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Potential of Banana Peel and Coconut Fiber as Biosorbents for Pb Heavy Metals in Water

Potensi Kulit Pisang Kepok dan Sabut Kelapa sebagai Biosorben Logam Berat Pb di Air

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Abstract. Excessive amounts of the heavy metal Pb in the environment can cause pollution due to its high toxicity, so it needs to be treated using an efficient and economical adsorption method using banana peel (*Musa paradisiaca* L.) and young coconut fiber (*Cocos nucifera*). This research aims to identify the potential of kepok banana peel, young coconut fiber, and a combination of the two as biosorbents for heavy metal lead. This research used a Completely Randomized Design (CRD) with 2 treatment factors, namely the type of biosorbent (kepok banana peel; young coconut fiber; a combination of both) and the mass of the biosorbent (0.5; 1; 2 grams). This research was repeated 3 times, resulting in a total of 27 experimental units. The parameters measured were levels of the heavy metal lead before and after treatment. Data were analyzed using statistical methods using 2-way ANOVA, then continued with the Duncan test. The research results showed that the optimum mass for reducing Pb levels was a mass of 1 grams with an absorption percentage of 99.01±0.381%. Optimum adsorption effectiveness was found in the combined biosorbent type with an absorption percentage of 99.85±0.214%.
Keywords: *Musa paradisiaca* L.; *Cocos nucifera*; biosorbent; heavy metal lead

Abstrak. *Keberadaan logam berat Pb yang berlebih di lingkungan dapat menimbulkan pencemaran karena toksisitasnya yang tinggi, sehingga perlu dilakukan pengolahan menggunakan metode adsorpsi yang efisien dan ekonomis dengan menggunakan kulit pisang (Musa paradisiaca L.) dan sabut kelapa muda (Cocos nucifera). Penelitian ini bertujuan untuk mengidentifikasi potensi kulit pisang kepok, sabut kelapa muda, dan kombinasi keduanya sebagai biosorben logam berat timbal. Penelitian ini menggunakan Rancangan Acak Lengkap (RAL) dengan 2 faktor perlakuan yaitu jenis biosorben (kulit pisang kepok; sabut kelapa muda; kombinasi keduanya) dan massa biosorben (0.5; 1; 2 gram). Penelitian ini diulang sebanyak 3 kali sehingga diperoleh total 27 satuan percobaan. Parameter yang diukur adalah kadar logam berat timbal sebelum dan sesudah perlakuan. Data dianalisis menggunakan metode statistik menggunakan ANOVA 2 arah, kemudian dilanjutkan dengan uji Duncan. Hasil penelitian menunjukkan massa optimum untuk menurunkan kadar Pb adalah massa 1 gram dengan persentase penyerapan 99.01±0.381%. Efektivitas adsorpsi optimal terdapat pada jenis biosorben kombinasi dengan persentase penyerapan 99.85±0.214%.*
Kata kunci: *Musa paradisiaca L.; Cocos nucifera; biosorben; logam berat timbal*

INTRODUCTION

Water is one of the essential things for living creatures. However, over time, many large industries have been established, resulting in an increase in waste that can pollute waters. Based on Badan Pusat Statistik (BPS) data, it is known that the number of industries in East Java reached 816,804 industries as of February 12 2024. As industrial growth continues to increase, the burden of environmental pollution, especially in waters, is increasing. One example is an increase in levels of heavy metals dissolved in water.

Lead is a heavy metal which is included in the category of dangerous pollutants in the environment and can accumulate in the body over time (Nuradi *et al.*, 2023). Based on PPRI Number 22 of 2021 Appendix VI concerning the Implementation of Environmental Protection and Management, the maximum level of Lead (Pb) in waters is 0.03 ppm. Excessive lead content in the human body can reduce children's intelligence, hinder development, and can cause paralysis. (Widayanto *et al.*, 2017). In addition, the presence of lead in the human body through consumption of water, food and air can cause abnormalities in various organs such as the nervous system, kidneys, reproduction, blood system, and also the central nervous system, especially in children (Nafi'ah, 2016).

Efforts to reduce the heavy metal content in wastewater are very important so that it does not pollute the environment when disposed of in waters. Prambodo (2016) stated that overcoming heavy metal pollution can be done through physical, chemical and biological methods. Large obstacles and high costs encourage humans to turn to biological approaches as an alternative in managing heavy metal waste. The adsorption method is the right choice because the cost is affordable and does not create new pollutants (Rahmi and Sajidah, 2018). Currently, intensive research is being carried out to explore the use of environmentally friendly natural adsorbents. Natural adsorbents are not only effective in the adsorption process, but also more economical.

