the content of harmful heavy metals (Xavier et al. 2018, Hayati & Sawir 2017). Porous materials, such as activated carbon (Antika et al. 2019, Saleem et al. 2019), silica (Ouyang et al. 2019, Abuhatab et al. 2020), and zeolite (Hong et al. 2019, Shi et al. 2018), have been widely used as adsorbents. Activated carbon is considered one of the high-efficiency adsorbents due to its low toxicity, large size, rapid adsorption/desorption, good adsorption capacity, high efficiency compared to other materials, and most importantly, easier treatment process, and relatively affordable cost (Wang et al. 2023, Abuelnoor et al. 2021).

The use of activated carbon has a significant ability to reduce the content of heavy metals such as Hg, Cd, Cu, Ni, Pb, and Cr in liquid waste (Abdulrazak et al. 2017, Li et al. 2018) Because some studies only use nutmeg shell (*Myristica fragrans*) to adsorb dyes (Burakov et al. 2018). Activated carbon can be produced from agricultural and plantation waste. One of the wastes that can be utilized is a nutmeg shell (*Myristica fragrans*) (Prasetya et al. 2023). The quality of nutmeg shell (*Myristica fragrans*) activated carbon is very good for use as an adsorbent according to the Indonesian National Standard 06-3730-1995 (Hitijahubessy 2019).

Hazardous metals pose new threats to humans, such as lead and copper that can damage the environment (Thomas & Thalla 2022). These heavy metals are usually present in small amounts, but they are considered to be the most toxic and widespread components in liquid waste effluents (Asiagwu et al. 2017), so systematic and environmentally safe methods are needed. Currently, adsorption is considered an effective and efficient method to remove harmful heavy metal ions from liquid waste effluents. The process is flexible in design and procedure and allows high-quality treated effluent. In addition, in some situations, adsorption is reversible, and the adsorbent can be regenerated through desorption (Cheng et al. 2019, Idris et al. 2023). Contact time and optimum pH are factors that affect adsorption. The optimum time of adsorption of a metal depends on the type of adsorbent used and its optimum pH, so it will be investigated to determine the optimum conditions for adsorption (Chai et al. 2021).

Therefore, this study aims to analyze the effectiveness of activated carbon from nutmeg shell (*Myristica fragrans*) in reducing Pb(II) and Cu(II) ion levels.

MATERIALS AND METHODS

Tools and Materials

The tools that will be used in this research are glassware commonly used in laboratories, drop pipettes, volume pipettes, Buck Scientific model 205 VPG Atomic Absorption Spectrophotometer (AAS), FTIR (Shimadzu, type: IR Prestige 21), SEM (Hitachi Flexsem 1000) Magnetic stirrer, 100 mesh sieve, Oven (type SPNISOSFD), Hotplate (Ika C MAG Hs 7), Shaker (Oregon KJ-201BD), Analytical Balance (Shimadzu AW220), plastic spray flask, Desiccator. The materials that will be used in this research are nutmeg shell (*Myristica fragrans*), H_3PO_4 10%, distilled water, aquabides, $Pb(NO_3)_2$ Merck, $CuSO_4.5H_2O$ Merck, Universal pH paper, Whatman No.42 filter paper, liquid waste.

Sample Preparation, Carbonization, and Carbon Activation

The nutmeg shell waste samples were washed with clean water and dried in the sun. The clean and dry nutmeg shells were broken into small pieces. A total of 3 kg of nutmeg shell was then put into a porcelain cup and heated in a furnace at 400°C for 1 h. This process will produce nutmeg shell carbon. After carbonization, the nutmeg shell carbon was cooled, smoothed, and sieved with a 100-mesh sieve. The sample used is the one that passes the sieve. The carbonization results were then characterized using SEM (Labbani' et al. 2015).

During the activation process, nutmeg shell carbon was immersed in a 10% H_3PO_4 activator solution. The volume ratio of 10% H_3PO_4 and carbon mass was 4:1. Soaking lasted for 24 h. The mixture was filtered using a Buchner funnel. Afterward, the precipitate was washed with hot distilled water repeatedly until the pH of the filtrate was close to neutral. After that, the precipitate was heated for 3 h in an oven at 110°C, then cooled in a desiccator. The activation results were characterized using SEM and SAA (Laupa et al. 2019).

