Jurnal Teknik Kimia

Vol. 30, No. 1, 2024, 34-43
e-ISSN: 2721-4885
DOI: https://doi.org/10.36706/jtk.v30i1.1505
Online at http://ejournal.ft.unsri.ac.id/index.php/jtk

Analysis of coconut shell adsorption capability as greywater waste adsorbent

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Abstract

As coconut plantations increase in Indonesia, coconut shell waste has the potential to damage the environment if it is not processed properly. Various studies state that coconut shell waste can be used as a greywater adsorbent. Greywater is a domestic waste that is much less polluted than domestic wastewater because it does not contain urine, feces, and toilet paper, and only contains about 30% of the total organic load. Therefore, it is important to determine the right adsorbent for appropriate processing. So this research will test the adsorption capacity of coconut shell waste as a greywater adsorbent using iodine absorption analysis. In the analysis of iodine absorption capacity, coconut shell adsorbents have high adsorption capabilities in absorbing adsorbate (iodine molecules) with high molecular concentrations. Based on iodine absorption analysis data, it is known that the coconut shell waste adsorbent has a maximum adsorption capacity of 2.86 x 10^{-3} mg g^{-1} by following the Langmuir isotherm model. The coconut shell waste adsorbent used as a medium in the adsorption column was able to reduce total dissolved solids by 3.7 %, total suspended solids by 23.3 %, and phosphate removal efficiency by 6.3 % in greywater waste samples. This proves that coconut shell waste can act as an adsorbent in managing greywater waste.

Keywords: adsorbent, coconut shell, greywater, iodine, langmuir

How to Cite: D. Cendekia and Dian A. Afifah. (2024). Analysis of coconut shell adsorption capability as greywater waste adsorbent. *Jurnal Teknik Kimia*, 30(1), 34-43. http://doi.org/10.36706/jtk.v30i1.1505

1. INTRODUCTION

Indonesian coconut plantations are included in commodities that have important selling value. Based on data from the Centre for Plantation Research and Development, in 2019 Indonesia had a coconut area of 3,500,726 (ha) and produced 2,992,190 (tons). This coconut commodity produces solid waste from processed coconuts where the coconut meat has been taken to get coconut milk. One of the most commonly produced solid wastes is coconut shells. Shells are generally used as fuel, for household purposes, or recycled as souvenirs (Nustini & Allwar, 2019).

The abundance of coconut shell waste along with the development of coconut plantations from year to year means that coconut shells are starting to be widely used as raw materials for other appropriate products. Several methods have been applied to increase the economic value of coconut shell waste, such as liquid smoke from

Received October 2023, Revised December 2023, Accepted for publication March 2024

coconut shells which is effective as a pesticide for armyworms which generally attack corn, potatoes, tobacco, green beans, spinach, and cabbage. With a coconut shell liquid smoke concentration of 7 %, capable of producing armyworm mortality of 88.89 % (Isa et al., 2019). In addition, coconut shell-activated carbon products are known to be able to reduce ammonia levels in industrial waste by 87.6 % by using a KOH activator (Nurhidayanti et al., 2020). Coconut shell-activated carbon is also effective in improving water quality by 25%, which is installed in a water filter at the water source in Sumberwudi Karanggeneng Lamongan Village ((Silvia et al., 2021).

By using adsorption capacity analysis using an isotherm model, the performance of coconut shells as an adsorbent can be determined for greywater management. The Langmuir isotherm model assumes that the adsorption process takes place only in a monolayer on the outer surface of the adsorbent, making it possible to calculate the maximum adsorption capacity according to the level of saturation on the surface. adsorbent (Azizian et al., 2018) The Freundlich isotherm model assumes that the adsorption process occurs in several heterogeneous surface layers on the adsorbent material, so it can be used to estimate the adsorption intensity (Rangabhashiyam et al., 2014). The basic composition of coconut shells contains cellulose, lignin, and hemicellulose with C, O, H, and N atoms, making coconut shell waste potential as raw material for making active carbon. Activated carbon derived from coconut shells is known to have advantages compared to other materials, namely having an upper surface area of 1500 m^2/g, low ash, high absorption capacity, and a high level of hardness, making it easier to handle later (Susmanto et al., 2020).

