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Synthesis and Optimization of Snake Fruit Peel Ash-Derived Silica for Iron (Fe) Removal from Batik Wastewater

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ABSTRAK

Hasil samping industri batik berupa limbah cair yang mengandung logam berat seperti besi (Fe) yang dapat membahayakan lingkungan dan ekosistem perairan. Tujuan dari penelitian ini adalah untuk mensintesis dan mengoptimalkan silika yang berasal dari abu kulit salak sebagai adsorben besi (Fe) pada limbah cair industri batik. Kulit buah salak seringkali diabaikan sebagai limbah karena diketahui memiliki kandungan silika yang tinggi. Metode penelitian yang dilakukan adalah proses kalsinasi pada suhu 650°C selama 1 jam untuk mengubah dan mengubah serbuk kulit buah salak menjadi abu, kemudian diekstraksi menggunakan larutan HCl 2M. Tahap akhir sintesis silika adalah pengeringan dan penggilingan. Karakterisasi silika dianalisis dengan menggunakan uji FTIR (*Fourier Transform Infrared Spectroscopy*) dan *Surface Area Analyzer (SAA)*. Kandungan logam dalam limbah dianalisis dengan AAS (spektrometer serapan atom). Hasil penelitian menunjukkan bahwa silika dari abu kulit buah salak mengandung gugus penyusun silika yaitu silanol (Si-OH) sebagai situs aktif pada proses adsorpsi. Luas permukaan silika sekitar 56,347 m^2/g, volume pori total sekitar 0,0193 cc/g, dan diameter pori rata-rata sekitar 26,6745 mm. Uji aplikasi pada limbah cair batik menunjukkan adanya penurunan konsentrasi Fe dari 0,487 mg/L menjadi 0,343 mg/L pada waktu kontak 60 menit. Penelitian ini membuktikan bahwa silika dari abu kulit salak menawarkan solusi inovatif dan berkelanjutan untuk pengolahan limbah cair industri batik dan pengolahan limbah cair lainnya.

Keywords: Industri Batik, Logam Fe, Silika, Kulit salak, Air Limbah

ABSTRACT

The byproduct of the batik industry is a liquid waste containing heavy metals like iron (Fe) which can be harmful to the environment and aquatic ecosystems. The aim of this study is to synthesize and optimize silica derived from snake fruit peel ash as an adsorbent for iron (Fe) in the liquid waste of the batik industry. Snake fruit peel is often overlooked as waste and is identified to have a high silica content. The research method was carried out in the calcination process at a temperature of 650°C for 1 hour to convert and change the snake fruit peel powder into ash, then extracted using a 2M HCl solution. The final stage of silica synthesis is drying and grinding. The Silica characterization was analyzed using the FTIR (Fourier Transform Infrared Spectroscopy) and Surface Area Analyzer (SAA) tests. The metal content in the waste was analyzed with AAS (Atomic Absorption Spectrometer). The results showed that the silica from snake fruit peel ash contains silica constituent groups, namely silanol (Si-OH), as an active site for the adsorption process. The surface area of the silica is around 56.347 m^2/g, the total pore volume is about 0.0193 cc/g, and the average pore diameter is approximately 26.6745 mm. The application test on batik liquid waste showed a decrease in Fe concentration from 0.487 mg/L to 0.343 mg/L at contact time of 60 minutes. This research proves that silica from snake fruit peel ash offers an innovative and sustainable solution for the treatment of batik industry liquid waste and in other liquid waste processing.

Keywords: Batik Industry, Fe Metal, Silica, Snake fruit skin, Wastewater

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1. INTRODUCTION

Indonesia's batik industry has experienced a remarkable surge in recent years. Batik's intricate patterns and vibrant colors have transcended cultural boundaries, gaining appreciation not only as a beautiful art form but also as a symbol of national identity (Steelyana, 2012; Suleman, 2017). This is evident in its widespread adoption as a uniform in schools, offices, and even community activities. In recognition of its cultural significance, UNESCO inscribed batik on the Representative List of the Intangible Cultural Heritage of Humanity on October 2, 2009 (Ich.unesco.org, 2009). The batik industry's growth presents a promising avenue for economic development and social empowerment.

