BAB V
KESIMPULAN DAN SARAN

V.1. Kesimpulan

Dari hasil penelitian yang telah dilakukan, diperoleh selulosa berbasis sabut kelapa dengan diameter berkisar 7-15 μm dan berbentuk serat. Analisa EDX dan XRD juga menunjukkan adanya kandungan elemen Fe pada selulosa magnetik. Kapasitas maksimum selulosa magnetik dengan rasio massa prekusor magnetik/volume larutan selulosa teroksidasi TEMPO 0,7% (b/v) sebesar 1:4,8:25 dalam mengadsorpsi RhB adalah sebesar 228,09 mg/g pada kondisi suhu 30 ^{o}C, pH 6, konsentrasi awal RhB 103,4028 ppm dan proses adsorpsi selama 5 jam. Studi kinetik dari penelitian ini sesuai dengan model *pseudo-first order* yang menujukkan bahwa mekanisme adsorpsi didominasi oleh mekanisme fisisorpsi. Model BET adalah model yang paling sesuai untuk studi isoterm dengan jumlah lapisan pada suhu 30℃, 40℃, dan 50℃ secara berturut-turut $1{,}07\times10^{6}$; $2{,}02\times10^{12}$; dan $1{,}2\times10^{7}$. Permukaan selulosa magnetik bersifat heterogen yang ditunjukkan melalui persamaan Freundlich. Mekanisme adsorpsi secara fisisorpsi juga diperkuat dengan hasil isoterm pada persamaan Dubinin-Radushkevinch. Parameter termodinamika menujukkan hasil bahwa proses adsorpsi bersifat eksotermis, sehingga suhu menjadi parameter yang berpengaruh dalam proses adsorpsi dan degradasi RhB. Selulosa magnetik yang dihasilkan memiliki kemampuan dalam menggunakan kembali (*reuse*) adsorben yang telah dipakai karena memiliki sifat paramagnetis dan mudah dipisahkan dari larutan.

V.2. Saran

Pada proses pembuatan selulosa, sabut kelapa perlu dilakukan *pretreatment* yang lebih efisien untuk mendapatkan kandungan selulosa dari sabut kelapa. Pada setiap proses pada *pretreatment* diperlukan adanya pencucian dengan akuades untuk mencapai pH netral supaya komposisi dan kualitas dari selulosa tetap terjaga dengan baik dan memastikan bahwa reaksi telah berhenti. Proses pemanasan pada hidrolisis perlu dijaga pada suhu yang telah ditentukan supaya mendapatkan hasil yang diinginkan dan meminimalisasi terbentuknya glukosa akibat pemanasan yang berlebih. Pada proses oksidasi TEMPO, pH reaksi perlu dipastikan dan dijaga dalam kondisi basa supaya reaksi dapat berjalan pada kondisi optimal dan hasil sesuai dengan yang diinginkan. Proses adsorpsi dilakukan pada pH 12 untuk mendapatkan kapasitas adsorpsi yang lebih optimal. Selain itu, dalam meregenerasi selulosa magnetik perlu dilakukan pencucian dengan metanol untuk menghilangkan RhB yang masih terikat pada sisi aktif adsorben dan dilakukan pengeringan untuk menghilangkan sisa metanol dan adsorbat yang terdapat dalam pori selulosa magnetik. Namun, penggunaan metanol dalam proses regenerasi selulosa magnetik perlu diperhatikan kembali karena dimungkinkan adanya limbah baru yang dihasilkan.

DAFTAR PUSTAKA

[1] C. Feng, L. Yu, Y. Xiao, and C. An, "Environmental Behavior and Effects of Pollutants in Water," *J. Chem.*, vol. 2020, 2020, doi: 10.1155/2020/2639389.

[2] N. Amiralian *et al.*, "Magnetic nanocellulose: A potential material for removal of dye from water," *J. Hazard. Mater.*, vol. 394, no. February, p. 122571, 2020, doi: 10.1016/j.jhazmat.2020.122571.

[3] D. J. Gardner, G. S. Oporto, R. Mills, and M. A. S. A. Samir, "Adhesion and surface issues in cellulose and nanocellulose," *J. Adhes. Sci. Technol.*, vol. 22, no. 5–6, pp. 545–567, 2008, doi: 10.1163/156856108X295509.

[4] Setiyanto, I. Riwayati, and L. Kurniasari, "ADSORPSI PEWARNA TEKSTIL RODHAMIN B MENGGUNAKAN SENYAWA XANTHAT PULPA KOPI," pp. 24–28, 2007.

[5] H. Fouad, L. K. Kian, M. Jawaid, M. D. Alotaibi, O. Y. Alothman, and M. Hashem, "Characterization of microcrystalline cellulose isolated from conocarpus fiber," *Polymers (Basel).*, vol. 12, no. 12, pp. 1–11, 2020, doi: 10.3390/polym12122926.

