Turnitin Chemica UAD

by Lia Cundari

Submission date: 15-Apr-2023 10:12AM (UTC+0700)
Submission ID: 2064999006
File name: ARrtikel_Chemica_LC.pdf (684.3K)
Word count: 4573
Character count: 23735

CHEMICA : Jurnal Teknik Kimia
ISSN 2355-8776
Vol. 9, No. 3, December 2022, pp. 142-152

Characterization of Biosorbent from *Musa acuminata balbisian* Peel using FTIR Spectroscopy and Its Application to Cadmium (Cd) Removal: Effect of Activator Type, pH, and Biosorbent Ratio

Lia Cundari [a,1,*], Alna Livia Fanneza [a,2], Nanda Citra Arisma [a,3]

[a] Department of Chemical Engineering, Faculty of Engineering, Universitas Sriwijaya, Jl. Raya Palembang Prabumulih Km. 32, Inderalaya, Ogan Ilir (OI), 30662, Indonesia
[1] liacundari@ft.unsri.ac.id*; [2] alnaliviaf@gmail.com; [3] nandacitra@gmail.com
* corresponding author

ARTICLE INFO

Article history
Received May 26, 2022
Revised January 25, 2023
Accepted February, 1 2023

Keywords
Biosorption
Cadmium
Kepok banana peel
Strong acid activator
Weak acid activator

ABSTRACT

Biosorbent that use in this study made from kepok banana peel (Musa acuminata balbisian). The present study is done to determine the characteristic of biosorbent and the effect of activator type, pH, and ratio of biosorbent for the cadmium removal. The experiments were carried out in batch process, laboratorium scale, room temperature, and 60 mesh of biosorbent size particle. The biosorbent produced by using chemical activation method onto dry banana peel. The variation in this research was the type of activator (H_3PO_4 and H_2SO_4), pH of Cadmium (3, 4, and 5), and the ratio of biosorbent dosage to the volume of cadmium solution (1:20, 1.5:20, and 2:20 (g/ml)). The biosorbent characterized by using Fourier Transform Infra-Red (FTIR). The cadmium concentration analyzed by using Atomic Absorption Spectroscopy (AAS). Characterization with FTIR showed the differences in functional groups onto biosorbent before and after adsorption. There was a change in the spectral band of C-H and C=O functional groups for biosorbent that activated with H_3PO_4 and a change in the spectral band of C-H functional groups for biosorbent that activated with H_2SO_4. The acid activators showed the best condition was at 90 minutes contact time, pH 4 and the ratio of biosorbent dosage and the volume of 1.5:20 (g/ml). The result showed that the H_3PO_4 was the best acid activator in the removal of cadmium with amount of 99.91%.

1. Introduction

Cadmium metal is widely used in the metal alloy industry, metal coating, electronics, and textiles. Cadmium discharged into water will cause damage to the body's physiological systems such as breathing, blood circulation, smell and vital organs [1]. Therefore, grade II cadmium carrying heavy metal content according to Government Regulation No. 82 of 2001 concerning Water Quality Management and Water Pollution Control should not exceed 0.01 mg/l [2].

One of the alternatives in managing waste containing heavy metal is by using biological materials as biosorbent with a process called biosorption. Among the advantages of using biosorption process are the relatively low cost, high efficiency, and ease of the regeneration process. Various alternative agricultural waste products can be used as a biosorbent raw material such as rice husk, beet powder, and banana peel [3] [4] [5].

Kepok banana (*Musa acuminata balbisian*) is one type of tropical fruit with abundant availability with production reaching 7.162 million tons based on the release of the Indonesian Central Statistics Agency in 20[illegible] [6]. The amount of banana peels is about 1/3 of the unpeeled bananas [7]. Banana peels contain lignin (6-12%), pectin (10-21%), cellulose (7.6-9.6%) and hemicellulose (6.4-9.4%) [8]. Pectin compounds in banana peels can be used to remove excess cations or heavy metals [9].

Percentage of the absorption of cadmium metal towards activated carbon from the banana peel is 98.35%, 89.65%, and 64.2% [3] [9] [10]. On the other hand, the cadmium metal biosorption with banana peel biosorbent has the percentage of 89.2%, and 73.15% [11] [12]. Likewise, the percentage of the absorption from the durian skin is 72.17% and 64.54% [12] [13]. Referring to the average percentage of cadmium metal adsorption between biosorbent and activated carbon that is not too significant. The activated carbon is obtained from pyrolysis method and/or chemical activation, while the biosorbent is obtained from chemical activation. Production of biosorbent is simpler than activated carbon. This experiment does the absorbing process of cadmium metal using *kepok* banana peel as the biosorbent. The characteristic of biosorbent is analized by using Fourier Transform Infra-Red (FTIR) method. The effectivity *kepok* banana peel as biosorbent is tested to adsorp cadmium metal in aqueous solution by modifying the activator type. The effect of pH and biosorbent ratio is also determined in the adsorption process.