However, this flourishing industry comes with a hidden cost – environmental pollution. The batik production process generates significant amounts of liquid waste, which can pose a serious threat to our waterways and ecosystems (Kavisa et al., 2020; Phang et al., 2022).

Liquid waste from the batik industry can contain various hazardous materials such as heavy metals (including copper, chromium, nickel, lead and iron), volatile organic compounds (VOC), reactive chemicals (sodium hydroxide and hydrogen peroxide), phenol compounds, and alkaline and acid (Hossain & Hossain, 2020). Iron (Fe) was chosen as the element analyzed because it is often found in significant quantities in batik industry wastewater, can cause serious water pollution, and is regulated by environmental standards due to its detrimental impact on ecosystems and human health(Islam et al., 2011). AAS (Atomic Absorption Spectrophotometer) is an effective method for detecting and measuring iron concentrations with high accuracy, making it important in monitoring and controlling iron pollution in liquid waste from the batik industry. In addition, iron (Fe) can accumulate in the environment and disrupt delicate ecological balances (Oginawati et al., 2022). Discharging untreated batik wastewater directly into rivers has severe. It can significantly degrade water quality, harm aquatic life, and endanger the entire ecosystem (Budiyanto et al., 2018; Lestari et al., 2018).

An innovative solution offered by several researchers is to use adsorb technology (Geremew, 2017; Gorzin & Bahri Rasht Abadi, 2018). Adsorption is a physical or chemical process in which a reaction occurs between atoms, ions, or molecules of another substance (adsorbent) (Aini et al., 2024). Another technology that can be used is the modification of activated charcoal with other ingredients (Jamilatun et al., 2023; Salamah et al., 2023), biodegradation technology (Abromaitis et al., 2016; Nguyet et al., 2021), membrane technology (Adam et al., 2022; Qalyoubi et al., 2021), and oxidation technology. Among these technologies, adsorption technology offers the most effective solution in terms of cost and performance because it has a simple design with low operational costs and raw materials that are easy to find (Idris et al., 2023). In addition, adsorption technology has the ability to capture and retain pollutants through the adsorbent surface. Based on previous research, adsorption technology can be applied to overcome water pollution caused by dyes and other organic material contamination (Jiang et al., 2018). Adsorption technology can use chemically modified biochar materials with several chemical agents to increase adsorption capabilities such as Fe (Guo et al., 2023), $KMnO4$ (Yue et al., 2023), Mg (Zhu, 2020), nitrat, fosfat (Nuraini et al., 2023), dan HCl. Adsorbent technology was developed with the principle of solid phase extraction using certain adsorbents and does not require dangerous solvents. The extraction method is an efficient and easy method (Awadh & Yaseen, 2019). Adsorbent technology can be obtained from biomass extraction such as snake fruit peel waste into silica. snake fruit peel waste is an abundant agricultural waste that has not been utilized optimally. According to (Deni Agus Triawan, Salprima Yudha S, 2021) snake fruit peel contains 55.73% carbon, oxygen (23.28%, silicon (20.36), and other components (0.63%) so that the bark of snake fruit is used as an adsorbent in the form of silica which can adsorb cations. Silica has a functional group in the form of silanol (Si- OH) and siloxane (Si-O-Si) where these two functional groups function as ligands that are used to react with cation groups in metal ions. Indonesia, being one of the largest producers of snake fruit in the world, generates a significant amount of snake fruit peel waste annually. With extensive cultivation of snake fruit in Indonesia, the supply of snake fruit peel waste is continuous and abundant. This ensures a steady and reliable source of raw material for adsorbent production (Brunerová et al., 2021).

Therefore, the aim of this research is to determine the characteristics of silica from snake fruit ash and the potential application of silica in liquid waste from the batik industry. The silica synthesis in this research was made using a calcination process, activation with HCl solution, stirring and filtration, and drying. The calcination process uses a temperature of 650^{o}C within 1 hour then the bark ash is extracted using an HCl solution. In addition, silica effectiveness testing was carried out on 500 mL of batik industry liquid waste. The characteristics of silica from snake fruit ash were analyzed using FTIR and AAS.

