

DAFTAR PUSTAKA

- Afdal dan Niarti, L., 2013, Karakterisasi sifat magnet dan kandungan mineral pasir besi sungan Batang Kuranji Padang Sumatera Barat, *JIF*, 5, 24–30.
- Aguado, J., Arsuaga, J.M., Arencibia, A., Lindo, M., dan Gascón, V., 2009, Aqueous heavy metals removal by adsorption on amine-functionalized mesoporous silica, *J Hazard. Mater.*, 163, 213–221.
- Ahmad, M.I., Li, Y., Pan, J., Liu, F., Dai, H., Fu, Y., Huang, T., Farooq, S., dan Zhang, H., 2024, Collagen and gelatin: Structure, properties, and applications in food industry, *Int. J. Biol. Macromol.*, 254, 128037.
- Andonegi, M., Peñalba, M., de la Caba, K., dan Guerrero, P., 2020, ZnO nanoparticle-incorporated native collagen films with electro-conductive properties, *Mater. Sci. Eng., C*, 108, 110394.
- Arya, S., Patel, A., Kumar, S., dan Pau-Loke, S., 2021, Urban mining of obsolete computers by manual dismantling and waste printed circuit boards by chemical leaching and toxicity assessment of its waste residues, *Environ. Pollut.*, 283, 117033.
- Barik, B., Kumar, A., Nayak, P.S., Achary, L.S.K., Rout, L., dan Dash, P., 2020, Ionic liquid assisted mesoporous silica-graphene oxide nanocomposite synthesis and its application for removal of heavy metal ions from water, *Mater. Chem. Phys.*, 239, 122028.
- Bilesan, M.R., Makarova, I., Wickman, B., dan Repo, E., 2021, Efficient separation of precious metals from computer waste printed circuit boards by hydrocyclone and dilution-gravity methods, *J. Clean. Prod.*, 286, 125505.
- Birloaga, I., De Michelis, I., Ferella, F., Buzatu, M., dan Vegliò, F., 2013, Study on the influence of various factors in the hydrometallurgical processing of waste printed circuit boards for copper and gold recovery, *Waste Manage.*, 33, 935–941.
- Boughrara, L., Zaoui, F., Guezoul, M., Sebba, F.Z., Bounaceur, B., dan Kada, S.O., 2022, New alginic acid derivatives ester for methylene blue dye adsorption: kinetic, isotherm, thermodynamic, and mechanism study, *Int. J. Biol. Macromol.*, 205, 651–663.
- Bozec, L. dan Odlyha, M., 2011, Thermal denaturation studies of collagen by microthermal analysis and atomic force microscopy, *Biophys. J.*, 101, 228–236.
- Buhani dan Suharso, 2010, Modifikasi silika dengan 3-aminopropiltrimetoksisilan melalui proses sol gel untuk adsorpsi ion Cd(II) dari larutan, *Journal Sains MIPA*, 16, 177–183.

- Can, M., Sayin, M., dan Imamoğlu, M., 2021, Adsorption of Pd(II) and Au(III) ions by commercial tris(2-aminoethyl) amine polystyrene polymer beads, *J. Chem. Eng. Data*, 66, 1132–1143.
- Cao, J., Wang, Q., Ma, T., Bao, K., Yu, X., Duan, Z., Shen, X., dan Li, C., 2020, Effect of EGCG-gelatin biofilm on the quality and microbial composition of tilapia fillets during chilled storage, *Food Chem.*, 305, 125454.
- Catalina, M., Cot, J., Balu, A.M., Serrano-Ruiz, J.C., dan Luque, R., 2012, Tailor-made biopolymers from leather waste valorisation, *Green Chem.*, 14, 308–312.
- Chang, S.H. dan Jampang, A.O.A., 2023, Enhanced adsorption selectivity of Au(III) over Cu(II) from acidic chloride solutions by chitosan/palm kernel fatty acid distillate/magnetite nanocomposites, *Int. J. Biol. Macromol.*, 252, 126491.
- Chang, S.H., Jampang, A.O.A., dan Din, A.T.M., 2025, Adsorption isotherms, kinetics, and thermodynamics of Au(III) on chitosan/palm kernel fatty acid distillate/magnetite nanocomposites, *Int. J. Biol. Macromol.*, 304, 140913.
- Chang, Z., Gong, X., Zeng, L., Wang, J., dan Zhu, Y., 2022, Magnetic Zr-based metal-organic frameworks: A highly efficient Au(III) trapper for gold recycling, *Materials*, 15, 6531.
- Chang, Z., He, B., Gong, X., Qi, X., dan Liu, K., 2023, Cr-based metal-organic frameworks (MOFs) with high adsorption selectivity and recyclability for Au (III): Adsorption behavior and mechanism study, *Sep. Purif. Technol.*, 325, 124612.
- Chao, A.C., 2008, Preparation of porous chitosan/GPTMS hybrid membrane and its application in affinity sorption for tyrosinase purification with *Agaricus bisporus*, *J. Memb. Sci.*, 311, 306–318.
- Chassary, P., Vincent, T., Sanchez Marcano, J., MacAskie, L.E., dan Guibal, E., 2005, Palladium and platinum recovery from bicomponent mixtures using chitosan derivatives, *Hydrometallurgy*, 76, 131–147.
- Chauhan, G.S., Kumar, S., Kumari, A., dan Sharma, R., 2003, Study on the synthesis, characterization, and sorption of some metal ions on gelatin-and acrylamide-based hydrogels, *J. Appl. Polym. Sci.*, 90, 3856–3871.
- Chen, G., Qiao, C., Wang, Y., dan Yao, J., 2014, Synthesis of magnetic gelatin and its adsorption property for Cr(VI), *Ind. Eng. Chem. Res.*, 53, 15576–15581.
- Chen, S., Chinnathambi, S., Shi, X., Osaka, A., Zhu, Y., dan Hanagata, N., 2012, Fabrication of novel collagen-silica hybrid membranes with tailored biodegradation and strong cell contact guidance ability, *J. Mater. Chem.*, 22, 21885–21892.
- Chen, S., Osaka, A., Ikoma, T., Morita, H., Li, J., Takeguchi, M., dan Hanagata, N., 2011, Fabrication, microstructure, and BMP-2 delivery of novel

