P-ISSN : 2598-1277
E-ISSN : 2621-3966

JOURNAL OF GREEN SCIENCE AND TECHNOLOGY

CHARACTERIZATION OF COFFEE BUSINESS WASTE IN THE FORM OF ROBUSTA COFFEE DREGS AS ADSORBENT: A PRELIMINARY STUDY

Bambang Soeswanto[1], Alfiana Adhitasari[1], Yusmardhany Yusuf[2], Alifhah Ananda Putri[1], Khalaida Fania Fatah[1], Shintiya Clarisa[1], Sinna Chaerunnabila Gunawan[1], Unung Leoanggraini[1] , Emma Hermawati Muhari[1], Dianty Rosirda Dewi Kurnia[1], Rony Pasonang Sihombing[1*]

[1]) Chemical Engineering Departement, Politeknik Negeri Bandung, Bandung.*
Corresponding Author's Email: rony.pasonang.sihombing@polban.ac.id
No. HP Corresponding Author: 085399998087
[2]) Universitas Pembangunan Nasional Veteran Yogyakarta.

ABSTRACT

Robusta coffee grounds are widely produced in several types of businesses, one of which is the coffee industry (coffee shop). This pulp can be reused by business people by being used as an adsorbent and paired with the industrial waste. The purpose of this research is to identify the carbon of Robusta coffee grounds between before and after chemical activation. The methods used were sieving, drying at 25°C to 110°C, carbonization at 600°C, immersion in 0.1M HCl solution. Carbonization of Robusta coffee grounds was carried out using BET, FTIR and SEM. The results showed an increase in carbon surface area from 0.588 m^2/g to 14.609 m^2/g. The results of the FTIR method showed a change in functional groups on several peaks between pre- and post-activation conditions. The results of the SEM method showed an increase in pore size from 5.5 µm (before activation) to 11 µm (after activation).

Keywords: Robusta coffee, Coffee grounds, FTIR, Adsorbent

1. INTRODUCTION

Robusta coffee is one type of coffee that is very abundant in Indonesia. The total area of coffee plantations in Indonesia reaches 1.3 million hectares with Robusta coffee land share at 1 million hectares [1]. One of the priorities in agricultural development in Indonesia is coffee development. The development of coffee nationally will have a positive impact on the economy of the community [2], [3]One of those affected by coffee development is coffee shops, which are currently growing in many regions [4], [5], [6] .

The adsorption process occurs when fluid molecules from a liquid or gas state stick to the exterior of a solid surface. Adsorption offers multiple benefits because it removes organic materials through its simpler process which proves to be more cost-effective compared to alternative methods and it avoids toxic side effects. The adsorbent represents the adsorbing phase while the adsorbate stands for the adsorbed phase [7], [8] . The adsorption process requires consideration of the solid adsorbent type and the adsorbate molecule type in addition to concentration and temperature factors [9], [10] .

Coffee ground-derived activated carbon demonstrates substantial adsorbent potential especially when chemically activated. The BET method-based pore characterization studies show that this process results in a significant specific surface area increase. The activation of carbon surfaces through acidic solutions like HCl is essential for eliminating non-carbon substances and developing active functional groups such as carbonyl (-C=O), hydroxyl (-OH), and ester (-COO-) groups. Functional groups presence enhances adsorbate-adsorbent interactions which leads to better adsorption capacity for multiple

P-ISSN : 2598-1277
E-ISSN : 2621-3966

pollutants or target substances[11]. FTIR analysis results demonstrate altered spectral peaks that reflect chemical transformations on the carbon surface which boost its adsorptive capabilities[12].

In addition to increasing the number of active functional groups, activation also induces significant structural changes in the pores of activated carbon. SEM characterization results indicate that pore size after activation more than doubles compared to pre-activation conditions [10]. This enlargement allows more adsorbate molecules to interact with the activated carbon surface, directly enhancing adsorption capacity. Other studies have also reported that the specific surface area of activated carbon derived from biomass waste can increase several times after the activation process, with varying effects depending on the type of activator used [4], [13]. This increase in surface contact area is one of the primary objectives in the development of carbon-based adsorbents, particularly for applications in water purification, heavy metal removal, and hazardous gas adsorption [3]. Thus, optimizing the activation of coffee grounds as a carbon source can be an effective strategy in developing high-performance adsorbent materials.

