Science Education and Application Journal (SEAJ)
Natural Science Education Study Program
Universitas Islam Lamongan
http://jurnalpendidikan.unisla.ac.id/index.php/SEAJ

September, 2026. Vol. 8, No. 2,
p-ISSN: 2656-6672
e-ISSN: 2656-8365
pp.170-179

Rice Husk–Sugarcane Bagasse-Derived Silica for Methylene Blue Removal in a Fixed-Bed Column: Synthesis and Characterization

[1*]Linda Ekawati, [2]Syariful Maliki, [3]Dwi Indah Lestari, [4]Aulia Chunissya Salsabila, [5]Eci Septiani
[1,3,4,5]Department of Industrial Chemical Technology, Chemical Engineering, Politeknik Negeri Sriwijaya. Jl. Srijaya Negara, Bukit Besar District, Palembang, South Sumatra 30139, Indonesia.
[2]Department of Chemical Engineering, Politeknik Negeri Sriwijaya. Jl. Srijaya Negara, Bukit Besar District, Palembang, South Sumatra 30139, Indonesia.
**Email Correspondence: linda.ekawati@polsri.ac.id*

Article Info
Article History
Received: September 7th, 2026
Revised: September 29th, 2026
Accepted: September 29th, 2026
Published: September 30th, 2026
Keywords
Adsorption, Biomass waste, Fixed-bed column, Methylene blue, Silica

Abstract
Methylene blue is a persistent dye that can impair light penetration and aquatic photosynthesis, while its chemical stability complicates conventional wastewater treatment. This study developed silica from a 3:1 mixture of rice husk and sugarcane bagasse, enabling the simultaneous valorization of two abundant agricultural residues, and evaluated its performance in a fixed-bed column. We subjected the mixed ash to alkaline extraction and acid precipitation, then characterized it by FTIR, XRD, SEM, and EDX. The product contained characteristic silanol and siloxane groups, exhibited an amorphous structure with a broad XRD peak at 2θ = 22.6°, and showed a rough, agglomerated nanoscale morphology that may provide accessible adsorption sites. At an initial methylene blue concentration of 23.846 mg L^{-1} and a flow rate of 60 mL min^{-1}, the residual concentration decreased to 0.192 mg L^{-1} after 80 min, corresponding to 99.19% removal. Removal reached 99.52% after 200 min, indicating promising performance under the tested conditions.

Citations: Ekawati, L., Maliki, S., Lestari, D. I., Salsabila, A. C., & Septiani, E. (2026). Rice husk–sugarcane bagasse-derived silica for methylene blue removal in a fixed-bed column: Synthesis and characterization. Science Education and Application Journal (SEAJ), 8(2), 170–179.

INTRODUCTION

Methylene blue (MB) is a chemically stable synthetic dye widely used in the textile, paper, and printing industries. Approximately 0.8 million tonnes of synthetic dyes are produced annually, of which an estimated 10–15% may enter aquatic environments through industrial effluents (Yadav et al., 2024). Its presence in aquatic environments can inhibit light penetration, interfere with photosynthesis in aquatic organisms, and potentially cause toxic effects on the environment (Khan et al., 2022; Liang et al., 2024). These environmental concerns, combined with MB's resistance to natural degradation, highlight the need for an effective and economically feasible wastewater-treatment method. Among the available approaches, adsorption is attractive because of its simple operation, high removal efficiency, relatively low energy requirement, and compatibility with continuous fixed-bed systems. Fixed-bed adsorption enables continuous contact between wastewater and the adsorbent and is more applicable to continuous treatment than conventional batch operation. However, the relatively high cost of commercial adsorbents and the challenges associated with their regeneration and disposal have encouraged the development of inexpensive and renewable adsorbents derived from biomass waste (Nurmutaaqimah et al., 2025).