Given the potential of coconut shell waste as active carbon, this research will examine the potential of coconut shell waste as a greywater adsorbent. Greywater is domestic waste that comes from kitchen sinks, sinks, and bathroom floor drains. The characteristics of greywater waste vary greatly depending on the number and age of occupants, people's living habits, customs, and the use of household detergents, as well as the chemicals and body care products used (Spychala et al., 2019). Location and time also play an important role in the composition of greywater waste because water consumption varies with the number of substances discharged. In general, greywater contains a lot of fat and soap, which can cause blockages in drains. The negative effects of greywater can occur directly or indirectly on the physical and chemical conditions of water flowing with waste.

Greywater is generally divided into two types based on the concentration of pollutant sources, namely, light greywater and dark greywater. Light greywater includes wastewater that comes from bathtubs, showers, tubs, hand-washing facilities, and bathroom sinks. Wastewater from laundry washing, rinsing, washing machines, kitchens, and dishwashers is dark greywater (Alsulaili & Hamoda, 2015). The effects of greywater on the environment include decreasing dissolved oxygen levels in waters, eutrophication, and changes in the physical and chemical properties of water (Yuliani et al., 2015). Increasing coconut shell waste can be used as an alternative to making adsorbents in the greywater management process. Therefore, the potential of coconut shell waste as an adsorbent needs to be studied about the adsorption capacity and adsorbate removal efficiency of coconut shells as a greywater adsorbent.

2. MATERIALS AND METHODS

This research used activated carbon made from coconut shells which was then followed by an adsorption test using the Langmuir isotherm model and the Freundlich isotherm model. By using the isotherm model, we can see the relationship between the adsorbent distribution between the adsorbed phase on the surface and the adsorbate in equilibrium at a certain temperature. In other words, the isotherm model can describe the interaction of the solute with the adsorbent, so it can be used to optimize the use of the adsorbent (Al-Ghouti & Da'ana, 2020).

2.1 Adsorption Test

Analysis of the capacity of adsorbents made from coconut shell waste using the iodine absorption test. Measurement of iodine absorption in this study was carried out using the Iodometric titration method using sodium thiosulfate solution. The iodine solution functions as an adsorbate which will be absorbed by the adsorbent (Kadang, M.R.A.M., Anas, M., Mongkito, 2020). Iodine power analysis can show the maximum ability of the adsorbent as an adsorption medium. All adsorption experiments were carried out using a batch system with constant contact time (15 minutes) in a 100 mL Erlenmeyer and stirring with a stirrer. In all treatments, the amount of shell waste-based adsorbent used was 5 grams, then mixed with 25 mL of iodine solution with different concentration variations, namely 0.25 N, 0.5 N; 0.1 N; 0.15 N; and 0.2 N. For each treatment, the initial concentration and final concentration of iodine were calculated using the iodometric method.

In the iodometric method, 10 mL of sample is used, 30 mL of distilled water is added, then titration is carried out using a standardized 0.1 N sodium thiosulfate solution. If the yellow color of the solution begins to fade, add 1 % starch solution as an indicator. Titrate the solution again until the dark blue colour disappears. The analysis was carried out 3 times using the iodine absorption calculation formula as in Equation 1 (Cendekia et al., 2021).

$$Daya\ serap\ Iod = \frac{A\frac{B\ x\ N_{Na_2S_2O_3}}{N_{iodine}}}{c}\ x\ 126{,}93\ x f_p \quad (1)$$

where A represents the volume of iodine solution (mL), B represents the volume of $Na_2S_2O_3$ used (mL), fp represents the dilution factor, c represents the weight of activated carbon (g), $N_{Na_2S_2O_3}$ concentration $Na_2S_2O_3$ (N), N_{iodine} represents the concentration of iodine (N), and 126.93 represents the amount of iodine corresponding to 1 mL of solution $Na_2S_2O_3$

The performance of adsorbents made from coconut shell waste can be seen froe ability to absorb iodine which is calculated from experimental results as adsorption capacity (q, mol g^{-1}), using Equation 2 (Muhammad, 2014)

$$q = \frac{(C_0 - C_1)\ X\ (\frac{V}{1000})}{m} \quad (2)$$

where Co and C are the initial concentration and final concentration of the iodine solution (mol L), V is the volume of iodine solution used (mL), and m is the mass of the adsorbent used in the experiment.

