

DAFTAR PUSTAKA

- Adegoke, H.I., Adekola, F.A., Olowookere, I.T., Yaqub, A.L. (2017) 'Thermodynamic studies on adsorption of lead (II) Ion from aqueous solution using magnetite, activated carbon and composites', *Journal of Applied Sciences and Environmental Management*, 21(3), p. 440.
- Ahmed, W., Xu, T., Mahmood, M., Núñez-Delgado, A., Ali, S., Shakoor, A., Qaswar, M., Zhao, H., Liu, W., Li, W., Mehmood, S. (2022) 'Nano-hydroxyapatite modified biochar: Insights into the dynamic adsorption and performance of lead (II) removal from aqueous solution', *Environmental Research*, 214(May).
- Aisyah, N.A., Trisnawati, I., Muryono, M., Sen, H.T.T. (2025) 'The potential of rice husk-derived biochar as a bio-silica source in the agricultural area of Tuban, East Java', in *BIO Web of Conferences 202*, pp. 1–7.
- Al-Maliky, E.A., Gzar, H.A. and Al-Azawy, M.G. (2021). 'Determination of Point of Zero Charge (PZC) of Concrete Particles Adsorbents', *IOP Conference Series: Materials Science and Engineering*, 1184(1), p. 012004.
- Ali, D.A., Saad, F.A., dan Elsayy, H.A. (2025). 'Kinetics and Isotherm Studies for Adsorption of Gentian Violet Dye from Aqueous Solutions Using Synthesized Hydroxyapatite', 2023.
- Alif, M.F., Fitria, R.A., Arief, S., Triandini, S., Manawan, M., Purnama, P., Goei, R. (2024) 'Peat water purification using nanohydroxyapatite synthesized from Carbon Negative Precipitated Calcium Carbonate precursor', *Sustainable Chemistry for the Environment*, 6, p. 100105.
- Alif, M.F., Darajat, S., dan Azizah, S. (2024) 'Utilization of Hydroxyapatite from Quail Eggshells as an Adsorbent for Lead', *Indonesian Journal of Environmental Management and Sustainability*.
- Amalia, T.R., Nurlily, dan Sari, Y.W. (2020) 'Synthesis of Hidroxyapatite Using Microwave Irradiation and Sintering with Variation pH and Time', *Journal of Physics: Conference Series*, 1505(1).
- Arogundade, I., Hefnawy, M., Ofudje, E.A., El Gamal, A., Emran, T.B. (2025) 'Pb and Cd removal from aqueous solutions onto calcium-phosphate hydroxyl surface: kinetics, isotherms and thermodynamic investigations', 19.
- Asadi, H., Ghorbani, M., Rezaei-Rashti, M., Abrishamkesh, S., Amirahmadi, E., Chengrong, C., Gorji, M. (2021) 'Application of Rice Husk Biochar for Achieving Sustainable Agriculture and Environment', *Rice Science*, 28(4), pp. 325–343.
- Bee, S.L. and Hamid, Z.A.A. (2020) 'Hydroxyapatite derived from food industry bio-wastes: Syntheses, properties and its potential multifunctional applications', *Ceramics International*, 46(11), pp. 17149–17175.
- Bernalte, E., Kamieniak, J., Randviir, E.P., Bernalte-García, Á. (2019) 'The preparation of hydroxyapatite from unrefined calcite residues and its application for lead removal from aqueous solutions', *RSC Advances*, 9(7), pp. 4054–4062.
- Bharath, G., Jagadeesh K.A., Karthick, K., Mangalaraj, D., Viswanathan, C., Ponpandian, N. (2014) 'Shape evolution and size controlled synthesis of

- mesoporous hydroxyapatite nanostructures and their morphology dependent Pb(II) removal from waste water', *RSC Advances*, 4(70), pp. 37446–37457.
- Cahyaningrum, S.E., Herdyastuty, N., Devina, B., Supangat, D. (2018) 'Synthesis and Characterization of Hydroxyapatite Powder by Wet Precipitation', in *International Conference on Chemistry and Material Science*, pp. 1–5.
- Castro, M.A.M., Portela, T.O., Correa, G.S., Oliveira, M.M., Rangel, J.H.G., Rodrigues, S.F., Mercury, J.M.R. (2022) 'Synthesis of hydroxyapatite by hydrothermal and microwave irradiation methods from biogenic calcium source varying pH and synthesis time', *Boletín de la Sociedad Española de Cerámica y Vidrio*, 61(1), pp. 35–41.
- Collin, M.S., Venkatraman, S.K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S.M., Stacey, R.G.S., Anusha, J., Choudhary, R., Lvov, V., Tovar, G.I., Senatov, F., Koppala, S., Swamiappan, S. (2022) 'Bioaccumulation of lead (Pb) and its effects on human: A review', *Journal of Hazardous Materials Advances*, 7(March), pp. 0–7.