The development of biomass-based adsorbents has emerged as an attractive alternative because it utilizes abundant and low-value waste materials. Rice husk is known to have considerable potential both as an adsorbent and as a silica source due to the high SiO_2 content of rice husk ash (Nurfitria et al., 2019). Previous studies have demonstrated that rice husk can adsorb MB, with an adsorption capacity of up to 38 mg/g reported in a batch system (Sukmana et al., 2025). In a separate study, torrefied rice husk applied in a fixed-bed column exhibited an adsorption capacity of approximately 2.76 mg/g and a removal efficiency of 52%(Hummadi et al., 2022). Therefore, the adsorption performance of silica derived from combined rice husk and sugarcane bagasse remains to be established in fixed-bed systems, particularly in terms of adsorption capacity, breakthrough behavior, bed saturation time, and stability under continuous flow.

Silica is a promising material for use as an adsorbent because of its porous structure, high surface area, and the presence of silanol (Si–OH) groups that can act as active adsorption sites. Silica can also be recovered from biomass waste through a relatively simple alkaline extraction process (Widyastuti & Panggabean, 2021). Studies have demonstrated that silica extracted from rice husk has considerable potential for methylene blue (MB) adsorption because of its surface characteristics and available adsorption sites (Lee et al., 2025). Although nanoparticle-modified silica exhibits high adsorption efficiency, silica derived from rice husk and sugarcane bagasse provides an alternative based on agricultural-waste valorization without requiring additional nanoparticle modification. (Hussein & Rasheed, 2025).

Rice husk and sugarcane bagasse are established silica-rich biomass residues, supporting their combined utilization as raw materials for producing a mixed-biomass adsorbent for MB removal. A study on hybrid adsorbents derived from jengkol peel and coconut shell activated using NaOH revealed the formation of a honeycomb-like surface morphology with various pore sizes and demonstrated Cu(II) removal efficiencies of up to 95% (Lestari et al., 2026). Furthermore, a calcium alginate–activated carbon composite was reported to remove up to 95.28% of methylene blue after 110 min, indicating the potential of integrating carbonaceous materials with supporting matrices in adsorbent development (Wardana Putra et al., 2024). In this study, the surface functional groups and particle morphology of the synthesized silica were investigated because silanol groups and accessible particle surfaces may provide adsorption sites for MB removal in the fixed-bed column (Yang et al., 2025).

Based on the aforementioned considerations, this study aims to synthesize and characterize a silica composite derived from a mixture of rice husk and sugarcane bagasse for the adsorption of MB in a fixed-bed column system. The study focuses on the physicochemical characterization of the adsorbent and the evaluation of its adsorption performance under continuous-flow conditions. This approach may contribute to biomass-waste valorization and provide a potential silica-based adsorbent for dye-contaminated wastewater treatment.

METHODS

Preparation of Mixed-Biomass Silica

Rice husk and sugarcane bagasse were separately dried at 105 °C and carbonized at 700 °C for 4 h. The resulting ashes were ground and sieved through a 200-mesh sieve. After carbonization, rice husk ash and sugarcane bagasse ash were mixed at a ratio of 3:1 (w/w), corresponding to 15 g of rice husk ash and 5 g of sugarcane bagasse ash. The resulting 20 g mixed-ash sample was extracted with 120 mL of 2.5 M NaOH at 85 °C for 90 min.

Application of Mixed-Biomass Silica as an Adsorbent

Methylene blue adsorption using silica as the adsorbent was carried out in a fixed-bed column system. In this study, 1 g of adsorbent was used, and the adsorption process was conducted at a

flow rate of 60 mL/min. A 20 ppm methylene blue solution was analyzed at adsorption times of 0, 40, 80, 120, 160, and 200 min. The methylene blue concentration after adsorption was determined using a UV spectrophotometer.

Characterization of the Mixed-Biomass Silica Adsorbent

The synthesized adsorbent was characterized using Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and X-Ray Diffraction (XRD). FTIR analysis was performed to identify the functional groups and chemical bonds present on the adsorbent surface in the wavenumber range of 4000–400 cm^{-1} using the KBr pellet method for sample preparation. SEM characterization was used to examine the morphology and surface structure of the adsorbent. The samples were sputter-coated with a thin layer of gold to minimize the charging effects, and the observations were conducted at an accelerating voltage of 15 kV, while XRD analysis was conducted over a 2θ range of 5–85° to determine the structural characteristics and crystallinity of the synthesized silica.