2. RESEARCH METHOD

The raw materials used in the manufacture of adsorbents include robusta coffee grounds, distilled water, 0.1M hydrochloric acid solution. The coffee grounds were washed using distilled water to remove impurities and then dried naturally in the sun for 24 hours. The next step was heating in an oven at 105-110°C. The dried coffee grounds are then carbonized for 90 minutes at 600°C, then after becoming carbon, the coffee grounds carbon is cooled at 25°C. The next process is sieving at 60 mesh size. The carbon activation process was carried out using a 0.1M HCl solution at a carbon:HCL 0.1M ratio of 1:3 and soaked for 48 hours. The coffee grounds carbon was then filtered and washed with distilled water until the pH was neutral and dried using an oven at 105-110°C for 30 minutes. After that, the coffee grounds carbon is ready to be characterized. The tools used in this research include furnace, sizing, oven, desiccator, FTIR tool and SEM tool.

3. RESULTS AND DISCUSSION

3.1. Characteristics Adsorben Dengan BET (Brunauer Emmett Teller)

BET testing is done to determine the surface area of a sample. Surface area is an important parameter because it can affect the adsorption capacity. The BET characteristic results are shown in Table 1. This shows that the activation process on both adorbents is effective in improving the pore structure that can have high adsorption capacity.

Tabel 1. Adsorben BET Result

Coffee Dregs	Surface Area (m^2/g)
Before activation	0.588
After activation	14.609

The BET (Brunauer-Emmett-Teller) method is a fundamental technique for determining the surface area and porosity of adsorbent materials, crucial for understanding their adsorption efficiency. The specific surface area, pore volume, and pore size distribution are key parameters affecting adsorption performance. A larger surface area, as observed in activated carbon derived from robusta coffee grounds (from 0.588 m^2/g to 14.609 m^2/g), significantly enhances the adsorbent's capacity by increasing the number of active sites available for pollutant interaction [14]. The increase in surface area following chemical activation with acids such as HCl is due to the removal of residual organic and inorganic matter, which enhances porosity and accessibility to micropores and mesopores [15]. Studies have shown that acid activation improves the pore structure by eliminating impurities and creating a well-developed porous network, which aligns with findings on other biomass-based adsorbents such as coconut shell carbon and sawdust biochar [16], [17].
Additionally, pore size distribution is critical for adsorption efficiency, influencing the type of molecules that can be adsorbed. Adsorbents with micropores (<2 nm) are effective for gas adsorption, while

P-ISSN : 2598-1277
E-ISSN : 2621-3966

mesoporous (2–50 nm) and macroporous (>50 nm) materials are preferable for liquid-phase adsorption [17]. In the case of robusta coffee ground-derived carbon, the pore size increased from 5.5 µm to 11 µm, suggesting a transition towards a mesoporous structure, making it ideal for wastewater treatment applications, particularly in heavy metal and dye adsorption. This observation is consistent with previous studies on agricultural waste-based activated carbons, where larger pore sizes facilitated higher pollutant uptake. Furthermore, nitrogen adsorption-desorption isotherms confirmed that HCl activation enhances pore connectivity, crucial for achieving high adsorption capacities. Such characteristics make activated coffee waste carbon a sustainable and efficient alternative for industrial adsorption processes.

3.2. FTIR (Fourier Transform Infra-Red) Characterization

The FTIR results of Robusta coffee grounds carbon in the condition before and after activation are shown in Figure 1, Figure 2 and Table 2. The spectrum of Robusta coffee grounds carbon experienced a peak shift to the wavelength from 1566.20 cm-1 (before activation) to 1624.06 cm^{-1} (after activation). The peak of 1566.20 cm^{-1} is associated with the stretching of the aromatic C=C group which indicates medium carbon and 1624.06 cm^{-1} is an aromatic C=C group which indicates high carbon. Vibration of the C=C functional group of lignin compounds occurs at a wavelength of 1500 - 1600 cm^{-1}. This shows that the activation of coffee grounds affects the chemical structure and enriches the aromatic carbon content. The peak of 1145.72 cm^{-1} which shifts to 1161.15 cm^{-1} is the C-O strain which indicates the presence of ester or ether groups, where the content contains carbon. The change in spectra shape (shift) is due to the carbonization and activation process which causes dehydration and decomposition of complex groups into simpler groups [11], [18] .