Determination of the Optimum Time

Activated carbon 0.5 g was put into nine Erlenmeyers containing 50 mL of Pb(II) ion solution with a concentration of 10 $mg.L^{-1}$. Using a shaker, the mixture was stirred for 10, 20, 30, 40, 50, 60, 70, 80 and 90 min. Afterward, the mixture was filtered using the Whatman 42 filter paper, and the concentration of Pb(II) ions in the resulting filtrate was measured by SSA. A blank solution was prepared without adsorbent as previously done. The optimum time was determined from the number of ions adsorbed the most (Tandigau et al. 2018). The concentration adsorbed for each time can be calculated by equation (1).

$$C_{adsorption} = C_{beginning} - C_{end} \qquad \ldots(1)$$

The amount of metal ions adsorbed ($mg.g^{-1}$) of adsorbent (nutmeg shell) was determined through equation (2).

$$q_e = \frac{C_0 - C_e}{W} \times V \qquad \ldots(2)$$

Description:

q_e: amount of metal ions adsorbed ($mg.g^{-1}$)
C_0: concentration before adsorption ($mg.L^{-1}$)
C_e: concentration after adsorption ($mg.L^{-1}$)
V: volume of metal ion solution (L)
W: amount of adsorbent (g)

The same was done for the determination of optimum time on Cu(II) metal ions.

Determination of Optimum pH

Activated carbon 0.5 g was put into five Erlenmeyers, then 50 mL of Pb(II) ion solution, which has a concentration of 10 $mg.L^{-1}$ at pH 2. After that, the mixture was stirred with a shaker and filtered. An atomic absorption spectrophotometer was used to measure the concentration of Pb(II) ions in the collected filtrate. Then the same way was done at pH 3, 4, 5, and 6 with the same method. A blank solution was made without the addition of activated carbon. The optimum pH is the pH that has the highest number of adsorbed ions ($C_{adsorption}$) (Tandigau et al. 2018). The same applies to the Cu(II) ion solution.

Determination of Adsorption Capacity

Activated carbon was added to seven Erlenmeyers of 0.5 g each. Next, 50 mL of Pb(II) ion solutions with concentrations of 10, 20, 40, 60, 100, 140, and 200 $mg.L^{-1}$ were added. Using a shaker, the mixture was mixed at the optimum time and pH obtained previously. The mixture was filtered, and AAS measured the resulting filtrate to determine the concentration of Pb(II). A blank solution was prepared without the addition of activated carbon (Tandigau et al. 2018). The same applies to the Cu(II) ion solution. The adsorption capacity can be determined by the Freundlich equation (Equation 3).

$$[\log(x/m) = \log k + 1/n(\log C)] \quad \ldots (3)$$

Or by using Langmuir Equation (4)

$$\frac{C_e}{q_e} = \frac{1}{Q_0 b} + \frac{1}{Q_0} C_e \quad \ldots (4)$$

Description:

X: amount adsorbed

m: amount of adsorbent used (g)

C_e: equilibrium concentration ($mg.L^{-1}$)

Q_0: adsorption capacity ($mg.g^{-1}$)

b: adsorption intensity ($L.mg^{-1}$)

q_e: the amount of substance adsorbed per gram of adsorption ($mg.g^{-1}$)

Determination of Adsorption Effectiveness of Pb(II) and Cu(II) Metal Ions

Activated carbon was put into two Erlenmeyers as much as 0.5 g each. Then, each 25 mL of Pb(II) and Cu(II) solution with a concentration of 10 $mg.L^{-1}$ was mixed in one beaker and homogenized. After that, the solution that has been mixed is pipetted as much as 50 mL and put into an Erlenmeyer that contains activated carbon. The mixture was stirred using a shaker at the optimum time and optimum pH according to the results obtained previously for each solution. The mixture was then filtered, and the filtrate was measured for Pb(II) and Cu(II) using AAS. A blank solution was made without the addition of activated carbon. The same thing was done to determine the effectiveness of adsorption of liquid waste for Pb and Cu metals whose concentrations were unknown.

RESULTS AND DISCUSSION

SEM Characterization

The morphology of nutmeg shell carbon and nutmeg shell activated carbon can be observed by Scanning Electron Microscope (SEM), which provides a detailed picture of the surface morphology of both materials. SEM surface morphology is shown in Fig. 1 (A) and Fig. 1 (B).

