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Effect of Activated Carbon Mass Variation from NaOH-Activated Coconut Coir on Lead (Pb) Adsorption Efficiency

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Abstract

Lead (Pb) contamination in water bodies poses a serious threat to human health and the environment. This study aimed to examine the effect of varying the mass of activated carbon derived from coconut coir waste and activated with 1 M NaOH on Pb adsorption efficiency using an initial Pb concentration of approximately. The activated carbon was prepared through carbonization and chemical activation using 1 M NaOH for 24 h. The adsorbent masses used were 3 g, 5 g, and 7 g. Pb concentration was measured using an Atomic Absorption Spectrophotometer (AAS). The results showed that a larger mass of activated carbon produced higher adsorption efficiency. The highest removal efficiency was obtained at 7 g, reaching 97.92% with a final Pb concentration of 2.1864 mg/L. Coconut-coir-based activated carbon has the potential to serve as a low-cost and environmentally friendly alternative adsorbent for reducing Pb levels in contaminated water. Nevertheless, as the final concentrations remained above the regulatory standard of 0.03 mg/L, combining this adsorbent with advanced treatment methods such as coagulation or membrane filtration is recommended for future applications to achieve regulatory compliance.

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INTRODUCTION

Lead (Pb) is one of the priority pollutants commonly found in industrial and mining wastewater. Pb is toxic, non-biodegradable, and capable of bioaccumulating in the human body, where it can cause nervous system disorders, kidney damage, anemia, and other chronic diseases (Putra et al., 2023; Flora et al., 2012). According to Government Regulation of the Republic of Indonesia No. 22 of 2021, the quality standard for Pb in surface water is 0.03 mg/L, so effective treatment methods are needed to reduce Pb concentrations before wastewater is released into the environment.

One effective, economical, and easy-to-apply water treatment method is adsorption using activated carbon. Activated carbon has a high specific surface area, a well-developed pore structure, and active functional groups that can interact with heavy metal ions through both physical and chemical mechanisms (Kurniawan & Babel, 2006; Wijayanti & Mahatmanti, 2022). However, commercial activated carbon is relatively expensive, so alternative raw materials that are cheaper and more readily available are needed.

Coconut coir is a biomass waste generated in large quantities in Indonesia, yet its utilization remains very limited. Based on its chemical characteristics, coconut coir contains 54-60% cellulose and up to approximately 41% lignin, which are the main lignocellulosic components used as precursors for activated carbon (Wang & Sarkar, 2018). This high lignocellulosic content makes coconut coir a promising raw material for conversion into activated carbon with good adsorption performance.

Chemical activation using NaOH plays an important role in improving the adsorption capacity of activated carbon because NaOH can enlarge the pore volume and pore distribution and develop polar functional groups such as hydroxyl (-OH) and carboxyl (-COOH) groups on the carbon surface, which contribute to Pb^{2+} binding through complexation and ion exchange (Hamid et al., 2022).

Previous research by Fatimah et al. (2023) reported that coconut-coir-based activated carbon activated with NaOH showed high adsorption efficiency for Fe and Cu cations, with efficiencies of 71.54% and 70.89%, respectively. However, that study focused on varying the activator concentration while keeping the adsorbent mass constant and targeted Fe and Cu. Studies on the effect of varying the mass of NaOH-activated coconut coir carbon on Pb adsorption efficiency remain limited, despite Pb being one of the most hazardous heavy metals and acutely and chronically toxic to humans and aquatic ecosystems (Busroni et al., 2022).

Therefore, this study aimed to determine the effect of varying the mass of 1 M NaOH-activated coconut-coir carbon on Pb adsorption efficiency and to identify the optimum adsorbent mass that produced the highest removal efficiency.

METHODS

Materials and Instruments

The instruments used in this study included scissors, a mortar and pestle, a sieve, a glass funnel, a 100 mL beaker, a 100 mL Erlenmeyer flask, a stirring rod, a spatula, a hot plate, a porcelain crucible, sample bottles, and an Atomic Absorption Spectrophotometer (AAS). The materials used were coconut coir and 1 M NaOH.