[6] K. R. Ningtyas, M. Muslihudin, and I. N. Sari, "Sintesis Nanoselulosa dari Limbah Hasil Menggunakan Variasi Konsentrasi Asam Pertanian dengan Synthesis of Nanoselulosa from Agricultural Waste Using Variation Acid Concentration," *J. Penelit. Pertan. Terap.*, vol. 20, no. 2, pp. 142–147, 2020.

[7] S. F. Sahat, “Introducing Indonesian Various Coconut Products,” *Export News Indones.*, no. February, pp. 1–12, 2017.

[8] O. Nurdiana, S. T. Sam, and A. M. Faiq, “Optimization of the product of nanocrystalline cellulose from coconut husks,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 429, no. 1, pp. 0–6, 2018, doi: 10.1088/1757-899X/429/1/012041.

[9] L. G. Devi, M. Srinivas, and M. L. ArunaKumari, “Heterogeneous advanced photo- Fenton process using peroxymonosulfate and peroxydisulfate in presence of zero valent metallic iron: A comparative study with hydrogen peroxide photo-Fenton process,” *J. Water Process Eng.*, vol. 13, pp. 117–126, 2016, doi: 10.1016/j.jwpe.2016.08.004.

[10] J. C. Alouw and S. Wulandari, “Present status and outlook of coconut development in Indonesia,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 418, no. 1, 2020, doi: 10.1088/1755-1315/418/1/012035.

[11] Direktorat Jenderal Perkebunan, “Produksi Kelapa Menurut Provinsi di Indonesia, 2017-2021,” 2021.

[12] Direktorat Jenderal Perkebunan, “Luas Areal Kelapa Menurut Provinsi di Indonesia , 2017-2021,” 2021.

[13] Subiyanto, “PROSPEK INDUSTRI PENGOLAHAN LIMBAH SABUT KELAPA,” pp. 1–9, 1997.

[14] H. C. B. Man, C. O. Akinbile, and C. X. Jun, “Coconut husk adsorbent for the removal of methylene blue dye from wastewater,” *BioResources*, vol. 10, no. 2, pp. 2859–2872, 2015, doi: 10.15376/biores.10.2.2859-2872.

[15] O. Hamdaoui, “Dynamic sorption of methylene blue by cedar sawdust and crushed brick in fixed bed columns,” vol. 138, pp. 293–303, 2006, doi: 10.1016/j.jhazmat.2006.04.061.

[16] Z. Aksu, “Application of biosorption for the removal of organic pollutants : a review,” vol. 40, pp. 997–1026, 2005, doi: 10.1016/j.procbio.2004.04.008.

[17] E. Baldev, D. MubarakAli, A. Ilavarasi, D. Pandiaraj, K. A. S. S. Ishack, and N. Thajuddin, “Degradation of synthetic dye, Rhodamine B to environmentally non-toxic products using microalgae,” *Colloids Surfaces B Biointerfaces*, vol. 105, pp. 207–214, 2013, doi: 10.1016/j.colsurfb.2013.01.008.

[18] M. F. Attallah, I. M. Ahmed, and M. M. Hamed, “Treatment of industrial wastewater containing Congo Red and Naphthol Green B using low-cost adsorbent,” *Environ. Sci. Pollut. Res.*, vol. 20, no. 2, pp. 1106–1116, 2013, doi: 10.1007/s11356-012-0947-4.

[19] S. S. Vieira, Z. M. Magriotis, N. A. V. Santos, M. das G. Cardoso, and A. A. Saczk, “Macauba palm (Acrocomia aculeata) cake from biodiesel processing: An efficient and low cost substrate for the adsorption of dyes,” *Chem. Eng. J.*, vol. 183, pp. 152–161, 2012, doi: 10.1016/j.cej.2011.12.047.

[20] V. K. Gupta and Suhas, “Application of low-cost adsorbents for dye removal - A review,” *J. Environ. Manage.*, vol. 90, no. 8, pp. 2313–2342, 2009, doi: 10.1016/j.jenvman.2008.11.017.

[21] L. M. Skjolding *et al.*, “Assessing the aquatic toxicity and environmental safety of tracer compounds Rhodamine B and Rhodamine WT,” *Water Res.*, vol. 197, p. 117109, 2021, doi:

10.1016/j.watres.2021.117109.

[22] N. L. P. Putri, N. L. Suriani, and D. A. Yulihastuti, "Penentuan Jenis Dan Kadar Zat Pewarna Merah Pada Makanan Yang Beredar Di Sekolah Dasar Di Kelurahan Jimbaran , Kecamatan Kuta Selatan , Kabupaten Badung – Bali Determination Levels of Substances and Type in Red Dye in Food Sold At Elementary School in Jim," *J. Biol.*, vol. 16, no. 2, pp. 48–51, 2012.