The number of pores formed is still small, and there are still pores that have not opened completely, as shown in (Fig. 1a). This is because the carbonization process only removes volatile compounds that cover the carbon, leaving a residue that covers the surface and pores of the carbon. To make the difference on the carbon surface clearer, an activation process is carried out to enlarge and multiply the carbon pores.

This study used 10% H_3PO_4 for the activation process. The carbon was soaked in the activation solution, 10% H_3PO_4, with a ratio of 1:4 (b/v). This soaking was done to maximize the contact of the carbon-activating solution. (Fig. 1b). Shows the cleaner surface morphology of the carbon compared to the unactivated carbon and the number of pores that appear after activation. The use of 10% H_3PO_4 will open small pores to become larger so that the more pores formed on the surface, the more substances are absorbed. The resulting activated carbon shows that a 10% H_3PO_4 activator is one of the best activators to produce highly porous activated carbon with a high mesopore content. By enlarging the surface area of activated carbon by pores, the adsorption capacity of activated carbon can be increased (Yang et al. 2020, La Hasan et al. 2014).

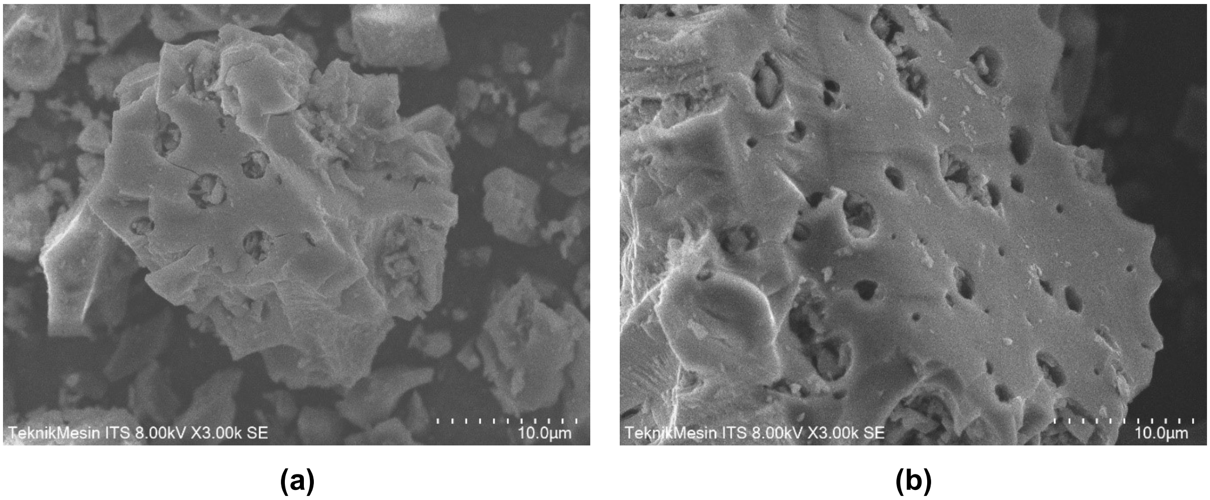

Fig. 1: (a) SEM analysis results of 3000x magnification on nutmeg shell carbon, (b) SEM analysis results of 3000x magnification on nutmeg shell activated carbon.