- biodegradable and biocompatible silicate-collagen hybrid fibril sheets, *J. Mater. Chem.*, 21, 10942–10948.
- Chen, X., Lam, K.F., Mak, S.F., dan Yeung, K.L., 2011, Precious metal recovery by selective adsorption using biosorbents, *J. Hazard. Mater.*, 186, 902–910.
- Chen, Z., Chen, Y., Xu, T., Guo, Y., He, T., Xie, H., dan Zhang, L., 2025, Upcycling of wool keratin for selective recovery of gold from aqueous solution, *Chem. Eng. J.*, 503, 158324.
- Cho, S.M., Kwak, K.S., Park, D.C., Gu, Y.S., Ji, C.I., Jang, D.H., Lee, Y.B., dan Kim, S.B., 2004, Processing optimization and functional properties of gelatin from shark (*Isurus oxyrinchus*) cartilage, *Food Hydrocoll.*, 18, 573–579.
- Choi, J.W., Song, M.H., Bediako, J.K., dan Yun, Y.S., 2020, Sequential recovery of gold and copper from bioleached wastewater using ion exchange resins, *Environ. Pollut.*, 266, 115167.
- Chung, J., Chun, J., Lee, J., Lee, S.H., Lee, Y.J., dan Hong, S.W., 2012, Sorption of Pb(II) and Cu(II) onto multi-amine grafted mesoporous silica embedded with nano-magnetite: Effects of steric factors, *J. Hazard. Mater.*, 239–240, 183–191.
- Cornell, R.M. dan Schwertmann, U., 2003, Structure, properties, reaction, occurrences and uses, second. Wiley-VCH GmbH & KGaA, London.
- Cui, C., Qiao, W., Li, D., dan Wang, L. jun, 2025, Dual cross-linked magnetic gelatin/carboxymethyl cellulose cryogels for enhanced Congo red adsorption: Experimental studies and machine learning modelling, *J. Colloid Interface Sci.*, 678, 619–635.
- Dal, M.C. dan Onursal, N., 2023, Two new linearized equations derived from a pseudo-second-order kinetic model, *Desalin. Water Treat.*, 308, 183–189.
- Damink, L.H.H.O., Dijkstra, P.J., Van Luyn, M.J.A., Van Wachem, P.B., Nieuwenhuis, P., dan Feijen, J., 1995, Glutaraldehyde as a crosslinking agent for collagen-based biomaterials, *J. Mater. Sci. Mater. Med.*, 6, 460–472.
- Dewi, S.H. dan Ridwan, D., 2012, Sintesis dan karakterisasi nanopartikel Fe₃O₄ magnetik untuk adsorpsi kromium heksavalen, *JUSAMI*, 13, 1411–1098.
- Dhawade, P. dan Jagtap, R., 2012, Comparative study of physical and thermal properties of chitosan-silica hybrid coatings prepared by sol-gel method, *J. Der. Chemica Senica*, 3, 589–601.
- Dong, Z., Liu, J., Yuan, W., Yi, Y., dan Zhao, L., 2016, Recovery of Au(III) by radiation synthesized aminomethyl pyridine functionalized adsorbents based on cellulose, *Chem. Eng. J.*, 283, 504–513.

- Duconseille, A., Astruc, T., Quintana, N., Meersman, F., dan Sante-Lhoutellier, V., 2015, Gelatin structure and composition linked to hard capsule dissolution: A review, *Food Hydrocoll*, 43, 360–376.
- Ermawati, R., Naimah, S., dan Ratnawati, E., 2011, Monitoring and extraction of TiO₂ from mineral sand, *J. Kim. Kemasan*, 33, 131–136.
- Esmaeili, A., Saremnia, B., dan Kalantari, M., 2015, Removal of mercury(II) from aqueous solutions by biosorption on the biomass of *Sargassum glaucescens* and *Gracilaria corticata*, *Arab. J. Chem.*, 8 (4), 506–511.
- Fahmiati, Nuryono, dan Suyanta, 2017, Characteristics of iron sand Magnetic material from bugel beach, Kulon Progo, Yogyakarta, in, *IOP Conf. Ser.: Mater. Sci. Eng.*, 172, 012020.
- Fahmiati, Nuryono, dan Suyanta, 2018, Functionalization of silica coated on iron sand magnetic material with diethylenetriamine, *Asian J. Chem.*, 30, 1805–1810.
- Faraji, M., Yamini, Y., dan Rezaee, M., 2010, Magnetic nanoparticles: synthesis, stabilization, functionalization, characterization, and applications, *J. Iran. Chem. Soc.*, 7, 1–37.
- Freundlich, H. Von, 1906, Über die Adsorption in Lösungen, *Z. Phys. Chem*, 57, 385–470.
- Friess, W., 1998, Collagen-biomaterial for drug delivery, *Eur. J. Pharm. Biopharm.*, 45, 113–136.
- Fujiwara, K., Ramesh, A., Maki, T., Hasegawa, H., dan Ueda, K., 2007, Adsorption of platinum (IV), palladium (II) and gold (III) from aqueous solutions onto l-lysine modified crosslinked chitosan resin, *J. Hazard. Mater.*, 146, 39–50.
- Gabrielli, L., Russo, L., Poveda, A., Jones, J.R., Nicotra, F., Jiménez-Barbero, J., dan Cipolla, L., 2013, Epoxide opening versus silica condensation during sol-gel hybrid biomaterial synthesis, *Chem. Eur. J.*, 19, 7856–7864.
- Gaspar-Pintiliescu, A., Stanciuc, A.M., dan Craciunescu, O., 2019, Natural composite dressings based on collagen, gelatin and plant bioactive compounds for wound healing: A review, *Int. J. Biol. Macromol.*, 138, 854–865.
- Gebremichael, G.T., Kim, H., Nisola, G.M., dan Chung, W.J., 2021, Asparagine anchored on mesoporous silica for Au (III) capture: Elucidation of adsorption-reduction mechanisms and their implications towards selective Au (III) recovery, *Appl. Surf. Sci.*, 567, 150743.
- Gemeay, A.H., Keshta, B.E., El-Sharkawy, R.G., dan Zaki, A.B., 2020, Chemical insight into the adsorption of reactive wool dyes onto amine-functionalized magnetite/silica core-shell from industrial wastewaters, *Environ. Sci. Pollut. Res. Int.*, 27, 32341–32358.