[23] C. Standard, "SN/T 2430-2010 Determination of rhodamine B in foods for import and export," 2010.

[24] A. Ebrahimi, M. Arami, H. Bahrami, and E. Pajootan, "Fish Bone as a Low-Cost Adsorbent for Dye Removal from Wastewater: Response Surface Methodology and Classical Method," *Environ. Model. Assess.*, vol. 18, no. 6, pp. 661–670, 2013, doi: 10.1007/s10666-013-9369-z.

[25] K. Y. Foo and B. H. Hameed, "An overview of dye removal via activated carbon adsorption process," no. July, 2017, doi: 10.5004/dwt.2010.1214.

[26] M. T. Yagub, T. K. Sen, S. Afroze, and H. M. Ang, "Dye and its removal from aqueous solution by adsorption : A review," *Adv. Colloid Interface Sci.*, vol. 209, pp. 172–184, 2014, doi: 10.1016/j.cis.2014.04.002.

[27] K. Y. Foo and B. H. Hameed, "Detoxification of pesticide waste via activated carbon adsorption process," *J. Hazard. Mater.*, vol. 175, no. 1–3, pp. 1–11, 2010, doi: 10.1016/j.jhazmat.2009.10.014.

[28] M. S. Larrechi, M. P. Callao, and V. Go, "Kinetic and

adsorption study of acid dye removal using activated carbon," vol. 69, pp. 1151–1158, 2007, doi: 10.1016/j.chemosphere.2007.03.076.

[29] K. Y. Foo and B. H. Hameed, "An overview of dye removal via activated carbon adsorption process," *Desalin. Water Treat.*, vol. 19, no. 1–3, pp. 255–274, 2010, doi: 10.5004/dwt.2010.1214.

[30] K. Shen and M. A. Gondal, "Removal of hazardous Rhodamine dye from water by adsorption onto exhausted coffee ground," *J. Saudi Chem. Soc.*, vol. 21, no. March 2014, pp. S120–S127, 2017, doi: 10.1016/j.jscs.2013.11.005.

[31] A. Thakur and H. Kaur, "Response surface optimization of Rhodamine B dye removal using paper industry waste as adsorbent," *Int. J. Ind. Chem.*, vol. 8, no. 2, pp. 175–186, 2017, doi: 10.1007/s40090-017-0113-4.

[32] Z. L. Cheng, Y. X. Li, and Z. Liu, "Novel adsorption materials based on graphene oxide/Beta zeolite composite materials and their adsorption performance for rhodamine B," *J. Alloys Compd.*, vol. 708, pp. 255–263, 2017, doi: 10.1016/j.jallcom.2017.03.004.

[33] Y. Li, X. Yan, X. Hu, R. Feng, and M. Zhou, "Trace pyrolyzed ZIF-67 loaded activated carbon pellets for enhanced adsorption and catalytic degradation of Rhodamine B in water," *Chem. Eng. J.*, vol. 375, no. June, p. 122003, 2019, doi: 10.1016/j.cej.2019.122003.

[34] R. Ianoş, C. Păcurariu, S. G. Muntean, E. Muntean, M. A. Nistor, and D. Nižňanský, "Combustion synthesis of iron

oxide/carbon nanocomposites, efficient adsorbents for anionic and cationic dyes removal from wastewaters," *J. Alloys Compd.*, vol. 741, pp. 1235–1246, 2018, doi: 10.1016/j.jallcom.2018.01.240.

[35] S. Rahdar, A. Rahdar, M. N. Zafar, S. S. Shafqat, and S. Ahmadi, "Synthesis and characterization of MgO supported Fe-Co-Mn nanoparticles with exceptionally high adsorption capacity for Rhodamine B dye," *J. Mater. Res. Technol.*, vol. 8, no. 5, pp. 3800–3810, 2019, doi: 10.1016/j.jmrt.2019.06.041.

[36] W. Xiao *et al.*, "Preparation and evaluation of an effective activated carbon from white sugar for the adsorption of rhodamine B dye," *J. Clean. Prod.*, vol. 253, p. 119989, 2020, doi: 10.1016/j.jclepro.2020.119989.

[37] J. Zhang, X. Hu, X. Yan, R. Feng, M. Zhou, and J. Xue, "Enhanced adsorption of Rhodamine B by magnetic nitrogen-doped porous carbon prepared from bimetallic ZIFs," *Colloids Surfaces A Physicochem. Eng. Asp.*, vol. 575, no. January, pp. 10–17, 2019, doi: 10.1016/j.colsurfa.2019.04.091.