- Deng, H., Li, Y.F., Tao, S.Q., Li, A.Y., Li, Q.Y., Hu, L.N. (2022) 'Efficient adsorption capability of banana and cassava biochar for malachite green: Removal process and mechanism exploration', *Environmental Engineering Research*, 27(3), pp. 0–2.
- Dhamala Shobita C., Ahmad Fadli, K. (2020) 'Model Kesetimbangan Pada Adsorpsi Ion Logam Timbal (Pb^{2+}) Menggunakan Hidroksiapatit', 7, pp. 1–5.
- E, Sinurat., Li, Y.F., Tao, S.Q., Li, A.Y., Li, Q.Y., Hu, L.N. (2022) 'Synthesis and Characterization of Hydroxyapatite of Cockle Shells (*Anadara granosa*) Originated from Indonesia Through Precipitation Method', *IOP Conf. Series: Earth and Environmental Science*, 1118, pp. 0–11.
- Ehiomogue, P., Ahuchaogu, I.I., dan Ahaneku, I.E. (2022) 'Review of adsorption isotherms models', *Acta Technica Corviniensis*, 14(4), pp. 87–96.
- Eka P.M., Hasnaa B., Elisabeth, H.P., Felicia, S.F., Az-zhaffirah.R.A. (2024) 'A Comprehensive Review on Atomic Absorption Spectroscopy: Principles, Techniques, and Applications', 10(15), pp. 20–29.
- El-Baz, A., Hendy, I., Dohdoh, A., Srouf, M.I. (2020) 'Adsorption technique for pollutants removal; current new trends and future challenges – A Review', *The Egyptian International Journal of Engineering Sciences and Technology*, 32(1), pp. 1–24.
- El Hammari, L., Hamed, R., Azzaoui, K., Jodeh, S., Latifi, S., Saoiabi, S., Boukra, O., Krime, A., Boukra, A., Saoiabi, A., Hammouti, B., Khan, M.M., Sabbahi, R., Hanbali, G., Berisha, A., Taleb, M., Dagdag, O. (2023) 'Optimization of the adsorption of lead(II) by hydroxyapatite using a factorial design: Density functional theory and molecular dynamics', *Frontiers in Environmental Science*, 11(March), pp. 1–17.
- Ellerbrock, R.H. dan Gerke, H.H. (2021) 'FTIR spectral band shifts explained by OM – cation interactions', *Journal of Plant Nutrition and Soil Science*, 1, pp. 1–10.
- Elline, E. dan Ismiyatin, K. (2021) 'Nanohydroxiapatite Using Chicken Eggshell Waste and Its Characterization', *Malaysian Journal of Medicine and Health Sciences*, 17(2), pp. 83–86.

- Feng, W., Xiao, X., Li, J., Xiao, Q., Ma, L., Gao, Q., Wan, Y., Huang, Y., Liu, T., Luo, X., Luo, S., Zeng, G., Yu, K. (2023) 'Bioleaching and immobilizing of copper and zinc using endophytes coupled with biochar-hydroxyapatite: Bipolar remediation for heavy metals contaminated mining soils', *Chemosphere*, 315.
- Fernandes, I.J., Calheiro, D., Sánchez, F.A.L., Camacho, A.L.D., Rocha, T.L., Moraes, C.A., Sousa, V.C. (2017) 'Characterization of Silica Produced from Rice Husk Ash: Comparison of Purification and Processing Methods', 20, pp. 512–518.
- Figueiredo, M., Fernando, A., Martins, G., Freitas, J., Judas, F., Figueiredo, H. (2010) 'Effect of the calcination temperature on the composition and microstructure of hydroxyapatite derived from human and animal bone', *Ceramics International*, 36(8), pp. 2383–2393.
- Goh, K.W., Wong, Y.H., Ramesh, S., Chandran, H., Krishnasamy, S., Sidhu, A., Teng, W.D. (2021) 'Effect of pH on the properties of eggshell-derived hydroxyapatite bioceramic synthesized by wet chemical method assisted by microwave irradiation', *Ceramics International*, 47(7), pp. 8879–8887.
- González-González, B.G., García-Sifuentesb, C.O., Santacruz-Ortega, H., Brown-Bojórquez, F., Navarro-Gautrín, R.E., Sugich-Miranda, R., Carvajal-Millán, E. (2023) 'Properties of hydroxyapatite from tilapia (*Oreochromis niloticus*) bones: An approach towards its potential use as a dye adsorbent', *Journal of Applied Research and Technology*, 21, pp. 447–456.
- Gowri, A. dan Kala, K. (2022) 'Evaluating synthesis of Novel Hydroxyapatite from Egg Shell Compared with Chemically Synthesized HAp for Orthopedic application', *Journal of Pharmaceutical Negative Results*, 13(4).
- Hajati, S.N. (2025) 'Adsorpsi Ion Logam Cr(III) Menggunakan Limbah Ampas Kelapa Terimobilisasi Silika dengan Bantuan Gelombang Ultrasonik', *CHEDS: Journal of Chemistry, Education, and Science*, 9(1), pp. 75–85.