To measure the performance of the adsorbent for iodine ion adsorption, the experimental data has been modeled using the Langmuir isotherm (Equation 3) and Freundlich isotherm (Equation 4) models (Wijayanti and Kurniawati 2019).

$$\frac{1}{q} = \frac{1}{q_{max}} + \frac{1}{q_{max} \cdot K_L} \cdot \frac{1}{c} \quad (3)$$

$$\log q = \log K_f + \frac{1}{n} . \log c \qquad (4)$$

where q is the equilibrium adsorption capacity, qmax is the maximum adsorption capacity, KL is the Langmuir constant, KF is the Freundlich constant, n is the heterogeneity factor.

2.2 Adsorbate Removal Efficiency

After knowing the characteristics of the coconut shell adsorbent, the next step was to look at the efficiency of adsorbate removal in greywater. The experiment was carried out as in previous research, using adsorption column media with an adsorbent height of 5 cm (Figure 1) (Cendekia et al., 2024), where samples would be analyzed at contact times of 10 minutes, 20 minutes, 30 minutes, and 40 minutes, which were then calculated based on Equation 5 (Azizian et al., 2018)

$$R\ (\%) = \frac{C_i - C_f}{C_i} x\ 100 \qquad (5)$$

where C_i is the initial concentration of greywater, and C_f is the final concentration of greywater after passing through the adsorption column media.

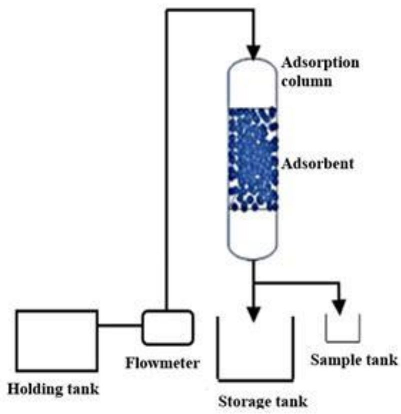


Figure 1. Adsorption Column Design of Continue System

3. RESULTS AND DISCUSSION

By analyzing the adsorption capacity and efficiency of adsorbate insertion in adsorbents made from coconut shells, the capacity of coconut shell waste as a greywater adsorbent can be determined. The adsorption capacity is calculated based on the Langmuir equation and the Freundlich equation, while the efficiency of adsorbate reduction can be seen from the performance of the adsorbent as an adsorption column medium.

3.1. Adsorptive Characteristics of Coconut Shell Waste

Adsorbent materials obtained from coconut shells have been used for the adsorption of iodine from aqueous solutions. In the adsorption experiment, 0.5 g of adsorbent was mixed with 25 mL of iodine solution, with an initial concentration (0.025–0.2 N), stirred for 15 minutes, and centrifuged for 5 minutes at room temperature (26±1.0 °C). Adsorption capacity and percent removal values, calculated from experimental data, are presented in Figure 2.

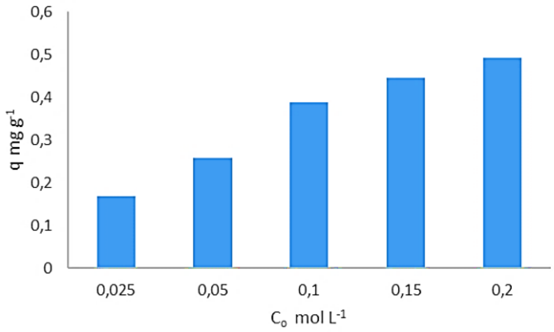
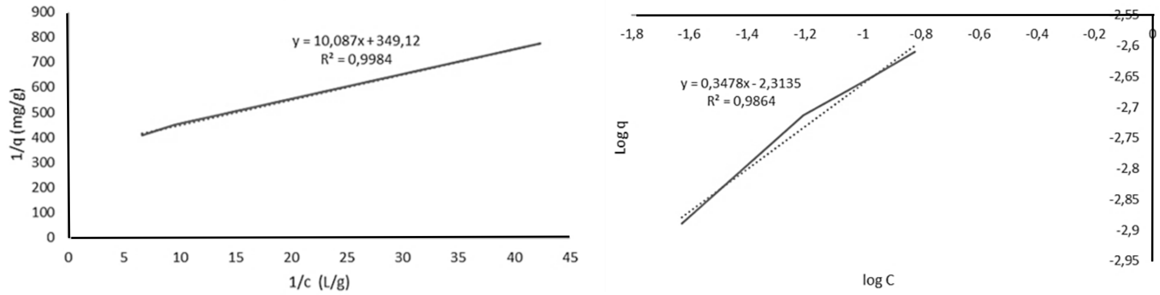