[38] J. Wu, J. Yang, G. Huang, C. Xu, and B. Lin, "Hydrothermal carbonization synthesis of cassava slag biochar with excellent adsorption performance for Rhodamine B," *J. Clean. Prod.*, vol. 251, p. 119717, 2020, doi: 10.1016/j.jclepro.2019.119717.

[39] D. Wang *et al.*, "SiO2/TiO2 composite powders deposited on cement-based materials: Rhodamine B removal and the

bonding mechanism," *Constr. Build. Mater.*, vol. 241, p. 118124, 2020, doi: 10.1016/j.conbuildmat.2020.118124.

[40] A. Zahir, Z. Aslam, U. Aslam, A. Abdullah, R. Ali, and M. M. Bello, "Paspalum notatum grass-waste-based adsorbent for rhodamine B removal from polluted water," *Chem. Biochem. Eng. Q.*, vol. 34, no. 2, pp. 93–104, 2020, doi: 10.15255/CABEQ.2020.1830.

[41] R. Rusli and S. J. Eichhorn, "Determination of the stiffness of cellulose nanowhiskers and the fiber-matrix interface in a nanocomposite using Raman spectroscopy," *Appl. Phys. Lett.*, vol. 93, no. 3, 2008, doi: 10.1063/1.2963491.

[42] H. Voisin, L. Bergström, P. Liu, and A. P. Mathew, "Nanocellulose-based materials for water purification," *Nanomaterials*, vol. 7, no. 3, 2017, doi: 10.3390/nano7030057.

[43] M. N. Faiz Norrrahim *et al.*, "Nanocellulose: a bioadsorbent for chemical contaminant remediation," *RSC Adv.*, vol. 11, no. 13, pp. 7347–7368, 2021, doi: 10.1039/d0ra08005e.

[44] N. Lin, J. Huang, and A. Dufresne, "Preparation, properties and applications of polysaccharide nanocrystals in advanced functional nanomaterials: A review," *Nanoscale*, vol. 4, no. 11, pp. 3274–3294, 2012, doi: 10.1039/c2nr30260h.

[45] N. Mahfoudhi and S. Boufi, "Nanocellulose as a novel nanostructured adsorbent for environmental remediation: a review," *Cellulose*, vol. 24, no. 3, pp. 1171–1197, 2017, doi: 10.1007/s10570-017-1194-0.

[46] H. M. H. Trache Djalal, Tarchoun Ahmed Fouzi, Derradji

Mehdi, Hamidon Tuan Sherwyn, Masruchin Nanang, Brosse Nicolas, “Nanocellulose: From Fundamentals to Advanced Applications,” *Front. Chem.*, vol. 8, p. 392, 2020, doi: 10.3389/fchem.2020.00392.

[47] K. P. Y. Shak, Y. L. Pang, and S. K. Mah, “Nanocellulose: Recent advances and its prospects in environmental remediation,” *Beilstein J. Nanotechnol.*, vol. 9, no. 1, pp. 2479–2498, 2018, doi: 10.3762/bjnano.9.232.

[48] T. Saito, Y. Nishiyama, J. L. Putaux, M. Vignon, and A. Isogai, “Homogeneous suspensions of individualized microfibrils from TEMPO-catalyzed oxidation of native cellulose,” *Biomacromolecules*, vol. 7, no. 6, pp. 1687–1691, 2006, doi: 10.1021/bm060154s.

[49] Y. F. Shih, V. K. Kotharangannagari, and T. C. Tsou, “Development of eco-friendly modified cellulose nanofiber reinforced polystyrene nanocomposites: thermal, mechanical, and optical properties,” *J. Polym. Res.*, vol. 27, no. 7, 2020, doi: 10.1007/s10965-020-02156-8.

[50] A. Isogai, “Individualization of nano-sized plant cellulose fibrils: Achieved by direct surface carboxylation using TEMPO catalyst,” *Int. Conf. Nanotechnol. For. Prod. Ind. 2009*, vol. 1, no. Figure 1, pp. 49–72, 2009.

[51] I. G. N. J. A. Prasetia, S. Deviana, T. Damayanti, A. Cahyadi, and I. M. A. G. Wirasuta, “PENGARUH KONSENTRASI NaOH PADA PROSES DELIGNIFIKASI TERHADAP SELULOSA MIKROKRISTAL DARI ALGA HIJAU (Cladophora sp.) SEBAGAI PRODUK BAHARI

TERBARUKAN," *J. Farm. Sains Dan Komunitas*, vol. 15, no. 2, pp. 68–71, 2018.

[52] H. Chen and L. Wang, "Pretreatment Strategies for Biochemical Conversion of Biomass," *Technol. Biochem. Convers. Biomass*, pp. 40–42, 2017, doi: 10.1016/B978-0-12-802417-1/00003-X.