- Hama Aziz, K.H., Mustafa, F.S., Omer, K.M., Hama, S., Hamarawf, R.F., Rahman, K.O. (2023) 'Heavy metal pollution in the aquatic environment: efficient and low-cost removal approaches to eliminate their toxicity: a review', *RSC Advances*, 13(26), pp. 17595–17610.
- Hamidu, I., Afotey, B., Kwakye-awuah, B., Adjah, D. (2025) 'Synthesis of silica and silicon from rice husk feedstock: A review', *Heliyon*, 11(4), p. e42491.
- Hariani, P.L., Riyanti, F., Fatma, Rachmat, A., Herbanu, A. (2020) 'Removal of pb(II) using hydroxyapatite from golden snail shell (*pomacea canaliculata* l.) modified with silica', *Molekul*, 15(2), pp. 130–139.
- Hariani, P.L., Said, M., dan Salni (2019) 'Effect of sintering on the mechanical properties of hydroxyapatite from fish bone (*Pangasius Hypophthalmus*)', *IOP Conference Series: Materials Science and Engineering*, 509(1).
- Hassan, A. dan Kaewsichan, L. (2016) 'Removal of Pb(II) from Aqueous Solutions Using Mixtures of Bamboo Biochar and Calcium Nagrajan Nagarani, Arumugam Kuppusamy Kumaraguru, Velmurugan J', *EnvironmentAsia*,

- 9(1), pp. 37–44.
- Hassan, M.N., Mahmoud, M.M., El-Fattah, A.Abd., Kandil, S. (2016) 'Microwave-assisted preparation of Nano-hydroxyapatite for bone substitutes', *Ceramics International*, 42(3), pp. 3725–3744.
- He, M., Zhang, Z., Wang, M., Liang, C., Wang, H., Cheng, C., Li, Y., Wang, Y., Zhang, Z. (2025) 'A review of hydroxyapatite synthesis for heavy metal adsorption assisted by machine learning', *Journal of Hazardous Materials*, 481.
- Heikal, F.E.T., Sarhan, Y.B., Maamoun, M.A., Bakry, A.M., Abdel-Monem, Y.K., Ghayad, I.M. (2022) 'Hydrothermal Microwave-Assisted Fabrication of Nanohydroxyapatite Powder and Optimization of Its Nanocomposite Coatings on Magnesium Alloy for Orthopedic Applications', *ACS Omega*, 7(1), pp. 1021–1034.
- Hidayat, R., Saputra, A. and Fitria, M. (2022) 'Material MOFs (Metal Organic Frameworks) dalam Aplikasi Fotokatalisis : Mini Review', *Indonesian Journal of Chemical Analysis*, 05(02), pp. 120–137.
- Hossain, S. dan Ahmed, S. (2023) 'FTIR spectrum analysis to predict the crystalline and amorphous phases of hydroxyapatite : a comparison of vibrational motion to reflection', *RSC Advances*, 13, pp. 14625–14630.
- Iconaru, S.L., Motelica-Heino, M., Guegan, R., Beuran, M., Costescu, A., Predoi, D. (2018) 'Adsorption of Pb(II) ions onto hydroxyapatite nanopowders in aqueous solutions', *Materials*, 11.
- Imran, E., Mei, M.L., Li, K.C., Ratnayake, J., Ekambaram, M., Cooper, P.R. (2024) 'Dental Applications of Ion-Substituted Hydroxyapatite: A Review of the Literature', *Dentistry Journal*, 12(10).
- Irwansyah, F.S., Yusuf, A., Eddy, D.R., Risdiana, R., Noviyanti, A.R. (2022) 'Effect of Sensitive pH on Hydroxyapatite Properties Synthesized from Chicken Eggshell', *Indonesian Journal of Chemistry*, 22(5), pp. 1418–1426.
- Irwansyah, F.S., Amal, A.I., Hadisantoso, E.P., Noviyanti, A.R., Eddy, D.R., Risdiana, R., Suryana, S., Zain, S.M. (2024) 'How to Read and Determine the Specific Surface Area of Inorganic Materials using the Brunauer-Emmett-Teller (BET) Method', *ASEAN Journal of Science and Engineering*, 4(1), pp. 61–70.
- Jaffar, F.H., Othman, M.H.D., Ismail, N.J., Puteh, M.H., Kurniawan, T. A., Abu Bakar, S., Abdullah, H. (2024) 'Hydroxyapatite-based materials for adsorption, and adsorptive membrane process for heavy metal removal from wastewater: Recent progress, bottleneck and opportunities', *Journal of the Taiwan Institute of Chemical Engineers*, 164.
- Janu, R., Mrlik, V., Ribitsch, D., Hofman, J., Sedl'áček, P., Soja, G., Bielsk, L. (2021) 'Biochar surface functional groups as affected by biomass feedstock, biochar composition and pyrolysis temperature', *Carbon Resources Conversion*, 4, pp. 36–46.