- Gojkovic, Z., Marova, I., Matouskova, P., Obruca, S., dan Miloslav, P., 2014, Use of ultrasonic spectroscopy and viscosimetry for the characterization of chicken skin collagen in comparison with collagens from other animal tissues, *Prep. Biochem. Biotechnol.*, 44, 761–771.
- Gomez-Guillen, M.C., Gimenez, B., Lopez-Caballero, M.E., dan Montero, M.P., 2011, Functional and bioactive properties of collagen and gelatin from alternative sources: A review, *Food Hydrocoll.*, 25, 1813–1827.
- Gönen, N., Körpe, E., Yildirim, M.E., dan Selengil, U., 2007, Leaching and CIL processes in gold recovery from refractory ore with thiourea solutions, *Miner. Eng.*, 20, 559–565.
- Gopalakannan, V. dan Viswanathan, N., 2015, Development of nano-hydroxyapatite embedded gelatin biocomposite for effective chromium(VI) removal, *Ind. Eng. Chem. Res.*, 54, 12561–12569.
- Groenewald, T., 1976, The dissolution of gold in acidic solution of thiourea, *Hydrometallurgy*, 1, 277–290.
- Hastuti, S. dan Kuncaka, A., 2015, L-arginine-modified silica for adsorption of gold(III), *Indones. J. Chem*, 15, 108–115.
- He, X., Lin, L., Jiang, S., dan Lu, J., 2024, Characterization of acid-soluble collagen (ASC) derived from walleye pollock and silver carp skin and comparison them with the collagen from pig and duck skin, *Food Chem. Adv.*, 4, 100746.
- He, X., Xu, H., dan Li, H., 2015, Cr(VI) removal from aqueous solution by chitosan/carboxymethyl cellulose/silica hybrid membrane, *World J. Eng. Technol.*, 03, 234–240.
- Herman, P., Fábíán, I., dan Kalmár, J., 2020, Mesoporous silica-gelatin aerogels for the selective adsorption of aqueous Hg(II), *ACS Appl. Nano Mater.*, 3, 195–206.
- Ho, Y.S. dan Mckay, G., 1999, Pseudo-second order model for sorption processes, *Process Biochem.*, 34, 451–465.
- Hossain, M.D., Hossain, M.A., dan Sikder, S.S., 2022, Hysteresis loop properties of rare earth doped spinel ferrites: A review, *J. Magn. Magn. Mater.*, 564, 170095.
- Hu, X., Zhang, T., Yang, B., Hao, M., Chen, Z., Wei, Y., Liu, Y., Wang, X., dan Yao, J., 2024, Water-resistant nanocellulose/gelatin biomass aerogel for anionic/cationic dye adsorption, *Sep. Purif. Technol.*, 330, 125367.
- Huang, C. dan Hu, B., 2008, Silica-coated magnetic nanoparticles modified with γ -mercaptopropyltrimethoxysilane for fast and selective solid phase extraction of trace amounts of Cd, Cu, Hg, and Pb in environmental and biological samples prior to their determination by inductively coupled plasma mass spectrometry, *Spectrochim. Acta, Part B.*, 63, 437–444.

- Huang, D.H., Ooi, A.W.S., dan Moment, A.J., 2025, Investigation of in-situ mechanical and chemical etching: A milder hydrometallurgical approach for Au, Ni, and Cu recovery from printed circuit boards, *Resour. Conserv. Recycl.*, 212, 108013.
- Huy Do, M., Tien Nguyen, G., Dong Thach, U., Lee, Y., dan Huu Bui, T., 2023, Advances in hydrometallurgical approaches for gold recovery from E-waste: A comprehensive review and perspectives, *Miner. Eng.*, 191, 107977.
- Ianăși, C., Svera, P., Popa, A., Lazău, R., Negrea, A., Negrea, P., Duteanu, N., Ciopec, M., dan Nemes, N.S., 2023, Adsorbent material based on carbon black and bismuth with tunable properties for gold recovery, *Materials*, 16, 2837.
- Indriyanti, N.Y., Manuhutu, J.B., dan Tanaka, S., 2013, Sorption of Au(III) and Ag(I) on amino-and mercapto-silica hybrid columns, *Malays. J. Anal. Sci.*, 17, 244–254.
- Irzon, R., 2018, Geochemical character of coastal sediments from Southern Kulon Progo with implications for provenance, *J. Geol. Mineral Resources*, 19, 31–35.
- Jackson, D., Ames, W.M., Sci Food and Agr, J., Bowes, J.H., dan Kenton, R.H., 1957, Observations on amino acid-dependent exchanges of inorganic pyrophosphate and ATP*, *Am. Leather Chem. Assoc.*, 26, 638–639.
- Jal, P.K., Patel, S., dan Mishra, B.K., 2004, Chemical modification of silica surface by immobilization of functional groups for extractive concentration of metal ions, *Talanta*, 62, 1005–1028.
- Jalil, Z., Sari, E.N., Ab, I., dan Handoko, E., 2014, Studi komposisi fasa dan sifat kemagnetan pasir besi pesisir Pantai Aceh yang dipreparasi dengan metode mechanical milling, *Indones. J. Appl. Phys.*, 04, 110–114.
- Jang, J.H. dan Lim, H.B., 2010, Characterization and analytical application of surface modified magnetic nanoparticles, *Microchem. J.*, 94, 148–158.
- Javadian, H., Sorkhrodi, F.Z., dan Koutenaiei, B.B., 2014, Experimental investigation on enhancing aqueous cadmium removal via nanostructure composite of modified hexagonal type mesoporous silica with polyaniline/polypyrrole nanoparticles, *J. Ind. Eng. Chem.*, 20, 3678–3688.
- Jing, L., Yang, S., Li, X., Jiang, Y., Lou, J., Liu, Z., Ding, Q., dan Han, W., 2022, Effective adsorption and sensitive detection of Cr⁶⁺ by degradable collagen-based porous fluorescent aerogel, *Ind. Crops. Prod.*, 182, 114882.
- Kalpathy, U., Proctor, A., dan Shultz, J., 2002, An improved method for production of silica from rice hull ash, *Bioresour. Technol.*, 85, 285–289.
- Kaur, S. dan Jindal, R., 2018, Synthesis of interpenetrating network hydrogel from (gum copal alcohols-collagen)-co-poly(acrylamide) and acrylic acid: Isotherms and kinetics study for removal of methylene blue dye from aqueous solution, *Mater. Chem. Phys.*, 220, 75–86.