2. Research Methodology

2.1. Materials

Materials used in the research were *kepok* banana peel (*Musa acuminata balbisian*), aquadest, H_3PO_4 (technical solution, 6 M), H_2SO_4 (technical solution, 2 M), Cd (cadmium) solution (Synthetic solution, 2 ppm). The tools used were Atomic Absorption Spectroscopy (AAS), Fourier Transform Infra-Red (FTIR), erlenmeyer 25 ml, measuring cup 25 ml, beaker 500 ml, volumetric flask 250 ml, stirring rod, spatula, oven, magnetic stirrer, filtering paper, funnel, blender, 60 mesh sieve, pH meter, analytical balance, and sample bottle.

2.2. Procedures

1) *The Making of Kepok Banana Peel Biosorbent*

The inside of *kepok* banana peel (*Musa acuminata balbisian*) is cleaned and then washed with water. The clean banana peel is dried under the sun for approximately 48 hours. The size of dry banana peel is reduced to 60 mesh, next will be called as biosorbent.

2) *Activating* biosorbent *using H_3PO_4 and H_2SO_4 as an Activator*

The activator used in this research was H_3PO_4 and H_2SO_4. The activator and biosorbent are mixed with ratio 2:1 by using a magnetic stirrer at the speed of 90 rpm for 30 minutes. After that, the biosorbent is rinsed by using aquadest until neutral or the pH near 7. Then the neutralized biosorbent is dried by using an oven at a temperature of 105 °C for 2 hours.

3) *Application of adsorption process*

The cadmium solution is made according to the Indonesian National Standard (SNI) 6989.16:2009 with pH 3, 4, and 5. Then, 1 gram, 1.5 gram and 2 gram of biosorbent is mixed with 20 ml cadmium solution and stirred with the speed of 90 rpm for about 10, 45, 90 and 120 minutes. This procedure is repeated for another variation. The experiments were carried out in batch process, laboratorium scale, and room temperature [28]. The solution is filtered and then the filtrate is analized by using Atomic Absorption Spectroscopy (AAS) [29]. The fresh and reused biosorbent is characterized by using Fourier Transform Infra-Red (FTIR).

2.3. Data Analysis

The ability of biosorbent in adsorb of the cadmium is called Adsorption Efficiency (% Removal) that can be calculated with the equation (1), where C_o and C_e are the initial and final concentration of Cd (mg/l) [28].

$$\%Removal = \frac{C_o - C_e}{C_o} \times 100\% \quad (1)$$

3. Results and Discussion

3.1 Characteristics of Biosorbent made from *Kepok* Banana Peel (*Musa acuminata balbisian*)

Functional group analysis method in a sample based on absorbing spectra infra-red through FTIR [14]. Infra-red spectrum can be obtained through a light transmission that passes the sample and light intensity measuring with a detector. Infra-red spectrum that has been obtained then is plotted as heat function intensity and wavelength (cm^{-1}) [15]. FTIR spectrum on *kepok* banana peel before and after being in contact with cadmium solution is approximately 4000-500 cm^{-1} to identify functional groups in biosorbent.

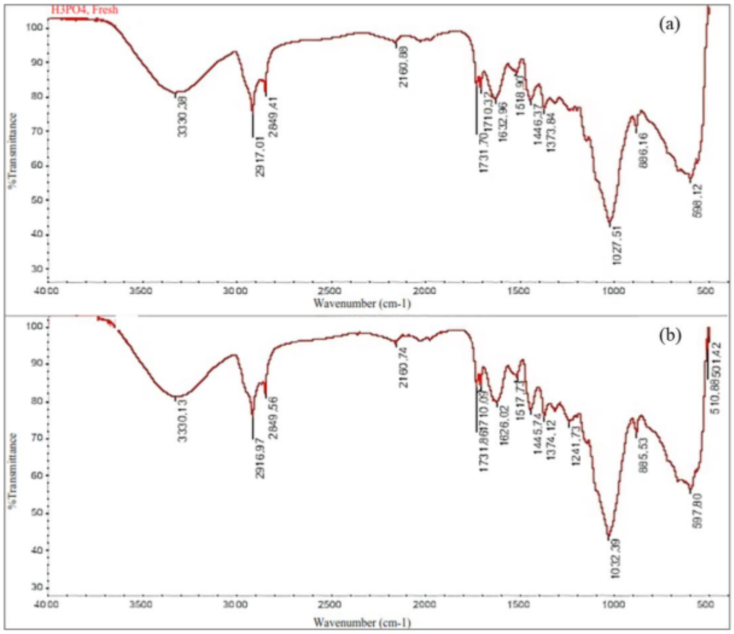

Fig. 1. FTIR spectrum of *kepok* banana peel biosorbent with activator H_3PO_4 (a) fresh, (b) reused