Biosorbent is a biological material used as an absorbent substance. The process of absorbing metal ions by biosorbents has two mechanisms, namely through ion exchange and absorption. Ion exchange occurs when Pb^{2+} ions replace H^+ ions in the carboxylic group of the biosorbent. This mechanism is caused by electrostatic forces between the metal and the deprotonated functional group (-OH from COOH) (Wase and Foster, 2003; Verma *et al*., 2008). Meanwhile, absorption via a weak Van der Waals force mechanism occurs between the adsorbent surface and the adsorbate molecules, so that the metal molecules are absorbed into the pores of the adsorbent through diffusion. (Rakhmania *et al*., 2017).

The use of biomass derived from agricultural waste as an adsorbent has been widely investigated due to its low cost, easy availability, and high removal efficiency (Tejada-Tovar *et al*., 2023). Raw agricultural solid waste and waste materials from industry such as sawdust (Intan *et al*., 2016), bagasse (Nenohai *et al*., 2023), coconut fiber (Wardani *et al*., 2018), moringa seeds (Nenohai *et al*. , 2023), rice husks (Halim *et al*., 2021), banana peels (Yollanda *et al*., 2019), egg shells (Satriani *et al*., 2016), etc. have been used as biosorbents. Some biomass that can be used as a biosorbent, one of which is banana peel. According to BPS data, banana production in East Java Province will reach 2.6 tons in 2022. The high production potential of this fruit has an impact on increasing the waste produced, so it is necessary to use waste well, one of which is by making it into a biosorbent. According to Sa'diyah (2020) banana peels can be used as adsorbents to adsorb heavy metal ions because they contain cellulose, hemicellulose and pectin. In dry conditions, the content of cellulose compounds is (7.6-9.6%), hemicellulose (6.4-9.4%), and pectin (10-21%) (Ragab *et al*., 2016). The content in this component can function as an adsorbent because there are hydroxyl groups in each polymer unit. This functional group will interact and bond with existing metal ions. Research conducted by Putra *et al*. (2019) shows that biosorbent from banana peel (*Musa paradisiaca* L.) is effective in absorbing metal ions, especially Pb metal with a removal rate of up to 95.6%.

Biomass that also contains a lot of cellulose is young coconut fiber. According to data from BPS, in 2020 young coconut production in East Java Province was 240,168 tons. This figure is the largest figure in young coconut production in the last 5 years, where 2020 was during the Covid-19 pandemic. Then, production figures decreased every year, namely in 2021 and 2020 with figures of 239,650 tons and 235,020 tons respectively, so the waste produced was still quite large. Young coconut fiber is a by-product of young coconuts because this part is not utilized because it is difficult to manage because of its shape and nature (Anggraini *et al*., 2021). Based on research conducted by Kardiman *et al*. (2020) coconut fiber waste contains hemicellulose, cellulose and lignin compounds which have the potential to act as biosorbents to reduce metal levels contained in water. The effectiveness of biosorbent from young coconut fiber was proven in research conducted by Jolly *et al*. (2022) which used young coconut fiber to adsorb the heavy metal ion Pb with the effectiveness of removing the heavy metal Pb of 95.04%.

Based on the description above, it is important to carry out research regarding alternatives for processing the heavy metal Pb in liquid waste that is effective and economical. For this reason, research was carried out on the potential of kepok banana peel (*Musa paradisiaca* L.) and young coconut fiber (*Cocos nucifera*) and their combination as a biosorbent for the heavy metal Lead (Pb).

MATERIALS AND METHODS

This research was carried out in November - December 2023 in the Physiology Laboratory and Microtechnical Laboratory, Building C10, Biology Department, FMIPA Unesa to carry out biosorbent manufacture and the activation process of the biosorbent. The carbonization process was carried out in the A8 Building Coating Laboratory, Department of Mechanical Engineering, FT Unesa. The Pb heavy metal content test was carried out at the Environmental Laboratory of the East Java Province Environmental Service.

This experiment was carried out using a Completely Randomized Design (CRD) involving two treatment factors, namely the type of biosorbent and the mass of the biosorbent, with 3 repetitions, so that in total there were 27 experimental units. Types of biosorbents include biosorbents from kepok banana peels, young coconut fiber, and their combinations, as well as biosorbent masses of 0.5; 1; 2 g. This research consists of three stages. The tools used in this research include an orbital shaker, 140 mesh sieve, oven, furnace, analytical balance, pH meter, filter paper, funnel, erlenmeyer, volume pipette, measuring flask, beaker glass, desiccator, mortar pestle, spatula, and absorption spectrophotometry. atomic (AAS). The materials used in this research include kepok banana peel, 0.1 M NaOH, distilled water, HNO_3, and $Pb(NO_3)_2$ powder.