- Kikuchi, M., Matsumoto, H.N., Yamada, T., Koyama, Y., Takakuda, K., dan Tanaka, J., 2004, Glutaraldehyde cross-linked hydroxyapatite/collagen self-organized nanocomposites, *Biomaterials*, 25, 63–69.
- Kim, E.Y., Kim, M.S., Lee, J.C., dan Pandey, B.D., 2011, Selective recovery of gold from waste mobile phone PCBs by hydrometallurgical process, *J. Hazard. Mater.*, 198, 206–215.
- Kittiphattanabawon, P., Benjakul, S., Visessanguan, W., Nagai, T., dan Tanaka, M., 2005, Characterisation of acid-soluble collagen from skin and bone of bigeye snapper (*Priacanthus tayenus*), *Food Chem.*, 89, 363–372.
- Kobyliukh, A., Olszowska, K., Szeluga, U., dan Pusz, S., 2020, Iron oxides/graphene hybrid structures – Preparation, modification, and application as fillers of polymer composites, *Adv Colloid Interface Sci.*, 285, 102285.
- Komatina, M. dan Gudenau, H.-W., 2004, The sticking problem during direct reduction of fine iron ore in fluidized bed, *J. Met.*, 10, 309–328.
- Kraus, A., Jainae, K., Unob, F., dan Sukpirom, N., 2009, Synthesis of MPTS-modified cobalt ferrite nanoparticles and their adsorption properties in relation to Au(III), *J. Colloid Interface Sci.*, 338, 359–365.
- Kumar, A., Gaurav, Malik, A.K., Tewary, D.K., dan Singh, B., 2008, A review on development of solid phase microextraction fibers by sol-gel methods and their applications, *Anal. Chim. Acta.*, 610, 1–14.
- Kumar, R., Barakat, M.A., Taleb, M.A., dan Seliem, M.K., 2020, A recyclable multifunctional graphene oxide/SiO₂@polyaniline microspheres composite for Cu(II) and Cr(VI) decontamination from wastewater, *J. Clean. Prod.*, 268, 122290.
- Kumar, R., Rashid, J., dan Barakat, M.A., 2014, Synthesis and characterization of a starch- AlOOH-FeS_2 nanocomposite for the adsorption of congo red dye from aqueous solution, *RSC Adv.*, 4, 38334–38340.
- Kuzugüdenli, Ö.E. dan Kantar, Ç., 1999, Alternates to gold recovery by cyanide leaching, *Erc. Univ. Fen Bil. Derg.*, 15, 119–127.
- Lagergren, S., 1898, About the theory of so-called adsorption of soluble substances, *Kungl. Svenska Vetenskapskad.*, 24, 1–39.
- Lakshminarayana, G. dan Nogami, M., 2009, Synthesis and characterization of proton conducting inorganic-organic hybrid nanocomposite membranes based on tetraethoxysilane/trimethylphosphate/3-glycidoxypropyltrimethoxysilane/heteropoly acids, *Electrochim. Acta*, 54, 4731–4740.
- Lam, K.F., Fong, C.M., Yeung, K.L., dan McKay, G., 2008, Selective adsorption of gold from complex mixtures using mesoporous adsorbents, *Chem. Eng. J.*, 145, 185–195.

- Langmuir, I., 1918, Adsorption of gases on glass, mica and platinum, *J. Am. Chem. Soc.*, 40, 1361–1403.
- Li, J., Liao, X., Liao, G., He, Q., Zhang, W., dan Shi, B., 2010, Separation of flavonoid and alkaloid using collagen fiber adsorbent, *J. Sep. Sci.*, 33, 2230–2239.
- Li, J., Liao, X. pin, Zhang, Q. xian, dan Shi, B., 2013, Adsorption and separation of proteins by collagen fiber adsorbent, *J. Chromatogr. B.*, 928, 131–138.
- Li, X.H., Yang, H.J., Ma, Y.X., Li, T.Z., Meng, W.L., dan Zhong, X.M., 2023, A novel PAN/GO electrospun nanocomposite fibrous membranes with rich amino groups for highly efficient adsorption of Au(III), *Diam. Relat. Mater.*, 137, 110175.
- Lihl, N., May, N. V., Udvardy, A., Najóczki, F., Bonczidai-Kelemen, D., Diószegi, R., Szalóki, D., Sánta, S.O., dan Fábíán, I., 2023, Complexes of 1,10-phenanthroline-mono-N-oxides with copper(II) and nickel(II) in aqueous solution and solid phase, *Inorganica. Chim. Acta.*, 557, 121715.
- Lim, C.W. dan Lee, I.S., 2010, Magnetically recyclable nanocatalyst systems for the organic reactions, *Nano Today*, 5, 412–434.
- Lin, X., Song, M.H., Tran, D.T., Lee, Y.S., dan Yun, Y.S., 2023, Development of polyethylenimine-functionalized cellulose fibers for recovery of Au(0) from Au(III)-containing acidic solutions through an adsorption–reduction–detachment–aggregation mechanism, *J. Clean. Prod.*, 389, 136019.
- Lin, Y.C., Wang, H.Y., Tang, Y.C., Lin, W.R., Tseng, C.L., Hu, C.C., dan Chung, R.J., 2024, Enhancing wound healing and adhesion through dopamine-assisted gelatin-silica hybrid dressings, *Int. J. Biol. Macromol.*, 258, 128845.
- Lin, Y.F., Chen, H.W., Chien, P.S., Chiou, C.S., dan Liu, C.C., 2011, Application of bifunctional magnetic adsorbent to adsorb metal cations and anionic dyes in aqueous solution, *J. Hazard. Mater.*, 185, 1124–1130.
- Liu, F., Wang, Z., dan Li, G., 2014, Adsorption of Ag⁺ by persimmon tannins immobilized on collagen fiber, *Desal. Water Treat.*, 52, 7172–7179.
- Liu, J., Jin, C., dan Wang, C., 2020, Hyperbranched thiourea-grafted electrospun polyacrylonitrile fibers for efficient and selective gold recovery, *J Colloid Interface Sci.*, 561, 449–458.
- Liu, L., Liu, S., Zhang, Q., Li, C., Bao, C., Liu, X., dan Xiao, P., 2013, Adsorption of Au(III), Pd(II), and Pt(IV) from aqueous solution onto graphene oxide, *J. Chem. Eng. Data.*, 58, 209–216.
- Liu, W., Yin, P., Liu, X., Dong, X., Zhang, J., dan Xu, Q., 2013, Thermodynamics, kinetics, and isotherms studies for gold(III) adsorption using silica functionalized by diethylenetriaminemethylenephosphonic acid, *Chem. Eng. Res. Des.*, 91, 2748–2758.