The FTIR spectra of durian and banana peel materials were before and after cadmium ion biosorption. These spectra were obtained from scanning in the range of 400-4000 cm^{-1}. The band of durian and banana peel represented overlapping of O-H and N-H stretching vibration at 3369 and 3388 cm^{-1}, respectively. The band represented C=O stretching vibration of carboxylic acids at 1741 and 1731 cm^{-1}, respectively. The significant shifts of these specific peaks to the higher wave number after the cadmium ions biosorption suggested that chemical interactions between the cadmium ions and the amide groups occurred on the biomass surface. The influences of the shift peaks were very similar for the fruits peel materials. The band of durian, and banana peel shifted to 3416 and 3416 cm^{-1}. The spectra of banana and durian peel at 1741 and 1731 cm^{-1}, respectively became smoother and a band of banana peel at 1427 cm^{-1}, respectively, appeared, which would result from the complications of cadmium ions with the functional groups from protein. These results indicated that carboxyl, hydroxyl and amide groups on the fruit peels' surfaces were involved in the biosorption of the cadmium ions [12].

FTIR spectrum *kepok* banana peel biosorbent with activator H_3PO_4 before and after being in contact with Cd solution can be seen on the Fig. 1. Fig. 1(a) shows that both H_3PO_4 activated biosorbents have hydroxyl O-H peak whose wavelength vibration is 3300 cm^{-1} that explains that there is a hydroxyl group free of a polymeric compound like lignin or pectin that has functional group like alcohol, phenol, and carboxylic acid. This matches the approximated frequency for hydroxyl group between 3600-2800 cm^{-1} [16]. Also, the result of the characterizing shows the existence of C-H and C=O group with a wavelength of 2917 cm^{-1} and 1626 cm^{-1}.

Fig. 1 (b) shows that the absorption band formed at wave number 1241 cm^{-1} which is the absorption of the amine C-N functional group. In both spectrums, it can be seen that the biosorbent of *kepok* banana peel that has been contacted will experience a decrease in transmittance value and a change in absorption band with a shift in wavelength from 2917 cm^{-1} to 2916 cm^{-1} for the C-H functional group. Meanwhile, in the functional group C=O there is a shift in the absorption band which indicates the vibration and the transmittance value decreased from 1632 cm^{-1} to 1626 cm^{-1}. Shifting the absorption band that occurs in each functional group in the biosorbent and the appearance of a new peak indicates that the cadmium metal is absorbed on the surface of the banana skin biosorbent. Based on the identification of the functional groups from the FTIR analysis it was proven that the biosorbent of the *kepok* banana peel was activated H_3PO_4 effective in absorbing cadmium metal.

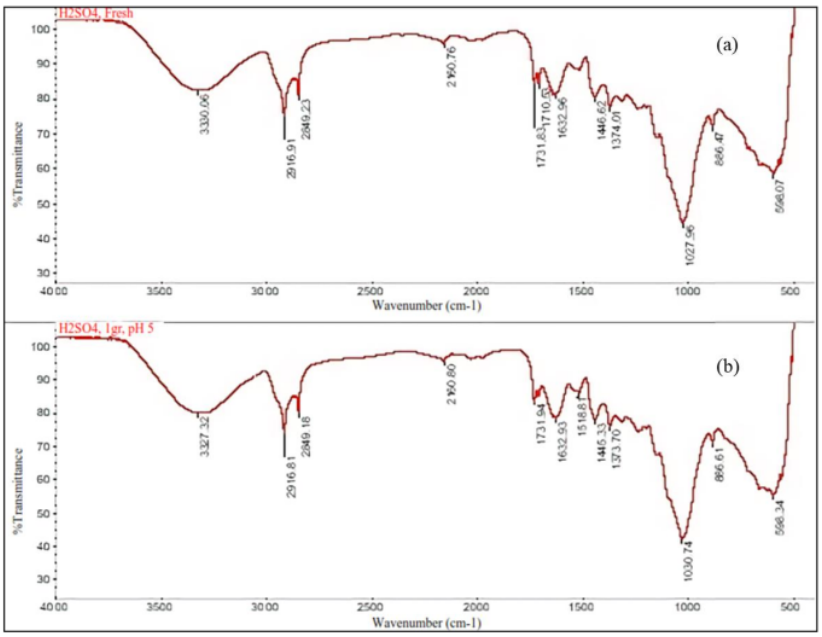

Fig. 2. FTIR Spectrum of *kepok* banana peel biosorbent with activator H_2SO_4 (a) fresh, (b) reused