In this research, the first stage involved making a $Pb(NO_3)_2$ solution. The stage for making the Pb solution is the stage of diluting the 1000 ppm Pb solution to 2 ppm. Making a standard solution of 1000 ppm is 0.16 grams of $Pb(NO_3)_2$ powder put into a 100 ml volumetric flask, dissolved with distilled water in a 100 ml volumetric flask up to the mark, then 7 ml of HNO_3 is added, so that it becomes a 1000 ppm Pb solution. A total of 10 ml of 1000 ppm Pb solution was taken and put into a 100 ml measuring flask, then distilled water was added to the level, so that it became a 100 ppm Pb solution. Then, 5 ml of the Pb solution with a concentration of 100 ppm was taken and put into a 100 ml measuring flask, then distilled water was added until it reached the limit mark, thus producing a Pb solution with a concentration of 5 ppm. Next, 40 ml of the Pb solution with a concentration of 5 ppm was taken, put into a 100 ml measuring flask, and dissolved again with distilled water until it reached the tera level, thus producing a Pb solution with a concentration of 2 ppm.

The second stage is making biosorbent. Kepok banana skins and coconut husks, 2 kilogram (kg) each, were washed clean and cut into small pieces with a size of ±5 mm, then dried in the oven at 150°C for 1 hour. Next, the material is converted into charcoal through a carbonization process in a furnace at a temperature of 400°C for 1.5 hours. After the carbonization process is complete, the charcoal from the Kepok banana peel is cooled in a desiccator for ±30 minutes. The charcoal is then crushed and sifted using a 140 mesh sieve. Next, the charcoal powder was activated with 0.1 M NaOH solution for 1 hour, washed with distilled water repeatedly until it reached neutral pH. After that, the charcoal is filtered, dried in an oven at a temperature of around 105°C for 1 hour, and placed in a desiccator for ±30 minutes.

The third stage, the adsorption stage by preparing a 250 ml erlenmeyer flask. Take 100 ml of 2 ppm Pb solution and put it in each erlenmeyer flask. Measuring each type of biosorbent with a weight of 0.5; 1; 2 g, then 2 ppm $Pb(NO_3)_2$ solution is put into an erlenmeyer. After that, it was stirred homogeneously using an orbital shaker for 60 minutes with a stirring speed of 200 rpm. Filter was filtered using filter paper and filtered water was sampled to analyze the Pb content after treatment with biosorbent. The final stage was Pb analysis stage using AAS referring to SNI 7119-:2017.

RESULTS

Based on the research that has been carried out, data were obtained: 1) Results of two-way ANOVA analysis and Duncan's advanced test; and 2) Average pH and temperature in lead heavy metal wastewater after treatment are presented in (Table 1) and (Table 2).

Table 1. Results of two-way ANOVA analysis (mean, F test, and SD) of heavy metal Pb levels in water after treatment with biosorbent followed by Duncan test

Treatment	Percentage of Heavy Metal Pb Absorption (%)		
	0.5 g	1 g	2 g
Biosorbent Type			
A (Banana peel)	96.09 ± 0.326^{bA}	98.82 ± 0.266^{bC}	94.95 ± 0.794^{bB}
B (Coconut fibers)	92.80 ± 0.404^{aA}	95.35 ± 0.562^{aC}	96.34 ± 0.009^{aB}
C (Combination)	97.43 ± 0.437^{cA}	99.01 ± 0.381^{cC}	99.85 ± 0.214^{cB}
F count Type		187.07; P<0.05	
F count Mass		66.64; P<0.05	
F count Type*Mass		37.61; P<0.05	

R Square = .973 (adjusted to R square = .962)

Note: Numbers followed by similar letter notations indicate that there is no significant difference based on the Duncan test at the 5% level. Lowercase letters indicate significant differences between types of biosorbent that are read vertically (column), and capital letters indicate significant differences between biosorbent masses that are read horizontally (row).

Based on the results of statistical analysis in Table 1, the data obtained were normally distributed with a Sig value. equal to 0.200 and homogeneously distributed with a Sig value. of 0.210. In addition, the type F count was 187.07 and the mass F count was 66.64 with a P value <0.05, which means that the type and mass treatment had an effect on reducing levels of the heavy metal Pb. The calculated F interaction between type and mass was 37.61 with a P value <0.05, which means that there was an interaction between type and mass which influenced the reduction in levels of the heavy metal Pb.

Duncan's further test was carried out to ensure that the factors used had a real effect on the results. In this test, results were obtained that were significantly different in the variation of biosorbent type and biosorbent concentration on the percentage of absorption of the heavy metal Pb levels (efficiency). This is stated in the form of a notation for each type of biosorbent, so that it can be seen that the greatest efficiency sequentially occurs in biosorbent type C (combination of banana peel and coconut fiber), type A (banana peel), type B (coconut fiber)

Based on the data in Table 1, the greatest adsorption effectiveness of the heavy metal Pb content is the biosorbent type from a combination of kepok banana peel and young coconut fiber with a mass of 2 g, namely 99.85 ± 0.214%, while the absorption of the heavy metal Pb is the smallest in the coir biosorbent type. young coconut with a mass of 0.5 g, which is 92.80 ± 0.404%. The optimum percentage of absorption of the heavy metal Pb according to its mass is at a mass of 1 g with the kepok banana peel biosorbent type, namely 99.01 ± 0.381%, while the smallest percentage of absorption of the heavy metal Pb is at a mass of 0.5 g with the young coconut fiber biosorbent type. namely 92.80 ± 0.404%.