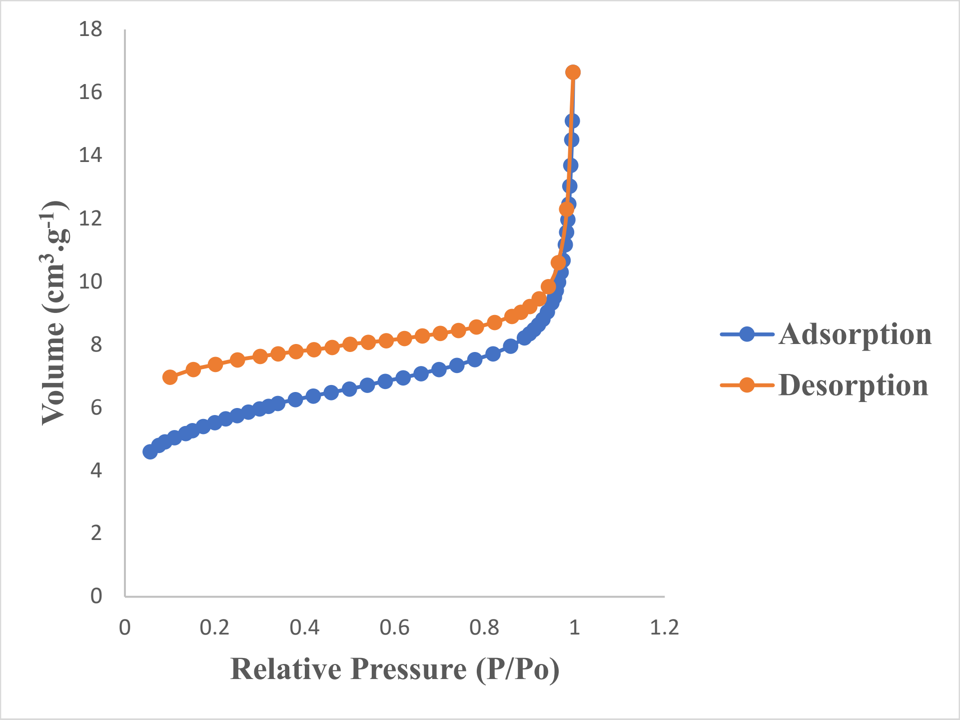

Fig. 2: N_2 Adsorption-desorption isotherm curve on activated nutmeg shell carbon.
(Source: Data Analysis in 2023)

N_2 Adsorption - Desorption Isotherm

N_2 adsorption-desorption characterization was performed to determine the surface area and pore size of the activated carbon material. The surface area was measured by the BET (*Brunauer-Emmet-Teller*) method. This method uses the inert adsorbate gas N_2. Isothermal curves were created by graphing the volume of N_2 adsorbed and desorbed against the relative gas pressure (P/P_0).

The N_2 adsorption isotherm obtained for the activated carbon is shown in Fig. 2. The activated carbon shows an isotherm shape similar to the type IV isotherm based on the *International Union of Pure and Applied Chemistry* (IUPAC) (Bonelli et al. 2001).

Based on the data obtained, the surface area of activated carbon is 19.6243 $m^2.g^{-1}$, the pore volume is 0.023665 $cm^3.g^{-1}$, and the pore diameter is 4.8237 nm. Type IV isotherms originate from micro and mesoporous solids, where capillary condensation occurs when gas molecules interact with the mesoporous surface of the adsorbent. The results of the IUPAC type classification show that the activated carbon with the resulting pore diameter belongs to the mesoporous surface type (Bardestani et al. 2019).

The optimum time of adsorption of Pb(II) and Cu(II) metal ions

The optimum time is the time required for the adsorbent to adsorb the largest amount of metal ions observed. Fig. 3 shows the amount of Pb(II) and Cu(II) ions adsorbed by nutmeg shell-activated carbon at different contact times.

The results showed that the amount of Pb(II) and Cu(II) ions adsorbed increased with time. At the 40th and 70th min, the amount of ions adsorbed by the nutmeg shell activated carbon was 0.9718 $mg.g^{-1}$ and 0.18 $mg.g^{-1}$, respectively.

The absorbency of nutmeg shell activated carbon to Pb(II) ions increased from the 10th minute to the 40th minute, but after the 50th minute, the absorbency decreased. For Cu(II) ions, the absorbency of nutmeg shell activated carbon increased from the 10th minute to the 70th minute, but after the 80th minute, the absorbency decreased. This is because, in the first minute, the absorbency of Pb(II) ions is relatively increased due to the effective bonding between metal ions and adsorbents. All active sites on the nutmeg shell activated carbon bind to Pb(II) and Cu(II) ions in solution (Li et al. 2017).

The size of the adsorbent affects the adsorption mechanism, which can lead to a larger interaction surface area. This allows the active side of the adsorbent to interact with Pb(II) and Cu(II) ions very well (Bohli et al. 2017). In the adsorption process, contact time is very important. The longer the contact lasts, the more interactions occur. At a certain point, the number of interactions reaches a high point and then drops. When the adsorbent can no longer adsorb the adsorbed material, it is because the surface is saturated and uniform desorption occurs. This shows that the physical phenomenon of adsorption occurs, which states that the adsorption process is reversible (Bhatnagar & Sillanpaa 2017).