FTIR spectrum of *kepok* banana peel biosorbent with H_2SO_4 activator before and after contacting is seen in the Fig. 2. Fig. 2 (a) proves the existence of O-H functional groups that are characterized by wavelengths ranging from 3330-3327 cm^{-1}. The next absorption band appears at wave number 2916 cm^{-1} which is the absorption of the aliphatic and aromatic C-H functional groups. Wavenumber 1632 cm^{-1} appears as a third absorption band with a wavelength of 1675-1500 cm^{-1} indicating the presence of C=O functional groups which can be acidic compounds, aldehydes, ketones, amides, esters, anhydrides, in this case, the bonds are perhaps included in the third absorption area is the C=O ketone functional group because in the lignin structure there are only C=O ketone bonds. However, in Fig. 2 (b) a new absorption band is formed at the wave number 1518 cm^{-1} which is the absorption of the N-O functional group.

Fig. 2 (b) shows that the biosorbent of *kepok* banana peel activated H_2SO_4 after contacting did not change the transmittance value and absorption band for the functional groups C-H and C O. This shows that cadmium metal only binds to O-H functional groups and N-O functional groups as new peaks. The results of the characterization of banana skin biosorbents prove that H_2SO_4-activated *kepok* banana peel biosorbents are not very effective when used as biosorbents to absorb cadmium metal. The comparison of functional group presented in the biosorbents based on different activator type is shown in Table 1.

Table 1. The Results of FTIR Analysys

Activator	Frequency Range (cm^{-1})	Functional Group
H_3PO_4	3300	Hydroxyl Compound
	1241	Amine C-N
H_2SO_4	2916	The aliphatic and aromatic C-H
	1518	N-O Nitro Compound

3.2. The Effect of Activator Type, pH and Biosorbent Ratio to Removal of Cadmium

pH is a parameter in maximizing the adsorption capacity of solution metal ions. In this case, pH affects the surface properties of the adsorbent and the ionic shape of the cadmium solution. Cadmium adsorption is sensitive to changes in acidity or alkalinity conditions so that proper pH is needed in cadmium adsorption [17]. [18] in his research, proved that at pH below 2, the percentage of cadmium metal absorption is very low. However, at high pH, i.e above pH 7, the percentage of absorption of cadmium metal is also not optimum due to the precipitation of cadmium to $Cd(OH)_2$ in the solid phase. Therefore, the absorption process of cadmium metal in this study occurred at pH 3, 4 and 5.

Fig. 3 shows a graph of the percentage of cadmium adsorption at pH 3 with a weak acid activator H_3PO_4. Cadmium absorption is good, indicated by the percentage of adsorption in the range of 65.35-95.87%. Similar to the H_2SO_4 strong acid activator, Fig. 3 shows good cadmium absorption with adsorption percentage of 61.41-97.64%. However, the absorption of cadmium metal at pH 3 in both H_2SO_4 and H_3PO_4 activators is still unstable. At low pH, high concentrations of hydrogen ions cause fewer surface functional groups available in the biosorbent to bind cadmium metal. The best condition at pH 3 with H_3PO_4 weak acid activator was at 45 minutes and the adsorbent dose was 1.5 grams while the best condition at pH 3 with strong acid activator H_2SO_4 was shown at 120 minutes and the adsorbent dose was 2 grams.

As known, H_2SO_4 is a strong acid that has higher ionization energy compared to H_3PO_4 [19]. High ionization energy at higher H_2SO_4 activators produces a more acidic atmosphere and causes more H^+ ions to be present on the surface. This causes more competition between H^+ and Cd^{2+} ions so that the absorption of cadmium metal at pH 3 requires a longer time and more adsorbent dose to get the best absorption conditions. In contrast, the ionization energy of H_3PO_4 is not so high that it does not require a lot of time and a dose of adsorbent to achieve the best conditions in the absorption of cadmium metal. However, acidic conditions that are too concentrated at pH 3 cause the cadmium ions attached to the biosorbent are unstable and easily detached from the surface. [20] also states that effective desorption of heavy metals is carried out at low pH.

The graph of the percentage absorption of cadmium metal at pH 4 with H_3PO_4 and H_2SO_4 activators respectively is shown in Fig. 4. The absorption of cadmium at pH 4 is more stable when compared to pH 3. Under acidity conditions at pH 4, it also produces the best average percent absorption with a range of percentage absorption at 97.3-99.91% for H_3PO_4 and 96.5-98.8 % for H_2SO_4. The best conditions for the absorption of cadmium metal in this study with H_3PO_4 and H_2SO_4 activators were located at 90 minutes and 2 grams of adsorbent dose. This is because at pH 4 the concentration of hydrogen ions in the biosorbent is less so that it provides more functional groups on the surface of the biosorbent to densely absorb cadmium metal.