2. METHODS

2.1. Device and Material

In this research, modern technology is combined with materials obtained from nature as waste. The equipment used consists of: 1) a magnetic stirrer as a constant stirring tool and creates a homogeneous solution in the extraction process. The stirring speed of the magnetic stirrer can be adjusted according to research needs, 2) Atomic Absorption Spectrophotometer (AAS) as a tool to analyze chemical components specifically to detect heavy metal content in this research sample. The AAS tool has a high sensitivity to measure Fe concentrations with precision, and 3) Fourier Transform Infrared Spectroscopy (FTIR) as a tool for qualitative analysis of functional groups of chemical compounds and 4) Surface area analyzer is used to analyze surface area, total pore volume and average pore diameter.

Meanwhile, the materials used consist of 1) Snake Fruit Peel. As a natural source of silica, Snake Fruit Peel (Pondoh salak) is processed to extract silica, which will then be used as an adsorbent; 2) Liquid

Batik Waste obtained from Giriloyo Batik Village, Yogyakarta, Indonesia. This waste is the main subject of this experiment, especially in determining the effectiveness of the silica produced as an adsorbent for the heavy metal Fe. 3) HCl (Pro Analysis Merck) (2M): Hydrochloric acid is used as a solvent agent in the extraction process of silica from snake fruit bark. HCl concentration and acidic nature help dissolve unwanted components, and 4) Aquadest, as distilled water, is used as a universal solvent and as a medium in the washing process, ensuring that materials do not contain contaminants.

2.2. Experimental Setup

This research was carried out in several research stages including: 1) making silica from snake fruit ash, 2) testing snake fruit peel silica in liquid batik waste, 3) data analysis carried out using FTIR and AAS. The research stages that have been implemented can be seen in Figure 1.

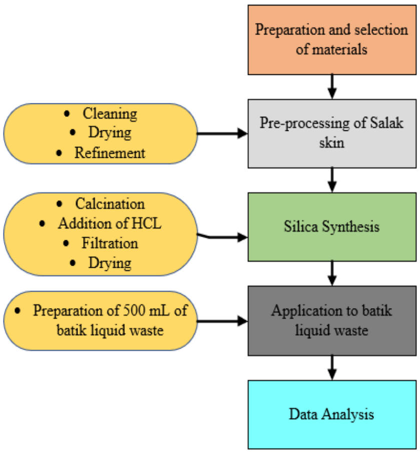


Figure 1. Research Stages

2.3. Preparation and Selection of Material

The process of preparation and selection of materials is an important process to carry out in choosing the quality of snake fruit skin that will be used as an adsorbent. The preparatory stage carried out is cleaning the snake fruit skin with running water which is used to remove dirt on the snake fruit.

2.4. Pre-processing

After the snake fruit skin is cleaned using running water, the next stage is pre-processing which consists of drying and smoothing the snake fruit skin. Snake fruit peel was dried using an oven at 100 °C within 4 hours. The drying process functions to remove or reduce the water content of the snake fruit skin. The dried snake fruit skin is then mashed using a blender. The process of smoothing snake fruit skin is to increase the surface area of snake fruit skin. snake fruit skin is ground to a size of 80 mesh.

2.4.1. Silica Synthesis

Silica synthesis is carried out using calcination processes, solution formation, stirring and filtration, and drying. The calcination process uses a temperature of 650 °C within 1 hour. The calcination process is used to convert or change snake fruit bark powder into ash and to reduce organic matter. Then take 20 grams of the snake fruit skin ash and mix it with 50 mL of 2M HCl. This solution formation process produces an acidic solution that is used to extract silica from the ash. The HCl solution and snake fruit ash were stirred using a magnetic stirrer for 6 hours. Then filter using distilled water until the pH reaches 6-7 to identify that the mixed solution is neutral. The final stages of the silica synthesis process are drying and grinding. The resulting silica precipitate was then dried again using an oven at 110 °C within 1 hour. The dry silica is processed and sifted until it reaches a particle size of 100 mesh.