pH Optimum Adsorption of Pb(II) and Cu(II) Metal Ions

To determine the optimum pH of adsorption of Pb(II) and

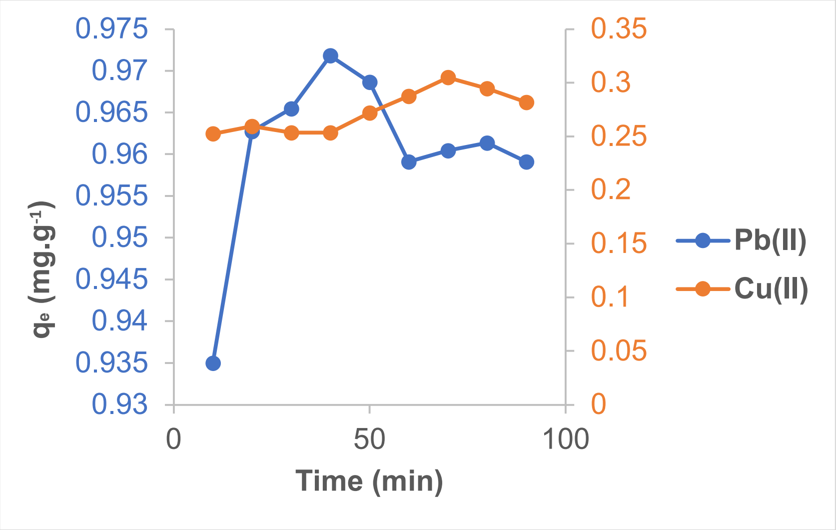

Fig. 3: Effect of contact time on the amount of Pb(II) and Cu(II) metal ions adsorbed by nutmeg shell activated carbon.
(Source: Data Analysis in 2023)

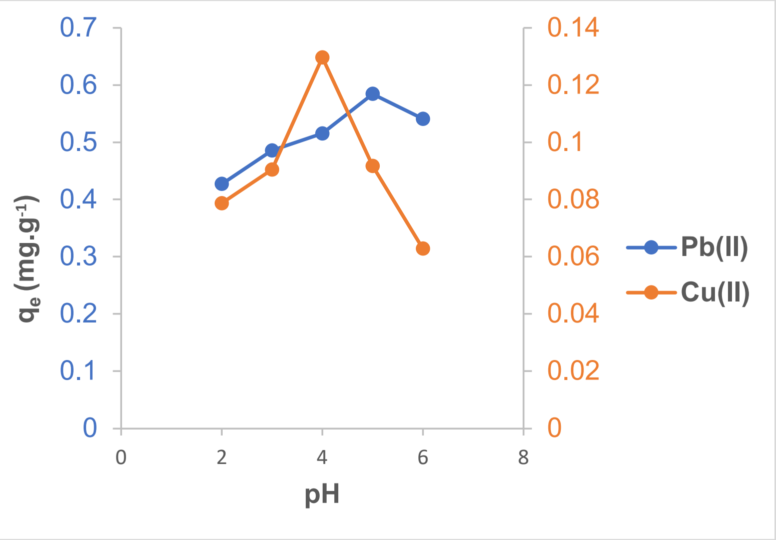

Fig. 4: Effect of pH time on the amount of Pb(II) and Cu(II) metal ions adsorbed by nutmeg shell activated carbon.
(Source: Data Analysis in 2023)

Cu(II) ions, the optimum stirring time of Pb(II) ions was 40 min, and Cu(II) ions 70 min was used. The effect of pH on the adsorption of metal ions by nutmeg shell-activated carbon is shown in Fig. 4.

Acidity (pH) is an important parameter that determines metal sorption on activated carbon nutmeg shells of Pb(II) and Cu(II) ions. Changes in pH can affect the chemical and surface properties of the adsorbent, the solubility of metal ions, and the competition of metal ions during the adsorption process (Wang et al. 2015).

Fig. 4 shows that the adsorption process increases with increasing pH but decreases after reaching the optimum pH. pH 2 to 5, the adsorption of Pb(II) ions increases. The amount of ions adsorbed at pH 5 is 0.5845 mg.g^{-1}. While at pH 6 the amount of Pb(II) ions adsorbed decreased to 0.5409 mg.g^{-1}. In Cu(II) ions, the number of adsorbed ions increases at pH 2 to 4. The number of adsorbed ions at pH 4 is 0.1296 mg.g^{-1}. While at pH 5-6, it decreased, the amount of Cu(II) ions adsorbed to 0.0628 mg.g^{-1}.