- Jiang, J., Long, Y., Hu, X., Hu, J., Zhu, M., Zhou, S. (2020) 'A facile microwave-assisted synthesis of mesoporous hydroxyapatite as an efficient adsorbent for Pb²⁺ adsorption', *Journal of Solid State Chemistry*, 289, p. 121491.
- Jung, K., Yong, S., Choi, J., Jae, Y. (2019) 'A facile one-pot hydrothermal synthesis

- of hydroxyapatite/biochar nanocomposites : Adsorption behavior and mechanisms for the removal of copper(II) from aqueous media', *Chemical Engineering Journal*, 369, pp. 529–541.
- Kareem, Z. dan Eyiler, E. (2024) 'Synthesis of hydroxyapatite from eggshells via wet chemical precipitation: a review', *RSC Advances*, 14(30), pp. 21439–21452.
- Kasera, N., Chatterjee, G., Joshi, S., Shah, P. (2023) 'Synthesis of Nano-Silica Material from Agricultural Wastes', *International Research Journal of Engineering and Technology (IRJET)*, pp. 1–11.
- Kawsar, M., Hossain, S., Bahadur, N.M., Islam, D., Ahmed, S. (2025) 'Crystalline structure modification of hydroxyapatite via a hydrothermal method using different modifiers', *Material advances*, 6, pp. 3889–3902.
- Kim, H.J., Han, J.W., Yu, J.H., Kwak, J., Son, C., Jun, B.M., Chon, K. (2025) 'Hydroxyapatite and magnetic hydroxyapatite biochar from pine nut husks for anionic azo dye adsorption : Performance and reusability assessment', *Applied Surface Science*, 707.
- L. Ćurković, I. Žmak, S. Kurajica, M. E. Tonković, Z. Šokčević, M. Majic Renjo (2017) 'From eggshells biowaste to hydroxyapatite biomaterial', *Materials Science and Engineering Technology*, 48, pp. 797–802.
- Le, D.T., Le, T.P.T., Do, H.T., Vo, H.T., Pham, N.T., Nguyen, T.T., Cao, H.T., Nguyen, P.T., Dinh, T.M.T., Le, H.V., Tran, D. L. (2019) 'Fabrication of Porous Hydroxyapatite Granules as an Effective Adsorbent for the Removal of Aqueous Pb(II) Ions', *Journal of Chemistry*, 2019.
- Li, J., Dong, X., Liu, X., Xu, X., Duan, W., Park, J., Gao, L., Lu, Y., (2022) 'Comparative Study on the Adsorption Characteristics of Heavy Metal Ions by Activated Carbon and Selected Natural Adsorbents', *Sustainability (Switzerland)*, 14(23).
- Li, Y., Zhang, Y., Wang, G., Li, S., Han, R., Wei, W. (2018) 'Reed biochar supported hydroxyapatite nanocomposite : Characterization and reactivity for methylene blue removal from aqueous media', *Journal of Molecular Liquids*, 263, pp. 53–63.
- Li, Z., Zheng, Z., Li, H., Xu, D., Li, X., Xiang, L., Tu, S. (2023) 'Review on Rice Husk Biochar as an Adsorbent for Soil and Water Remediation', *Plants*, 12(7).
- Liu, M., Gong, Z., He, J., Pan, J., Xiao, J., Li, X. (2025) 'Hydroxyapatite immobilized on peanut shell biochar toward Pb²⁺ efficient capture: Performance and mechanism', *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 714(March), p. 136570.
- Mahmud, M., Hossain, S., Mobarak, M., Quddus, S., Bashir, Muhammad S., Akhtar, U.S., Jahan, S.A., Islam, D., Ahmed, S. (2022) 'Engineering GO@Zn-Hap@CA porous heterostructure for ultra-fast and ultra-high adsorption efficacy: investigation towards the remediation of chromium and lead', *Environmental Science: Advances*, 1(5), pp. 827–848.
- Maihendra, Ahmad Fadli, Z. (2016) 'Kinetika Adsorpsi pada Penjerapan Ion Timbal Pb²⁺ Terlarut dalam Air Menggunakan Partikel Tricalcium Phosphate', 3, pp. 1–5.
- Malau, N.D. (2021) 'Manufacture And Characterization Of Hydroxyapatite From Quail Eggshell Using Precipitation Methods', *International Journal of*

- Progressive Sciences and Technologies (IJPSAT*, 29(1), pp. 484–490.
- Maniar, V., Kalsara, K. and Upadhyay, U. (2023) 'A Review of Ftir-An Useful Instrument', *International Journal of Pharmaceutical Research and Applications*, 8(1), p. 2486.
- Marguí, E., Queralt, I., dan de Almeida, E. (2022) 'X-ray fluorescence spectrometry for environmental analysis: Basic principles, instrumentation, applications and recent trends', *Chemosphere*, 303.
- Martika, Iskandar, T., dan Anggraini, A. (2019) 'Pra Rancang Bangun Pupuk Biochar dari Sekam Padi dengan Kapasitas 1.100 Ton/Tahun dengan Menggunakan Alat Utama Oven', 2(2), pp. 230–237.