2.4.2. Application of Silica in Liquid form The Batik Industry

Silica from snake fruit skin peel ash as an adsorbent weighed 2 grams. Then, testing was carried out or applied to 500 mL of liquid batik waste obtained from Giriloyo Batik Village, Indonesia. The adsorption process between liquid batik waste and silica is carried out in a glass beaker. The mixture was stirred using a magnetic stirrer. Adsorption efficiency was carried out by varying time at each interval. This study's adsorption quality is characterized by the level of Fe metal that has been adsorbed. The test method uses an atomic absorption spectrometer (AAS) to determine the Fe content in the solution.

2.5. Silica Caracteristic Analysis Using FTIR and SAA

FTIR (Fourier Transform Infrared Spectroscopy) testing was used to identify functional groups contained in snake fruit ash silica. The working principle of FTIR utilizes wavelengths that are absorbed by molecules. FTIR (Fourier-transform infrared) spectroscopy is used for characterization with important specifications including spectral range (generally 4000-400 cm^{-1}), and detector type (DTGS for general sensitivity or MCT for high sensitivity). This research aims to identify the presence of silica constituent groups such as Si-OH (silanol), Si-O-Si (siloxane), S-H groups, and other constituent groups. Surface area analyzer is used to silica analyze surface area, total pore volume and average pore diameter.

2.6. Adsorption Quality Analysis Using AAS

Atomic Absorption Spectroscopy (AAS) is an analytical method used to determine the concentration of certain elements in a sample by measuring the amount of light absorbed by the free atoms of the element. AAS is highly sensitive and accurate, often used for heavy metal analysis in various types of samples such as water, soil, and biological materials. In this research, AAS was used to determine the concentration of Fe elements in batik waste as much as 50 mL.

3. RESULTS AND DISCUSSION

3.1. Chemical Composition of Silica from Snake Fruit Peel Ash

Fourier Transform Infrared Spectroscopy (FT-IR) is an instrument that provides facilities for qualitative analysis of functional groups of chemical compounds in snake fruit peel ash as silica. FT-IR is known as an effective and suitable analytical method for determining the components contained in organic and inorganic materials. The working principle of this instrument is to use infrared radiation to test/examine samples and show chemical properties. When molecules are passed through infrared radiation, some frequencies of radiation are absorbed by the molecules and cause the molecules to vibrate which shows each chemical bond. Fourier transformation is used to convert time data into frequency data to produce a spectrum. Variation in stirring speed during the acidification process is an important factor that influences the formation of silica from snake fruit ash. The stirring speeds used in this research were 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, and 300 rpm for sample 1, 2, 3, 4, 5, and 6. This variation was designed to determine the effect of stirring speed on the efficiency of the acidification process and the quality of the silica produced. The chemical groups obtained can be seen in Table 1 and the results of FTIR analysis of silica from snake fruit ash can be seen in Figure 2.

Table 1. Functional groups in snake fruit peel ash silica

Wavelength (cm^{-1})	Groups	Compounds
511	C-I Stretching	Halo compound
764	C-H Bending	Mono Substituted
867	C=C bending	Alkene
1147	C-O Stretching	Alcohol
1433	O-H bending	Carboxylic acid
1638	C=C Stretching	Alkene