[53] D. Irawan, N. Muslimah, and Z. Arifin, "Lignin isolation from coconut coir with variation of time and concentration of NaOH in the process of alkaline delignification," *Rasayan J. Chem.*, vol. 11, no. 4, pp. 1458–1460, 2018, doi: 10.31788/RJC.2018.1144039.

[54] Y. Wu, J. Wu, F. Yang, C. Tang, and Q. Huang, "Effect of H2O2 bleaching treatment on the properties of finished transparent wood," *Polymers (Basel).*, vol. 11, no. 5, pp. 1–13, 2019, doi: 10.3390/polym11050776.

[55] S. Niju, M. Swathika, and M. Balajii, *Pretreatment of lignocellulosic sugarcane leaves and tops for bioethanol production*. INC, 2019.

[56] A. Verardi, I. De, E. Ricca, and V. Calabr, "Hydrolysis of Lignocellulosic Biomass: Current Status of Processes and Technologies and Future Perspectives," *Bioethanol*, no. February, 2012, doi: 10.5772/23987.

[57] T. Saito, S. Kimura, Y. Nishiyama, and A. Isogai, "Cellulose nanofibers prepared by TEMPO-mediated oxidation of native cellulose," *Biomacromolecules*, vol. 8, no. 8, pp. 2485–2491, 2007, doi: 10.1021/bm0703970.

[58] T. Saito, M. Hirota, N. Tamura, and A. Isogai, "Oxidation of

bleached wood pulp by TEMPO/NaClO/NaClO2 system: Effect of the oxidation conditions on carboxylate content and degree of polymerization," *J. Wood Sci.*, vol. 56, no. 3, pp. 227–232, 2010, doi: 10.1007/s10086-009-1092-7.

[59] T. Saito and A. Isogai, "Wet strength improvement of TEMPO-oxidized cellulose sheets prepared with cationic polymers," *Ind. Eng. Chem. Res.*, vol. 46, no. 3, pp. 773–780, 2007, doi: 10.1021/ie0611608.

[60] T. Saito, Y. Okita, T. T. Nge, J. Sugiyama, and A. Isogai, "TEMPO-mediated oxidation of native cellulose: Microscopic analysis of fibrous fractions in the oxidized products," *Carbohydr. Polym.*, vol. 65, no. 4, pp. 435–440, 2006, doi: 10.1016/j.carbpol.2006.01.034.

[61] A. S. Teja and P. Y. Koh, "Synthesis, properties, and applications of magnetic iron oxide nanoparticles," *Prog. Cryst. Growth Charact. Mater.*, vol. 55, no. 1–2, pp. 22–45, 2009, doi: 10.1016/j.pcrysgrow.2008.08.003.

[62] W. S. Peternele *et al.*, "Experimental investigation of the coprecipitation method: An approach to obtain magnetite and maghemite nanoparticles with improved properties," *J. Nanomater.*, vol. 2014, no. 1, pp. 1–11, 2014, doi: 10.1155/2014/682985.

[63] W. Cheng, K. Tang, Y. Qi, J. Sheng, and Z. Liu, "One-step synthesis of superparamagnetic monodisperse porous Fe 3O4 hollow and core-shell spheres," *J. Mater. Chem.*, vol. 20, no. 9, pp. 1799–1805, 2010, doi: 10.1039/b919164j.

[64] L. K. Sholihah, "Sintesis Dan Karakterisasi Partikel Nano

Fe3O4 Yang Berasal Dari Pasir Besi Dan Fe3o4 Bahan Komersial (Aldrich)," *Inst. Teknol. Sepuluh Novemb.*, pp. 2–15, 2010.

[65] L. Winarti, "Sistem Penghantaran Obat Tertarget, Macam, Jenis-Jenis Sistem Penghantaran, Dan Aplikasinya," *Stomatognatic*, vol. 10, no. 2, pp. 75–81, 2013.

[66] I. Kazeminezhad and S. Mosivand, "Phase transition of electrooxidized Fe3O4 to γ and α-Fe2O3 nanoparticles using sintering treatment," *Acta Phys. Pol. A*, vol. 125, no. 5, pp. 1210–1214, 2014, doi: 10.12693/APhysPolA.125.1210.

[67] M. S. Ansari, K. Raees, M. A. Khan, M. Z. A. Rafiquee, and M. Otero, "Kinetic studies on the catalytic degradation of rhodamine b by hydrogen peroxide: Effect of surfactant coated and non-coated iron (III) oxide nanoparticles," *Polymers (Basel).*, vol. 12, no. 10, pp. 1–15, 2020, doi: 10.3390/polym12102246.

