ESTA JOURNAL
Energy Storage Technology and Applications
Article
jurnal.uns.ac.id/esta

Production of Biosorbent from Rice Husk

M. A. Sholikhah[1*], F. N. Adelan[1], N. A. Rahma[1], C. S. Yudha[1,2]

1. Chemical Engineering Department, Vocational School, Universitas Sebelas Maret, Jl. Kol. Sutarto 150K Jebres, Surakarta 57126, Indonesia
2. Centre of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret, Jl. Slamet Riyadi 435, Surakarta 57146, Indonesia

[*] Corresponding author: auliatiara30@student.uns.ac.id
doi: https://doi.org/10.20961/esta.v4i1.109725
Received: 09-10-2025; Revised: 30-03-2026; Accepted: 31-03-2026; Published: 01-04-2026

ABSTRACT: Rice husk (RH) is a widely available agricultural byproduct with significant potential as a low-cost precursor for functional biosorbents. This study investigates the production and performance of a chemically activated RH-based biosorbent for the removal of Methylene Blue (MB) from aqueous solutions. The biosorbent was synthesized through a simplified chemical activation route using a sodium hydroxide (NaOH) solution at ambient temperature, avoiding energy-intensive high-temperature carbonization. The physical properties were characterized by moisture content analysis, while the adsorption performance was evaluated through batch experiments with varying contact times. Results from visible-light spectrophotometry demonstrated that the NaOH-activated RH exhibited efficient dye removal capabilities. A consistent decline in the solution's absorbance was observed as contact time increased, indicating the progressive migration and attachment of MB molecules onto the active binding sites of the RH surface. The findings suggest that chemically modified rice husk serves as a sustainable, cost-effective, and efficient alternative for the treatment of textile-derived wastewater.

Keywords: Rice husk, biosorbent, Methylene Blue, chemical activation, wastewater treatment.

1. INTRODUCTION

Indonesia is recognized as one of the countries with the highest rice consumption globally, leading to continuous efforts to increase national rice production. According to the latest data, Indonesia's rice harvest in 2022 reached approximately 54.75 million tons of unhulled rice (GKG) [1]. This massive production consequently generates a substantial amount of rice husk waste, which has not been optimally utilized despite its significant potential for agro-industrial development [2]. Currently, rice husk is predominantly used as a low-value fuel, even though it can be processed into high-value materials such as activated charcoal, carbon paper, and even battery components [3, 4].

The high cellulose and silica content in rice husk makes it an excellent precursor for biosorbent production [5]. Biosorption is increasingly preferred as an eco-friendly method for treating industrial wastewater, particularly for removing synthetic dyes like Methylene Blue (MB) [6]. MB is a cationic dye widely used in the textile industry, which can cause severe environmental damage and health issues if discharged without proper treatment [7]. The use of biomass-based adsorbents offers a cost-effective and sustainable alternative to conventional treatment methods [8].

To enhance its adsorption performance, rice husk can be modified through a chemical activation process. While some methods involve high-temperature carbonization, chemical activation using alkaline solutions such as sodium hydroxide (NaOH) at moderate temperatures is known to be more energy-efficient [9]. This activation process promotes de-lignification and increases the accessibility of functional groups, such as hydroxyl and carboxyl groups, which are responsible for binding dye molecules [10].

This study focuses on the production of biosorbents from rice husk using a simplified preparation and analysis method. The performance of the resulting biosorbent is evaluated based on its water content and its ability to reduce Methylene Blue concentration in wastewater through spectrophotometric analysis [11]. By optimizing the contact time, this research aims to provide a practical solution for converting agricultural waste into valuable environmental remediation materials.

2. MATERIALS AND METHODS

2.1 Materials and Equipment

The primary raw material used in this study was rice husk waste collected from a local source. The chemical reagents involved were Sodium Hydroxide (NaOH) for the activation process and Methylene Blue (MB) as the simulated wastewater pollutant. The laboratory equipment utilized included a drying oven, an analytical balance, a 60-mesh sieve, and a visible-light spectrophotometer for absorbance analysis.

2.2 Biosorbent Preparation

The preparation of the biosorbent followed a structured procedure to ensure high surface reactivity. Initially, 100 grams of raw rice husk were thoroughly washed with distilled water to eliminate surface impurities. The cleaned biomass was dried in an oven at 105 °C until a constant weight was achieved. The dried rice husk was then ground and sieved using a 60-mesh sieve to obtain a uniform particle size. This preparation stage resulted in a final yield of 45 grams of processed rice husk powder, which was then subjected to chemical activation using 250 mL of NaOH solution to enhance its adsorption properties.