RESULTS AND DISCUSSION

Synthesis and Characterization of the Adsorbent

Silica synthesized from rice husk and sugarcane bagasse exhibited characteristics indicating successful recovery of silica from the biomass waste. The EDX analysis confirmed the presence of silicon (Si) and oxygen (O) as the major elements in the synthesized material, demonstrating that the obtained solid was predominantly composed of silica. In this study, silica was obtained from biomass waste, namely rice husk and sugarcane bagasse, using a precipitation method (Sania et al., 2026). The precipitation process is based on the solubility of silica under alkaline conditions, followed by precipitation under acidic conditions. Silica contained in the biomass was reacted with NaOH to produce sodium silicate (equation 1). The sodium silicate solution obtained after filtration was subsequently precipitated using H_2SO_4 to form silica (equation 2) (Sarma et al., 2024). The precipitation method was selected because it is capable of producing silica with a high degree of purity (Kumalasari et al., 2024).

$$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O \quad (1)$$

$$Na_2SiO_3 + H_2SO_4 \rightarrow SiO_2 + Na_2SO_4 + H_2O \quad (2)$$

The synthesized silica was characterized using FTIR, SEM, and XRD to determine its functional groups, surface morphology, and crystalline structure. The characterization results were used to evaluate the material properties and confirm the successful formation of silica from the mixture of rice husk and sugarcane bagasse.

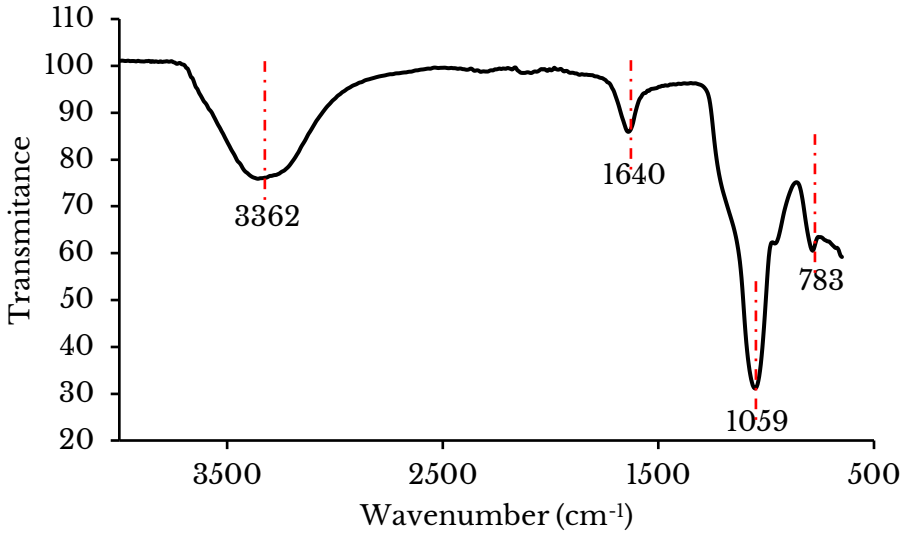

Figure 1. FTIR Spectrum of Silica

Based on the FTIR spectrum shown in Figure 1 and Table 1, the synthesized silica exhibited an absorption band at 3362 cm^{-1}, which is associated with O–H stretching vibrations of silanol (Si–OH) groups (Nurdin et al., 2023; Tritean et al., 2024). Meanwhile, the band at 1640 cm^{-1} corresponds to the bending vibration of O–H from H_2O molecules that remained adsorbed on the silica surface (Sarma et al., 2024). The strong band at 1059 cm^{-1} was attributed to the asymmetric stretching vibration of Si–O–Si, which is a major characteristic of the siloxane structure, while the band at 783 cm^{-1} was associated with Si–O–Si vibrations (Anisara et al., 2024). These absorption features indicate the presence of characteristic siloxane (Si–O–Si) and silanol (Si–OH) functional groups in the synthesized material. The FTIR characterization data were supported by XRD, SEM, and EDX data.