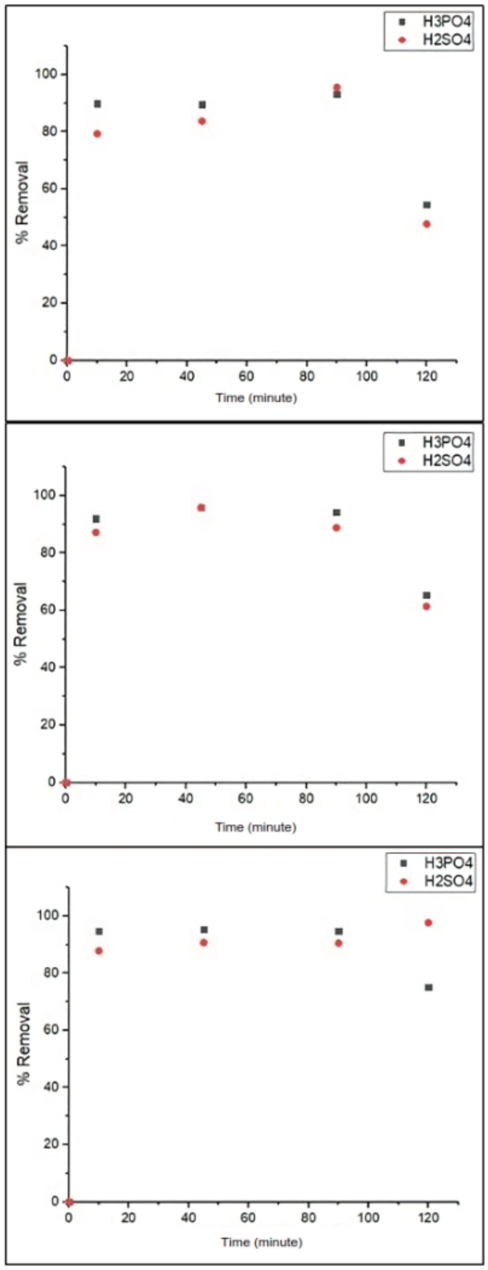

Fig. 3. The Effect of absorbent dosage towards cadmium metal adsorption using activator H_3PO_4 and H_2SO_4 on pH 3 with dosage (a) 1 gr ; (b) 1.5 gr ; (c) 2 gr

Chemica: Jurnal Teknik Kimia
Vol. 9, No. 3, December 2022, pp. 143-153
ISSN 2355-8776

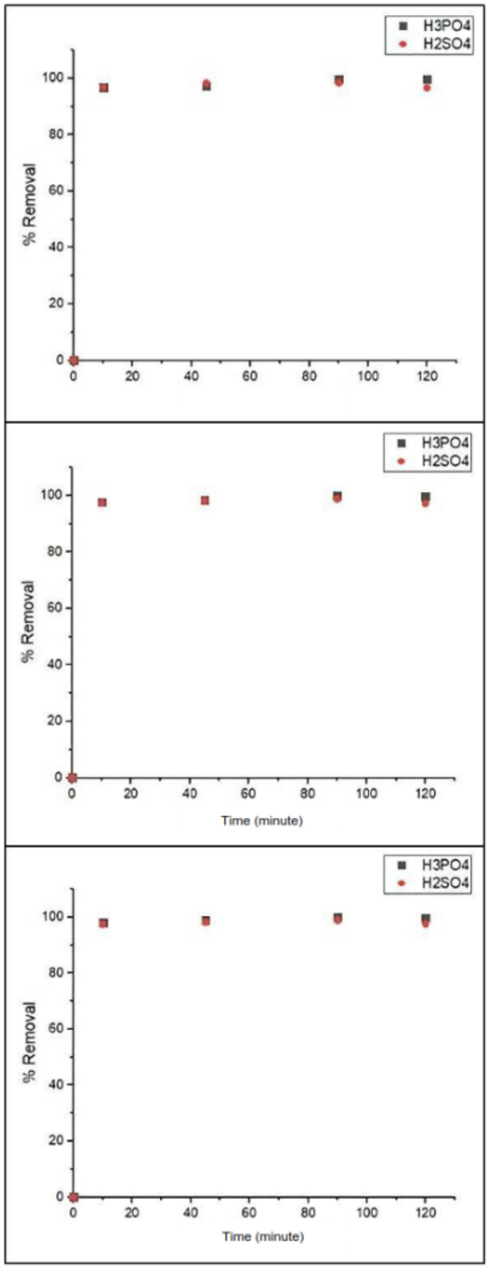

Fig. 4. The Effect of adsorbent dosage towards cadmium metal adsorptionusing activator H_3PO_4 and H_2SO_4 on pH 4 with dosage (a) 1 gr, (b) 1,5 gr, (c) 2 gr