Preparation of Activated Carbon

The coconut coir was first washed with water, then dried. It was then cut into ±5 cm pieces with scissors. Carbonization was carried out in a furnace at 500°C for 1 h until the coconut coir turned into charcoal. The resulting charcoal was ground with a mortar and pestle, then sieved to obtain a uniform particle size.

Chemical activation was performed by soaking the coconut-coir charcoal in 1 M NaOH solution for 24 h. After activation, the activated carbon was filtered using Whatman No. 41 filter paper, then dried in an oven at 60°C for 3 h. The dried activated carbon was ground again until fine and was ready to be used as the adsorbent.

Adsorption Test

The adsorption test was carried out by preparing three sample bottles containing 100 mL of water with an initial Pb concentration of approximately 100 mg/L. Each sample bottle was treated with activated carbon masses of 3 g, 5 g, and 7 g (C_0). The mixtures were stirred and then filtered using filter paper. The filtrate obtained was analyzed using AAS to determine the final Pb concentration (C_e).

Data Analysis

Data analysis in this study was conducted to determine the adsorption capacity of NaOH-activated coconut-coir carbon in reducing Pb concentration in the test solution. The main parameter used to evaluate adsorbent performance was adsorption efficiency (removal percentage), calculated using the following equation:

$$\% \text{ Removal} = (C_0 - C_e) / C_0 \times 100\%$$

Where:
C_0 = initial Pb concentration (mg/L);
C_e = final Pb concentration after adsorption (mg/L).

RESULTS AND DISCUSSION

Activation Yield of Activated Carbon from Coconut Coir

The preparation of activated carbon from coconut coir in this study included raw material pretreatment, carbonization, and chemical activation, as presented in Figure 1. Based on the results, using 200 g of coconut coir as the raw material produced activated carbon with a yield of 58%. This yield indicates that the carbonization process followed by chemical activation using 1 M NaOH, was able to convert a large portion of the initial material into activated carbon. The yield obtained is influenced by several factors, including the lignocellulosic characteristics of the raw material, carbonization temperature and time, and the type and concentration of activator used during activation (Namazi et al., 2010).

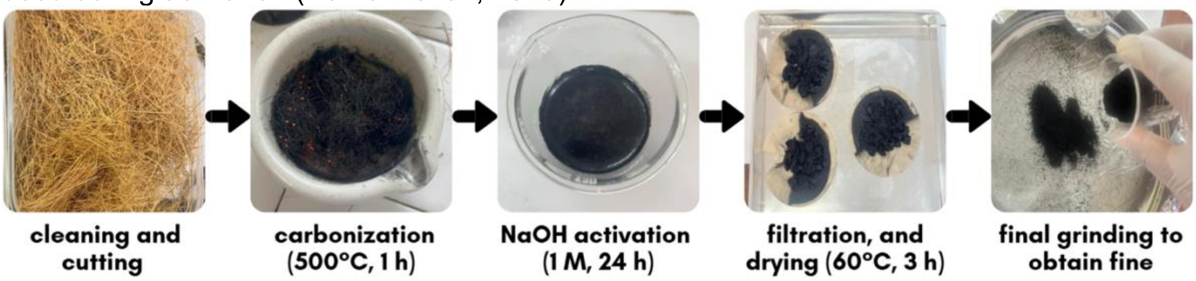

Figure 1. Activated carbon activation procedure from coconut coir

The 58% yield obtained in this study is still within the range reported in previous studies. Budiman et al. (2013) reported that chemically activated lignocellulosic biomass-derived activated carbon typically has yields ranging from 56% to 80%, depending on the type of raw material and the applied process conditions. The relatively lower yield compared with the maximum reported value may be associated with the use of NaOH, a strong activator that dissolves non-carbon components and enlarges pores, causing some mass loss during activation (Amran & Zaini, 2020). Nevertheless, the 58% yield is still considered good and indicates that the resulting activated carbon has adequate structural quality and potential for use as a heavy-metal adsorbent, particularly for Pb.