Table 1. FTIR Spectral Analysis of Silica

Wavenumber (cm^{-1})	Vibration types	Functional Groups
3362	O–H Stretch	Si–OH (silanol)
1640	H–O–H Bend	Molecule H_2O
1059	Si–O–Si Asymmetric stretching	Si–O–Si (siloxane)
783	Si–O–Si Asymmetric stretching	Si–O–Si (siloxane)

These results are consistent with recent studies reporting bands at approximately 1070–1100 cm^{-1} as asymmetric Si–O–Si stretching vibrations and bands in the range of 795–972 cm^{-1} as Si–O–Si vibrations in rice husk-derived silica (Rashad et al., 2025). These findings are also in agreement with Habte et al. (2025), who identified bands at approximately 1094 cm^{-1}, 796.5 cm^{-1}, and 3401 cm^{-1} as characteristic of Si–O–Si and Si–OH groups in silica synthesized from sugarcane bagasse.

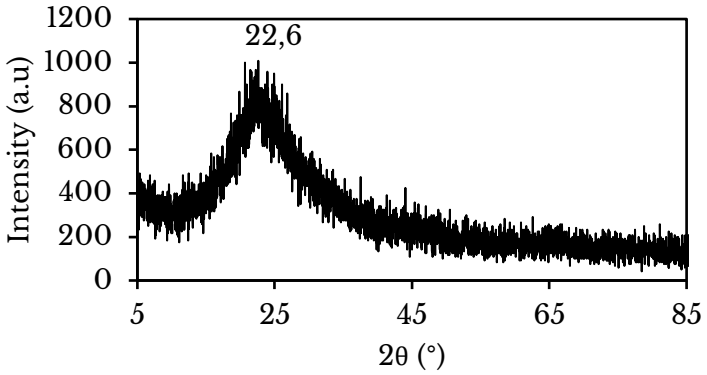

Figure 2. XRD Diffractogram of the Silica Adsorbent

The XRD diffractogram in Figure 2 shows a broad diffraction pattern with a main peak at 2θ = 22.6°. The presence of a broad diffraction peak without distinct sharp diffraction peaks indicates that the synthesized silica possesses an amorphous structure with a low degree of crystallinity. This structural characteristic is relevant to the adsorption application because the disordered silica network can provide accessible surface sites for interactions with methylene blue molecules. Thus, the amorphous structure may support the adsorption performance of the synthesized silica, although the contribution of surface area, pore characteristics, and surface chemistry should also be considered when interpreting its adsorption behavior. Silica synthesized from sugarcane bagasse has been reported to exhibit a broad XRD peak at approximately 2θ = 22.4°, indicating its amorphous nature (Habte et al., 2025). A similar pattern was observed in a silica-based catalyst, which showed a broad peak at approximately 2θ = 22.8°, confirming the amorphous nature of the silica support (Arora et al., 2025). In addition, rice husk-derived bio-silica was reported to exhibit a broad peak at 2θ = 22.77°, which is also characteristic of amorphous silica (Ngabirano et al., 2026).

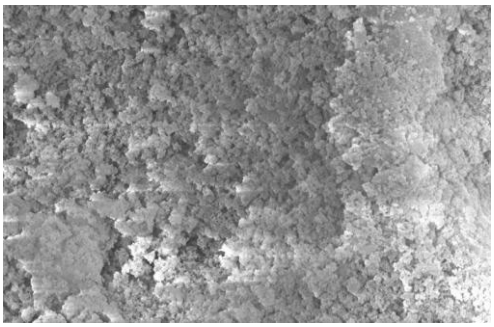

Figure 3. SEM Image of the Silica Adsorbent

The SEM image in Figure 3 shows that the silica exhibits a spherical morphology. A spherical morphology has also been reported for silica nanoparticles synthesized from rice husk ash using the sol–gel method (Alhadhrami et al., 2022). However, the particle size distribution appears relatively non-uniform, and the surface is comparatively rough. A similar non-uniform morphology and tendency toward agglomeration have also been observed in rice husk-derived biosilica, where silica nanoparticles were reported to cluster and form agglomerates (Shareef Radha et al., 2026). The rough surface and nanoscale particle characteristics may provide a larger surface area and more active sites, thereby supporting the potential application of silica as an adsorbent (Hussein & Rasheed, 2025).