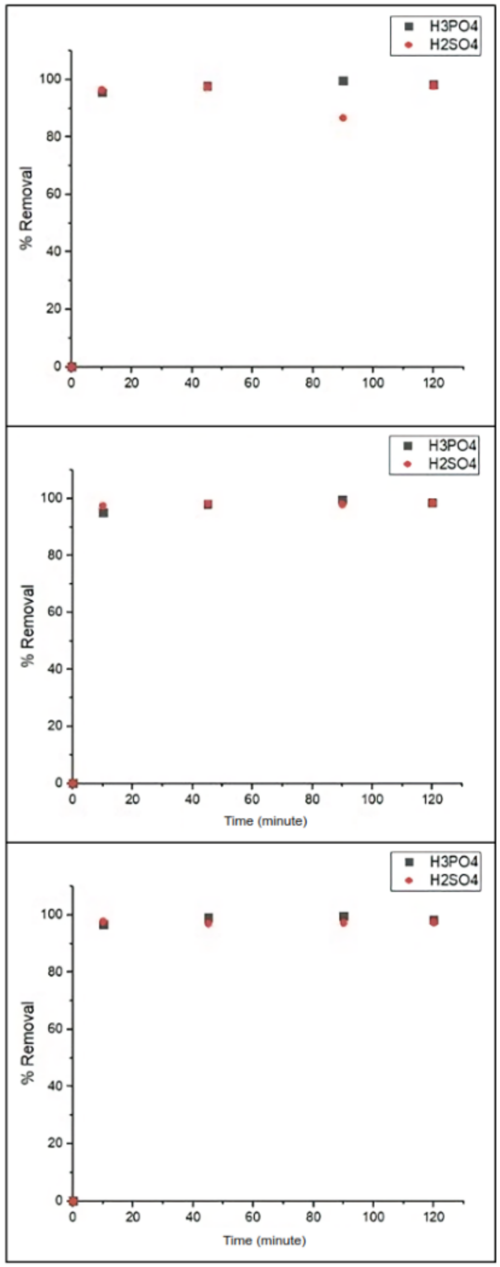

Fig. 5. The Effect of adsorbent dosage towards cadmium metal adsorptionusing activator H_3PO_4 and H_2SO_4 on pH 5 with dosage (a) 1 gr, (b) 1.5 gr, (c) 2 gr

The absorption of cadmium metal at pH 5 with H_3PO_4 and H_2SO_4 activators is approximately the same as pH 5 with an adsorption percentage range of 95.5-99.76% for H_3PO_4 activators and 86.68-98.5% for H_2SO_4 activators. The data is presented in Fig. 5. The best conditions for the absorption of cadmium metal with an H_3PO_4 activator at pH 5 occurred in the 90th minute with a dose of 2 grams of adsorbent. In contrast, the best conditions for absorption of cadmium metal with H_2SO_4 activator occurred in the minute 90 with a doseof 1.5 grams of adsorbent.

In essence, metal absorption increases with increasing doses of the adsorbent. However, cadmium concentrations under certain conditions in H_3PO_4 and H_2SO_4 activators have increased after the adsorption process, although not significantly. The addition of biosorbent doses under certain conditions may cause aggregation of biosorbents. Aggregation can reduce the biosorbent density, causing the absorption of cadmium metal to decrease because the active site on the biosorbent is reduced [21].

3.3. The comparisson of biosorbent ability in Cadmium degradation

The best acid activator for the absorption of cadmium metal with biosorbent *kepok* banana peel in this study is the H_3PO_4 solution. [3] and [22] explained the classification of metal ions into metal cations of type A (strong acids), transition metals and type B (weak acids) according to the acidity of a solution with a tendency towards ligands and metal stability [22, 23]. Based on these classifications, cadmium is a type B metal cation that is more suited to weak acid activators, in this case, phosphoric acid. Type B metal cations have a tendency to bind to S and N ligands. This description supported the reason for the absorption band in the biosorbent of *kepok* banana peel with H_3PO_4 activator in Fig. 3 (b) where the wavenumber 1241 cm^{-1} is formed which is the absorption of the CN amine functional group.

Phosphoric acid has a pKa value of 2.15-7.12 while the carboxyl bonds in the *kepok* banana peel pectin which are an important group in the absorption of cadmium metal have pKa of 3.5-5.0 [24]. The corresponding pKa values between the two create the right acid atmosphere so that the carboxyl bonds are deprotonated into negative ions ($-COO^-$). In these circumstances, the cadmium metal adheres to the carboxyl bonds so that the percentage of cadmium absorption becomes maximum. On the other hand, sulfuric acid has a low pKa of -3 resulting in an acid atmosphere that is too thick. This causes competition between H^+ ions and cadmium metal and causes the cadmium metal absorbed to be unstable so that the percentage of cadmium absorption goes up and down. There was some adsorbent that ever used as agent to remove cadmium in aqueous solution that showed in Table 2.