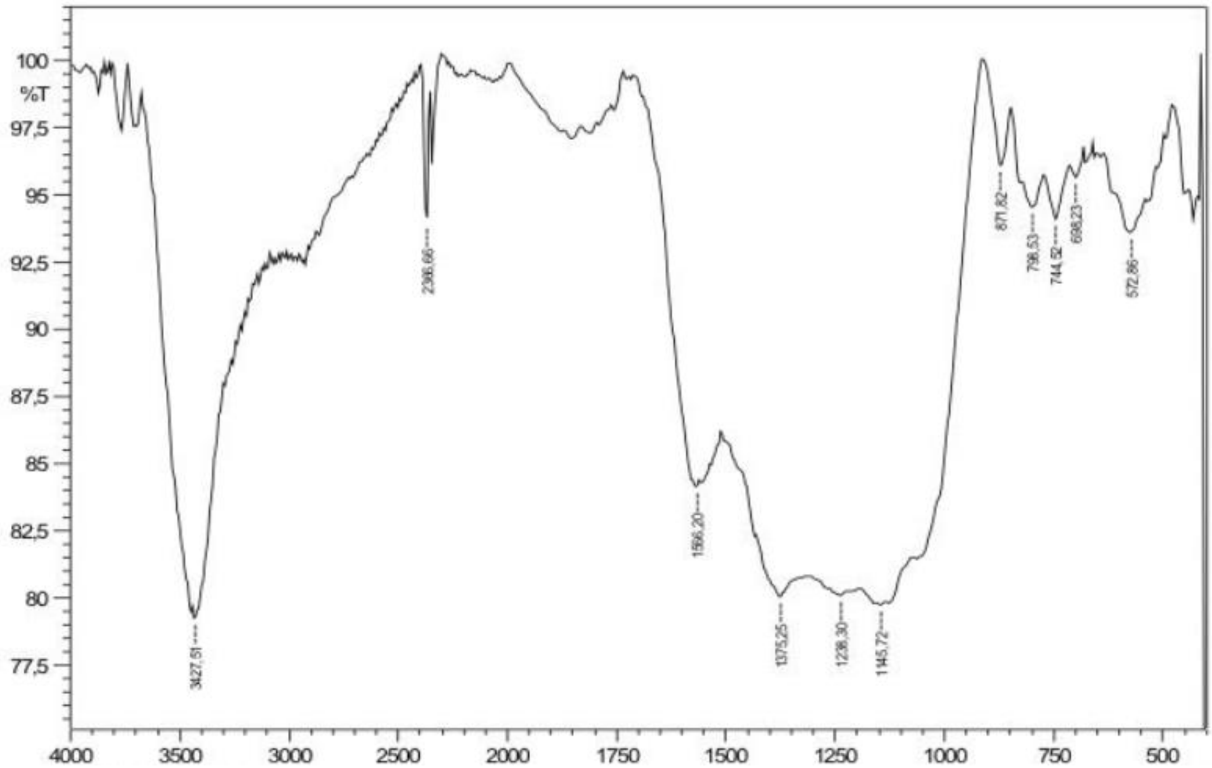

Figure 1. FTIR spectrum of Robusta coffee grounds before activation

P-ISSN : 2598-1277
E-ISSN : 2621-3966

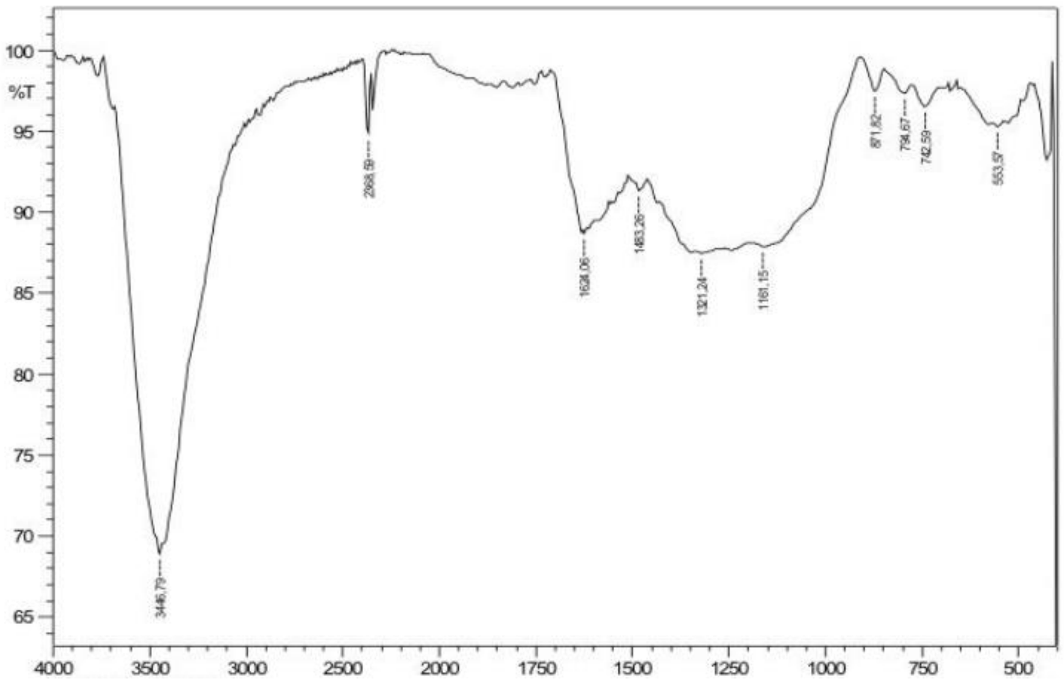

Figure 2. FTIR spectrum of Robusta coffee grounds after activation

Table 2. FTIR Spectrum Results of Robusta Coffee Dreg Carbon

peak	Before activation (cm-1)	after activation (cm-1)	Wavelength (cm-1)	Function Group
A	3427.51	3446.79	3200-3600	O-H
B	2366.66	2368.59	2850-2960	C-H
C	1566.20	1624.06	1500-1600	C=C
D	1375.25	1483.26	1500-1650	C=C
E	1145.72	1161.15	1000-1300	C-O

3.3. SEM (Scanning Electron Microscopy) Characterization

The results of SEM testing on Robusta coffee grounds carbon in conditions before and after activation are shown in Figure 3 and Figure 4. The surface condition of Robusta coffee grounds carbon can be observed at 3000 times magnification. Based on Figure 3 and Figure 4, it can be seen that the pore size of Robusta coffee grounds carbon after activation has more than 2 times the size compared to before activation. Activation using hydrochloric acid solution causes the dissolution of metal oxides on the carbon so that the oxide is lost and results in a wider contact area surface and more porous [19] .

SEM analysis delivers essential insights into how Robusta coffee ground-derived activated carbon morphologically transforms throughout the chemical activation process. The SEM images demonstrate that the material displays a dense and uneven structure featuring few pores before the activation procedure. Residual organic substances and impurities exist and may obstruct the adsorption capabilities. Chemical activation with hydrochloric acid (HCl) causes substantial surface topology changes which boost porosity along with the enhancement of material textural characteristics. The removal of volatile substances combined with the dissolution of inorganic impurities produces an enlargement of pores resulting in a pore size increase from 5.5 µm to 11 µm. Previous research confirms that acid activation removes amorphous carbon deposits to enhance adsorptive site accessibility and surface area expansion. The observed increase in pore connectivity plays a vital role in enhancing adsorption rates that benefit applications like wastewater treatment and gas-phase adsorption processes[20], [21].

The activated carbon exhibits improved adsorption ability because morphological changes create additional active sites for pollutant capture. Multiple studies confirmed that acid treatment enhanced microporous and mesoporous structures when producing activated carbon from agricultural wastes like coconut shells, rice husks, and banana peels [22], [23]. The BET surface area analysis confirmed that enhanced porosity led to a substantial increase in surface area after the activation process. Higher porosity and surface roughness lead to better mass transfer kinetics which results in improved adsorption capabilities for both organic and inorganic pollutants [14], [24]. The SEM analysis demonstrates that acid activation effectively transforms the surface structure of activated carbon from coffee grounds which shows promise for sustainable adsorption technologies.