Figure 2. Adsorption capacity of adsorbent made from coconut shell

Adsorption capacity states the amount of adsorbate that can accumulate on the surface of the adsorbent. In Figure 2, the adsorption capacity of coconut shell adsorbents increases for higher molecular concentrations. An iodine solution with a concentration of 0.025 N has an adsorption capacity of 0.167 mg g^{-1}. An iodine solution with a concentration of 0.2 N has an adsorption capacity of 0.491 mg g^{-1}. The higher the concentration of the iodine solution, the more interacting iodine molecules that collide with the adsorbent so that the adsorption capacity increases (Wijayanti & Kurniawati, 2019). Apart from being effective as a greywater adsorbent, coconut shell waste shows the highest percentage of efficiency and adsorption capacity using a bioadsorbent of 1.25 gr of coconut shell: 3.75 gr of coconut fiber with a stirring time of 45 minutes of 92 % and 0.628 mg/g (Ismiyati et al., 2021).



(a) (b)

Figure 3. Linear representation of the Langmuir (a) and *Freundlich (b) isotherm models* in the adsorption process of coconut shell adsorbents

Table 1. Calculation of adsorption *isotherm parameters* for adsorbents made from coconut shells

Isotherm model	Parameter	Coconut shell-based adsorbent
	R^2	0.9984
Langmuir model	q_{max}, mg g^{-1}	2.86 x 10^{-3}
	K_L, L g^{-1}	34.60
	R^2	0.9864
Freundlich model	N	2.87
	K_f, L g^{-1}	4.85 x 10^{-3}

The adsorptive characteristics of coconut shell adsorbent can be seen from the ability of the adsorbent to absorb the amount of adsorbate (iodine molecules). The adsorption power of an adsorbent is indicated by the amount of iodine that appears. The iodine number is the number or ability of the adsorbent to adsorb iodine which acts as an adsorbate. The greater the value of the iodine number, the greater the adsorption power of the adsorbent (Sulaiman, N. H., Malau, L.A., Lubis, F. H., Harahap, N. B., Manalu, F. R., Kembaren, 2018)

In other words, coconut shell adsorbent can absorb more adsorbate as the adsorbate concentration increases. This shows that coconut shells have potential as a greywater adsorbent, because most greywater is complex and varies in terms of the adsorption ability of existing mixtures such as molecular structure, solubility, and so on (Syauqiah et al., 2011). The iodine adsorption process is the establishment of an equilibrium concentration interface followed by slow diffusion into the adsorbent particles. The overall adsorption rate is controlled by the diffusion speed of the solute molecules in the capillary pores of the adsorbent particles. The adsorption rate varies along with the square root of the contact time with the adsorbent. The adsorption capacity of an adsorbent for a solute depends on the pores of the adsorbent and adsorbate. By studying the iodine adsorption process on adsorbents made from coconut shells, it can be seen that the adsorption process can be applied to other forms of adsorbates. The adsorption capacity value obtained can be used to predict the amount of adsorbate in greywater that can be adsorbed.

Based on Figure 2, the adsorption capacity of coconut shell-based adsorbents increases with increasing initial iodine ion concentration at specified intervals. This shows that the retention of iodine ions in coconut shell-based adsorbents occurs through an interaction and there is no saturation point, indicating that at the highest initial iodine ion concentration, not all functional groups are occupied.

The isotherm model is used to determine the adsorption phenomenon and evaluate what occurs between adsorbate and adsorbent. The isotherm model obtained from experimental data is used to determine the characterization of equilibrium adsorption (Hadiah et al., 2020). In Figure 3, the correlation coefficient (R^2) in the Langmuir isotherm model is higher than in the isotherm model Freundlich. This shows that the Langmuir model with a value of R^2 = 0.998 is the one that best describes the experimental data related to the adsorption mechanism that occurs on coconut shell waste adsorbents. This means that the adsorption process that occurs on the coconut shell waste adsorbent occurs in a monolayer.

Langmuir isotherm model, it can be explained that the adsorption process takes place in a monolayer on the surface of the adsorbent and is reversible. So it can be seen that the maximum adsorption capacity of the coconut shell waste adsorbent is 2.86 x 10^{-3} mg g^{-1} (Table 1). The Langmuir adsorption model explains that there is more than one type of adsorption site available on the adsorbent surface.