Table 2. Comparison of cadmium removal using different adsorbents

Adsorben Type	% Removal	Activator	Reference
Active Carbon Banana Peel	98.35	-	[25]
Active Carbon *Kepok* Banana Peel	64.2	H_2SO_4	[10]
Banana Peel Biosorbent	89.2	-	[11]
Banana Peel Biosorbent	85	-	[26]
Banana Peel Biosorbent	73.15	-	[12]
Durian Skin Biosorbent	72.17	-	[12]
Active Carbon *Durian* Skin	64.54	HCl	[13]
Orange Skin Adsorbent	93.72	HCl	[27]
Kepok Banana Peel Biosorbent	99.91	H3PO4	Present Study
Kepok Banana Peel Biosorbent	98.81	H_2SO_4	Present Study

4. Conclusion

Biosorbent that use in this study made from *kepok* banana peel (*Musa Acuminata balbisian*). The type of H_3PO_4 activator which is in the form of a weak acid produces the best percentage of absorption in the cadmium removal when it compared with the H_2SO_4 activator. Characterization with FT-IR showed the differences in functional groups onto biosorbent before and after adsorption. There was a change in the spectral band of C-H and C=O functional groups for biosorbent that activated with H_3PO_4 and a change in the spectral band of C-H functional groups for biosorbent that activated with H_2SO_4. Both of the activator types showed the best condition was at 90 minutes contact time, pH 4 and the ratio of biosorbent dosage and the volume of 1.5: 20 mg/l. The result showed that the H_3PO_4 was the best acid activator in the removal of cadmium with amount of 99.91%.

Notation

C_o = the initial concentration of Cadmium (Cd) (mg/l)

C_e = the final concentration of Cadmium (Cd) (mg/l)

Acknowledgment

Authors want to thank to Separation and Purification Laboratory, Faculty of Engineering, Universitas Sriwijaya for facilities and supports.

References

[1] T. Agustina, “Kontaminasi Logam Berat pada Makanan dan Dampaknya pada Kesehatan,” Jurnal Teknologi Busana dan Boga, vol. 1, no. 1, pp. 53-65, June 2014.

[2] R. Indonesia, "Peraturan Pemerintah Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air," Indonesia, Jakarta, 2001.

[3] Stumm and Morgan, Aquatic Chemistry; chemical equilibria and rates in natural waters, New York: Wiley, 1999.

[4] D. Mohapatra, S. Mishra and N. Sutar, “Banana and its by-product utilisation: an overview,” Journal of Scientific and Industrial Research, vol. 69, pp. 323-329, May 2010.

[5] J. R. Memon, S. Q. Memon, M. I. Bhanger, G. Z. Memon, A. El-Turki and G. C. Allen, “Characterization of banana peel by scanning electron microscopy and FT-IR spectroscopy and its use for cadmium removal,” Colloids and Surface B: Biointerfaces, vol. 66, no. 2, pp. 260-265, October 2008.

[6] B. P. S. Indonesia, Produksi Pisang Nasional., Jakarta: Bhratara karya Aksara, 2017.

[7] Basse, Compost Engineering, London: An Arbour Science, 2000.

[8] Z. Reddad, C. Gerente, Y. Andres, M. C. Ralet, J. F. Thibault and P. L. Cloirec, “Ni(II) and Cu(II) binding properties of native and modified sugar beet pulp,” Carbohydrate Polymer, vol. 49, no. 1, pp. 23-31, July 2002.

[9] A. Sherly, “Aktivasi kulit Pisang Kepok (*Musa Acuminate L.*) dengan H_2SO_4 dan aplikasinya sebagai adsorben ion logam Cr(VI),” UNESA Journal of Chemistry, vol. 3, no. 1, pp. 22-25, January 2014.

[10] Ayu, “Efektifitas penggunaan limbah Kulit Pisang Kepok (*Musa Paradisiacal Linn*) sebagai karbon aktif dalam penyerapan Pb Dan Cd,” Fakultas Pertanian- Peternakan, University of Muhammadiyah Malang, Malang, 2018.

[11] J. Anwar, U. Shafique, W. Zaman, M. Salman, A. Dar and S. and Anwar, “Removal of Pb(II) and Cd(II) from water by adsorption on peels of banana,” Bioresource Technology, vol. 101, no. 6, pp. 1752-1755, March 2010.

[12] W. Saikaew and P. Kaewsarn, “Cadmium ion removal using biosorbent derived from fruit peel wastes,” Songklanakarin Journal of Science Technology, vol. 31, no. 5, pp. 547-554, October 2009.

[13] Marlinawati, B. Yusuf and Alimuddin, “Pemanfaatan arang aktif dari kulit durian (*Durio Zibethinus L.*) sebagai adsorben ion logam kadmium (II),” Jurnal Kimia Mulawarman, vol. 13, no. 1, pp. 23-27, January 2016.