Below is a graph showing the percentage absorption of the heavy metal Pb content in water after treatment with various types of biosorbent and biosorbent mass.

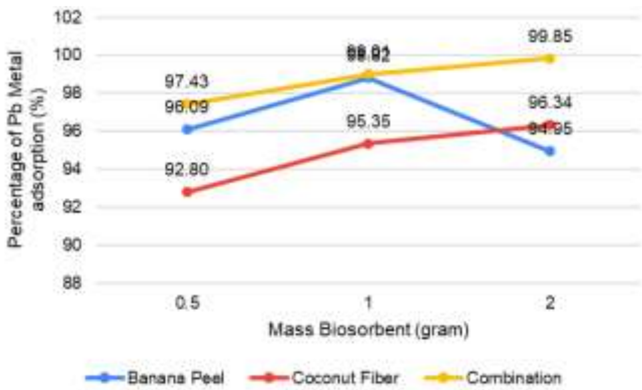

Figure 1. Efficiency of increasing the adsorption capacity of the heavy metal lead (Pb) in water based on the type and mass of biosorbent)

In this study, physical factors were measured to determine the pH and temperature values in synthetic heavy metal lead (Pb) wastewater before and after treatment. The results of pH measurements can be seen in Table 2.

Tabel 2. Average pH and temperature of the water after treatment

Biosorbent Type	Biosorbent Mass (g)	pH		Temperature (°C)	
		Before	$\bar{X}$ After	Before	$\bar{X}$ After
	0.5		7.0		
Banana peel	1		7.2		
	2		7.4		
	0.5		6.2		
Coconut fiber	1	3	6.8	25	25
	2		7.2		
	0.5		7.0		
Combination	1		7.2		
	2		7.5		

Based on research carried out, the initial pH and temperature values before treatment are 3 and 25°C. After being treated, the pH value increased as the concentration increased with relatively the same temperature conditions. In the biosorbent type, the combination of kepok banana peel and young coconut fiber with a biosorbent mass of 2 g produces the largest average pH, namely 7.5, while the smallest pH is produced in the young coconut fiber biosorbent type with a biosorbent mass of 0.5 g, namely 6.2. Below is a graph of the relationship between biosorbent mass and pH value in water.

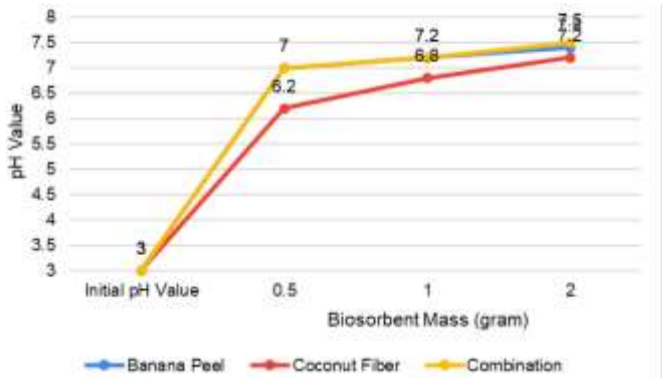

Figure 2. Effect of biosorbent mass on the pH value of water

DISCUSSION

According to data from research that has been carried out, biosorbent from a combination of Banana peel and *Cocos nucifera* fibers is able to absorb levels of the heavy metal Pb up to 99.85%, so it can be said to be an effective biosorbent in the adsorption process. The greatest effectiveness of absorption of the heavy metal Pb occurred in the biosorbent type from a combination of Kepok banana peel and young coconut fiber with a ratio of 1:1. This has been proven in research conducted by Roni *et al*. (2021) who combined rice husks and kepok banana peels to absorb the heavy metal iron (Fe) in river water treatment, achieving an adsorption level of 100%. The effectiveness of the biosorbent combination has also been proven in research conducted by Bako *et al*. (2022) who used a combination of coconut fiber and bentonite as a biosorbent to adsorb the heavy metal lead in liquid waste with an adsorption percentage of 31.07%.

A combination of organic adsorbent types can be a more optimal choice in some cases. This is because combining various types of adsorbents combines the advantages of each type and overcomes the weaknesses that may exist in one type of adsorbent. Meanwhile, the lowest effectiveness of absorption of the heavy metal Pb occurred in the type of biosorbent from coconut fiber, followed by biosorbent from kepok banana peels. This is caused by the higher cellulose content of kepok banana peel at 41.8% (Ifelebuegu and Johnson, 2017) compared to young coconut fiber at 28% (Sarumaha and Zairuddin, 2022).