- Liu, X., Tang, R., He, Q., Liao, X., dan Shi, B., 2010, Fe(III)-loaded collagen fiber as a heterogeneous catalyst for the photo-assisted decomposition of Malachite Green, *J. Hazard. Mater.*, 174, 687–693.
- Liu, Y.L., Su, Y.H., dan Lai, J.Y., 2004, In situ crosslinking of chitosan and formation of chitosan-silica hybrid membranes with using γ -glycidoxypopyltrimethoxysilane as a crosslinking agent, *Polymer*, 45, 6831–6837.
- Lv, L.C., Huang, Q.Y., Ding, W., Xiao, X.H., Zhang, H.Y., dan Xiong, L.X., 2019, Fish gelatin: The novel potential applications, *J. Funct. Foods*, 63, 103581.
- Madhavi, W.A.M., Weerasinghe, S., Fullerton, G.D., dan Momot, K.I., 2019, Structure and dynamics of collagen hydration water from molecular dynamics simulations: implications of temperature and pressure, *J. Phys. Chem. B.*, 123, 4901–4914.
- Mahony, O., Yue, S., Turdean-Ionescu, C., Hanna, J. V., Smith, M.E., Lee, P.D., dan Jones, J.R., 2014, Silica-gelatin hybrids for tissue regeneration: Interrelationships between the process variables, *J. Solgel. Sci. Technol.*, 69, 288–298.
- Maity, J. dan Ray, S.K., 2017, Removal of Cu (II) ion from water using sugar cane bagasse cellulose and gelatin based composite hydrogels, *Int. J. Biol. Macromol.*, 97, 238–248.
- Mandal, C. dan Nandi, U.S., 1978, Kinetic studies on the interaction of gold (III) with nucleic acids.IV.RNA-Au (III) system, *Chem. BioL. Interactions*, 21, 125–134.
- Mekonnen, B.T., Ragothaman, M., dan Palanisamy, T., 2017, Bifunctional hybrid composites from collagen biowastes for heterogeneous applications, *ACS Omega*, 2, 5260–5270.
- Mihăilescu, M., Negrea, A., Ciopec, M., Davidescu, C.M., Negrea, P., Duțeanu, N., dan Rusu, G., 2019, Gold (III) adsorption from dilute waste solutions onto Amberlite XAD7 resin modified with L-glutamic acid, *Sci. Rep.*, 9, 8757.
- Mir, A.A., Amooey, A.A., dan Ghasemi, S., 2018, Adsorption of direct yellow 12 from aqueous solutions by an iron oxide-gelatin nanoadsorbent; kinetic, isotherm and mechanism analysis, *J. Clean. Prod.*, 170, 570–580.
- Moura, L.I.F., Dias, A.M.A., Carvalho, E., dan De Sousa, H.C., 2013, Recent advances on the development of wound dressings for diabetic foot ulcer treatment - A review, *Acta. Biomater.*, 9, 7093–7114.
- Muflikhah, Rusdiarso, B., Putra, E.G.R., dan Nuryono, 2017, Modification of silica coated on iron sand magnetic material with chitosan for adsorption of Au(III), *Indones. J. Chem.*, 17, 264–273.
- Naat, J.N., Suyanta, S., dan Nuryono, N., 2024, Hydrophobic modification of naturally magnetic silica with methyltrimethoxysilane for enhanced

- adsorption of chloramphenicol and ciprofloxacin, *Case Stud. Chem. Environ. Eng.*, 10, 100878.
- Nagpal, V., Chaudhary, S., Kumar, P., Sudesh, dan Patnaik, S., 2022, Evidence of ferromagnetic clusters in magnetic Weyl semimetal $\text{Co}_3\text{Sn}_2\text{S}_2$, *J. Magn. Mater.*, 564, 170059.
- Nayeem, J., Al-Bari, M.A.A., Mahiuddin, M., Rahman, M.A., Mefford, O.T., Ahmad, H., dan Rahman, M.M., 2021, Silica coating of iron oxide magnetic nanoparticles by reverse microemulsion method and their functionalization with cationic polymer P(NIPAm-co-AMPTMA) for antibacterial vancomycin immobilization, *Colloids Surf. A Physicochem. Eng. Asp.*, 611, 125857.
- Negrea, A., Mihailescu, M., Mosoarca, G., Ciopec, M., Duteanu, N., Negrea, P., dan Minzatu, V., 2020, Estimation on fixed-bed column parameters of breakthrough behaviors for gold recovery by adsorption onto modified/functionalized amberlite xad7, *Int. J. Environ. Res. Public Health*, 17, 1–14.
- Negrea, A., Ronka, S., Ciopec, M., Duteanu, N., Negrea, P., dan Mihailescu, M., 2021, Kinetics, thermodynamics and equilibrium studies for gold recovery from diluted waste solution, *Materials*, 14, 5325.
- Nitsuwat, S., Zhang, P., Ng, K., dan Fang, Z., 2021, Fish gelatin as an alternative to mammalian gelatin for food industry: A meta-analysis, *LWT*, 141, 110899.
- Nouri-Felekori, M., Khakbiz, M., Nezafati, N., Mohammadi, J., dan Eslaminejad, M.B., 2019, Comparative analysis and properties evaluation of gelatin microspheres crosslinked with glutaraldehyde and 3-glycidoxypropyltrimethoxysilane as drug delivery systems for the antibiotic vancomycin, *Int. J. Pharm.*, 557, 208–220.
- Nugraha, P.A., Sari, S.P., Hidayati, W.N., Dewi, C.R., dan Kusuma, D.Y., 2016, The origin and composition of iron sand deposit in the southern coast of Yogyakarta, in *AIP Conf. Proc.*, 1746, 020028.
- Nurilmala, M., Suryamarevita, H., Husein Hizbullah, H., Jacob, A.M., dan Ochiai, Y., 2022, Fish skin as a biomaterial for halal collagen and gelatin, *Saudi J. Biol. Sci.*, 29, 1100–1110.
- Nuryono, N., Miswanda, D., Sakti, S.C.W., Rusdiarso, B., Krisbiantoro, P.A., Utami, N., Otomo, R., dan Kamiya, Y., 2020, Chitosan-functionalized natural magnetic particle@silica modified with 3-(chloropropyl)trimethoxysilane as a highly stable magnetic adsorbent for gold(III) ion, *Mater. Chem. Phys.*, 255, 123507.
- Nuryono, N., Muliaty, E., Rusdiarso, B., Candra, S., Sakti, W., dan Tanaka, S., 2014, Adsorption of Au(III), Cu(II) and Ni(II) on magnetite coated with mercapto groups modified rice hull ash silica, *J. Ion Exch.*, 25, 114–121.