- Mavropoulos, E., Rossi, A.M., Costa, A.M., Perez, C.A.C., Moreira, J.C., Saldanha, M. (2002) 'Studies on the mechanisms of lead immobilization by hydroxyapatite', *Environmental Science and Technology*, 36(7), pp. 1625–1629.
- Mitić, Ž., Stolić, A., Stojanović, S., Najman, S., Ignjatović, N., Nikolić, G., Trajanović, M. (2017) 'Instrumental methods and techniques for structural and physicochemical characterization of biomaterials and bone tissue: A review', *Materials Science and Engineering C*, 79, pp. 930–949.
- Mitra, S., Chakraborty, A.J., Tareq, A.M., Emran, T., Nainu, F., Khusro, A., Idris, A.M., Khandaker, M.U., Osman, H., Alhumaydhi, F.A., Simal-Gandara, J. (2022) 'Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity', *Journal of King Saud University - Science*, 34(3).
- Mukhlis, Hidayat, B., dan Sabrina, T. (2015) 'Buku Biochar', *IAARD Press*, pp. 1–45.
- Musah, M., Azeh, Y., Mathew, J., Umar, M., Abdulhamid, Z., Muhammad, A. (2022) 'Adsorption Kinetics and Isotherm Models: A Review', *Caliphate Journal of Science and Technology*, 4(1), pp. 20–26.
- Nayak, A. dan Bhushan, B. (2021) 'Hydroxyapatite as an advanced adsorbent for removal of heavy metal ions from water: Focus on its applications and limitations', *Materials Today: Proceedings*, 46, pp. 11029–11034.
- Ngueagni, P.T., Kumar, P.S., Woumfo, E. D., dan Prasanth, S. M. (2020) 'Adsorption of Pb(II) and Cd(II) ions onto modified biogenic slaughterhouse waste: equilibrium and kinetic analysis', *International Journal of Environmental Analytical Chemistry*, 00(00), pp. 1–20.
- Nkoh, J.N., Al Baquy, M.A., Mia, S., Shi, R., Kamran, M.A., Mehmood, K., Xu, R. (2021) 'A critical-systematic review of the interactions of biochar with soils and the observable outcomes', *Sustainability (Switzerland)*, 13(24).
- Nungsiyati, Taufiq, Novantry, S., Muslihudin, M. (2018) 'Aplikasi pakar menentukan telur puyuh terbaik menggunakan simple additive weighting', *Prosiding Seminar Nasional Teknologi dan Bisnis*, pp. 75–84.
- Owuamanam, S. dan Cree, D. (2020) 'Progress of bio-calcium carbonate waste eggshell and seashell fillers in polymer composites: A review', *Journal of Composites Science*, 4(2).
- Palniandy, L.K., Yoon, L.W., Wong, W.Y., Yong, S.T., Pang, M.M. (2019) 'Application of Biochar Derived from Different Types of Biomass and

- Treatment Methods as a Fuel Source for Direct Carbon Fuel Cells', *energies*, 12, pp. 1–15.
- Panda, S., Biswas, C.K., dan Paul, S. (2021) 'A comprehensive review on the preparation and application of calcium hydroxyapatite: A special focus on atomic doping methods for bone tissue engineering', *Ceramics International*, 47(20), pp. 28122–28144.
- Pandao, M.R., Lalitha, G.R., Kishore, A.J., Padhan, S.R., Panotra, N., Gulaiya, S., Pandey, S.K. (2023) 'A Comprehensive Review on Biochar', *International Journal of Environment and Climate Change*, 13(11), pp. 3453–3461.
- Panwar, N.L., Jagnade, P., dan Divyangkumar, N. (2025) 'Characterization, Activation, and Life Cycle Analysis of Rice Husk Biochar', *Journal of Agricultural Engineering*, 62(1), pp. 222–236.
- Pehlivan, E., Özkan, A.M., Dinç, S., Parlayici, Ş. (2009) 'Adsorption of Cu^{2+} and Pb^{2+} ion on dolomite powder', *Journal of Hazardous Materials*, 167(1–3), pp. 1044–1049.
- Perwiranegara, S.A., Athanasius Priharyoto Bayuseno, dan Rifky Ismail (2021) 'Pengaruh Daya Microwave Terhadap Karakterisasi Hidroksiapatit Behbahan Cangkang Rajungan', *Jurnal Teknik Mesin S-1*, 9(4), pp. 1–6.
- Pham, L.T.C., Luu, H.G., Vu, M.D., Truong, H.C., Nguyen, M.T.B., Nguyen, M.K.D (2026) 'Unraveling adsorption mechanisms of Pb(II) and Cu(II) on Mn-HAp/BC composite via kinetic and diffusion analysis', *Journal of Environmental Chemical Engineering*, 14.