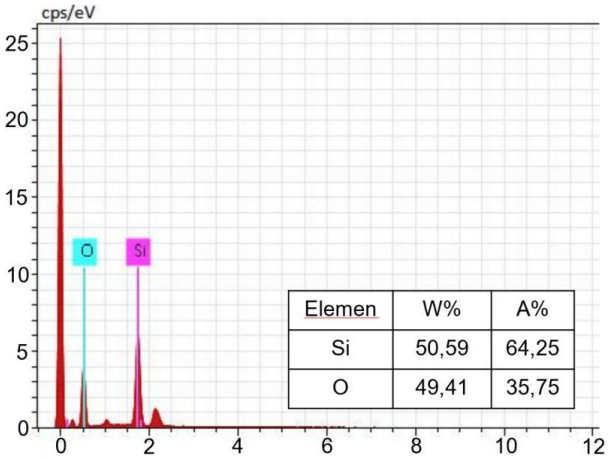

Figure 4. EDX Spectrum of the Silica Adsorbent

Meanwhile, the EDX results shown in Figure 4 indicate that Si and O are the dominant elements, suggesting that the obtained product is primarily composed of SiO_2. The presence of minor elements is likely associated with residual materials from the synthesis process or with the coating material used during sample preparation for SEM-EDX analysis. This finding is consistent with Hussein and Rasheed (2025), who also reported Si and O as the major elements in silica-based materials, while minor elements such as C and Au may appear as a result of sample preparation or contamination during analysis. Therefore, the EDX results further confirm that the synthesized material is predominantly silica with Si and O as its main components.

Adsorption Performance of the Mixed-Biomass Silica Adsorbent

The obtained silica was used as an adsorbent for methylene blue dye, and its adsorption performance was evaluated using a fixed-bed column system. In this study, 1 g of silica was used, corresponding to an adsorbent bed height of 3 cm in the column. The adsorption time was varied to evaluate the ability of silica to adsorb methylene blue under continuous column conditions. The adsorption experiments were conducted at contact times of 40, 80, 120, 160, and 200 min. The initial methylene blue concentration was 23,846 ppm. The methylene blue concentrations after adsorption are presented in Table 2 and Figure 6.

Table 2. Adsorption Data of Methylene Blue Using Mixed-Biomass Silica

Time (minute)	C_0 (ppm)	C_t(ppm)	C_t/C_0	qt (mg/g)	Adsorption efficiency (%)
0	23,846	23,846	1	0	0
40	23,846	1,262	0,05229	27,10	99.71
80	23,846	0,192	0,00806	82,59	99.19
120	23,846	0,146	0,00613	139,41	99.39
160	23,846	0,123	0,00516	196,32	99.48
200	23,846	0,115	0,00484	253,26	99.52

The cumulative adsorption capacity is determined using the following formula

$$q_t = \frac{Q \times A_{comulative}}{1000 \times m}$$

q_t = cumulative adsorption capacity (mg/g)
Q = flow rate (mL/min)
$A_{comulative}$ = Cumulative area under the adsorption curve
m = Mass of adsorbent
C_0 = Initial concentration
C_t = Concentration after adsorption

Based on Table 2, methylene blue adsorption increased rapidly during the first 0–80 min because a large number of active sites were still available and the concentration gradient between the solution and the adsorbent surface remained high, thereby promoting faster mass transfer and adsorbate diffusion (Matharage et al., 2025). A similar trend has been reported in various methylene blue adsorption studies, where adsorption increased rapidly during the initial stage before approaching equilibrium conditions (Maranggi et al., 2026). After 80 min, the decrease in the methylene blue (MB) concentration in the column effluent became less pronounced. The residual MB concentration decreased from 1.262 ppm at 40 min to 0.192 ppm at 80 min, corresponding to an increase in removal efficiency from 94.71% to 99.19%. Subsequently, the effluent concentration changed only slightly, reaching 0.115 ppm at 200 min, with a removal efficiency of 99.52%. This trend indicates that the column maintained a high MB removal performance throughout the investigated period. The relatively small changes in effluent concentration after 80 min may suggest that the mass-transfer zone had not yet reached the column outlet and that a substantial portion of the adsorbent bed remained effective for MB removal. However, this interpretation should be regarded as a proposed explanation because the present data do not directly demonstrate the distribution or movement of the mass-transfer zone. Under these conditions, extending the contact time no longer resulted in a significant increase in adsorption (Khushnood et al., 2024).