The low uptake that occurs at pH 6 for Pb(II) ions and at pH 5 for Cu(II) ions is due to several possibilities. First, at low pH, H$^+$ competes with Pb(II) and Cu(II) ions to interact with functional groups on the surface of nutmeg shell-activated carbon. Second, at low pH, the functional groups on the surface of nutmeg shell activated carbon are surrounded by H$^+$ ions, thus preventing interaction between Pb(II) and Cu(II) ions with functional groups on the surface of nutmeg shell activated carbon (Tumin et al. 2008). Third, the surface of nutmeg shell activated carbon is positively charged, resulting in electrostatic repulsion of Pb(II) and Cu(II) ions (Sharma et al. 2009).

The effect of pH on adsorption is very large because it affects the charge of the active site and the charge of metal ions in the solution (Ariyani et al. 2018). Conversely, at pH 5 and pH 4, there is a very strong adsorption of Pb(II) and Cu(II) ions. This is because the number of H$^+$ ions decreases, and the surface of nutmeg shell-activated carbon releases H$^+$ ions so that the surface of nutmeg shell-activated carbon becomes negative (Vasu 2008), and electrostatic interactions occur between the surface of nutmeg shell-activated carbon and Pb(II) and Cu(II) ions.

Isotherms and Adsorption Capacity of Pb(II) and Cu(II) Metal Ions

In this study, Pb(II) and Cu(II) metal ions were used for 40 min and 70 min, with pH 5 and 4, respectively. (Fig. 5a) and (Fig. 5b) Shows information about the effect of ion concentration on the amount of Pb(II) and Cu(II) ions adsorbed.

Fig. 5a and Fig. 5b show that the amount of Pb(II) and Cu(II) ions adsorbed increases with increasing concentrations of Pb(II) and Cu(II) ions. In Pb(II) ions with an initial concentration (C0) of 200 mg.L^{-1} after going through the adsorption process, the final concentration (Ce) becomes 1.5909 mg.L^{-1}, indicating that the number of adsorbed ions is 19.8409 mg.g^{-1}. For Cu(II) ions with an initial concentration (C0) of 200 mg.L^{-1} after going through the adsorption process, the final concentration (Ce) becomes 51.2222 mg.L^{-1}; this indicates that the number of adsorbed

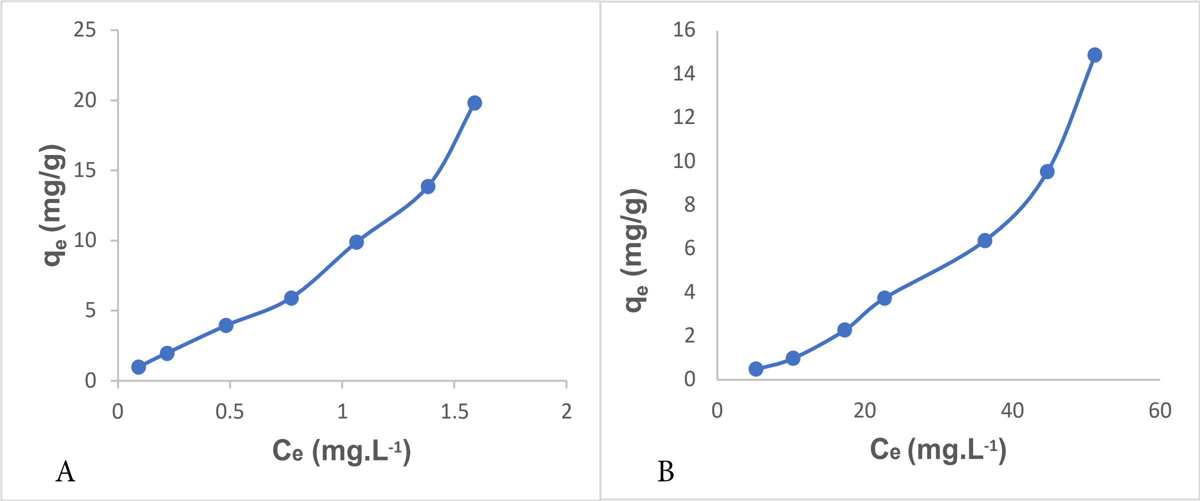

Fig. 5: Graph of concentration effect (a) adsorption of Pb(II) ions by nutmeg shell activated carbon and (b) adsorption of Cu(II) ions by nutmeg shell activated carbon. (Source: Data Analysis in 2023)

Table 1: Adsorption parameter data of Pb(II) ions.