- Pu'ad, N.A.S.M., Alipal, J., Abdullah, H.Z., Idris, M.I., Lee, T.C. (2021) 'Synthesis of eggshell derived hydroxyapatite via chemical precipitation and calcination method', *Materials Today : Proceedings*, 42, pp. 172–177.
- Qin, L., Wu, Y., Hou, Z., Jiang, E. (2020) 'Influence of biomass components , temperature and pressure on the pyrolysis behavior and biochar properties of pine nut shells', *Bioresource Technology*, 313, p. 123682.
- Radwan, N.M., Hassan, M.A., Awad, A.M., Hassan, M.A., Marzouk, E.R. (2026) 'A Novel Hybrid Smart Fertilizer of Biochar and Nano-Hydroxyapatite : Characterization and Performance for Improving Sandy Soil Fertility', *Sustainability*, 18, pp. 1–23.
- Raji, Z., Karim, A., Karam, A., Khalloufi, S. (2023) 'Adsorption of Heavy Metals: Mechanisms, Kinetics, and Applications of Various Adsorbents in Wastewater Remediation—A Review', *Waste*, 1(3), pp. 775–805.
- Ramdani, A., Kadeche, A., Adjdir, M., Taleb, Z., Ikhrou, D., Taleb, S., Deratani, A. (2020) 'Lead and cadmium removal by adsorption process using hydroxyapatite porous materials', *Water Practice and Technology*, 15(1), pp. 130–141.
- Rashed, M.N., Gad, A.A.E., dan Fath, N.M. (2019) 'Adsorption of Cd(II) and Pb(II) Using Physically Pretreated', 2(4), pp. 347–364.
- Rasmiyanti, Amalia, V., dan Setiadi, D.S. (2022) 'Sintesis dan Karakterisasi Komposit Hidroksiapatit / Kitosan / Alginat sebagai Injectable Bone Substitute (IBS)', *Prosiding Seminar Nasional Kimia 2022 UIN Sunan Gunung Djati Bandung*, 15.
- Razak, A., Isa, N.M., dan Adzila, S. (2021) 'Synthesis of calcium phosphate extracted from eggshell waste through precipitation method',

- Biointerface Research in Applied Chemistry*, 11(6), pp. 15058–15067.
- Reza, S.M., Afroze, S., Bakar, M.S.A., Saidur, R., Aslfattahi, N., Taweekun, J., Azad, A.K. (2020) 'Biochar characterization of invasive *Pennisetum purpureum* grass : effect of pyrolysis temperature', *Biochar*.
- Rojas, D.F.H., Gómez, P.P., dan Rivera, A.R. (2019) 'Production and characterization of silica nanoparticles from rice husk', 10(1), pp. 67–73.
- Rout, P.R., Bhunia, P., dan Dash, R.R. (2014) 'A mechanistic approach to evaluate the effectiveness of red soil as a natural adsorbent for phosphate removal from wastewater', *Desalination and Water Treatment*, pp. 37–41.
- Roy, A. dan G, S.R.A. (2022) 'A Review on X-Ray Diffraction', 7(2), pp. 786–788.
- Sabu, U., Logesh, G., Rashad, M., Joy, A., Balasubramanian, M. (2019) 'Microwave assisted synthesis of biomorphic hydroxyapatite', *Ceramics International*, 45(6), pp. 6718–6722.
- Sadeghizadeh, A., Ebrahimi, F., Heydari, M., Tahmasebikohyani, M., Ebrahimi, F., Sadeghizadeh, A. (2019) 'Adsorptive removal of Pb (II) by means of hydroxyapatite/chitosan nanocomposite hybrid nano-adsorbent: ANFIS modeling and experimental study', *Journal of Environmental Management*, 232, pp. 342–353.
- Saisa-Ard, O., Somphon, W., Dungkaew, W., Haller, K.J. (2014) 'Evidence of a lead metathesis product from calcium hydroxyapatite dissolution in lead nitrate solution', *Advances in Materials Science and Engineering*, pp. 1–7.
- Sajahan, N.A. dan Wan Ibrahim, W.M.A. (2014) 'Microwave irradiation of nanohydroxyapatite from chicken eggshells and duck eggshells', *Scientific World Journal*, 2014.
- Salsyabil, A. (2018) 'Perkembangan Teknologi Deionisasi Air', *Jurusan Teknik Kimia, Fakultas Teknologi Industri, Institut Teknologi Bandung*, pp. 1–14.
- Sen, K., Mondal, S., dan Kumar, N. (2026) 'Surface charge behavior of natural and modified adsorbents: Insights into pH_{Zpc}, mechanisms, and methodological perspectives', *Next Materials*, 11(February), p. 101938.
- Sen, T.K. (2023) 'Agricultural Solid Wastes Based Adsorbent Materials in the Remediation of Heavy Metal Ions from Water and Wastewater by Adsorption: A Review', *Molecules*, 28(14).
- Shi, D., Tong, H., Lv, M., Luo, D., Wang, P., Xu, X., Han, Z. (2021) 'Optimization of hydrothermal synthesis of hydroxyapatite from chicken eggshell waste for effective adsorption of aqueous Pb(II)', *Environmental Science and Pollution Research*, 28(41), pp. 58189–58205.