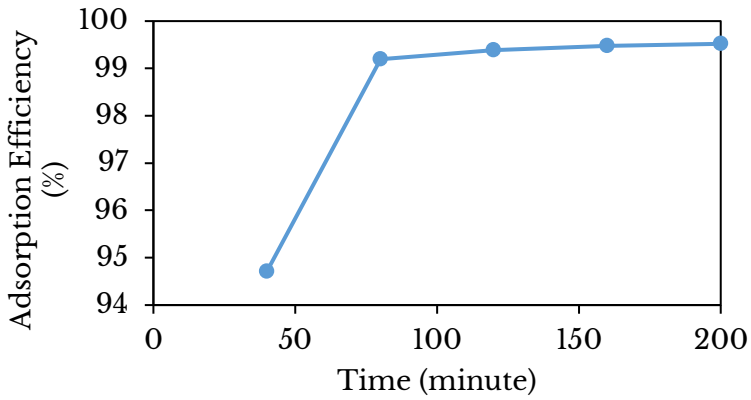

Figure 5. Methylene Blue Adsorption Efficiency Using Silica

The trend shown in Figure 5 illustrates the ability of silica to adsorb methylene blue at different adsorption times. The results indicate that the silica adsorbent exhibited excellent adsorption performance, achieving a methylene blue removal efficiency of 99.71% within 80 min. Adsorption beyond 80 min did not result in a significant increase in removal efficiency, indicating that the selected operating time was close to the optimum adsorption time. The cumulative adsorption capacity (qt) increased continuously from 27.10 mg/g at 40 min to 253.26 mg/g at 200 min. This increase is characteristic of a fixed-bed column, where qt represents the cumulative amount of methylene blue adsorbed per unit mass of adsorbent as the solution continuously passes through the column. The relatively consistent increase in qt after 80 min indicates that the adsorbent continued to retain methylene blue during the operating period. This behavior was supported by the low effluent concentration (0.115–1.262 ppm) and high adsorption efficiency (99.19–99.71%). Since breakthrough was not observed up to 200 min, the value of 253.26 mg/g should be considered the cumulative adsorption capacity at the end of the experimental period, rather than the maximum adsorption capacity of the adsorbent.

CONCLUSION

The silica synthesized from rice husk and sugarcane bagasse exhibited structural and surface characteristics consistent with its application as an adsorbent for methylene blue. In a fixed-bed column, the mixed-biomass silica achieved high methylene blue removal, with the residual concentration decreasing rapidly during the first 80 min and removal efficiency remaining above 99% up to 200 min. The cumulative adsorption capacity increased from 27.10 mg/g at 40 min to 253.26 mg/g at 200 min, representing the cumulative capacity under the investigated column conditions rather than the maximum adsorption capacity. This study contributes to biomass-derived silica research by demonstrating the use of a combined rice husk–sugarcane bagasse feedstock and evaluating the resulting silica under fixed-bed column conditions. However, the findings are limited to the operating conditions examined in this study and require further validation under broader column conditions before implications for practical or large-scale wastewater treatment can be established.

ACKNOWLWDGMENT

The authors would like to express their sincere gratitude to the Politeknik Negeri Sriwijaya for providing financial support through the PNBP Penelitian-Kerjasama Dosen dan Mahasiswa, under Contract No. 5337/PL6.2.1/LT/2026. The authors also gratefully acknowledge the support and contributions of all parties who assisted in the implementation of this research.

REFERENCES

Alhadhrami, A., Mohamed, G. G., Sadek, A. H., Ismail, S. H., Ebnalwaled, A. A., & Almalki, A. S. A. (2022). Behavior of Silica Nanoparticles Synthesized from Rice Husk Ash by the Sol–Gel Method as a Photocatalytic and Antibacterial Agent. *Materials*, *15*(22). https://doi.org/10.3390/ma15228211

Anisara, R., P.K.W., G. A., & Taufiq, A. (2024). Silica Gel From Bagasse Ash for Methylene Blue Adsorption. *14*, 142–153. https://doi.org/https://doi.org/10.31938/jsn.v%2014i3.738

Arora, S., Sitanshu, Katoch, G., & Santhosh, A. J. (2025). Efficient biomass valorization using silica-supported imidazolium-based ionic liquid catalysts. *Scientific Reports*, *15*(1), 1–13. https://doi.org/10.1038/s41598-025-17712-9