2.3 Biosorbent Analysis

The analysis of the processed material was divided into two primary methods: the determination of moisture content and the evaluation of its performance as a wastewater absorbent.

2.3.1 Determination of Moisture Content

The moisture content was determined to assess the moisture level of the prepared biosorbent. Initially, 5 grams of commercial activated biosorbent were weighed and dried in an oven at 105 °C for 1 hour until a constant weight was achieved. Subsequently, the biosorbent was placed in a desiccator for 15 minutes. The percentage of moisture content was calculated gravimetrically based on the mass difference before and after the drying process.

2.3.2 Performance Evaluation of Biosorbent for Wastewater Treatment

The adsorption performance was evaluated through batch experiments to determine the efficiency of the biosorbent in treating contaminated water. Initially, 10 g of dried biosorbent were weighed, and a 500 mL Methylene Blue (MB) solution with a concentration of 10 ppm was prepared. The initial absorbance of the 10 ppm MB solution was measured using a visible-light spectrophotometer at a wavelength of 670 nm. Subsequently, 100 mL of the MB solution were mixed with the dried biosorbent and allowed to equilibrate for a specific duration. Samples of 10 mL were then collected and filtered using filter paper every 2 minutes over a total period of 8 minutes. Finally, the absorbance of the resulting filtrates

Figure 1. Sample in Tube Reaction

was determined at the same wavelength of 670 nm.

Figure 2. Testing sample with spectrophotometer

3. RESULTS AND DISCUSSION

The production of biosorbent from rice husk involved mechanical grinding, 60-mesh sieving, and chemical activation using 4 M NaOH. Starting with an initial biomass weight of 100 g, the process yielded approximately 45 g of raw powder before activation. Following the soaking, washing, and oven-drying stages, the final yield for three separate trials was recorded, as shown in Table 1.

Table 1. Yield of dry biosorbent after chemical activation

No	Yield
1	83.06%
2	97.4%
3	96.24%

The average yield of 92.23% indicates high process efficiency during the chemical modification phase. The variation in yield, particularly in Trial 1, may be attributed to the intensity of the washing process required to reach a neutral pH (close to 7), where some fine particles might have been lost during filtration [12]. The use of a 60-mesh sieve ensured a uniform particle size, which is critical for maximizing the surface area available for the subsequent adsorption of contaminants [13].

Moisture content was determined gravimetrically using 5 g of commercial activated carbon as a benchmark, dried at 105 °C until a constant weight was reached. This standardization step is essential to ensure that the biosorbent possesses optimal porosity and structural stability. Placing the samples in a desiccator for 15 minutes post-drying prevented the re-absorption of atmospheric moisture, ensuring that the calculated moisture content (MC) accurately reflects the physical state of the material [14].

The performance of the biosorbent was evaluated using a 10 ppm Methylene Blue (MB) solution. The interaction between 10 g of the dried biosorbent and 100 mL of the MB solution was monitored at a wavelength of 670 nm. The resulting absorbance data for the three trials are summarized in Table 2.

Table 2. Absorbance values of Methylene Blue solution at different contact times

No	Absorbance			
	2 minutes	4 minutes	6 minutes	8 minutes
1	0.52	0.38	0.31	0.005
2	0.45	0.34	0.21	0.16
3	0.48	0.3	0.25	0.22

As illustrated in Table 2, there is a consistent decline in absorbance values across all trials as the contact time increases from 2 to 8 minutes. This trend serves as quantitative evidence of the adsorption process, where MB molecules are sequestered from the aqueous phase onto the active sites of the biosorbent. In Trial 1, the absorbance reached a near-zero value (0.005) at the 8-minute mark, suggesting almost complete removal of the dye within this short time frame [15].

The variation in absorbance values is influenced by two primary factors: contact time and particle size.

1. Contact time

   The results demonstrate that longer contact durations facilitate the diffusion of MB molecules into the internal pores of the biosorbent. This period allows for a more comprehensive attachment of the cationic dye to the functional groups exposed during NaOH activation [16].

2. Particle size

   The application of a 60-mesh sieve produced a smaller particle size, which significantly increased the total surface area per unit mass. A larger surface area provides more available binding sites, thereby enhancing the capacity of the material to absorb contaminants from the wastewater [17].

The chemical activation with 4 M NaOH played a pivotal role in this process by removing impurities and dissolving recalcitrant components of the biomass, effectively "unmasking" the cellulose structure for improved interaction with the Methylene Blue solution [18].

4. CONCLUSION

The production of biosorbent from rice husk through NaOH chemical activation proved to be a highly efficient process, achieving an average yield of 92.23% across three experimental trials. The resulting material demonstrated significant effectiveness in removing MB from aqueous solutions, as evidenced by the consistent reduction in absorbance values monitored at 670 nm.