- Nuryono, N., Mutia Rosiati, N., Rusdiarso, B., Sakti, S.C.W., dan Tanaka, S., 2014, Coating of magnetite with mercapto modified rice hull ash silica in a one-pot process, *Springerplus*, 3, 1–12.
- Nuryono, Rosiati, N.M., Rettob, A.L., Suyanta, dan Arryanto, Y., 2019, Coating of 2-aminobenzimidazole and 1-(O-tolyl)biguanide functionalized silicas on iron sand magnetic material for sorption of $[\text{AuCl}_4]^-$, *Indones. J. Chem.*, 19, 395–404.
- Ogata, T. dan Nakano, Y., 2005, Mechanisms of gold recovery from aqueous solutions using a novel tannin gel adsorbent synthesized from natural condensed tannin, *Water Res.*, 39, 4281–4286.
- Omonov, T.S. dan Curtis, J.M., 2015, Plant Oil-Based Epoxy Intermediates for Polymers, in, *Bio-based Plant Oil Polymers and Composites*. Elsevier Inc., pp. 99–125.
- Paclawski, K. dan Fitzner, K., 2004, Kinetics of gold(III) chloride complex reduction using sulfur(IV), *Metall. Mater. Trans. B.*, 35, 1071–1085.
- Pal, P., Syed, S.S., dan Banat, F., 2017, Gelatin-bentonite composite as reusable adsorbent for the removal of lead from aqueous solutions: Kinetic and equilibrium studies, *J. Water Process Eng.*, 20, 40–50.
- Panda, R., Mishra, S., Pant, K.K., Bhaskar, T., dan Naik, S.N., 2023, A closed loop recycling strategy for sustainable recovery of group 11 metals (Cu, Au, and Ag) from waste PCBs: An amalgamation of low-temperature NH_4Cl roasting, HCl leaching and cementation, *Sustain. Mater. Technol.*, 37, e00652.
- Panday, K.K., Prasad, G., dan Singh, V.N., 1985, Copper(II) removal from aqueous solutions by fly ash, *Water Res.*, 19, 869–873.
- Parodi, F., 1989, Physics and Chemistry of Microwave Processing, in, *Comprehensive Polymer Science and Supplements*. Elsevier Ltd, London, pp. 669–728.
- Pavón, S., Lorenz, T., Fortuny, A., Sastre, A.M., dan Bertau, M., 2021, Rare earth elements recovery from secondary wastes by solid-state chlorination and selective organic leaching, *Waste Manag.*, 122, 55–63.
- Pérez-Córdoba, L.J., Norton, I.T., Batchelor, H.K., Gkatzionis, K., Spyropoulos, F., dan Sobral, P.J.A., 2018, Physico-chemical, antimicrobial and antioxidant properties of gelatin-chitosan based films loaded with nanoemulsions encapsulating active compounds, *Food Hydrocoll.*, 79, 544–559.
- Perumal, R.K., Gopinath, A., Thangam, R., Perumal, S., Masilamani, D., Ramadass, S.K., dan Madhan, B., 2018, Collagen-silica bio-composite enriched with *Cynodon dactylon* extract for tissue repair and regeneration, *Mater. Sci. Eng. C.*, 92, 297–306.
- Porrang, S., Rahemi, N., Davaran, S., Mahdavi, M., Hassanzadeh, B., dan Gholipour, A.M., 2021, Direct surface modification of mesoporous silica

- nanoparticles by DBD plasma as a green approach to prepare dual-responsive drug delivery system, *J. Taiwan Inst. Chem. Eng.*, 123, 47–58.
- Prasdiatika, R. dan Susanto, S., 2017, Preparasi dan penentuan jenis oksida besi pada material magnetik pasir besi Lansilowo, *J. Teknosains.*, 6, 7.
- Putra, H., Satyarno, I., Budhie Wijatna, A., 2008, Penggunaan pasir besi dari Kulon Progo dengan berat jenis 4,311 untuk mortar perisai radiasi sinar gamma, *J. civil eng. forum*, XVIII, 909–920.
- Pyrzynska, K., 2012, Sorbent materials for separation and preconcentration of gold in environmental and geological samples - A review, *Anal. Chim. Acta.*, 741, 9–14.
- Qu, R., Wang, M., Sun, C., Zhang, Y., Ji, C., Chen, H., Meng, Y., dan Yin, P., 2008, Chemical modification of silica-gel with hydroxyl- or amino-terminated polyamine for adsorption of Au(III), *Appl. Surf. Sci.*, 255, 3361–3370.
- Quispe-Garrido, Lady V., Ruiz-Montoya, J.G., Baena-Moncada, A.M., dan La Rosa-Toro, A., 2024, Recent developments in materials containing N and S groups for gold recovering, *J. Environ. Chem. Eng.*, 12, 112585.
- Ramesh, A., Hasegawa, H., Sugimoto, W., Maki, T., dan Ueda, K., 2008, Adsorption of gold(III), platinum(IV) and palladium(II) onto glycine modified crosslinked chitosan resin, *Bioresour. Technol.*, 99, 3801–3809.
- Refiker, H., Merdivan, M., dan Aygun, R.S., 2018, Selective preconcentration of gold from ore samples, *Int. J. Anal. Chem.*, 2018, 1–8.
- Rettob, A.L. dan Karbeka, M., 2019, Pengaruh konsentrasi larutan HF pada proses preparasi terhadap kadar unsur bahan magnetik pasir besi, *Walisongo J. Chem.*, 2, 6–9.
- Rettob, A.L., Suyanta, S., dan Nuryono, N., 2025, Modification of magnetic silica with collagen through 3-glycidyoxypropyltrimethoxysilane for Au(III) selective adsorption, *Inorg. Chem. Commun.*, 174, 113954.
- Rigueto, C.V.T., Rosseto, M., Nazari, M.T., Ostwald, B.E.P., Alessandretti, I., Manera, C., Piccin, J.S., dan Dettmer, A., 2021, Adsorption of diclofenac sodium by composite beads prepared from tannery wastes-derived gelatin and carbon nanotubes, *J. Environ. Chem. Eng.*, 9, 105030.
- Ristiana, D.D., Suyanta, S., dan Nuryono, N., 2022, Sulfonic acid-functionalized silica with controlled hydrophobicity as an effective catalyst for esterification of levulinic acid, *Mater. Today Commun.*, 32, 103953.
- Rusdiarso, B., 2007, Study on solvent extraction of Au (III) in Cu-concentrate solution at PT Freeport by using 8-methylxantin, *Berkala MIPA*, 17, 15–21.
- Rusianto, T., Wildan, M.W., Abraha, K., dan Kusmono, 2012, The potential of iron sand from the Coast South of Bantul Yogyakarta, *J. Teknol*, 6, 62–69.