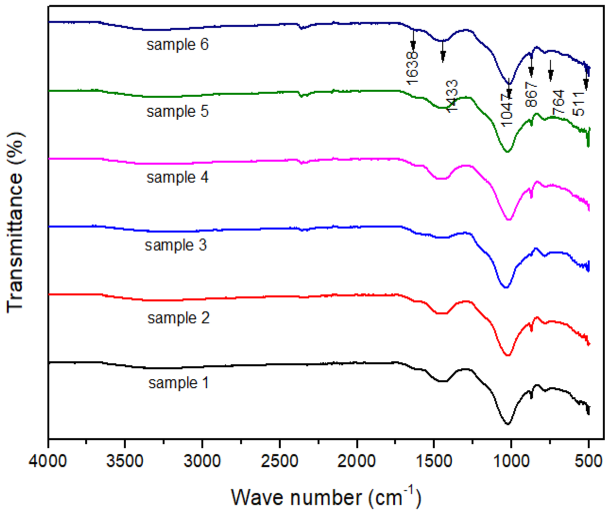


Figure 2. FT-IR Analysis of Silica

Based on Figure 2, FTIR analysis can provide an interpretation of silica data from snake fruit peel ash that has been extracted with a 2M HCl solution. In this research, FTIR analysis is used to detect/know the presence of silica constituent groups such as Si-OH (silanol), Si-O-Si (siloxane), S-H groups, and other constituent groups. The wavelength used is 400-4000 cm^{-1} for extracted snake fruit peel ash. The absence of the -OH functional group at wavenumbers 3000-3500 cm^{-1} in the FTIR analysis can be attributed to several factors. One primary reason is the potential overlap with other broad absorption bands, such as water or alcohols, which might mask the -OH signal. Additionally, the presence of hydrogen bonding can broaden and shift the -OH absorption band, making it less distinct and harder to identify. Another possibility is that the sample preparation or the presence of impurities could affect the detection of the -OH stretching vibration. Furthermore, the sensitivity and resolution of the FTIR instrument, as well as the concentration of the -OH groups in the sample, play significant roles. Low concentrations or weak interactions of -OH groups can result in signals that fall below the detection threshold of the instrument (Faghihzadeh et al., 2016)

Silica made from snake fruit ash experiences changes in wavelength. Based on the results of analysis using IR spectra, it shows that the wavelength of 511 cm^{-1} is not a typical wave of silica. Still, the wavelength of 511 cm^{-1} indicates the existence of a specific feature of the silica structure. The wavelength or band of 764 cm^{-1} shows the Si-O vibration of silica or silicates. The presence of the 764 cm^{-1} band identifies success in the synthesis of silica from snake fruit ash. Furthermore, the 867 cm^{-1} band is an unusual wavelength and is not a feature of pure silica. The wavelength results in this research are related to study conducted by (Nelson et al., 2023) with an extraction method where the silica wavelength is in the band between 516 cm^{-1} to 767 cm^{-1}. This condition is influenced by the presence of other contaminants from silica extraction from snake fruit bark ash and 2M HCl. According to (Nelson et al., 2023), HCl was the most effective acid for extracting high-purity silica from rice husk. The extracted silica had a high surface area and was characterized using FTIR to confirm its purity and structure This is of particular concern for future research that keeping the sample clean and not contaminated with other materials is very important so that other compounds do not appear as a result of silica extraction. Another IR spectra result is the 1147 cm^{-1} band, proving the presence of the C-O functional group in organic compounds. Band 1147 cm^{-1} is the vibration of the silanol group (Si-OH), which is the constituent group of silica. The silanol group is very important in the adsorption process via hydrogen bonds. A wavenumber of 1047 cm-1 detected on FTIR typically indicates the presence of Si-O-Si stretching vibrations in silica materials. This band is characteristic of the siloxane bond, which is a fundamental component of the silica structure. This wavenumber falls within the range that identifies the symmetric stretching mode of the Si-O-Si bonds, which is consistent with the structural properties of silica. The 1433 cm^{-1} band shows the C-H deformation (bending) vibration of organic compounds. This illustrates that silica contains organic residue from snake fruit ash and contamination from other materials. The existence of water molecules bound to snake fruit ash and water molecules adsorbed on the silica surface can be defined in this study because of the 1638 cm^{-1} band as a wavelength that describes the deformation (bending) vibrations of water molecules (H_20). According to (Usman et al., 2015) traces of water molecules and polar groups will disappear at a wavelength of 3450 cm^{-1}. The IR spectra results in this study show that silica from snake fruit ash contains silica constituent groups, namely silanol (Si-OH) as one of the active sites for adsorption processes such as batik liquid waste. The presence of silanol (Si-OH) groups is essential for adsorption processes via hydrogen bonding. The 1638 cm^{-1} band indicates water molecule bending vibrations, while the 1147 cm^{-1} band confirms the presence of silanol groups, crucial for adsorption. Contaminants from organic residues are evident in bands like 1433 cm^{-1} (C-H bending). Studies emphasize the need for maintaining sample purity to achieve accurate and effective adsorption properties in silica (Pan et al., 2011). Silica extraction from agricultural waste, such as rice husk and palm fruit bunch ash, often involves the use of HCl to enhance purity. Studies show that contaminants significantly impact the final product's quality. FTIR analysis confirms the presence of silica and identifies unwanted compounds, emphasizing the need for clean extraction methods. These findings support the potential of using snake fruit peel for silica production, highlighting the importance of maintaining sample purity during the extraction process (Nelson et al., 2023).