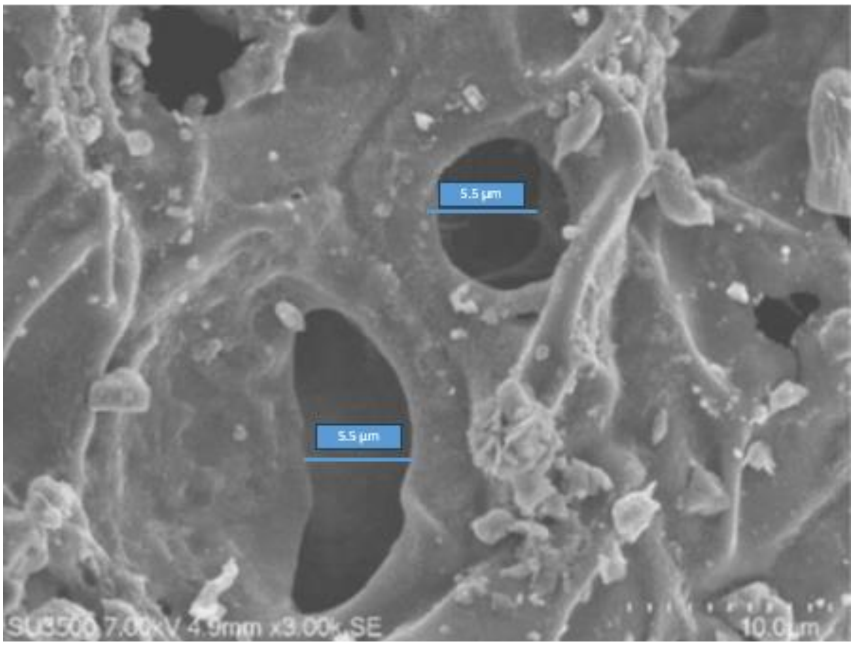

Figure 3. SEM Results of Robusta Coffee Dreg Carbon Before Activation.

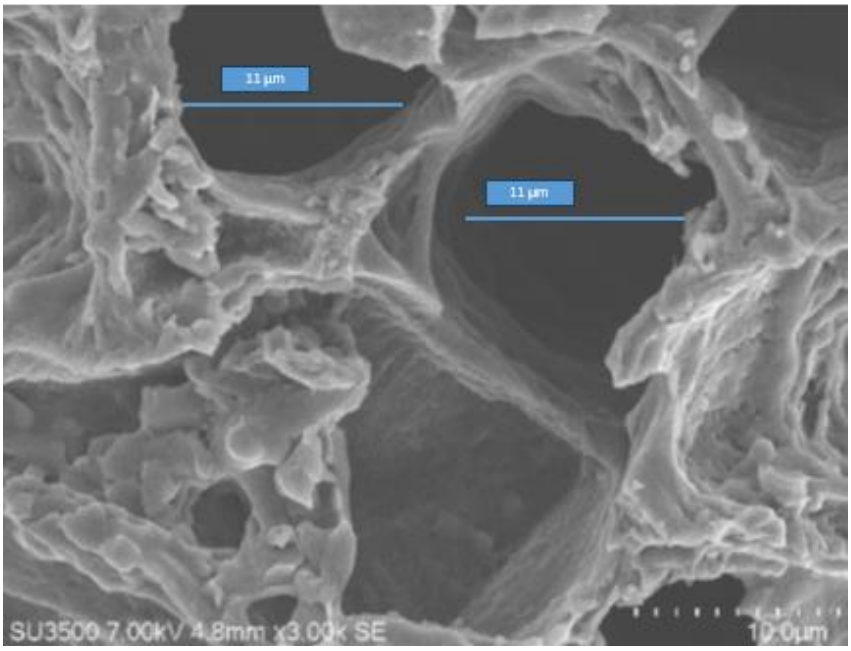

Figure 4. SEM results of Robusta coffee grounds carbon after activation

P-ISSN : 2598-1277
E-ISSN : 2621-3966

4. CONCLUSION

Characterization of coffee business waste in the form of robusta coffee grounds as an adsorbent has been successfully carried out. There are differences in the value of FTIR and SEM test results between Robusta coffee grounds carbon samples before and after the activation process. The results show that there are peak changes in 5 types of wavelengths and also for SEM results there is an increase in pore size by 2 times.

