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Characteristics of Banana Stem Adsorbent (Musa Paradisiaca) For Biogas Purification With Variation of Adsorption Contact Time

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Abstract

The features of the adsorbent utilized for biogas purification are covered in this study. The aim of this study was to investigate the features of the banana stem adsorbent that may be applied to the adsorption process for the purification of biogas. The research involved the preparation of banana stem powder, the removal of lignin, the creation of adsorbents, and the purification of biogas using the adsorption technique. The adsorption contact time variations used were (30; 60; 90) minutes, with a biogas flow rate of 1 l/minute and a banana stem particle size of 20 mesh. Samples were analyzed by lignocellulosic content analysis, FTIR (Fourier Transform Infrared Spectroscopy), SEM (Scanning Electron Microscope), and Gas Chromatography. According to the research findings, the adsorbent made from banana stems that can be used to purify biogas has a cellulose content of 47.5%, in the FT-IR analysis there is a shift in the peak number of stretching in the hydroxyl and carboxylic acid functional groups and has a surface structure of banana stem fiber that is orderly. The longer the contact time in the biogas purification process utilizing banana stem adsorbent with variations in adsorption contact time acquired, the more CO_2 was adsorbed and the higher the CH_4 concentration in the purified biogas. The biogas purification process resulted in a 39.893% reduction in CO_2 content and the best contact time to produce the largest CH_4 content was 90 minutes with the resulting CH_4 content of 64.786%.

INTRODUCTION

Fossil fuels are the main supplier of domestic energy sources, but currently the availability of fossil fuels is increasingly limited. Indonesia's crude oil energy reserves can only be produced or will run out within 22.99 years, gas for 58.95 years and coal for 82.01 years.

Therefore, alternative fuels are needed that are cheap, easy to produce, and mass-produced to maintain national energy security. According to Prihutama et al. (2017) One of the environmentally friendly alternative energies as a substitute for fossil energy is biogas.

Biogas products have the main composition consisting of methane (CH_4) 55-75%, carbon dioxide (CO_2) 25-45%, nitrogen (N_2) 0-0.3%, hydrogen (H_2) 1-5%, hydrogen sulfide (H_2S) 0-3%, oxygen (O_2) 0.1-0.5%, and water vapor (Burke, 2001). The CO_2 content in biogas greatly affects the calorific value produced by biogas, so the presence of CO_2 in biogas is not expected, this is because the higher the CO_2 content in biogas, the lower the calorific value of CH_4.

There are several methods to reduce the CO_2 content in it. Gas separation processes used in industrial chemistry, such as absorption (scrubbing) in a chemical solvent, adsorption in solid adsorbents, membrane separation and cryogenics, can be adapted for CO_2 capture (Javed et al. 2010). One alternative method to remove CO_2 content in biogas is adsorption where the adsorption has high efficiency.

Adsorption is an event of adsorption on the surface by an adsorbent or the adsorption capacity of an adsorbent that occurs on the surface (Suziyana

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et al., 2017). The adsorbent used for the adsorption process is relatively expensive, so a cheaper and environmentally friendly adsorbent is needed, for example from waste. The adsorbent obtained from waste raw materials, in addition to reducing the burden of solid waste in the surrounding environment, can also reduce the selling price of the adsorbent (Haura et al., 2017).

One of the plants that can be used as an adsorbent in the biogas purification process is banana stem. Indonesia is one of the largest banana producing countries in the world. This is supported by tropical climate conditions and fertile soil (Widihati et al., 2012).

The lignocellulosic composition in banana stems contains a fairly high cellulose content of 46%, followed by hemicellulose 38.54%, and lignin 9% (Lismeri, et al, 2019). The cellulose content contained in banana stems has considerable potential to be used as an absorbent because of the -OH groups bound to the cellulose, besides that banana stems are also easy to obtain and have economic value.

Previous research on CO_2 adsorption in biogas using water hyacinth pellets has also been carried out by Indrawati & Susilo (2019). In this process, variations in contact time and height of the adsorbent are used in the adsorption column. The contact time was varied from 30 minutes, 60 minutes, and 90 minutes, while the height of the adsorbent in the adsorption column was varied from 5 cm, 10 cm, and 15 cm.