Habte, G. A., Bullo, T. A., & Ahmed, Y. (2025). Statistical optimization characterizations and eco-friendly synthesis of silica from sugarcane bagasse. *Scientific Reports*, *15*(1), 1–17. https://doi.org/10.1038/s41598-025-89366-6

Hummadi, K. K., Luo, S., & He, S. (2022). Adsorption of methylene blue dye from the aqueous solution via bio-adsorption in the inverse fluidized-bed adsorption column using the torrefied rice husk. *Chemosphere*, *287*(P1), 131907. https://doi.org/10.1016/j.chemosphere.2021.131907

Hussein, E. B., & Rasheed, F. A. (2025). Sustainable removal of methylene blue from wastewater using silica sand coated with Al2O3nanoparticles: a comparative study of batch and fixed bed column reactors. *RSC Advances*, *15*(59), 50829–50843. https://doi.org/10.1039/d5ra07804k

Khan, I., Saeed, K., Zekker, I., Zhang, B., Hendi, A. H., Ahmad, A., Ahmad, S., Zada, N., Ahmad, H., Shah, L. A., Shah, T., & Khan, I. (2022). Review on Methylene Blue: Its Properties, Uses, Toxicity and Photodegradation. *Water*, *14*(2), 1–30. https://doi.org/https://doi.org/10.3390/w14020242

Khushnood, S., Khan, J. R., Hussain, S., Khan, H., Wahab, F., Ng, K. C., & Shahzad, M. W. (2024). Synthesis and characterization of mesoporous caged silica for efficient adsorption of methylene blue from aqueous solution. *International Communications in Heat and Mass Transfer*, *156*. https://doi.org/10.1016/j.icheatmasstransfer.2024.107706

Kumalasari, M. R., Beladona, S. U. M., Gracia, A. N., Sugiyani, T., Wulandari, O. R., Imelya,

M., Syaima, H., & Hanif, Q. A. (2024). Rice Husk Ash: A Promising Heavy Metal Adsorbent For Wastewater Treatment. *Walisongo Journal of Chemistry*, *7*(1), 26–36. https://doi.org/10.21580/wjc.v7i1.18852

Lee, Y.-J., Lee, J.-M., Park, J.-W., Wang, J., Wang, M., Seo, D.-C., & Park, J.-H. (2025). Zero waste realization method of rice husk: Silica extraction and methylene blue adsorption. *Sustainable Chemistry and Pharmacy*, *48*, 102211. https://doi.org/10.1016/j.scp.2025.102211

Lestari, D. I., Ekawati, L., Maliki, S., Putri, Z. P., & Maranggi, I. U. (2026). *Fixed-Bed Column Performance of NaOH-Activated Hybrid Adsorbent Derived from Jengkol Peels and Coconut Shells for Cu (II) Removal*. *8*(1), 23–33.

Liang, P., Yang, W., Peng, H., & Zhao, S. (2024). Efficient Degradation of Methylene Blue in Industrial Wastewater and High Cycling Stability of Nano ZnO. *Molecules*, *29*(23). https://doi.org/10.3390/molecules29235584

Maranggi, I. U., Maliki, S., Ekawati, L., Lestari, D. I., & Putri, Z. P. (2026). Utilization of Coconut Shell Activated Carbon as an Eco-Friendly Adsorbent for Cu(II) Remediation in a Continuous Column System. *Indonesian Journal of Chemical Science and Technology*, *9*(1), 158–167.