- Singh, N.B., Nagpal, G., Agrawal, S., Rachna. (2018) 'Water purification by using Adsorbents: A Review', *Environmental Technology and Innovation*, 11, pp. 187–240.
- Skwarek, E., Janusz, W., dan Sternik, D. (2017) 'The influence of the hydroxyapatite synthesis method on the electrochemical, surface and adsorption properties of hydroxyapatite', *Adsorption Science and Technology*, 35(5–6), pp. 507–518.
- Sun, L., Wu, J., Wang, J., Xu, M., Zhou, W., Du, Y., Li, Y. (2023) 'Fabricating hydroxyapatite functionalized biochar composite using steel slag and Hami melon peel for Pb (II) and Cd (II) removal', *Colloids and Surfaces*

- A: Physicochemical and Engineering Aspects*, 666, p. 131310.
- Supriyanto, N.S.W., Sukarni, Puspitasari, P., Permanasari, A.A. (2019) 'Synthesis and characterization of CaO/CaCO₃ from quail eggshell waste by solid state reaction process', *AIP Conference Proceedings*, 2120, pp. 1–8.
- Tan, Z., Truong, T.T.T., Le, A.L., Do, D.A.M., Nguyen, T.G., Tran, T. D., Pham, T.D. (2020) 'Mechanism of negative surface charge formation on biochar and its effect on the fixation of soil Cd', *Journal of Hazardous Materials journal*, 384.
- Tangahu, B.V., Abdullah, S.R.S., Basri, H., Idris, M., Anuar, N., Mukhlisin, M. (2011) 'A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation', *International Journal of Chemical Engineering*.
- Tran, T.K.C., Truong, T.T.T., Le, A.L., Do, D.A.M., Nguyen, T.G., Tran, T.D., Pham, T.D. (2025) 'Synthesis, characterization of novel protein-modified rice husk biochar and their applications for highly adsorptive removal azo dye in water', *Environmental Technology & Innovation*, 37, p. 104037.
- Vaishali, Anjaneyulu, B., Sushma, S., Pundeer, R. (2026) 'Next Nanotechnology Nano-hydroxyapatite (n-HAp) and its composites for heavy metal removal from water : A comprehensive review', *Next Nanotechnology*, 9, p. 100339.
- Vinayagam, R., Kandati, S., Murugesan, G., Goveas, L.C., Baliga, A., Pai, S., Varadavenkatesan, T., Kaviyarasu, K., Selvaraj, R. (2023) 'Bioinspiration synthesis of hydroxyapatite nanoparticles using eggshells as a calcium source: Evaluation of Congo red dye adsorption potential', *Journal of Materials Research and Technology*, 22, pp. 169–180.
- Wadu, I., Soetjipto, H., dan Cahyanti, M.N. (2018) 'Synthesis and Determination Level of Calcium-Phosphate Hydroxyapatite (HAp) from Chicken Eggshell', *JKPK (Jurnal Kimia dan Pendidikan Kimia)*, 3(1), p. 1.
- Wang, C., Luo, M., Xie, C., Li, K., Hang, F., Shi, C., Doherty, W.O.S. (2022) 'Effective Adsorption of Colorants from Sugarcane Juice by Bagasse-Based Biochar-Hydroxyapatite Composite', *foods*, 11, pp. 1–19.
- Wang, D., Zhou, X., Liang, M., Wu, Z. (2025) 'Synthesis of Hydroxyapatite Mulberry Stem Biochar Composites for Efficient Pb (II) Adsorption from Aqueous Solutions', pp. 1–18.
- Wang, J. dan Guo, X. (2020) 'Adsorption kinetic models: Physical meanings, applications, and solving methods', *Journal of Hazardous Materials*, 390(January), p. 122156.
- Wang, L., Sik, Y.O., Tsang, D.C.W., Rinklebe, J., Wang, H., Mašek, O., Hou, R., Connor, D.O., Hou, D. (2020) 'New trends in biochar pyrolysis and modification strategies : feedstock, pyrolysis conditions, sustainability concerns and implications for soil amendment', pp. 358–386.
- Wang, Y., Liu, Yu-xue., Lu, Hao-hao., Yang, Rui-qin., Yang, Sheng-mao (2018) 'Competitive adsorption of Pb(II), Cu(II), and Zn (II) ions onto hydroxyapatite-biochar nanocomposite in aqueous solutions', *Journal of Solid State Chemistry*, 261, pp. 53–61.
- Wardana, M.T. dan Kuntjoro, S. (2023) 'Analisis Kadar Logam Berat Timbal (Pb) di Perairan Pelabuhan Teluk Lamong dan Korelasinya terhadap Kadar

- Pb Kerang darah (*Tegillarca granosa*)', *LenteraBio : Berkala Ilmiah Biologi*, 12(1), pp. 41–49.