Activation Yield of Activated Carbon from Coconut Coir

The measured Pb concentrations before and after the adsorption process using coconut-coir activated carbon are presented in Table 1. The initial Pb concentration (C_0) in all treatments was the same, namely 105.2282 mg/L, indicating that the test solution had a homogeneous initial condition. Without adsorbent addition, no reduction in Pb concentration occurred, confirming that the decrease in Pb concentration in the other treatments was entirely due to adsorption by activated carbon.

Table 1. Pb concentration analysis and removal efficiency

Treatment	C_0 (mg/L)	C_e (mg/L)	Removal (%)
Without adsorbent	105.2282	—	—
Activated carbon 3 g	105.2282	28.6528	72.79%
Activated carbon 5 g	105.2282	7.3496	93.01%
Activated carbon 7 g	105.2282	2.1864	97.92%

After adsorption treatment, Pb concentration decreased significantly in all activated-carbon mass variations, as summarized in Table 1. With 3 g of activated carbon, the final Pb concentration (C_e) decreased to 28.6528 mg/L, with a removal efficiency of 72.79%. Increasing the adsorbent mass to 5 g further reduced Pb concentration to 7.3496 mg/L, achieving a removal efficiency of 93.01%, marking a substantial improvement of more than 20 percentage points from the 3 g dosage. The greatest reduction was achieved with 7 g of activated carbon, resulting in a final Pb concentration of 2.1864 mg/L and a removal efficiency of 97.92%, which represents an additional increase of approximately 5 percentage points over the 5 g treatment. These results clearly confirm that coconut-coir activated carbon possesses excellent adsorption performance for Pb(II) ions, with the removal efficiency exhibiting a strong positive correlation with the adsorbent mass, indicating that the availability of active binding sites is the primary limiting factor in the adsorption process.

Effect of Mass Variation on Adsorption Efficiency

The results show that variation in activated carbon mass had a significant effect on Pb adsorption efficiency. The increase in adsorption efficiency with increasing adsorbent mass is caused by the greater number of active sites available to bind Pb^{2+} ions. When the mass of activated carbon increases, its surface area increases, leading to higher adsorption capacity. (Wang et al., 2023). This is consistent with Narkesabad et al. (2023), who stated that increasing the mass of lignocellulosic adsorbent consistently improves the uptake of heavy metal ions.

Activation with 1 M NaOH plays an important role in improving the adsorption capacity of coconut-coir activated carbon. NaOH works by dissolving organic impurities, widening carbon pores, and developing active functional groups such as hydroxyl (-OH) and carboxyl (-COOH) groups on the carbon surface, which contribute to the chemical binding of Pb^{2+} ions (Hamid et al., 2022).

In relation to regulatory standards, based on Government Regulation No. 22 of 2021, the Pb quality standard for water is 0.03 mg/L. The final Pb concentration in all treatments remained above this standard. Nevertheless, the results show that coconut-coir activated carbon was able to substantially reduce Pb levels, up to 97.92%. To reach the specified standard, a larger adsorbent mass or a combination with advanced treatment methods such as coagulation or membrane filtration would be required.

CONCLUSION

Activated carbon derived from coconut-coir waste was successfully activated using 1 M NaOH and showed high adsorptive performance toward Pb(II) ions, confirming the potential of lignocellulosic biomass as an economical and sustainable adsorbent. Increasing the adsorbent mass significantly improved removal efficiency, reflecting the important role of active-site availability and surface area in the adsorption mechanism. The optimum condition was achieved at a mass of 7 g, resulting in a removal efficiency of 97.92% and a final Pb concentration of 2.1864 mg/L. These findings support further optimization of adsorption parameters and additional studies on activation conditions, regeneration, and real-wastewater testing to improve applicability and scalability.