The increase in the percentage of removal occurred gradually with the increase in the mass of the biosorbent which had been varied, namely 0.5; 1; 2 g. The particle size was 140 mesh and the contact time was 60 minutes. The highest increase in adsorption percentage occurred in the biosorbent from a combination of kepok banana peel and young coconut fiber with an adsorbent mass of 2 g at a stirring speed of 200 rpm, reaching 99.85%. The amount of adsorbent added affects the removal of lead metal. The mass of the adsorbent affects the surface area which can influence the adsorption ability of the substance being adsorbed. The greater the mass of the adsorbent, the greater the surface area of the adsorbent to interact with the adsorbate, so that more adsorbates will also be adsorbed (Anwar *et al*., 2022). The increase in adsorbent mass is related to the increase in the number of particles and surface area of the adsorbent, so that the number of metal ion binding sites also increases.

The effectiveness of adsorption was greatest according to the mass of the biosorbent, in the young coconut fiber biosorbent it occurred at a mass of 2 g, with an effectiveness level of 96.34% and in the combination of kepok banana peel and young coconut fiber, the maximum absorption occurred at an adsorbent mass of 2 g (ratio 1:1) with an effectiveness level of 99.85%. In the graph the results obtained for the biosorbent mass from coconut fiber and a combination do not show the optimum point but rather the highest point of adsorption. At this stage, saturation has not been reached because the active hydroxyl group (-OH) from cellulose is still able to absorb Pb metal, while the optimum mass of the biosorbent type from kepok banana peel is 1 g and experiences saturation at a mass of 2 g. In the type of biosorbent from kepok banana peel, the optimum adsorption process occurred at a biosorbent mass of 1 g, with an effectiveness level of 98.82%, then at a mass of 2 g the absorption of the heavy metal lead level decreased. This is caused by the adsorbent being saturated. According to Anjani (2014), the adsorption process stops when the amount of Pb adsorbed approaches equilibrium, due to the decrease in adsorbate molecules bound to the adsorbent. Approaching the percentage of Pb adsorbed to the equilibrium point shows that the number of adsorbate molecules bound to the adsorbent is decreasing, so the adsorption process is considered complete. The cause is the amount of adsorbent which influences the adsorption process, where an increase in mass will cause the adsorbent to reach a saturation point when the surface is filled with adsorbate. In the saturated state, the adsorption rate is reduced because the adsorbent surface has been filled by the adsorbate. This means that the adsorbent can no longer adsorb the adsorbate because there are no more active sides available to bind the adsorbate (Sellaoui, *et al.,* 2022).

According to Iwuozor *et al*. (2021), studies have consistently shown that the surface area of an adsorbent is directly proportional to its adsorption performance. The surface area of the adsorbent particles is related to the size of the adsorbent, where a particle size of 140 mesh was used in this study. Choosing a particle size of 140 mesh is considered ideal because the smaller the particle size, the more pores on the adsorbent surface are open, thereby increasing the effectiveness of metal ion absorption (Wardalia, 2016). According to Widayatno (2017), the wider the adsorbent surface (the smaller the size of the adsorbent), the stronger the adsorption process will be because it allows the amount of substances attached to the adsorbent surface to increase. After grinding, the inside, which previously did not function as a surface, will function as a surface.

This is related to the activation process, where this research uses physico-chemical activation. In physical activation, the carbonization process aims to expand the carbon pore structure through an oxidation process. Apart from that, the aim is also to remove unwanted volatile materials and impurities from the adsorbent material (Ramadhani *et al*., 2020). Meanwhile, the chemical soaking process has a more important role in pore formation, pore volume and active surface area so that adsorbents become superior in the process of separating pollutants from water solutions and liquid waste by releasing hydrocarbon bonds or oxidizing surface molecules, charcoal will undergo characteristic transformations, both from a physical and chemical perspective. This causes an increase in surface area which affects adsorption capacity (Anggriawan *et al*., 2019).

In this research, the chemical activation process was carried out using a 0.1 M NaOH solution to carry out the delignification process on the adsorbent which aims to dissolve compounds that can hinder the adsorption process, such as lignin compounds (Kusumawardani *et al*., 2018). Lignin compounds can block ion transfer to the active site of the adsorbent during the adsorption process. Lignin and cellulose compounds are broken down by NaOH solution (Utomo, 2014). OH^- ions originating from NaOH can break bonds in the basic structure of lignin, making it easier for lignin to dissolve (Alfaini and Sa'diyah, 2023). The chemical activation process has many advantages such as high yields, low energy costs and simple recovery of the agent activation process when compared to physical activation (Ho, 2022).