Matharage, H., Jayaweera, M., Bandara, N., Manatunge, J., Jayawardana, D., & Dissanayake, J. (2025). Fixed-bed column studies on the adsorption of bisphenol A from aqueous solutions using chemically activated king coconut biochar. *Discover Chemical Engineering*, *5*(1). https://doi.org/10.1007/s43938-025-00082-z

Ngabirano, A., Yiga, V. A., & Lubwama, M. (2026). Synthesis and characterization of mesoporous bio-silica nanoparticles developed from rice husks for oil spillage remediation. *Results in Engineering*, *29*(January), 109369. https://doi.org/10.1016/j.rineng.2026.109369

Nurdin, N. A., Syarif, T., & Nurjannah, N. (2023). SINTESIS SILIKA GEL DARI LIMBAH SEKAM PADI (Oryza sativa) DENGAN VARIASI KONSENTRASI JENIS ASAM. *Journal of Scientech Research and Development*, *5*(1 SE-Articles). https://doi.org/10.56670/jsrd.v5i1.169

Nurfitria, N., Febriyantiningrum, K., Utomo, W. P., Nugraheni, Z. V., Pangastuti, D. D., Maulida, H., & Ariyanti, F. N. (2019). Pengaruh Konsentrasi Aktivator Kalium Hidroksida (KOH) pada Karbon Aktif dan Waktu Kontak terhadap Daya Adsorpsi Logam Pb dalam Sampel Air Kawasan Mangrove Wonorejo, Surabaya. *Akta Kimia Indonesia*, *4*(1), 75. https://doi.org/10.12962/j25493736.v4i1.5071

Nurmutaaqimah, Siti Jamilatun, & Aster Rahayu. (2025). Effect of NaOH Concentration on Surface Width and Pore Volume of Silica Gel From Beef Shrain as Adsorbent. *Sains Natural: Journal of Biology and Chemistry*, *15*(2), 102–109. https://doi.org/10.31938/jsn.v15i2.814

Sania, R., Meidinariasty, A., & Ramayanti, C. (2026). *Ekstraksi Silika Gel dari Ampas Tebu dan Sekam Padi dengan Variasi Konsentrasi NaOH dan Rasio Bahan Baku*. *XI*(1), 16333–16339.

Sarma, J., Rajkhowa, S., & Das, S. (2024). Synthesis of White Silica From "Joha Rice Husk" (A Special Rice Variety of Assam, India), Characterization and Determination of Its Point of Zero Charge (pHPZC). *Journal of Chemistry*, *2024*(1). https://doi.org/10.1155/joch/5542855

Shareef Radha, F. H., Kareem, M. T., & Abdullah, O. G. (2026). Atmosphere-dependent synthesis and crystallization behavior of silica nanoparticles derived from rice husk biomass. *RSC Advances*, *16*(19), 16874–16886. https://doi.org/10.1039/d6ra00367b

Sukmana, H., Radojčin, M., Gyulavári, T., Kozma, G., Kónya, Z., & Hodúr, C. (2025). Utilization of rice husks as effective bioadsorbents for methylene blue removal from

wastewater: characterization, adsorption performance, and regeneration studies. *Applied Water Science*, *15*(7). https://doi.org/10.1007/s13201-025-02511-4

Tritean, N., Trică, B., Dima, Ş. O., Capră, L., Gabor, R. A., Cimpean, A., Oancea, F., & Constantinescu-Aruxandei, D. (2024). Mechanistic insights into the plant biostimulant activity of a novel formulation based on rice husk nanobiosilica embedded in a seed coating alginate film. *Frontiers in Plant Science*, *15*(May), 1–28. https://doi.org/10.3389/fpls.2024.1349573

Wardana Putra, A., Hermawan, H., Setyaningrum, S., & Paramitha, T. (2024). The Methylene Blue Adsorption by Calcium Alginate-Activated Carbon Composite in a Fixed-Bed Column. *Fluida*, *17*(2), 65–70. https://doi.org/10.35313/fluida.v17i2.4926

Widyastuti, H., & Panggabean, A. S. (2021). Sintesis Silika Gel Dari Abu Sekam Padi Termodifikasi Kitosan Serta. *Kimia FMIPA UNMUL*, 63–65.

Yadav, M., Singh, N., Annu, Khan, S. A., Raorane, C. J., & Shin, D. K. (2024). Recent Advances in Utilizing Lignocellulosic Biomass Materials as Adsorbents for Textile Dye Removal: A Comprehensive Review. *Polymers*, *16*(17). https://doi.org/10.3390/polym16172417

Yang, M., Yue, Q., & He, J. (2025). Evaluation of mesoporous silica synthesized for green adsorption by modeling via machine learning and mass transfer. *Scientific Reports*, *15*(1), 1–13. https://doi.org/10.1038/s41598-025-04324-6