[68] M. F. Hou, L. Liao, W. De Zhang, X. Y. Tang, H. F. Wan, and G. C. Yin, "Degradation of rhodamine B by Fe(0)-based Fenton process with H2O2," *Chemosphere*, vol. 83, no. 9, pp. 1279–1283, 2011, doi: 10.1016/j.chemosphere.2011.03.005.

[69] A. Mehrdad, B. Massoumi, and R. Hashemzadeh, "Kinetic study of degradation of Rhodamine B in the presence of hydrogen peroxide and some metal oxide," *Chem. Eng. J.*, vol. 168, no. 3, pp. 1073–1078, 2011, doi: 10.1016/j.cej.2011.01.087.

[70] S. Horikoshi, H. Hidaka, and N. Serpone, "Hydroxyl radicals in microwave photocatalysis. Enhanced formation of OH

radicals probed by ESR techniques in microwave-assisted photocatalysis in aqueous TiO2 dispersions," *Chem. Phys. Lett.*, vol. 376, no. 3–4, pp. 475–480, 2003, doi: 10.1016/S0009-2614(03)01007-8.

[71] L. Liang *et al.*, "Efficiency and mechanisms of rhodamine B degradation in Fenton-like systems based on zero-valent iron," *RSC Adv.*, vol. 10, no. 48, pp. 28509–28515, 2020, doi: 10.1039/d0ra03125a.

[72] Q. Wang, C. Chen, D. Zhao, M. Wanhong, and J. Zhao, "Change of adsorption modes of dyes on fluorinated TiO2 and its effect on photocatalytic degradation of dyes under visible irradiation," *Langmuir*, vol. 24, no. 14, pp. 7338–7345, 2008, doi: 10.1021/la800313s.

[73] P. Xu, D. Zheng, Z. Xie, J. Ma, J. Yu, and B. Hou, "The mechanism and oxidation efficiency of bio-electro-Fenton system with Fe@Fe2O3/ACF composite cathode," *Sep. Purif. Technol.*, vol. 234, no. July 2019, p. 116103, 2020, doi: 10.1016/j.seppur.2019.116103.

[74] K. Du, Y. Zhu, H. Xu, and X. Yang, "Multifunctional magnetic nanoparticles: Synthesis modification and biomedical applications," *Prog. Chem.*, vol. 23, no. 11, pp. 2287–2298, 2011.

[75] Z. Xu, Y. Hou, and S. Sun, "Magnetic core/shell Fe3O4/Au and Fe3O 4/Au/Ag nanoparticles with tunable plasmonic properties," *J. Am. Chem. Soc.*, vol. 129, no. 28, pp. 8698–8699, 2007, doi: 10.1021/ja073057v.

[76] D. Nath, B. Azizul, H. Murad, H. Shyamal, K. Paul, and H.

Dae, “Deconstruction of Pine Wood (Pinus sylvestris) Recalcitrant Structure Using Alkali Treatment for Enhancing Enzymatic Saccharification Evaluated by Congo Red,” *Waste and Biomass Valorization*, vol. 0, no. 0, p. 0, 2018, doi: 10.1007/s12649-018-00547-z.

[77] A. Isogai, T. Hänninen, S. Fujisawa, and T. Saito, “Review: Catalytic oxidation of cellulose with nitroxyl radicals under aqueous conditions,” *Prog. Polym. Sci.*, vol. 86, pp. 122–148, 2018, doi: 10.1016/j.progpolymsci.2018.07.007.

[78] F. C. Wu, R. L. Tseng, and R. S. Juang, “Initial behavior of intraparticle diffusion model used in the description of adsorption kinetics,” *Chem. Eng. J.*, vol. 153, no. 1–3, pp. 1–8, 2009, doi: 10.1016/j.cej.2009.04.042.

[79] A. Pholosi, E. B. Naidoo, and A. E. Ofomaja, “Intraparticle diffusion of Cr(VI) through biomass and magnetite coated biomass: A comparative kinetic and diffusion study,” *South African J. Chem. Eng.*, vol. 32, no. January, pp. 39–55, 2020, doi: 10.1016/j.sajce.2020.01.005.

[80] S. Chowdhury, R. Mishra, P. Saha, and P. Kushwaha, “Adsorption thermodynamics, kinetics and isosteric heat of adsorption of malachite green onto chemically modified rice husk,” *Desalination*, vol. 265, no. 1–3, pp. 159–168, 2011, doi: 10.1016/j.desal.2010.07.047.

[81] U. A. Edet and A. O. Ifelebuegu, “Kinetics, isotherms, and thermodynamic modeling of the adsorption of phosphates from model wastewater using recycled brick waste,” *Processes*, vol. 8, no. 6, 2020, doi: 10.3390/PR8060665.

[82] A. Ebadi, J. S. Soltan Mohammadzadeh, and A. Khudiev, "What is the correct form of BET isotherm for modeling liquid phase adsorption?," *Adsorption*, vol. 15, no. 1, pp. 65–73, 2009, doi: 10.1007/s10450-009-9151-3.