In the adsorption process, Van der Waals forces and ion exchange occur. Lead ions in solution interact with other ions in the adsorbent and other ions released into the solution. Under certain conditions, adsorbents can absorb metal ions through Van der Waals forces, the attractive force between metal ions and adsorbent particles. In this way, the metal ions adhere to the surface of the adsorbent and separate from the solution. In addition, hydroxide ions (OH^-) are produced from the ionization of water (H_2O) which can occur spontaneously in certain situations. In general, OH- ions are not adsorbed by adsorbents, so they remain in solution (Bonilla *et al*., 2017). In addition, the interaction between metal ions and biosorbent involves ion exchange. On the surface of biosorbents, acidic functional groups such as hydroxyl and carboxyl can serve as sites where metal ions are adsorbed. When metal ions interact with the adsorbent, the acid functional group attaches to the metal ion through an ion exchange process (Riduan *et al*., 2020).

Based on the data that has been obtained, the initial pH of synthetic Pb wastewater is 3 and the temperature is 25°C. The addition of biosorbent mass of each type can increase the pH of the Pb solution. The solution produced from $Pb(NO_3)_2$ powder is acidic. The pH value of the $Pb(NO_3)_2$ solution from this research is 3. The addition of biosorbent mass causes an increase in pH because chemical bonds occur between the adsorbent and the adsorbate. This occurs due to the metal ion exchange process in the functional groups in the biosorbent. Initially, the pH of the biosorbent which is at an acidic level will experience protonation, where the H^- ions will have a positive charge and be able to react to speciation in the form of anions. The presence of OH^- ions will cause deprotonation of the adsorbent group, so that cellulose will acquire a negative charge and increase its binding capacity (Nurafriyanti *et al*., 2017).

The temperature conditions after treatment tend to be stable and do not change significantly compared to the initial temperature before treatment, namely 25°C. This condition is caused by the stability of the room temperature at the research location, which does not affect the temperature during the research process.

CONCLUSION

Based on research that has been carried out, it was concluded that biosorbents from kepok banana peels and young coconut fiber can reduce levels of the heavy metal lead in water. Variations in sample type and biosorbent mass influence the results of the effectiveness of lead heavy metal absorption. The greater the mass of the dissolved biosorbent, the higher the effectiveness of absorbing the heavy metal lead. Optimum adsorption of the heavy metal lead occurred in the biosorbent type, a combination of kepok banana peel and young coconut fiber with a biosorbent mass of 2 g, which had an effectiveness value of 99.85%. Using a biosorbent mass of 1 g obtained optimum effectiveness, namely 99.01 ± 0.381%

REFERENCES

Alfaini ADW and Sa'diyah K, 2023. Pengaruh Jenis Biosorben Terhadap Kualitas Limbah Cair Domestik Pusat Perbelanjaan di Dinoyo Malang. *DISTILAT: Jurnal Teknologi Separasi*; 9(3): 225-239.

Anggraini R, Khabibi J and Adelka YF, 2021. Karakteristik Papan Partikel dari Campuran Limbah Akasia (*Acacia mangium* Willd.) dan Kulit Kelapa Muda (*Cocos nucifera*): Characteristics of Particle Board from Mixed Waste of Acacia (*Acacia mangium* Willd.) and Coconut Shell (*Cocos nucifera* L). *Jurnal Silva Tropika*; 5(1): 366-381.

Anggriawan A, Atwanda MY and Lubis N, 2019. Kemampuan Adsorpsi Logam Berat Cu Dengan Menggunakan Adsorben Kulit Jagung (*Zea Mays*). *Jurnal Chemurgy*; 3(2): 27-30.

Anjani RP, 2014. Penentuan Massa dan Waktu Kontak Optimum Adsorpsi Karbongranular sebagai Adsorben Logam Berat Pb (II) dengan Pesaing Ion Na^+. *UNESA Journal of Chemistry*; 3(3). 159-163

Anwar K, Mardiyono M and Harmastuti N, 2022. Karakteristik Pektin Kulit Buah Sukun (*Artocarpus altilis* (Park.) Fosberg) dan Uji Kemampuan Adsorpsi Logam Berat Pada Limbah Laboratorium Stifera Semarang. *Jurnal Ilmiah Sains*; 22(1): 8-16.

Badan Pusat Statistik, 2023 Produksi Buah–Buahan dan Sayuran Tahunan Menurut Jenis Tanaman di Provinsi Jawa Timur (kuintal), 2019 – 2022. Surabaya. Badan Pusat Statistik.

Badan Pusat Statistik, 2023. Produksi Perkebunan Kelapa Sawit/Oil Palm dan Kelapa/Coconut Menurut Kabupaten/Kota Jenis Tanaman di Provinsi Jawa Timur (ton), 2020 dan 2021. Surabaya. Badan Pusat Statistik.