REFERENCES

[1] R. Lestari Baso and R. Anindita, “Analisis Daya Saing Kopi Indonesia,” *Jurnal Ekonomi Pertanian dan Agribisnis*, vol. 2, no. 1, pp. 1–9, Jan. 2018, doi: 10.21776/ub.jepa.2018.002.01.1.

[2] M. Syakir and E. Surmaini, “Perubahan Iklim Dalam Konteks Sistem Produksi Dan Pengembangan Kopi Di Indonesia / Climate Change in the Contex of Production System and Coffee Development in Indonesia,” *Jurnal Penelitian dan Pengembangan Pertanian*, vol. 36, no. 2, p. 77, Dec. 2017, doi: 10.21082/jp3.v36n2.2017.p77-90.

[3] A. T. L. P. L. Haris, R. Tahir, A. I. Mundiyah, and A. W. Angka, “Strategi Pengembangan Agribisnis Kopi Robusta sebagai Wujud Penguatan Ekonomi Kerakyatan Pedesaan di Kecamatan Lembang Kabupaten Pinrang, Sulawesi Selatan, Indonesia,” *Agro Bali : Agricultural Journal*, vol. 6, no. 2, pp. 479–491, Oct. 2023, doi: 10.37637/ab.v6i2.1253.

[4] D. Sabita, N. H. Djanggu, and R. Budiman, “Strategi Pengembangan Bisnis Pada Usaha Coffee Shop Dengan Metode Qspm (Studi Kasus: Coffee Shop ’Rasio Coffee’).”

[5] L. Soelaiman and C. Liusca, “Penyusunan Rencana Bisnis Sebagai Langkah Pengembangan Usaha Coffee Shop,” *Madani : Jurnal Pengabdian Kepada Masyarakat*, vol. 8, no. 2, Dec. 2022, doi: 10.53834/mdn.v8i2.4883.

[6] J. Rekayasa dan Manajemen Agroindustri, K. Listia Damariyanti, A. Hartiati, and I. Wayan Gede Sedana Yoga, “Strategi Pengembangan Usaha Kedai Kopi ‘Kandera Coffee’ Denpasar Bali menggunakan Metode Swot dan QSPM Business Development Strategy for Coffee Shop ‘Kandera Coffee’ Denpasar Bali Using Swot and QSPM Methods,” 2021.

[7] “Studi Daya Serap Karbon Aktif Batubara terhadap penurunan Kadar Logam Cu dalam Larutan CUSO4”.

[8] W. Jurnal, R. Zein, P. Ramadhani, H. Aziz, and R. Suhaili, “Biosorben cangkang pensi (Corbicula moltkiana) sebagai penyerap zat warna metanil yellow ditinjau dari pH dan model kesetimbangan adsorpsi Pensi shell (Corbicula moltkiana)as a biosorbent for metanil yellow dyes removal: pH and equilibrium model evaluation,” 2019, doi: 10.24960/jli.v8i2.4661.15-22.

[9] “TUGAS AKHIR Pemanfaatan Media Bambu Sebagai Adsorbent Penyerap Logam Kadmium (Cd) dengan Perbandingan Tanpa Aktivasi dan Aktivasi dengan Asam Sitrat.”

[10] F. Matematika Dan, “Pembuatan Dan Karakterisasi Komposit Tio2/Serat Tandan Pisang Sebagai Adsorben Untuk Menyerap Metil Jingga” 2020.

[11] E. A. Khan, Shahjahan, and T. A. Khan, “Adsorption of methyl red on activated carbon derived from custard apple (Annona squamosa) fruit shell: Equilibrium isotherm and kinetic studies,” *J Mol Liq*, vol. 249, pp. 1195–1211, Jan. 2018, doi: 10.1016/j.molliq.2017.11.125.