3.2. Physical Characteristics of Silica from Snake Fruit Peel Ash

Silica has different physical characteristics. In the research, the physical characteristics of silica ash from snake fruit skin consisted of color, shape, surface area, total pore volume, and average pore diameter. The shape and color of silica changes based on the extraction process and contamination of other materials. The results of this research show that silica from snake fruit peel ash extracted using 2 M HCl has dark color characteristics with Red, Blue, Green (RGB) values of around 73-78-75 which are determined based on the RGB values in the online application. Meanwhile, silica is in the form of powder which can be seen in Figure 3.

The surface area test results on snake fruit ash silica can be seen in table 2. The surface area (m^2/g) shows the surface capacity of silica available per gram. This shows that the greater the surface area, the more surface reactions that occur on the silica. The research results show that the surface area of silica is around 56,347 (m^2/g). A large surface area can increase the rate of chemical reactions and adsorption. This can be useful for applications that require high chemical reaction or adsorption rates. Total pore volume testing in this study showed results of around 0.0193 cc/g. This can be useful for applications that require storage of liquids or gases. The total pore volume is used to determine the absorption and storage capacity of substances in silica. The average pore diameter measurement in this study was 26.6745 mm. This can be useful for applications that require easy flow of liquids or gas. The average diameter of pores can influence the types of molecules that can enter and exit the silica surface or silica pores.

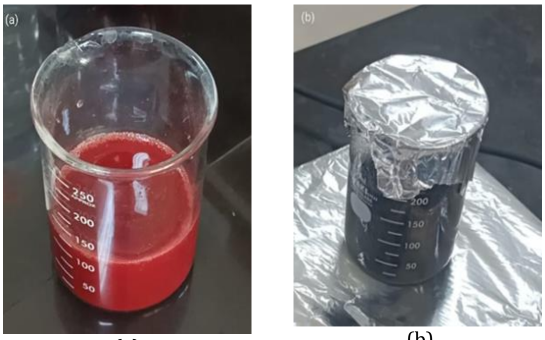
Figure 3. Shape And Color of Silica from Snake Fruit Ash

Table 2. Silica caractern with Surface Area Analyzer

Sample	Surface area (m^2/g)	Total pore volume (cc/g)	Average pore diameter (mm)
Silica (S)	56.3478	0.0193	26.6745

3.3. Potential for Silica Adsorption of Snake Fruit Peel Ash in Batik Liquid Waste

Silica made from snake fruit ash has been applied as an adsorbent to liquid batik waste using an adsorption process. Adsorption is the binding event of molecules in a fluid to the surface of a solid, the molecules will accumulate at the solid-fluid interface. The adsorption process was carried out with a variable mass of 20 grams in varying times of 20, 40 and 60 minutes. The implementation of silica in liquid batik waste can be seen in Figure 4.



(a) (b)

Figure 4. Liquid Batik Waste with an Adsorbent Mass of 50 mL (a) Before Adsorption and (b) After Adsorption of Liquid Batik Waste with an Adsorbent Mass of 20 grams.