[83] L. Laysandra *et al.*, "Adsorption and photocatalytic performance of bentonite-titanium dioxide composites for methylene blue and rhodamine B decoloration," *Heliyon*, vol. 3, no. 12, p. e00488, 2017, doi: 10.1016/j.heliyon.2017.e00488.

[84] D. A.O, "Langmuir, Freundlich, Temkin and Dubinin–Radushkevich Isotherms Studies of Equilibrium Sorption of Zn 2+ Unto Phosphoric Acid Modified Rice Husk," *IOSR J. Appl. Chem.*, vol. 3, no. 1, pp. 38–45, 2012, doi: 10.9790/5736-0313845.

[85] J. L. Sanchez-Salvador, C. Campano, C. Negro, M. C. Monte, and A. Blanco, "Increasing the Possibilities of TEMPO-Mediated Oxidation in the Production of Cellulose Nanofibers by Reducing the Reaction Time and Reusing the Reaction Medium," *Adv. Sustain. Syst.*, vol. 5, no. 4, 2021, doi: 10.1002/adsu.202000277.

[86] F. J. Kolpak and J. Blackwell, "Determination of the Structure of Cellulose II," *Macromolecules*, vol. 9, no. 2, pp. 273–278, 1976, doi: 10.1021/ma60050a019.

[87] Z. Tang *et al.*, "TEMPO-Oxidized cellulose with high degree of oxidation," *Polymers (Basel).*, vol. 9, no. 9, pp. 3–4, 2017, doi: 10.3390/polym9090421.

[88] M. F. Rosa *et al.*, "Cellulose nanowhiskers from coconut husk

fibers: Effect of preparation conditions on their thermal and morphological behavior," *Carbohydr. Polym.*, vol. 81, no. 1, pp. 83–92, 2010, doi: 10.1016/j.carbpol.2010.01.059.

[89] C. Prasad, S. Gangadhara, and P. Venkateswarlu, "Bio-inspired green synthesis of Fe3O4 magnetic nanoparticles using watermelon rinds and their catalytic activity," *Appl. Nanosci.*, vol. 6, no. 6, pp. 797–802, 2016, doi: 10.1007/s13204-015-0485-8.

[90] K. A. Cychosz and M. Thommes, "Progress in the Physisorption Characterization of Nanoporous Gas Storage Materials," *Engineering*, vol. 4, no. 4, pp. 559–566, 2018, doi: 10.1016/j.eng.2018.06.001.

[91] N. Habibi, "Preparation of biocompatible magnetite-carboxymethyl cellulose nanocomposite: Characterization of nanocomposite by FTIR, XRD, FESEM and TEM," *Spectrochim. Acta - Part A Mol. Biomol. Spectrosc.*, vol. 131, pp. 55–58, 2014, doi: 10.1016/j.saa.2014.04.039.

[92] S. Wahyuningsih, V. Anjani, H. Munawaroh, and C. Purnawan, "Optimization of Rhodamine B Decolorization by Adsorption and Photoelectrodegradation Combination System," *ALCHEMY J. Penelit. Kim.*, vol. 14, no. 2, p. 276, 2018, doi: 10.20961/alchemy.14.2.16440.277-290.

[93] V. da Silva Lacerda *et al.*, "Rhodamine B removal with activated carbons obtained from lignocellulosic waste," *J. Environ. Manage.*, vol. 155, no. March, pp. 67–76, 2015, doi: 10.1016/j.jenvman.2015.03.007.

[94] A. L. Adejumo, L. Azeez, A. O. Oyedeji, R. O. Adetoro, and

F. A. Aderibigbe, “Nanostructured and surface functionalized corncob as unique adsorbents for anionic dye remediation,” *SN Appl. Sci.*, vol. 2, no. 2, 2020, doi: 10.1007/s42452-020-2109-5.

[95] S. K. Milonjić, M. M. Kopečni, and Z. E. Ilić, “The point of zero charge and adsorption properties of natural magnetite,” *J. Radioanal. Chem.*, vol. 78, no. 1, pp. 15–24, 1983, doi: 10.1007/BF02519745.

[96] J. F. Leduc, R. Leduc, and H. Cabana, “Phosphate adsorption onto chitosan-based hydrogel microspheres,” *Adsorpt. Sci. Technol.*, vol. 32, no. 7, pp. 557–569, 2014, doi: 10.1260/0263-6174.32.7.557.

[97] S. Naidoo, N. Nomadolo, W. M. R. Matshe, Z. Cele, and M. Balogun, “Exploring the potential of N-acylated chitosan for the removal of toxic pollutants from wastewater,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 655, no. 1, 2019, doi: 10.1088/1757-899X/655/1/012047.