In previous studies, there were no characteristics of the adsorbent that could be used as biogas purification, so in this study the characterization of the adsorbent from banana stems as biogas purification was carried out using the adsorption process by varying the contact time, while the contact time variations were 30; 60 ; 90 minutes. The biogas stream enters from below at a flow rate of 1 l/min. With a banana stem particle size of 20 mesh. In order to obtain a characterization of the adsorbent of the stem pellets that can be used as biogas purification.

EXPERIMENTAL DESIGN

Materials

The equipment used in this research is an adsorption column. The materials used in this study were biogas from cow manure from the Biogas center in Gadingrejo, banana fronds after fruiting were obtained from gardens in the Mataram Udik area Central Lampung, tapioca flour, aquades, Sodium Hydroxide (NaOH) and Sodium Sulfite (Na_2SO_3) was purchased from Merck Chemical Company. Sulfuric Scid 96% (H_2SO_4) and Hydrogen Peroxide 50% (H_2O_2) was purchased from Supelco, Inc. In this study, the percentage of CH_4 content was 29.53% (from 8.99%), which occurred in the adsorption process with a contact time of 60 minutes and the height of the adsorbent in the adsorption column of 5 cm.

Drying and Preparation of Banana Stem Powder

The banana stems used in this study came from gardens in the Mataram Udik area, Central Lampung. The banana stems were chopped and then dried under the sun for approximately 3-5 days. The dried banana stems were then grounded using a grinder which aims to reduce the size. The banana stems were then filtered using a 20 mesh sieve. The sifted powder was stored in a storage jar/ziplock bag. Silica gel was then added to reduce the moisture of the powder.

Lignin Removal Procedure

The process of removing lignin from banana stems consists of an alkaline pretreatment stage, a delignification stage, and a bleaching stage.

Alkaline Pretreatment

A total of 30 grams of banana stem powder was refluxed using 1% NaOH and aquades, with a ratio of 1:10 to 1:10 for 1 hour at 50°C. The cooking mixture was then separated from the solvent and then filtered, washed using distilled water until the pH was neutral, and dried in an oven at 105°C. Then, the cellulose content was analyzed.

Delignification

The next stage was the delignification stage using 20% Na_2SO_3 with a ratio of weight to volume ratio of 1:10 for 2 hours at 105°C. Furthermore, the cellulose that has been delignified was separated from the solvent and washed with distilled water until the pH is neutral. Then it was dried in an oven at 100°C. The cellulose content was then analyzed.

Bleaching

At this stage, bleaching was carried out using 2% H_2O_2 with a ratio of weight and volume of 1:12 solution for 2 hours at a temperature of 60°C. The obtained cellulose was then separated from the peroxide solvent and then washed with distilled water until the pH was neutral. Then it was dried in an oven at 100^{o}C. The cellulose content was analyzed using SEM and FTIR methods.

Adsorbent Making Procedure

Banana stem powder that has been removed from lignin was formed into small balls using starch as an adhesive. With a composition of 300 grams of banana stem powder and 100 grams of starch dissolved in hot water. The banana stem adsorbent that has been printed was then heated using an oven at a temperature of 120°C with the aim of reducing the water content and activating the surface of the banana stem adsorbent.

Figure 1. Banana stem adsorbent.

Biogas Purification Procedure

The first stage was assembling the equipment to be used according to Figure 2. The initial biogas content was then analyzed. Next, the banana stem adsorbent was entered into the adsorption column. The valve above the column was then closed, and the biogas flow rate was adjusted to 1 liter/minute. The biogas was fed for 5 minutes after that close the valve under the column was then closed. Next, The biogas and banana stem

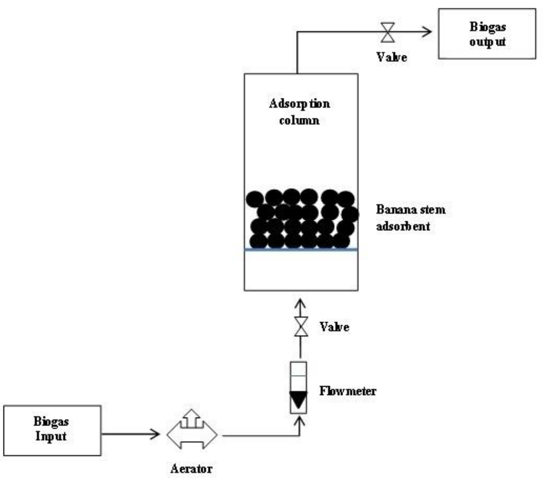


Figure 2. Schematic of the tool circuit

adsorbent was contacted with a contact time of 30 minutes. The sample of the biogas output was then taken using a sample bag. The biogas output samples was then analyzed using Gas Chromatography. The process was then repeated with a contact time of 60 and 90 minutes.