Based on Figure 4. The implementation of silica in liquid batik waste triggers color changes. The liquid batik waste before and after being adsorbed changes color, where the liquid batik waste before adsorption has a very dark red color, while the liquid batik waste after being absorbed using silica from snake fruit peel ash has a dark gray color. The color change in liquid batik waste is influenced by the chemical and physical interactions of snake fruit peel ash silica. The functional groups contained in silica interact with batik waste components involving hydrogen bonds because there is a silinol (Si-OH) content in the snake fruit skin ash silica produced from this research. Other indications of changes are caused by changes in pH, reduction of substances, etc

Furthermore, in this research a silica absorption test was applied using AAS on batik liquid waste. AAS is an analytical method for determining the concentration of certain elements in a sample. In this research, AAS was used to determine the concentration of Fe elements in batik waste (mg/l) as much as 50 mL that can be seen in Table 3.

Table 3. AAS (Atomic Absorption Spectrophotometer) Test for Batik Waste

Samples	Adsorption Times	Fe Concentration in Batik Waste (mg/L)
Original waste samples	-	0.487
Sample A	20	0.411
Sample B	40	0.579
Sample C	60	0.343

Based on Table 3, the AAS instrument test results on sample A with a contact time of 20 minutes had an Fe concentration of 0.411 mg/L, sample B with a contact time of 40 minutes had an Fe concentration of 0.579 mg/L. sample C with a contact time of 60 minutes had an Fe concentration of 0.343. In general, the longer the adsorption contact time, the greater the opportunity for Fe particles to interact with Fe particles. However, in the Fe study for sample 1 and sample 3, sample A and sample C experienced a decrease in Fe concentration over time, while sample B experienced an increase in Fe concentration. Sample C experienced a decrease even though it had the longest contact time (60 minutes). This was caused by sample contamination, such as contact between the sample and other substances during the adsorption process of liquid batik waste with adsorbents. And it is possible that the adsorbent used in this study has reached saturation capacity in absorbing Fe particles so that there is no significant difference in Fe concentration.

the ability of silica in this research was compared with previous research that used agricultural waste-derived silica for heavy metal adsorption. One relevant study examined the use of rice husk-derived silica for heavy metal adsorption, including Fe. This study found that silica nanoparticles produced from rice husk via various methods exhibited effective adsorption properties due to their high surface area and the presence of functional groups suitable for binding metal ions (Yuan et al., 2024). In another study, the effectiveness of different agricultural waste materials, including their conversion to silica for adsorbing heavy metals, was highlighted. The study demonstrated that agricultural wastes like rice straw and rice husk can be converted into silica with significant adsorption capacities for various metals, including (Hung & Holloman, 2021). These comparisons suggest that silica derived from snake fruit peel could potentially exhibit similar or even superior adsorption properties, considering its specific functional groups (Si-OH and Si-O-Si) that are conducive for metal ion adsorption. Further experimental validation would be necessary to confirm these potentials under similar conditions.

4. CONCLUSION

Liquid waste from industry contains heavy metals such as iron (Fe) which can have a negative impact on the environment and disrupt water ecosystems. In this research, snake fruit peel ash has been applied as an adsorbent to batik industry waste. FTIR analysis of silica obtained from snake fruit ash shows the presence of various chemical groups such as Si-OH (silanol), Si-O-Si (siloxane), and others. The silanol group is found in the silica ash of snake fruit skin which has an important role in the adsorption process. The physical characteristics of silica show that the surface area is around 56.3478 m^2/g, the total pore volume is around 0.0193 cc/g, and the average pore diameter is around 26.6745 mm. The greater the surface area, the greater the potential for surface reactions to occur. From visual observation, there was a change in the color of the liquid waste after the adsorption process was carried out. This indicates that there has been an interaction between silica and good waste components. There was a decrease in Fe concentration in samples with a contact time of 20 minutes and 60 minutes, while an increase in Fe concentration occurred in the sample with a contact time of 40 minutes. Silica from snake fruit ash has potential as an adsorbent for liquid batik waste. However, there are several factors such as contamination and specific process conditions that can affect adsorption efficiency. Therefore, further research is needed to optimize the adsorption process and understand the mechanisms involved in more depth.

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