Langmuir Isotherm		Freundlich Isotherm	
Q_0 [mg.g^{-1}]	90.9090	K_f [mg.g^{-1}]	9.6028
b [L.mg^{-1}]	0.0958	n [L.mg^{-1}]	0.99
R^2	0.1351	R^2	0.9762

Source: Data Analysis in 2023

Table 2: Adsorption parameter data of Cu(II) ions.

Langmuir Isotherm		Freundlich Isotherm	
Q_0 [mg.g^{-1}]	6.4308	K_f [mg.g^{-1}]	0.035
b [L.mg^{-1}]	0.0138	n [L.mg^{-1}]	0.6746
R^2	0.9003	R^2	0.9884

Source: Data Analysis in 2023

ions is 14.8777 mg.g^{-1}. The ability of nutmeg shell-activated carbon to adsorb Pb(II) ions is greater than that of Cu(II) ions. This occurs due to the nature of Pb, which is more electronegative than Cu so that Pb(II) ions will be more easily adsorbed on the adsorbent surface (Tsai et al. 2016), where most of the adsorbent surface is positively charged due to the presence of functional groups owned by the adsorbent such as hydroxyl, carboxylate, and others. Therefore, the affinity of Pb(II) ions to be adsorbed on the surface of activated carbon nutmeg shells is higher (Winata & Yanti 2020).

The Langmuir and Freundlich adsorption isotherm equations are plotted as linear equilibrium curves to determine the adsorption isotherm. The equilibrium model depends on the largest coefficient of determination (R). The purpose of determining adsorption isotherms is to determine how much Pb(II) and Cu(II) ions are adsorbed on the adsorbent. By using the nature of the adsorption isotherm, it can determine how the adsorbent adsorbs on the surface of the adsorbate (Sahara et al. 2018).

The correlation coefficient (R^2), which is used to determine the role of the variables used, was observed to test whether the isothermal model fits the research data. The closer the R^2 value approaches one, the greater the influence and the better it shows the influence between variables (Fitriansyah et al. 2021). Table 1 and 2 shows the parameter data obtained from the adsorption capacity of nutmeg shell-activated carbon on Pb(II) and Cu(II) ions.

Pb(II) ions follow the Freundlich isotherm, while Cu(II) ions follow the Langmuir and Freundlich isotherms because the R^2 values are both close to 1, but Freundlich is closer. This shows that the whole adsorbent activated carbon nutmeg shell follows the Freundlich isotherm characterized by R^2 values close to 1 against Pb(II) ions and Cu(II) ions. According to the Freundlich equation model, there is more than one surface layer, and the surface is heterogeneous, resulting in differences in binding energy on the two surfaces (Wijayanti & Kurniawati 2019). Freundlich adsorption isotherms were developed for heterogeneous systems and offer the concept of multilayer adsorption on an absorbent surface.

Freundlich adsorption isotherms assume that adsorption occurs physically, which means that more absorption occurs on the surface of activated carbon. In physical adsorption, the adsorbate is not strongly bound to the surface so that it can move from one surface to another, and another adsorbate can replace the abandoned surface (Jasmal & Ramlawati 2015). If adsorption follows the Freundlich isotherm type, the adsorption takes place by multilayer physisorption. The physisorption mechanism allows for bonding between metal ions in solution, in addition to bonding with the adsorbent. Both bonds are only bound by *Van Der Waals* forces; therefore, the bond between adsorbate and adsorbent is weak. This allows the adsorbate to move freely until, finally, a multilayered adsorption process occurs (Anggriani et al. 2021).

Adsorption Effectiveness of Pb(II) and Cu(II) Metal Ions in Liquid Waste Effluent

The results of the research were conducted with two experiments, namely, making a solution of Pb(II) ions from $Pb(NO_3)_2$ and Cu(II) ions from $CuSO_4.5H_2O$ with an initial concentration of 10 mg.L^{-1} each. After that, the solution is mixed into one container. The mixing process of the two solutions aims to see the effectiveness of adsorption that occurs and see the difference between the adsorption results with the mixed solution and the solution without mixing the solution. Adsorption of Pb(II) metal ions and Cu(II) metal ions using activated carbon adsorbent from nutmeg shell (*Myristica fragrans*). The adsorption process is carried out from a solution that has been mixed through a batch system using the optimum time and optimum pH that has been obtained previously and adjusted to each metal ion. Table 3 shows the comparison of the number of ions adsorbed on Pb(II) and Cu(II) ions as well as on Pb and Cu metals from liquid waste.