Figure 3. Adsorption column.

Analysis of Lignocellulosic Content

The way to analyze the cellulose content using the Chesson-Datta method. (Lismeri et al., 2017). One gram of dried banana stem powder (a) was placed into a beaker and then added with 150 ml of H_2O. The solution was then heated at 100^{o}C for 1 hour. The result was filtered and washed. The residue was then dried in an oven until constant and then weighed (b). The dried sample residue was put into an erlenmeyer and heated for 2 hours with 150 ml of 0.5 M H_2SO_4 at a temperature of 100^{o}C. The result was filtered to neutral and dried (c). The dried sample residue was treated with 10 ml of 72% H_2SO_4 at room temperature for 4 hours, then diluted to 0.5 M H_2SO_4 and heated at 100oC for 1 hour. The residue was filtered to neutral and dried (d). The dried sample residue was then ashed in a furnace at 600^{o}C until the weight was constant. The ash obtained is then weighed (e).Calculations are carried out using the Eq. (1) – (3).

$$hemicellulose = \frac{(b-c)}{a} \times 100\% \quad (1)$$

$$cellulose = \frac{(c-d)}{a} \times 100\% \quad (2)$$

$$lignin = \frac{(d-e)}{a} \times 100\% \quad (3)$$

FTIR (Fourier Transform Infrared Spectroscopy) analysis

FTIR (Fourier Transform Infrared) analysis was performed to identify compounds and detect functional groups in the analyzed samples. In the analysis of functional groups possessed, banana stem pellets were characterized using FTIR which was carried out at the Integrated Laboratory and Innovation Center, University of Lampung.

The equipment used is FTIR (SHIMADZU – 8400S) with the scanning range is 7800 cm^{-1} – 350 cm^{-1}. FTIR-8400S is combined with the spectral resolution 0.85 ,1, 2, 4 ,8 and 16 cm^{-1}.

SEM (Scanning Electron Microscope) analysis

Characterization using Scanning Electron Microscopes aims to describe the surface shape of the banana stem. SEM analysis was carried out at the Integrated Laboratory and Innovation Center, University of Lampung.

The equipment used is SEM3200 with the magnification x 1 – x 1000 and the image process with secondary electron (SE) and backscattered electron (BSE). The main stages of preparation of biological samples before being observed using SEM is sample cutting with that orientation clean the sample from dust then attach it to the sample stage use conductive tape like carbon or copper tape for easy excess electrons in the sample to flow towards ground.

Gas Chromatography Analysis

Gas Chromatography analysis was carried out to identify the levels of compounds present in a sample, namely knowing the levels of carbon dioxide (CO_2) and methane (CH_4) gases in biogas. The equipment used is GC 2014 – AT (SHIMADZU Corp 08128) with helium gas as the carrier.

The analysis process was conducted by using helium flowrate of 43 ml/min, detector temperature of 200°C, with heating rate of 15 °C/min.

RESULTS AND DISCUSSION

The characteristics of banana stem pellets (*Musa paradisiaca*) adsorbent have been studied as biogas purification. The banana stem pellets produced were round, white, and non-uniform in size with a diameter of ± 3-5 mm. The size is not uniform because the pellets were made manually.

Adsorbent Characteristics

The characteristics of banana stem (*Musa paradisiaca*) adsorbent have been studied as biogas purification. The banana stem adsorbent produced is white and round in shape with tapioca flour as the adhesive, apart from being an adhesive, it is possible that tapioca flour also has a helpful role in CO_2 absorption because there are hydroxyl groups derived from tapioca starch. However, this study did not examine the effect of adding tapioca flour to the adsorbent on CO_2 absorption. The resulting adsorbent is not uniform in size with a diameter of ± 3-5 mm. The size is not uniform because the adsorbent is made manually.

Results of Analysis of Lignocellulosic Content

Analysis of the physical and chemical characteristics of the adsorbent aims to determine the feasibility of a material used as an adsorbent medium. Since cellulose includes a hydroxyl group (-OH) that may adsorb carbon dioxide, the lignin removal method was carried out in three steps to acquire the cellulose content in banana stems. These phases included pretreatment, delignification, and bleaching. Table 1 shows the results of celulose analysis between raw material and at the different phases.