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REFERENCES

Hidayat, R., & Putri, M. E. (2020). Factors affecting oral hygiene behavior among Amran, F., & Zaini, M. A. A. (2020). Effects of chemical activating agents on physical properties of activated carbons: A commentary. Water Practice & Technology, 15(4), 863-876. https://doi.org/10.2166/wpt.2020.094.

Budiman, I., Ismail, et al. (2013). Carbon structure of coconut coir fibers. Jurnal Ilmu dan Teknologi Kayu Tropis, 11(2), 101-108. https://doi.org/10.51850/jitkt.v11i2.88.

Busroni, B., Siswanta, D., Jumina, J., Santosa, S. J., & Anwar, C. (2022). Adsorption of Pb(II) on calix[4]arene derivatives: Kinetics and isotherm studies. Indonesian Journal of Chemistry, 22(6), 1373-1384. https://doi.org/10.22146/ijc.70665.

Fatimah, S., Arnelli, & Astuti, Y. (2023). Pembuatan karbon aktif berbahan dasar sabut kelapa dengan aktivator H_2SO_4 dan NaOH sebagai adsorben kation Fe dan Cu. Greensphere: Journal of Environmental Chemistry. https://doi.org/10.14710/gjec.2023.16300.

Flora, G., Gupta, D., & Tiwari, A. (2012). Toxicity of lead: A review with recent updates. Interdisciplinary Toxicology, 5(2), 47-58. https://doi.org/10.2478/v10102-012-0009-2.

Hamid, A., Rahmawati, Z., Abdullah, M., Purbaningtyas, T. E., Rohmah, F., & Febriana, I. D. (2022). The influence of NaOH activator concentration on the synthesis of activated carbon from banana peel for Pb(II) adsorption. Eksakta: Berkala Ilmiah Bidang MIPA, 23(3), 158-166. https://doi.org/10.24036/eksakta/vol23-iss03/323.

Kurniawan, T. A., & Babel, S. (2006). Physico-chemical treatment techniques for wastewater laden with heavy metals. Chemical Engineering Journal, 118(1-2), 83-98. https://doi.org/10.1016/j.cej.2006.01.015.

Namazi, A. B., Jia, C. Q., & Allen, D. G. (2010). Production and characterization of lignocellulosic biomass-derived activated carbon. Water Science and Technology, 62(11), 2637-2646. https://doi.org/10.2166/wst.2010.981.

Narkesabad, Z. S., Rafiee, R., & Jalilnejad, E. (2023). Experimental study on evaluation and optimization of heavy metals adsorption on a novel amidoximated silane functionalized Luffa cylindrica. Scientific Reports, 13(1), 3670. https://doi.org/10.1038/s41598-023-30634-8

Putra, A., Fitri, W. E., & Febria, F. A. (2023). Toksisitas logam timbal terhadap kesehatan dan lingkungan: Literatur review. Jurnal Kesehatan Medika Saintika, 14(1). https://doi.org/10.30633/jkms.v14i1.1890.

Republik Indonesia. (2021). Peraturan Pemerintah Nomor 22 Tahun 2021 tentang penyelenggaraan perlindungan dan pengelolaan lingkungan hidup. https://peraturan.bpk.go.id/Home/Details/161852/pp-no-22-tahun-2021.

Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. International Journal of Energy Production and Management, 3(1), 34-43. https://doi.org/10.2495/EQ-V3-N1-34-43.

Wang, B., Lan, J., Bo, C., Gong, B., & Ou, J. (2023). Adsorption of heavy metal onto biomass-derived activated carbon: A review. RSC Advances, 13, 4275-4302. https://doi.org/10.1039/D2RA07911A.

Wijayanti, I. L. D., & Mahatmanti, F. W. (2022). Synthesis of chitosan/activated carbon composite beads as an adsorbent of Pb(II) and Cu(II) ions: A review. Indonesian Journal of Chemical Science, 11(2). https://journal.unnes.ac.id/sju/index.php/ijcs/article/view/54943.