Badan Pusat Statistik, 2024. Jumlah Perusahaan, Tenaga Kerja, Investasi dan Nilai Produksi pada Industri di Provinsi Jawa Timur Menurut Kabupaten/Kota. Surabaya. Badan Pusat Statistik.

Bako IP, Iqbal M and Muchtar S, 2022. Combination of Coconut Coir and Bentonite as a Biosorbent for Removal of Lead (Pb) in Wastewater. *Rasayan Journal of Chemistry*; 15(2). 1126-1131.

Bonilla-Petriciolet A, Mendoza-Castillo DI and Reynel-Ávila HE, 2017. Adsorption processes for water treatment and purification. Berlin: Springer.

Halim A, Romadon J, and Achyar MY, 2021. Pembuatan adsorben dari sekam padi sebagai penyerap logam berat tembaga (Cu) dan timbal (Pb) dalam air limbah. *Sustainable Environmental and Optimizing Industry Journal*; *3*(2): 66-74.

Ho SM, 2022. A review of chemical activating agent on the properties of activated carbon. *International Journal of Chemistry and Research*; 1(1): 1-13.

Ifelebuegu AO and Johnson A, 2017. 'Nonconventional low-cost cellulose- and keratin-based biopolymeric sorbents for oil/water separation and spill cleanup: A review', *Critical Reviews in Environmental Science and Technology*; 47(11): 964–1001. doi: 10.1080/10643389.2017.1318620.

Intan D, Said I and Abram PH, 2016. Pemanfaatan biomassa serbuk gergaji sebagai penyerap logam timbal. *Jurnal Akademika Kimia*; 5(4): 166-171.

Iwuozor KO, Ighalo JO, Emenike EC, Igwegbe CA, and Adeniyi AG, 2021. Do adsorbent pore size and specific surface area affect the kinetics of methyl orange aqueous phase adsorption?. *Journal of Chemistry Letters*; 2(4), 188-198.

Jolly FA, Abedin MZ, and Muyen Z, 2022. Wastewater treatment using coconut fiber ash as an adsorbent for removal of heavy metals. *Archives of Agriculture and Environmental Science*; *7*(2). 192-198.

Kardiman K, Ifa L and Rasyid R, 2020. Pembuatan Adsorben dari Sabut Kelapa Sebagai Penyerap Logam Berat Pb(II). *ILTEK : Jurnal Teknologi*; 14(2): 2083–2087.

Kusumawardani LJ, Suryadi TR and Taufik A, 2020. Optimasi Adsorpsi Kromium (VI) Oleh Arang Aktif dari Tempurung Kelapa (*Cocos nucifera*). *Prosiding Senantias*; 1(1). 1265-1276.

Nafi'ah R, 2016. Kinetika Adsorpsi Pb(II) Dengan adsorben Arang Aktif dari Sabut Siwalan or Kinetics Adsorption of Pb(II) By Siwalan Fiber Activated Carbon. *Jurnal Farmasi Sains dan Praktis*; 1(2): 28-37.

Nenohai JA, Minata ZS, Ronggopuro B, Sanjaya EH and Utomo Y, 2023. Penggunaan Karbon Aktif dari Biji Kelor dan Berbagai Biomassa dalam Mengatasi Pencemaran Air: Analisis Review. *Jurnal Ilmu Lingkungan*; 1(1): 29-35.

Nuradi N, Pratama R, Nasir MN, Jangga J and Indriani LI, 2023. Kadar Timbal (Pb) Pada Air Sumur Warga Yang Tinggal Di Sekitar Pembuangan Limbah Industri Kelapa Sawit Di Desa Bulili Sulawesi Barat. *Jurnal Media Analis Kesehatan*; 14(1): 64-72.

Nurafriyanti N, Prihatini NS and Syauqiah I, 2017. Pengaruh variasi pH dan berat adsorben dalam pengurangan konsentrasi Cr total pada limbah artifisial menggunakan adsorben ampas daun teh. *Jukung (Jurnal Teknik Lingkungan)*; 3(1): 56-65.

Peraturan Pemerintah RI Nomor 22 Tahun 2021 Tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup.

Prambodo MS, Hariyati R and Soeprobowati TR, 2016. Spirulina platensis geitler sebagai fikoremediator logam berat Pb skala laboratorium. *Bioma: Berkala Ilmiah Biologi, Vol. 18(2): 64-69*.

Putra IPKA, Narwati N, Hermiyanti P, and Trisyanti H, 2019. Bioadsorben kulit pisang kepok (*Musa acuminate* L.) dalam menurunkan kadar timbal (Pb) pada larutan Pb. *Jurnal Penelitian Kesehatan" SUARA FORIKES"(Journal of Health Research" Forikes Voice")*, *10*(1), 1-7.