Table 1. Cellulose analysis

	C (%)	H (%)	L (%)
Raw Material	23	36	1
Pretreatment	36	26	3
Delignification	43	20	2
Bleaching	47.5	17	0.8

*C = Cellulose; H = Hemicellulose; L = Lignin

From the Table 1, it is found that the lignocellulose content in banana stems before delignification is 23% cellulose, 36% hemicellulose, and 1% lignin. After the pretreatment, delignification, and bleaching stages, an increase in the cellulose content was found. The increase in cellulose content was due to the reduced content of lignin and hemicellulose in banana stems. The increase in cellulose content was also caused by partially dissolved lignin and hemicellulose during the delignification process so that the cellulose content increased (Lismeri, et.al., 2016).

Results of Structure Analysis of Fourier Transform Infra Red (FTIR)

FTIR analysis was carried out to see the characteristic wave absorptions of an adsorbent

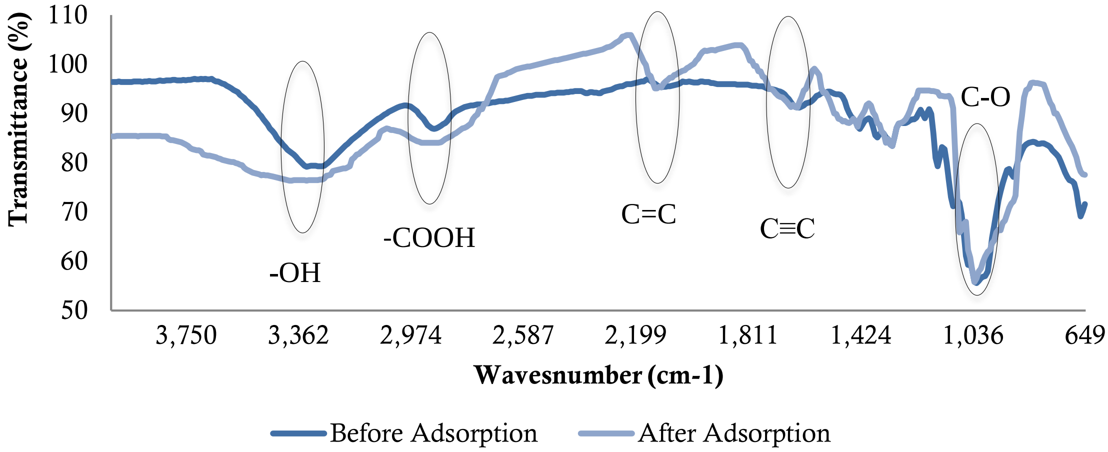


Figure 4. FT-IR analysis of adsorbent before and after adsorption.

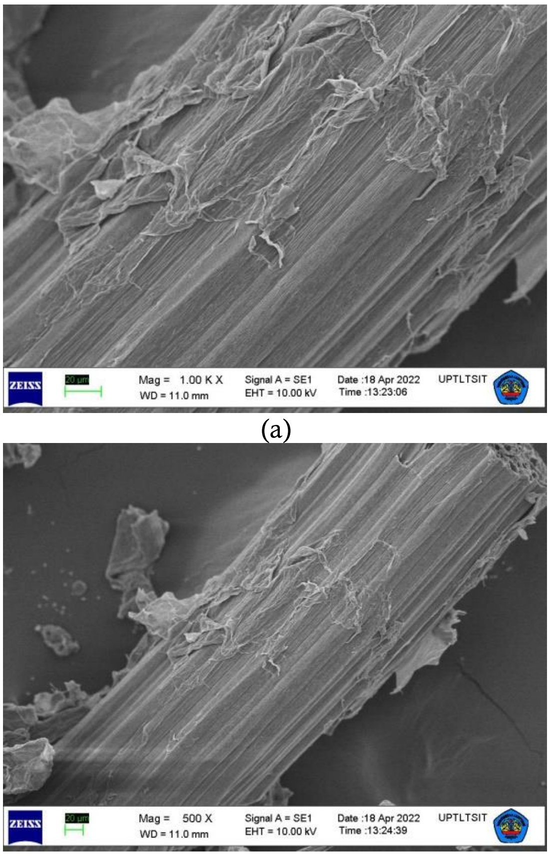
produced so that the type of functional group contained in the adsorbent could be predicted. Figure 4. shows the results of the FT-IR spectrum and the functional group of the adsorbent before and after adsorption.