- Windarti, T., Setiadi, Amalia, S., Fibriani, F., Azis, I.M.A., Putri, S.A. (2024) 'Sintesis dan Karakterisasi Hidroksiapatit dengan Metode Sol-Gel Sebagai Bahan Dasar Adsorben', *Greensphere: Journal of Environmental Chemistry*, 3(2), pp. 14–17.
- Wu, W., Liu, Z., Azeem, M., Guo, Z., Li, R., Li, Y. (2022) 'Hydroxyapatite tailored hierarchical porous biochar composite immobilized Cd(II) and Pb(II) and mitigated their hazardous effects in contaminated water and soil', 437.
- Xiao, X., Chen, Z., dan Chen, B. (2020) 'Proton uptake behaviors of organic and inorganic matters in biochars prepared under different pyrolytic temperatures', *Science of the Total Environment*, 746.
- Yaashikaa, P.R., Kumar, P.S., Varjani, S., Saravanan, A. (2020) 'A critical review on the biochar production techniques, characterization, stability and applications for circular bioeconomy', *Biotechnology Reports*, 28, p. e00570.
- Yang, W., Lu, C., Liang, B., Yin, C., Lei, G., Wang, B., Zhou, X., Zhen, J., Quan, S., Jing, Y. (2023) 'Removal of Pb(II) from Aqueous Solution and Adsorption Kinetics of Corn Stalk Biochar', *Separations*, 10.
- Yonata, D., Yonata, S., Aminah, S., Hersoelisyorini, W. (2017) 'Kadar Kalsium dan Karakteristik Fisik Tepung Cangkang Telur Unggas dengan Perendaman Berbagai Pelarut', *Jurnal Pangan dan Gizi*, 7(2), pp. 82–93.
- Yustinah, Hudzaifah, Maya Aprilia, S.A. (2019) 'Keseimbangan Adsorpsi Logam Berat (Pb) dengan Adsorben Tanah Diatomit Secara Batch', 8(2), pp. 37–43.
- Zaini, H. dan Sami, M. (2016) 'Kinetika Adsorpsi Pb(II) Dalam Air Limbah Laboratorium Kimia Menggunakan Sistem Kolom Dengan Bioadsorben Kulit Kacang Tanah', *Seminar Nasional Sains dan Teknologi*, pp. 1–9.
- Zein, R., Deswati, D., Fauzia, S., Pisya, N.F. (2024) 'Comparative study of Pb(II) and Cr(VI) removal using Cassava peel (*Manihot Esculenta* Crantz)', *International Journal of Phytoremediation*, 0(0), pp. 1–10.
- Zein, R., Putria, C.N., Deswati, D., Fauzia, S., (2024) 'Pb(II) Removal from Aqueous Solutions Using Citric Acid Modified Kepok Banana Peel: Batch and Kinetic Studies', *Analytical Bioanalytical Chemistry Research*, Vol. 11, pp. 227–238.
- Zhang, L., Li, Q., Yan, Y., Jiang, X., Shen, J., (2025) 'Development of nano-hydroxyapatite@biochar composite from low-cost precursors for enhanced immobilization of lead and cadmium', *Journal of Hazardous Materials*, 500, p. 140535.
- Zhang, Q., Lu, L., Liang, M., Wang, D., Huang, D., Zhu, Y. (2022) 'Efficient Treatment of Lead-containing Wastewater Using Bagasse Biochar Modified via Hydroxylapatite', pp. 1205–1231.
- Zhao, X., Yuan, P., Yang, Z., Peng, W., Meng, X., Cheng, J. (2022) 'Integration of Micro-Nano-Engineered Hydroxyapatite/Biochars with Optimized Sorption for Heavy Metals and Pharmaceuticals', *Nanomaterials*, 12(12), pp. 1–17.
- Zhou, C., Wang, X., Song, X., Wang, Y., Fang, D., Ge, S., Zhang, R. (2020) 'Insights into dynamic adsorption of lead by nano-hydroxyapatite

- prepared with two-stage ultrasound', *Chemosphere*, 253.
- Zhou, Y., Yao, H., Wang, J., Wang, D., Liu, Q., Li, Z. (2015) 'Greener synthesis of electrospun collagen/hydroxyapatite composite fibers with an excellent microstructure for bone tissue engineering', *International Journal of Nanomedicine*, 10, pp. 3203–3215.
- Zhu, S., Kashif, M., Ibrahim, M., Chen, Q., Shang, J., Zhang, Q. (2022) 'The distinctive role of nano-hydroxyapatite modified biochar for alleviation of cadmium and arsenic toxicity in aqueous system', *Journal of Water Process Engineering*, 49, p. 103054.
- Zhu, Y., Zhu, Z., Zhao, X., Liang, Y., Huang, Y. (2015) 'Characterization, dissolution, and solubility of lead hydroxypyromorphite [$\text{Pb}_5(\text{PO}_4)_3\text{OH}$] at 25-45°C', *Journal of Chemistry*, 2015.