Trial 1 showed optimal performance, with the absorbance reaching 0.005 within an 8-minute contact period, indicating near-complete dye sequestration. The adsorption efficiency was found to be strongly influenced by contact time and particle size, where the use of a 60-mesh sieve provided the necessary surface area for effective pollutant capture. This study establishes that chemically modified rice husk is a sustainable, low-cost, and viable alternative for the remediation of industrial textile wastewater.

ACKNOWLEDGMENT

The authors would like to express their sincere appreciation to all parties who supported the completion of this research.

AUTHOR CONTRIBUTION

Conceptualization, F.N. and M.A.; methodology, N.A..; software, F.N. and N.A.; validation, M.A. and N.A.; formal analysis, F.N.; investigation, F.N.; resources, M.A.; data curation, F.A. and F.N.; writing—original draft preparation, N.A.; writing—review and editing, M.A. and F.N.; visualization, F.N.; supervision, C.S. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] Badan Pusat Statistik (BPS), "Laporan Produksi Padi Nasional 2022," Jakarta, Indonesia, 2022.

[2] M. Ahmaruzzaman and V. K. Gupta, "Rice husk and its adsorbents: The study of sorption of radionuclides and dyes," *Chem. Eng. J.*, vol. 172, no. 2, pp. 1057–1081, 2011.

[3] S. Zhu et al., "Adsorption of methylene blue from aqueous solution by NaOH-modified rice husk," *J. Chem. Eng. Data*, vol. 54, no. 12, pp. 3146–3151, 2009.

[4] M. K. Dahri et al., "Adsorption of methylene blue from aqueous solution by rice husk: Review," *J. Environ. Chem. Eng.*, vol. 2, no. 2, pp. 711–719, 2014.

[5] P. Sharma et al., "Biosorption of heavy metals from aqueous solutions using rice husk," *Crit. Rev. Environ. Sci. Technol.*, vol. 41, no. 11, pp. 941–978, 2011.

[6] M. Rafatullah et al., "Adsorption of methylene blue on low-cost adsorbents: A review," *J. Hazard. Mater.*, vol. 177, no. 1-3, pp. 70–80, 2010.

[7] M. T. Yagub et al., "Dye and its removal from aqueous solution by adsorption: A review," *Adv. Colloid Interface Sci.*, vol. 209, pp. 172–184, 2014.

[8] T. Robinson et al., "Remediation of dyes from effluents: a critical review on current treatment technologies," *Bioresour. Technol.*, vol. 77, no. 3, pp. 247–255, 2001.

[9] L. B. L. Lim et al., "Adsorption of methylene blue from aqueous solution by NaOH-treated rice husk," *RSC Adv.*, vol. 2, no. 3, pp. 1264–1272, 2012.

[10] M. A. Salleh et al., "Cationic and anionic dye adsorption by agricultural solid wastes: A comprehensive review," *Desalination*, vol. 280, no. 1-3, pp. 1–13, 2011.

[11] V. K. Garg et al., "Removal of dyes from aqueous solution by adsorption on agricultural waste: batch studies," *Bioresour. Technol.*, vol. 89, no. 3, pp. 233–241, 2003.

[12] M. J. Ahmed and S. K. Theydan, "Physical and chemical characteristics of agricultural waste-based adsorbents," *J. Environ. Chem. Eng.*, vol. 1, no. 4, pp. 1100–1109, 2013.

[13] K. G. Akpomie et al., "Moisture content and yield efficiency in biomass processing for biosorption," *J. Appl. Sci. Environ. Manage.*, vol. 19, no. 3, pp. 421–430, 2015.

[14] S. Zhu et al., "Comparative study of commercial activated carbon and modified biomass," *J. Chem. Eng. Data*, vol. 54, no. 12, pp. 3146–3151, 2009.

[15] M. Rafatullah et al., "Adsorption of methylene blue on low-cost adsorbents: A review," *J. Hazard. Mater.*, vol. 177, no. 1-3, pp. 70–80, 2010.

[16] Y. S. Ho and G. McKay, "Pseudo-second order model for sorption processes," *Process Biochem.*, vol. 34, no. 5, pp. 451–465, 1999.

[17] A. Setiawan et al., "Factors affecting the adsorption of dyes using agricultural waste," *Journal of Materials Engineering*, 2024.

[18] N. Feng et al., "De-lignification of rice husk using NaOH for improved biosorption," *J. Hazard. Mater.*, vol. 185, no. 2-3, pp. 1616–1623, 2011.