[12] R. Lestari Baso and R. Anindita, “Analisis Daya Saing Kopi Indonesia,” *Jurnal Ekonomi Pertanian dan Agribisnis*, vol. 2, no. 1, pp. 1–9, Jan. 2018, doi: 10.21776/ub.jepa.2018.002.01.1.

[13] W. Jurnal, R. Zein, P. Ramadhani, H. Aziz, and R. Suhaili, “Biosorben cangkang pensi (Corbicula moltkiana) sebagai penyerap zat warna metanil yellow ditinjau dari pH dan model kesetimbangan adsorpsi Pensi shell (Corbicula moltkiana)as a biosorbent for metanil yellow dyes

P-ISSN : 2598-1277
E-ISSN : 2621-3966

removal: pH and equilibrium model evaluation," *Jurnal Litbang Industri*, 2019, doi: 10.24960/jli.v8i2.4661.15-22.

[14] M. A. Al-Ghouti and D. A. Da'ana, "Guidelines for the use and interpretation of adsorption isotherm models: A review," Jul. 05, 2020, *Elsevier B.V.* doi: 10.1016/j.jhazmat.2020.122383.

[15] K. Sun, K. Ro, M. Guo, J. Novak, H. Mashayekhi, and B. Xing, "Sorption of bisphenol A, 17α-ethinyl estradiol and phenanthrene on thermally and hydrothermally produced biochars," *Bioresour Technol*, vol. 102, no. 10, pp. 5757–5763, May 2011, doi: 10.1016/j.biortech.2011.03.038.

[16] I. A. W. Tan, A. L. Ahmad, and B. H. Hameed, "Adsorption of basic dye on high-surface-area activated carbon prepared from coconut husk: Equilibrium, kinetic and thermodynamic studies," *J Hazard Mater*, vol. 154, no. 1–3, pp. 337–346, Jun. 2008, doi: 10.1016/j.jhazmat.2007.10.031.

[17] J. M. Patra, S. S. Panda, and N. K. Dhal, "Biochar as a low-cost adsorbent for heavy metal removal: A review," *International Journal of Research in Biosciences*, vol. 6, no. 1, pp. 1–7, 2017, [Online]. Available: http://www.ijrbs.in

[18] L. Efiyanti, S. A. Wati, M. Maslahat, and J. I. Kehutanan, "Pembuatan dan Analisis Karbon Aktif dari Cangkang Buah Karet dengan Proses Kimia dan Fisika Manufacture and Analysis of Activated Carbon from Rubber Fruit Shell with Chemical and Physical Processing," 2020. [Online]. Available: https://jurnal.ugm.ac.id/jikfkt

[19] W. Aprilianti *et al.*, "Adsorpsi Ion Besi Pada Lindi Menggunakan Zeolit Alam Teraktivasi Asam Klorida (HCl)," 2023.

[20] G. Liu, Z. Dai, X. Liu, R. A. Dahlgren, and J. Xu, "Modification of agricultural wastes to improve sorption capacities for pollutant removal from water – a review," Dec. 01, 2022, *Springer Nature*. doi: 10.1007/s44246-022-00025-1.

[21] J. Wang and S. Wang, "Preparation, modification and environmental application of biochar: A review," Aug. 01, 2019, *Elsevier Ltd*. doi: 10.1016/j.jclepro.2019.04.282.

[22] L. Wang *et al.*, "Mechanisms and reutilization of modified biochar used for removal of heavy metals from wastewater: A review," Jun. 10, 2019, *Elsevier B.V.* doi: 10.1016/j.scitotenv.2019.03.011.

[23] M. Ahmad *et al.*, "Biochar as a sorbent for contaminant management in soil and water: A review," 2014, *Elsevier Ltd*. doi: 10.1016/j.chemosphere.2013.10.071.

[24] K. Y. Foo and B. H. Hameed, "Preparation and characterization of activated carbon from pistachio nut shells via microwave-induced chemical activation," *Biomass Bioenergy*, vol. 35, no. 7, pp. 3257–3261, Jul. 2011, doi: 10.1016/j.biombioe.2011.04.023.