Based on the results of the FT-IR analysis above, the hydroxyl group (-OH) showed a shift in the peak number of stretching from 3332.3 cm^{-1} to 3380.1 cm^{-1} and the carboxylic acid group (-COOH) also showed a shift in the peak number of stretching. from 2892.4 cm^{-1} to 2931.9 $cm^{-1.}$ This causes the absorption intensity of this functional group to decrease, which indicates a decrease in the number of hydroxyl and carboxylic acid functional groups in the banana stem adsorbent. The insignificant shift of the peak wave number indicates that there has been an interaction between the adsorbed substance molecule and the active group contained in the biosorbent (Zein et al., 2019).

The crest of the wave is 2109.7 ; 1640,0 ; and 1028.7 cm^{-1} before and after the adsorption process showed stretching vibrations in the C≡C, C=C and C-O groups. The results of the FT-IR analysis on these functional groups did not experience a shift in the absorption peak, so they were not involved during the adsorption process.

SEM (Scanning Electron Microscope) Analysis

Characterization utilizing Scanning Electron Microscopes intends to characterize the surface form of the banana stem. According to Figure 5, at 500x and 1000x magnification, the surface of the banana stem fiber is consistent. The uneven surface structure of banana stem fibers is a result of pretreatment, delignification, and bleaching procedures that reduced the amount of lignin that was still present in the banana stems. (Lismeri et al., 2019).



(a)

(b)

Figure 5. SEM results of banana stems with magnifications of (a) 500x and (b) 1000x.

Effect of Contact Time on CO_2 Absorption

A gas chromatography test was conducted to determine the impact of the contact period of the used banana stem adsorbent on the absorption of CO_2 in biogas purification. Figure 6 displays the test's findings on the impact of contact time.

Figure 6 shows the results of the analysis of carbon dioxide gas (CO_2) contained in biogas. The content of carbon dioxide gas before the purification process was 49.406%, then there was a reduction in the CO_2 content in the biogas after undergoing the purification process with the influence of contact time. As shown in the figure 6, the CO_2 gas content in the biogas purification process decreases with increasing contact time. This is due to the longer the gas contact with the adsorbent, the more CO_2 is absorbed, so that the CH_4 content becomes higher (Saleh, 2015). Therefore, the percent reduction in CO_2 content in the biogas purification process is 39.89%.

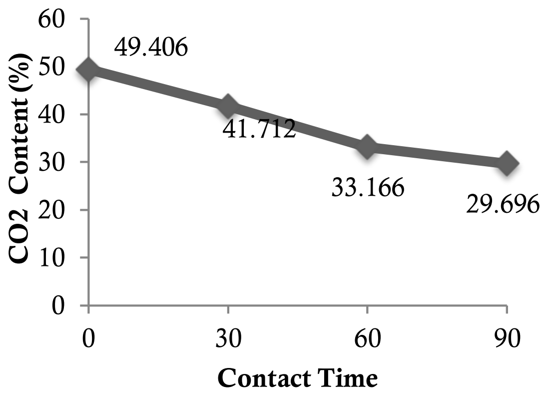


Figure 6. Effect of contact time on CO_2 absorption.

Figure 7 shows the effect of contact time on the increase in CH_4. The increase in the CO_2 content absorbed causes the CH_4 content to increase. The increase in CH_4 continued to increase to 64.786% at a contact time of 90 minutes, so from Figure 7 it can be concluded that the CH_4 content produced increased with increasing contact time. The same as the previous explanation, this is due to the longer the gas contact with the adsorbent, the more CO_2 gas is absorbed, so that the CH_4 gas content becomes higher (Saleh, 2015). The best contact time was obtained to produce the largest CH_4 content at a contact time of 90 minutes with a large CH_4 content of 64.786%