[98] V. J. Inglezakis and A. A. Zorpas, “Heat of adsorption, adsorption energy and activation energy in adsorption and ion exchange systems,” *Desalin. Water Treat.*, vol. 39, no. 1–3, pp. 149–157, 2012, doi: 10.1080/19443994.2012.669169.

[99] H. Panda, N. Tiadi, M. Mohanty, and C. R. Mohanty, “Studies on adsorption behavior of an industrial waste for removal of chromium from aqueous solution,” *South African J. Chem. Eng.*, vol. 23, pp. 132–138, 2017, doi: 10.1016/j.sajce.2017.05.002.

[100] C. Ferreiro, N. Villota, J. I. Lombraña, M. J. Rivero, V.

Zúñiga, and J. M. Rituerto, “Analysis of a hybrid suspended-supported photocatalytic reactor for the treatment of wastewater containing benzothiazole and aniline,” *Water (Switzerland)*, vol. 11, no. 2, 2019, doi: 10.3390/w11020337.

[101] Y. S. Ho, G. Mckay, T. Hong, W. Bay, H. Kong, and T. Hong, “Separation & Purification Reviews Kinetics of Pollutant Sorption by Biosorbents : Review,” *Sep. Purif. Rev.*, vol. 29, no. 2, pp. 189–232, 2000.

[102] W. Plazinski and W. Rudzinski, “Kinetics of adsorption at solid/Solution interfaces controlled by intraparticle diffusion: A theoretical analysis,” *J. Phys. Chem. C*, vol. 113, no. 28, pp. 12495–12501, 2009, doi: 10.1021/jp902914z.

[103] C. H. Giles and D. Smith, “A General Treatment and Classification of the Solute Adsorption Isotherm,” *Dep. Math. Univ. Strat. Glas. G1, Scotl.*, vol. 47, no. 3, pp. 755–765, 1973.

[104] C. H. Giles, T. H. MacEwan, S. N. Nakhwa, and D. Smith, “Studies in Adsorption. Part XI.* A System,” *J. Chem. Soc.*, vol. 846, pp. 3973–3993, 1960.

[105] M. A. M. Lawrence, N. A. Davies, P. A. Edwards, M. G. Taylor, and K. Simkiss, “Can adsorption isotherms predict sediment bioavailability?,” *Chemosphere*, vol. 41, no. 7, pp. 1091–1100, 2000, doi: 10.1016/S0045-6535(99)00559-7.

[106] C. Umpuch and S. Sakaew, “Removal of methyl orange from aqueous solutions by adsorption using chitosan intercalated montmorillonite,” *Songklanakarin J. Sci. Technol.*, vol. 35, no. 4, 2013.

[107] N. Yuan, H. Cai, T. Liu, Q. Huang, and X. Zhang, “Adsorptive removal of methylene blue from aqueous solution using coal fly ash-derived mesoporous silica material,” *Adsorpt. Sci. Technol.*, vol. 37, no. 3–4, pp. 333–348, 2019, doi: 10.1177/0263617419827438.

[108] V. C. Srivastava, M. M. Swamy, I. D. Mall, B. Prasad, and I. M. Mishra, “Adsorptive removal of phenol by bagasse fly ash and activated carbon: Equilibrium, kinetics and thermodynamics,” *Colloids Surfaces A Physicochem. Eng. Asp.*, vol. 272, no. 1–2, pp. 89–104, 2006, doi: 10.1016/j.colsurfa.2005.07.016.

[109] C. Tang *et al.*, “Comparison of the removal and adsorption mechanisms of cadmium and lead from aqueous solution by activated carbons prepared from Typha angustifolia and Salix matsudana,” *RSC Adv.*, vol. 7, no. 26, pp. 16092–16103, 2017, doi: 10.1039/c6ra28035h.

[110] R. Wijaya *et al.*, “Journal of Environmental Chemical Engineering Polystyrene-templated hollow mesoporous magnetite as a bifunctional adsorbent for the removal of rhodamine B via simultaneous adsorption and degradation,” *J. Environ. Chem. Eng.*, vol. 10, no. 4, p. 108194, 2022, doi: 10.1016/j.jece.2022.108194.

[111] E. Wierzbicka, K. Kuśmierek, A. Świątkowski, and I. Legocka, “Efficient Rhodamine B Dye Removal from Water by Acid- and Organo-Modified Halloysites,” *Minerals*, vol. 12, no. 3, 2022, doi: 10.3390/min12030350.

[112] N. Amiralian *et al.*, “Magnetic nanocellulose: A potential

material for removal of dye from water," *J. Hazard. Mater.*, vol. 394, no. March, p. 122571, 2020, doi: 10.1016/j.jhazmat.2020.122571.