The existence of a cooperative adsorption system in the Langmuir adsorption model explains the binding to surfaces that are identical but can accommodate many molecules. So more adsorption energy is needed which is influenced by the presence of various adsorbates bound to the active side of the adsorbent (Al-Ghouti & Da'ana, 2020). Although the Freundilch model does not properly describe the experimental data obtained on the adsorption of iodine ions, it can explain that the n value for the coconut shell waste adsorbent is 2.87, or the adsorption intensity value 1/n < 1 (table 1). This indicates that the chemical adsorption process is running and tends to be monolayer. Where there are several active sites that are able to absorb adsorbate and have different energy levels (Reni Yenti et al., 2018).

3.2. Adsorbate Removal Efficiency

Organic solids and phosphate are adsorbate components that are often found in greywater, so the parameter value is total dissolved solids (TDS), and total suspended solid value (TSS), and this phosphate content can be used to calculate the efficiency of adsorbate removal in greywater. The adsorbate removal efficiency was analyzed based on samples collected in the adsorbate column. The adsorption column is a system of better adsorbent pretreatment through the development of fluid flow pressure pattern uniformity (Bimantio & Ferhat, 2022). The adsorbent derived from coconut shell waste is arranged in an adsorption column and then flows into the greywater waste.

Greywater samples were taken when the contact time was 10 minutes, 20 minutes, 30 minutes, and 40 minutes. Each greywater sample was tested for water parameters in the form of TDS values, (TSS) and phosphate levels. Based on Figure 3, it can be seen that the longer the contact time, the greater the percent efficiency of adsorbate shrinkage in greywater. The use of coconut shell waste as an adsorbent and the contact time with greywater is influenced by the design of the adsorption media used. To be effective as an adsorption medium, the calculation of greywater pollutant levels is analyzed as an initial reference for determining the required contact time.

The estimated contact time will influence the design of activated carbon-based (Cendekia et al., 2021) greywater waste adsorption media. In Figure 4, it can be seen that the highest adsorbate removal efficiency was at a contact time of 40 minutes, namely the total dissolved solids removal percentage was 3.7 %, the suspended solids removal efficiency was 23.3 %, and the phosphate removal efficiency was 64.3 %. The longer the contact time of the coconut shell waste adsorbent with the greywater, the more adsorbates in the greywater will be absorbed. This can help overcome greywater problems in the environment.

In greywater, the most adsorbate is phosphate, because greywater is waste produced from most cleaning products which generally contain sodium tripolyphosphate (STTP) compounds. Where if the phosphate content is higher it can cause eutrophication problems in the environment (Mu'in et al., 2017).

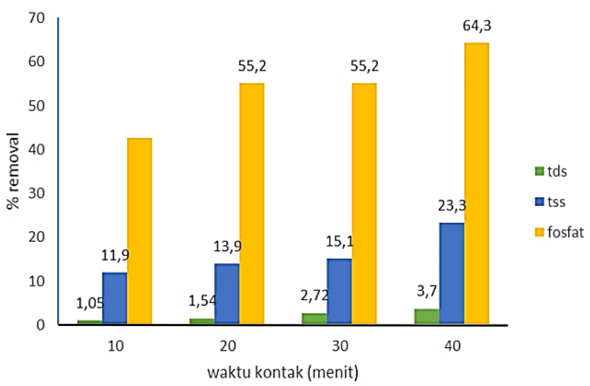


Figure 4. Adsorbate removal efficiency in greywater using coconut shell waste adsorbent media

With depleting water resources and increasing water demand, greywater reuse is becoming an alternative means of water conservation worldwide. So reliable innovation is needed regarding regeneration and greywater quality characteristics in determining treatment and techniques in greywater processing (Shaikh & Ahammed, 2020). By analyzing the data in this research, it can be used as an initial reference in reprocessing greywater into a potential water conservation facility. The cranium waste that becomes waste is used as an adsorbent which can help in dealing with environmental damage.

4. CONCLUSION

Coconut shell waste has the ability and potential as a greywater adsorbent. This can be seen from the adsorption capacity value which increases with increasing adsorbate concentration and the maximum absorption capacity is 2.86 x 10-3 mg g-1 following the Langmuir isotherm model. By adding active functional groups to the coconut shell-based adsorbent matrix, based on analysis of the efficiency of adsorbate on greywater samples, the coconut shell waste adsorbent was able to reduce the total dissolved solids value by 3.7 %, the efficiency of removing suspended solids levels by 23.3 %, and phosphate removal efficiency was 64.3 %.

ACKNOWLEDGEMENT

This work was supported by DIPA funding of Lampung State Polytechnic for applied research in 2022.

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