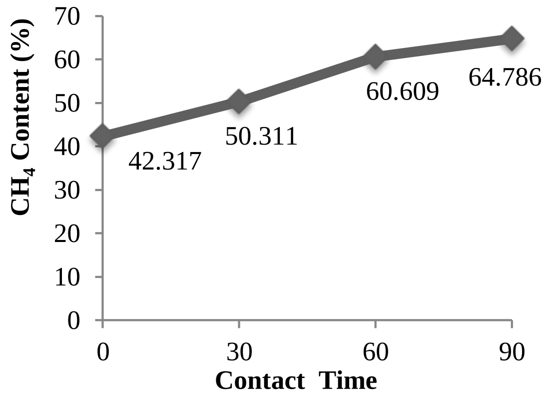


Figure 6. Effect of contact time on the increase in CH_4

CONCLUSION

Based on the results of the study it can be concluded that the cellulose content obtained in the banana stem delignification process is 47%, In the FT-IR analysis there is a shift in the number of peaks in the hydroxyl and carboxylic acid functional groups, In the SEM analysis, the surface of the banana stem fiber is uniform, The longer the contact time results in the amount of CO_2 being adsorbed more and more and increasing the CH_4 content in the purified biogas, The percentage reduction in CO_2 content in biogas purification is 39.893%, The best contact time to produce the largest CH_4 content is 90 minutes with the resulting CH_4 content of 64.786%.

REFERENCES

Burke, D. A. 2001. Dairy Waste Anaerobic Digestion Handbook. Options for Recovering Beneficial Products from Dairy Manure. Olympia: Environmental Energy Company.

Haura, U., Razi, F., Meilina, D. H. 2017. Karakterisasi Adsorben Dari Kulit Manggis Dan Kinerjanya Pada Adsorpsi Logam Pb(Ii) Dan Cr(Vi). Biopropal. 8(1): 47-54.

Indrawati, R., Susilo, J. 2019. Pengaruh Waktu Kontak Dan Tinggi Adsorben Pelet Eceng Gondok (*Euchernia Crassipes*) Terhadap Konsentrasi CH_4 Pada Purifikasi Biogas. Prosiding Seminar Nasional Lingkungan Lahan Basah. 4: 323–328.

Javed, K. H., Mahmud, T., Purba, E. 2010. The CO_2 Capture Performance of A High-Intensity Vortex Spray Scrubber. Chemical Engineering Journal. 162(2): 448–456.

Lismeri, L., Darni, Y., Dimas Sanjaya, M., Iqbal Immadudin, M. 2019. Pengaruh Suhu Dan Waktu Pretreatment Alkali Pada Isolasi Selulosa Limbah Batang Pisang. Journal of Chemical Process Engineering. 4: 19–22.

Lismeri, L., Darni, Y., Iqbal, M. I., Dimas Mitra, Dan S. 2017. Isolasi Mikrofibril Selulosa Dengan Pretreatment Alkali Dari Limbah Batang Pisang. Prosiding dalam Rangka Seminar Nasional Riset Industri Ke 3. 40-45.

Lismeri, L., Zari, P. M., Novarani, T., Darni, Y. 2016. Sintesis Selulosa Asetat Dari Limbah Batang Ubi Kayu. Jurnal Rekayasa Kimia & Lingkungan. 11(2): 82-91.

Prihutama, F. A., Firmansyah, N. D., Siahaan, K. S. H., Fahmi, B. 2017. Pemanfaatan Biogas Sebagai Energi Alternatif Ramah Lingkungan Daerah Desa Monggol, Kabupaten Gunungkidul, Yogyakarta. SNITT- Politeknik Negeri Balikpapan 2017. 87 – 95.

Saleh, A., Permana, D. A., Yuliandita, R. 2015. Pengaruh Komposisiadsorben Campuran (Zeolit-Semen Putih) Dan Waktuadsorpsi Produk Gas Metana Terhadap Kualitas Biogas Sebagai Bahanbakar Alternatif. Jurnal Teknik Kimia. 21(3): 1-6.

Suziyana, Daud, S., Edward Hs. 2017. Pengaruh Massa Adsorben Batang Pisang Dan Waktu Kontak Adsorpsi Terhadap Efisiensi Penyisihan Fe Dan Kapasitas Adsorpsi Pada Pengolahan Air Gambut. Jom Fteknik. 4(1): 1-9.

Widihati, I. A. G., Suastuti, N. G. A. M. D. A., Nirmalasari, M. A. Y. 2012. Studi Kinetika Adsorpsi Larutan Ion Logam Kromium (Cr) Menggunakan Arang Batang Pisang (*Musa Paradisiaca*). Jurnal Kimia. 6(1): 8 - 16.

Zein, R., Ramadhani, P., Aziz, H., Suhaili, R. 2019. Biosorben Cangkang Pensi (*Corbicula Moltkiana*) Sebagai Penyerap Zat Warna Metanil Yellow Ditinjau Dari Ph Dan Model Kesetimbangan Adsorpsi. Jurnal Litbang Industri. 9(1): 15-22.