Second, adsorption of laboratory liquid waste, especially for heavy metal ions Pb and heavy metal ions Cu using activated carbon adsorbent from nutmeg shell (*Myristica fragrans*). Liquid waste was obtained from the waste bin in the Analytical Chemistry Laboratory and Physical Chemistry Laboratory, Department of Chemistry, Hasanuddin University, Makassar. Then, the waste obtained was mixed into one container. The waste that has been mixed is then wet deconstructed using a strong acid, namely nitric acid, which aims as a process of breaking down organic and inorganic compounds into small parts so that they can be analyzed in

Table 3: Amount of ions adsorbed on Pb(II) and Cu(II) ions as well as on Pb and Cu metals from Liquid waste.

Parameters	C_0 [mg.L^{-1}]	C_e [mg.L^{-1}]	W [g]	q_e [mg.g^{-1}]	Absorbency [%]
$Pb(NO_3)_2$	10	2.0545	0.5	0.7945	79.4545
$CuSO_4.5H_2O$	10	5.1148	0.5	0.4885	48.8518
Liquid waste (heavy metal Pb)	42	22.5454	0.5	1.9454	46.3203
Liquid waste (heavy metal Cu)	62.4	58.1481	0.5	0.4251	6.8138

Source: Data Analysis in 2023

certain instruments. Before the adsorption process is carried out, the deconstructed waste is put into 2 Erlenmeyers with a volume of 50 mL each. Then the adsorption process is carried out with a batch system. The time used is the same as in the previous adsorption process on Pb(II) and Cu(II) metal ions, using the optimum time for Pb metal and Cu metal for 40 min and 70 min, respectively. Analysis using AAS was carried out to see the concentration after adsorption through calculation. The results of the calculation resulted in the number of adsorbed ions and the percentage of adsorption for Pb(II) metal ions and Cu(II) metal ions, as well as Pb metal and Cu metal contained in the liquid waste shown in Table 3.

Based on Table 3 shows that the number of adsorbed ions and the percentage of absorption for Pb(II), Cu(II), Pb metal, and Cu metal by nutmeg shell activated carbon are 0.7945 mg.g^{-1}; 0.4885 mg.g^{-1}; 1.9454 mg.g^{-1} and 6.8138 mg.g^{-1}, respectively. This shows that heavy metal Pb is more easily adsorbed compared to heavy metal Cu due to properties such as electronegativity and hydrolysis constant, with Pb metal being the most electronegative and easily hydrolyzed compared to Cu metal (Vijayaraghavan et al. 2009),$^{. T}$he affinity of Pb metal is greater than Cu metal (Futalan et al. 2011). The results obtained show that in the adsorption process using nutmeg shell-activated carbon adsorbent can reduce the concentration of heavy metals from the initial concentration before the adsorption process.

CONCLUSIONS

Based on the results of the study, it can be concluded that the nutmeg shell (*Myristica fragrans*) can be used as an adsorbent for Pb(II) and Cu(II) ions. The optimum contact time required by nutmeg shell activated carbon adsorbent (*Myristica fragrans*) to adsorb Pb(II) and Cu(II) ions occurred in the 40th min and 70th min with an adsorbent mass of 0.5 g each in 50 mL in the Batch system.

The optimum pH required to adsorb Pb(II) and Cu(II) ions using nutmeg (*Myristica fragrans*) shell-activated carbon adsorbent is at pH 5 and pH 4. The adsorption capacity of nutmeg shell activated carbon (*Myristica fragrans*) on Pb(II) and Cu(II) ions tend to follow the Freundlich isotherm, with maximum adsorbed ions of 9.6028 mg.g^{-1} and 0.035 mg.g^{-1}, respectively.

The effectiveness of activated carbon on liquid waste in reducing Pb and Cu metal levels is with the number of ions adsorbed at 1.9454 mg.g^{-1} and 0.4251 mg.g^{-1} from initial concentrations of 42 mg.L^{-1} and 62.4 mg.L^{-1}, respectively.

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