[14] R. Chaber, K. Lach, J. Depciuch, K. Szmuc, E. Michalak, A. Raciborska, A. Koziorowska and J. Cebulski, “Fourier Transform Infrared (FTIR) spectroscopy of paraffin and deparafinnized bone tissue samples as a diagnostic tool for ewing sarcoma of bone,” Journal Of Infrared Physics & Technology, vol. 85, pp. 364-371, September 2017.

[15] C. Anam, Sirojudin and K. S. Firdausi, “Analisis gugus fungsi pada sampel uji, bensin dan spiritus menggunakan metode spektroskopi FT-IR,” Jurnal Berkala Fisika, vol. 10, no. 1, pp. 79-85, April 2007.

[16] S. G. Mohammad, S. Ahmed, A. F. M. Badawi and D. S. El-Desouki, "Activated carbon derived from Egyptian Banana peels for removal of cadmium from water," Journal of Applied Life Sciences International, vol. 3, no. 2, pp. 77-88, January 2015.

[17] N. Balkaya and H. Cesur, "Adsorption of cadmium from aqueous solution by phosphogypsum," Chemical Engineering Journal, vol. 140, no. 1, pp. 247-254, July 2008.

[18] S. E. Ghazy, I. M. Gabr and A. H. M. Gad, "Cadmium (II) sorption from water samples by powdered marble wastes," Chemical Speciation and Bioavailability, vol. 20, no. 4, pp. 249-260, 2008.

[19] Frankael, "Structure and Ionization of Sulfuric Acid in Water," New Journal of Chemistry, vol. 39, no. 7, pp. 8-15, March 2015.

[20] N. F. Y. Tam, Y. S. Wong and C. G. Simpson, "Repeated removal of copper by alginate beads and the enhancement by microalgae," Biotechnology Techniques, vol. 12, p. 187–190, March 1998.

[21] A. A. Alghamdi, Al-Odayni, S. A. B., A.-K. A. W. S., F. A. Alharthi and T. Aouak, "Efficient adsorption of lead (II) from aqueous phase solutions using polypyrrole-based activated carbon," Materials (Basels), vol. 12, no. 12, June 2019.

[22] G. M. Gadd, "Biosorption: critical review of scientific rationale, environmental importance and significance for pollution treatment," Journal Chem Technol Biotechnol, vol. 84, no. 1, pp. 13-28, July 2008.

[23] T. D. Sostaric, M. S. Pectrovic, F. Pastor, D. R. Loncarevic, J. T. Petrovic, J. V. Milojcovic and M. D. Stojanovic, "Study of heavy metals biosorption on native and alkali-treated apricot shells and its application in wastewater treatment," Journal of Molecular Liquids, vol. 259, pp. 340-349, June 2018.

[24] Averill, Principles of General Chemistry, United States: Prentice Hall, 2005.

[25] Schiewer and Patil, "Pectin-rich fruit wastes as biosorbents for heavy metal removal: equilibrium and kinetics," Bioresource Technology, vol. 99, no. 6, pp. 1896-1903, April 2008.

[26] P. D. Deshmukh, G. K. Khadse, V. M. Shinde and P. Labhasetwar, "Cadmium removal from aqueous solutions using dried banana peels as an adsorbent: kinetics and equilibrium modeling," Journal Bioremediation Biodegradation, vol. 8, no. 3, pp. 1-7, April 2017.

[27] X. Li, Y. Tang, X. Cao, D. Lu, F. Luo and W. Shao, "Preparation and evaluation of orange peel cellulose adsorbents for effective removal of cadmium, zinc, cobalt and nickel," Colloids and Surfaces A: Physicochem, vol. 317, no. 1-3, pp. 512-521, March 2008.

[28] A. Elkhaleefa, I. H. Ali, E. I. Brima, I. Shigidi, A. B. Elhag, and B. Karama,"Evaluation of the adsorption efficiency on the removal of lead (II) ions from aqueous solutions using azadirachta indica leaves as an adsorbent," Journal Processes, vol. 9, no. 559, pp 1-15, March 2021.

[29] HK, Tsade. "Atomic absorption spectrocopic determination of heavy metal concentrations in Kulufo River, Arbaminch, Gamo Gofa, Ethiopia", Journal of Environmental Analytical Chemistry, vol. 3, no. 177, pp 1-3, January 2016.

Turnitin Chemica UAD

ORIGINALITY REPORT

13%	12%	5%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Muhammadiyah Purwokerto Student Paper	4%
2	pdffox.com Internet Source	3%
3	app.eng.ubu.ac.th Internet Source	2%
4	www.atlantis-press.com Internet Source	1%
5	eprints.uad.ac.id Internet Source	1%
6	media.neliti.com Internet Source	1%
7	repository.ub.ac.id Internet Source	1%
8	Submitted to Sriwijaya University Student Paper	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		