- Sadyrbaeva, T.Z., 2012, Gold(III) recovery from non-toxic electrolytes using hybrid electro dialysis-electrolysis process, *Sep. Purif. Technol.*, 86, 262–265.
- Saini, S., Frankel, R.B., Stark, D.D., dan Terucci Jr, Joseph T., 1988, Magnetism: a primer and review, *AJR Am. J. Roentgenol.*, 150, 735–743.
- Sakti, S.C.W., Siswanta, D., dan Nuryono, 2013, Adsorption of gold(III) on ionic imprinted amino-silica hybrid prepared from rice hull ash, *Pure Appl. Chem.*, 85, 211–223.
- Salamah, S., Trisunaryanti, W., Kartini, I., dan Purwono, S., 2021, Synthesis and characterization of mesoporous silica from beach sands as silica source, in, *IOP Conf. Ser.: Materials Science and Engineering*. IOP Publishing, 1053, 012027.
- Salazar-Camacho, C., Villalobos, M., Rivas-Sánchez, M. de la L., Arenas-Alatorre, J., Alcaraz-Cienfuegos, J., dan Gutiérrez-Ruiz, M.E., 2013, Characterization and surface reactivity of natural and synthetic magnetites, *Chem. Geol.*, 347, 233–245.
- Sarker, B., Lyer, S., Arkudas, A., dan Boccaccini, A.R., 2013, Collagen/silica nanocomposites and hybrids for bone tissue engineering, *Nanotechnol. Rev.*, 2, 427–447.
- Satria, B., Masrurah, Z., dan Fajar, S.J., 2021, Magnetic susceptibility and grain size distribution as prospective tools for selective exploration and provenance study of iron sand deposits: A case study from Aceh, Indonesia, *Heliyon*, 7, e08584.
- Sawitri, E., Azmiyawati, C., Siahaan, P., dan Darmawan, A., 2018, Synthesis of adsorbent magnetite silica functionalized cetyltrimethylammonium bromide (CTAB) from iron sand Klayar Beach Pacitan, *J. Sains Dasar*, 7, 29–34.
- Seku, K., Yamala, A.K., Kancherla, M., Kumar K, K., dan Badathala, V., 2018, Synthesis of moxifloxacin–Au (III) and Ag (I) metal complexes and their biological activities, *J. Anal. Sci. Technol.*, 9, 1–13.
- Seyedhakimi, A., Bastami, S.A., Ghassa, S., Razavi, H., dan Chehreh Chelgani, S., 2019, Exploring relationships between various activations of granular activated carbon on silver and gold adsorption: A kinetic and equilibrium study, *Sep. Sci. Technol.*, 54, 1710–1721.
- Shen, N. dan Chirwa, E.M.N., 2018, Biosorption and desorption potential of gold(III) by freshwater microalgae *Scenedesmus obliquus* AS-6-1, *Chem. Eng. Trans.*, 64, 19–24.
- Shi, H., Jiang, M., Zhang, X., Xia, G., dan Shen, X., 2025, Characteristics and food applications of aquatic collagen and its derivatives: A review, *Food Res. Int.*, 202, 115531.

- Shirosaki, Y., Tsuru, K., Hayakawa, S., Osaka, A., Lopes, M.A., Santos, J.D., dan Fernandes, M.H., 2005, In vitro cytocompatibility of MG63 cells on chitosan-organosiloxane hybrid membranes, *Biomaterials*, 26, 485–493.
- Sionkowska, A., 2021, Collagen blended with natural polymers: Recent advances and trends, *Prog. Polym. Sci.*, 122, 101452.
- Soares, S.F., Fateixa, S., Trindade, T., dan Daniel-da-Silva, A.L., 2022, A versatile synthetic route towards gelatin-silica hybrids and magnetic composite colloidal nanoparticles, *Adv. Compos. Hybrid. Mater.*, 5, 884–898.
- Sodipo, B.K. dan Aziz, A.A., 2016, Recent advances in synthesis and surface modification of superparamagnetic iron oxide nanoparticles with silica, *J. Magn. Magn. Mater.*, 416, 275–291.
- Su, X.N., Khan, M.F., Xin-Ai, Liu, D.L., Liu, X.F., Zhao, Q.L., Cheong, K.L., Zhong, S.Y., dan Li, R., 2025, Fabrication, modification, interaction mechanisms, and applications of fish gelatin: A comprehensive review, *Int. J. Biol. Macromol.*, 288, 138723.
- Sun, X., Huang, X., Liao, X.P., dan Shi, B., 2011, Adsorptive removal of Cu(II) from aqueous solutions using collagen-tannin resin, *J. Hazard. Mater.*, 186, 1058–1063.
- Sun, Y., Ding, Y., Zhou, W., Wang, X., Tan, C., Matsumura, Y., Ochiai, B., dan Chu, Q., 2021, Synthesis and Selective Au(III) Adsorption of Ureido Polymers Containing Large Repeating Rings, *ACS Omega*, 6, 28004–28011.
- Tadic, M., Kralj, S., Lalatonne, Y., dan Motte, L., 2019, Iron oxide nanochains coated with silica: Synthesis, surface effects and magnetic properties, *Appl. Surf. Sci.*, 476, 641–646.
- Tadić, M., Kusigerski, V., Marković, D., Panjan, M., Milošević, I., dan Spasojević, V., 2012, Highly crystalline superparamagnetic iron oxide nanoparticles (SPION) in a silica matrix, *J. Alloys. Compd.*, 525, 28–33.
- Taleb, M.A., Kumar, R., Barakat, M.A., Almeelbi, T., Seliem, M.K., dan Ahmad, A., 2024, Recent advances in heavy metals uptake by tailored silica-based adsorbents, *Sci. Total Environ.*, 955, 177093.
- Talha, M., Tanveer, M., Abid, A., Maan, A.A., Khan, M.K.I., Shair, H., Tanveer, N., dan Mustafa, A., 2024, Valorization of poultry slaughter wastes via extraction of three structural proteins (gelatin, collagen and keratin): A sustainable approach for circular economy, *Trends. Food Sci. Technol.*, 152, 104667.
- Thakur, S.S. dan Chauhan, G.S., 2014, Gelatin-silica-based hybrid materials as efficient candidates for removal of chromium(VI) from aqueous solutions, *Ind. Eng. Chem. Res.*, 53, 4838–4849.
- Tonda-Turo, C., Gentile, P., Saracino, S., Chiono, V., Nandagiri, V.K., Muzio, G., Canuto, R.A., dan Ciardelli, G., 2011, Comparative analysis of gelatin