Ragab M, Osman MF, Khalil ME and Gouda MS, 2016. Banana (*Musa* sp.) peels as a source of pectin and some food nutrients. *J. Agric. Res. Kafr El-Sheikh Univ*; 42(4): 88-102.

Rahmi R and Sajidah S, 2018. Pemanfaatan Adsorben Alami (Biosorben) untuk Mengurangi Kadar Timbal (Pb) dalam Limbah Cair. In *Prosiding Seminar Nasional Biologi, Teknologi dan Kependidikan*; 5 (1): 271-279.

Rakhmania CD, Khaeronnisa I, Ismuyanto B, Nanda J and Himma NF, 2017. Adsorpsi Ion Kalsium Menggunakan Biomassa Eceng Gondok (*Eichhornia crassipes*) Diregenerasi HCL. *Jurnal Rekayasa Bahan Alam dan Energi Berkelanjutan*; 1(1): 16-24.

Ramadhani LF, Nurjannah IM, Yulistiani R and Saputro EA, 2020. Teknologi Aktivasi Fisika pada Pembuatan Karbon Aktif dari Limbah Tempurung Kelapa. *Jurnal Teknik Kimia*; 26(2): 42-53.

Riduan A, Rainiyati R and Heraningsih SF, 2020. Palm Oil Fuel Ash [POFA]: innovative potential applications as heavy metal removal materials in gold mining wastewater. In *IOP Conference Series: Earth and Environmental Science* 497(1): 012041.

Roni KA, Martini S and Legiso L, 2021. Analisis Adsorben Arang Aktif Sekam Padi dan Kulit Pisang Kepok untuk Pengolahan Air Sungai Gasing, Talang Kelapa, Kabupaten Banyuasin Sumatera Selatan. *Jurnal Konversi*; 10(2): 13-18.

Sarumaha GE and Zainuddin M, 2022. Synthesis and Characterization of A-Cellulose From Young Coconut Coir (Cocos Nucifera L.). *Indonesian Journal of Chemical Science and Technology*; 5(1): 28-30.

Satriani D, Ningsih P and Ratman R, 2016. Serbuk dari Limbah Cangkang Telur Ayam Ras Sebagai Adsorben Terhadap Logam Timbal (Pb). *Jurnal akademika kimia*; 5(3), 103-108.

Sellaoui L, Dhaouadi F, Taamalli S, AlZahrani HYS, Louis F, Bakali AE, *et al.*, 2022. Application of a multilayer physical model for the critical analysis of the adsorption of nicotinamide and propranolol on magnetic-activated carbon. *Environmental Science and Pollution Research*; 29(20): 1-9.

Tejada-Tovar C, Villabona-Ortíz A and González-Delgado ÁD, 2023. High-Efficiency Removal of Lead and Nickel Using Four Inert Dry Biomasses: Insights into the Adsorption Mechanisms. *Materials (Basel, Switzerland)*; 16(13): 4884.

Utomo S, 2014. Pengaruh Waktu Aktivasi dan Ukuran Partikel Terhadap Daya Serap Karbon Aktif dari Kulit Singkong dengan Aktivator NaOH. *Prosiding Semnastek,* Jakarta 12 November 2014.

Verma Y, Pandey PK, Choubey S, Pandey M and Chandrasekhar K, 2008. Biosorptive Removal of Cadmium from Contaminated Groundwater and Industrial Effluents. *Journal of Bioresource Technology*; 99(10): 4420-4427.

Wardalia W, 2016. Karakterisasi Pembuatan Adsorben Dari Sekam Padi Sebagai Pengadsorp Logam Timbal Pada Limbah Cair. *Jurnal Integrasi Proses*; 6(2): 83-88.

Wardani GA, Pamungkas DD, Wulandari WT and Setiawan F, 2018. Pengaruh Waktu Kontak dan Keasaman Terhadap Daya Bio Adsorpsi Limbah Sabut Kelapa Hijau pada Ion Logam Timbal (II). *KOVALEN: Jurnal Riset Kimia*; 4(2): 215-220.

Wase J dan Forster C, 2003. Biosorbent for Metal Ions. UK: Taylor & Francis.

Widayanto T, Yuliawati T and Susilo A, 2017. Adsorpsi Logam Berat (Pb) dari Limbah cair dengan Adsorben Arang Bambu Aktif. Surakarta: *Jurnal Teknologi Bahan Alam*; 1(1): 17-23.

Yollanda D, Nasra E, Dewata DKI and Nizar UK, 2019. Pengaruh Ion Cu^{2+}, Zn^{2+}, Cd^{2+} dan Cr^{3+} terhadap Penyerapan Logam Pb^{2+} menggunakan Kulit Pisang Kepok (*Musa Paradisiaca* L.) sebagai Biosorben. *Menara Ilmu*; 13(2): 171-177.

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