- scaffolds crosslinked by genipin and silane coupling agent, *Int. J. Biol. Macromol.*, 49, 700–706.
- Ulman, A., 1996, Formation and Structure of self-assembled monolayers, *Chem. Rev.*, 96, 1533–1554.
- Urucu, O.A., Aracier, E.D., dan Çakmakçı, E., 2019, Allylimidazole containing OSTE based photocured materials for selective and efficient removal of gold from aqueous media, *Microchem. J.*, 146, 997–1003.
- Vate, N.K., Strachowski, P., Undeland, I., dan Abdollahi, M., 2023, Structural and functional properties of collagen isolated from lumpfish and starfish using isoelectric precipitation vs salting out, *Food Chem. X*, 18, 100646.
- Vehmaanperä, P., Sihvonen, T., Salmimies, R., dan Häkkinen, A., 2022, Dissolution of magnetite and hematite in mixtures of oxalic and nitric acid: Mechanisms and kinetics, *Minerals*, 12, 560.
- Wang, J. dan Guo, X., 2020, Adsorption kinetic models: Physical meanings, applications, and solving methods, *J. Hazard. Mater.*, 390, 122156.
- Wang, J., Wei, L., Ma, Y., Li, K., Li, M., Yu, Y., Wang, L., dan Qiu, H., 2013, Collagen/cellulose hydrogel beads reconstituted from ionic liquid solution for Cu(II) adsorption, *Carbohydr. Polym.*, 98, 736–743.
- Wang, L., Peng, H., Liu, S., Yu, H., Li, P., dan Xing, R., 2012, Adsorption properties of gold onto a chitosan derivative, *Int. J. Biol. Macromol.*, 51, 701–704.
- Wei, W., Qiu, Y., Zhao, Y., Zhang, K., Ji, Y., Gao, H., Bediako, J.K., dan Yun, Y.S., 2021, Development of melamine-impregnated alginate capsule for selective recovery of Pd(II) from a binary metal solution, *J. Clean. Prod.*, 288, 125648.
- Wojnicki, M., Rudnik, E., Luty-Błoch, M., Paclawski, K., dan Fitzner, K., 2012, Kinetic studies of gold(III) chloride complex reduction and solid phase precipitation in acidic aqueous system using dimethylamine borane as reducing agent, *Hydrometallurgy*, 127–128, 43–53.
- Workie, A.B., Ningsih, H.S., dan Shih, S.J., 2023, An comprehensive review on the spray pyrolysis technique: Historical context, operational factors, classifications, and product applications, *J. Anal. Appl. Pyrol.*, 170, 105915.
- Wu, S., Sun, A., Lu, Z., Cheng, C., dan Gao, X., 2015, Magnetic properties of iron-based soft magnetic composites with SiO₂ coating obtained by reverse microemulsion method, *J. Magn. Magn. Mater.*, 381, 451–456.
- Yang, H., Watanabe, H., dan Nakane, K., 2019, Synthesis and characterization of silica/ferric oxide nanofibers: Useful materials for catalysis in ethanol dehydration, *J. Solid. State. Chem.*, 270, 27–34.

- Yang, X., Roonasi, P., dan Holmgren, A., 2008, A study of sodium silicate in aqueous solution and sorbed by synthetic magnetite using in situ ATR-FTIR spectroscopy, *J. Colloid Interface Sci.*, 328, 41–47.
- Yildiz, I., 2016, Applications of magnetic nanoparticles in biomedical separation and purification, *Nanotechnol. Rev.*, 5, 331–340.
- Zeng, F., Liao, X., Lu, J., Pan, D., Qiu, Q., Ding, K., dan Zhang, W., 2020, Effect of iron salt modification on the adsorption of hydrogen sulfide by sludge-based activated carbon, *Desal. Water Treat.*, 202, 61–70.
- Zhang, J., Zhai, S., Li, S., Xiao, Z., Song, Y., An, Q., dan Tian, G., 2013, Pb(II) removal of Fe₃O₄@SiO₂-NH₂ core-shell nanomaterials prepared via a controllable sol-gel process, *Chem. Eng. J.*, 215–216, 461–471.
- Zhang, Q.X., Li, J., Zhang, W.H., Liao, X.P., dan Shi, B., 2013, Adsorption chromatography separation of baicalein and baicalin using collagen fiber adsorbent, *Ind. Eng. Chem. Res.*, 52, 2425–2433.
- Zhang, W., Li, M., Chen, J., Chen, Y., Liu, C., dan Wu, X., 2024, A Review of modified gelatin: Physicochemical properties, modification methods, and applications in the food field, *J Agric Food Chem*, 72, 20705–20721.
- Zhang, Y., Liu, S., Xie, H., Zeng, X., dan Li, J., 2012, Current status on leaching precious metals from waste printed circuit boards, in, *Procedia Environmental Sciences*. Elsevier BV, pp. 560–568.
- Zhao, J., Wang, C., Wang, S., Zhang, L., dan Zhang, B., 2019, Selective recovery of Au(III) from wastewater by a recyclable magnetic Ni_{0.6}Fe_{2.4}O₄ nanoparticles with mercaptothiadiazole: Interaction models and adsorption mechanisms, *J. Clean Prod.*, 236, 117605.
- Zulfalina dan Manaf, A., 2004, Identifikasi senyawa mineral dan ekstraksi titanium dioksida dari pasir mineral, *JUSAMI*, 5, 46–50.