

**DAFTAR PUSTAKA**

- Agacayak, T., Zedef, V. and Aras, A., (2016). Kinetic study on leaching of nickel from Turkish lateritic ore in nitric acid solution. *Journal of Central South University*, 23, pp.39-43.
- Ai, C., Wang, S., Liu, C. and Li, T., (2023). ‘Experimental Study on the Influence of Surfactants on Ore Surface Wettability’. *ACS Omega*.
- Ai, C.M., Sun, P.P., Wu, A.X., Chen, X. and Liu, C., (2019). ‘Accelerating leaching of copper ore with surfactant and the analysis of reaction kinetics’. *International Journal of Minerals, Metallurgy, and Materials*, 26, pp.274-281.
- Anbiyak, N. and Cahyaningrum, T. (2021) ‘Identifikasi zona kaya kobalt pada cebakan nikel laterit di Indonesia’, *Indonesian Mining Professionals Journal*, 2(2), pp.103-110. doi: <https://doi.org/10.36986/impj.v2i2.38>.
- Astuti, W. (2015). ‘Atmospheric leaching of nickel from low-grade Indonesia saprolite ores by biogenic citric acid’. Disertasi. Kyushu University <https://doi.org/10.15017/1543960>
- Ayanda, O.S., Adekola, F.A., Baba, A.A., Fatoki, O.S. and Ximba, B.J., (2011). Comparative study of the kinetics of dissolution of laterit in some acidic media.
- Bahfie, F., Manaf, A., Astuti, W., Nurjaman, F., and Herlina, U. (2021) ‘Tinjauan teknologi proses ekstraksi bijih nikel laterit’, *Jurnal Teknologi Mineral dan Batubara*, 17(3), pp. 135–152. Available at: <https://doi.org/10.30556/jtmb.Vol17.No3.2021.1156>.
- Behari, M., Mohanty, A.M., Das, D., (2022). ‘Influence of a plant-based surfactant on improving the stability of iron ore particles for dispersion and pipeline transportation’. *Powder Technol.* 407, 117620 <https://doi.org/10.1016/j.powtec.2022.117620>.
- Berger, V.I., Singer, D.A., Bliss, J.D. and Moring, B.C., (2011). ‘Ni-Co laterit deposits of the world; database and grade and tonnage models’. *US Geological Survey Open-File Report*, 1058, p.26.
- Bezerra, M.D.A., Arruda, M.A.Z. and Ferreira, S.L.C., (2005). ‘Cloud point extraction as a procedure of separation and pre-concentration for metal determination using spectroanalytical techniques: a review’. *Applied Spectroscopy Reviews*, 40(4), pp.269-299.
- Butt, C.R. and Cluzel, D., (2013). ‘Nickel laterit ore deposits: weathered serpentinites’. *Elements*, 9(2), pp.123-128.
- Canterford, J.H., (1978). ‘Leaching of some Australian nickeliferous laterits with sulphuric acid at atmospheric pressure’. *Proceedings of the Australasian Institute of Mining and Metallurgy*, 265, pp. 19–26
- Chi, R.A., Tian, J., Zhu, G.C., Wu, Y.X., Li, S.R., Wang, C.W. and Zhou, Z.A., (2006). ‘Kinetics of rare earth leaching from a manganese-removed weathered rare-earth mud in hydrochloric acid solutions’. *Separation Science and Technology*, 41(06), pp.1099-1113.
- Crundwell, F.K., Moats, M.S., Ramachandran, V., Robinson, T.G., and Davenport, W.G. (2011) ‘Extractive metallurgy of nickel, cobalt and platinum-group metals’. doi: <https://doi.org/10.1016/C2009-0-63541-8>
- Cui, H. and Anderson, C. (2016) ‘Literature review of hydrometallurgical recycling of printed circuitboards (PCBs)’, *Material Science*. doi: 10.4172/2090-4568.1000142.
- Dalvi, A.D., Bacon, W.G. and Osborne, R.C., (2004). ‘The past and the future of nickel laterits’, *International Convention, Trade Show & Investors Exchange* (pp. 1-27).



- Dias, A.P., Alves Dias, P. and Blagoeva, D. (2018) 'Cobalt: demand-supply balances in the transition to electric mobility', *European Commission Joint research Center*. doi: <https://doi.org/10.2760/97710>.
- Ding, M., Ren, S., (2020). 'Wettability alteration of solid surface to enhance the bitumen liberation and the water-based processability of weathered oil sands'. *Can. J. Chem. Eng.* 98, 1794–1802. <https://doi.org/10.1002/cjce.23736>.
- Dong, J., Wei, Y., Zhou, S., Li, B., Yang, Y., and Mclean, A. (2018) 'The Effect of Additives on Extraction of Ni, Fe and Co from Nickel Laterit Ores', *The Minerals, Metals and Materials Society*, 70(10), pp. 2365–2377. doi: <https://doi.org/10.1007/s11837-018-3032-8>.
- Eramet. (2010). Exploration and Development ESIA. In. Jakarta
- Fan, R., and Gerson, A.R., (2013). 'Mineralogical characterization of Indonesian laterits prior to and post atmospheric leaching', *Hydrometallurgy* 134-135, 102-109.
- Gaber, S. E., Rizk, M. S., and Yehia, M. M. (2011). 'Extraction of certain heavy metals from sewage sludge using different types of acids'. *Biokemistri* 23, (1) 41-48
- Griffin, A., Nofal, P., Johnson, G., Evans, H., (2002). 'Laterits — squeeze or ease? ALTA 2002 Nickel/Cobalt 8. ALTA Metallurgical Services', *Melbourne*. pp.18
- Harris, R. (2003). 'Geodynamic patterns of ophiolites and marginal basins in the Indonesian and New Guinea regions'. *Geological Society, London, Special Publications*, 218(1), 481-505.
- Havlik, T., (2008) "Hydrometallurgy principles and application," Cambridge Scientific publishing Limited, first edition., pp. 207.
- He, F., Ma, B., Qiu, Z., Wang, C., Chen, Y. and Hu, X., (2023). 'Enhanced extraction of nickel from limonitic laterit via improved nitric acid pressure leaching process'. *Minerals Engineering*, 201, p.108170.
- He, F., Ma, B., Wang, C., Zuo, Y. and Chen, Y., (2022). 'Dissolution behavior and porous kinetics of limonitic laterit during nitric acid atmospheric leaching'. *Minerals Engineering*, 185, p.107671.
- Hosseini, S.A., Raygan, S., Rezaei, A., and Jafari, A., (2017). 'Leaching of nickel from a secondary source by sulfuric acid'. *Journal of Environmental Chemical Engineering*, 5(4), 3922–3929. <https://doi.org/10.1016/j.jece.2017.07.059>
- Husain, A.A., Nur, I., Sufaridin and Irfan, U.R. (2021) 'Recommendation for lateritic Ni-ore processing: Garnierite mineralogical and geochemical approach', *IOP Conference Series: Earth and Environmental Science*. IOP Publishing Ltd. doi: <https://doi.org/10.1088/1755-1315/921/1/012029>.
- Javanshir, S., Mofrad, Z.H. and Azargoon, A., (2018). 'Atmospheric pressure leaching of nickel from a low-grade nickel-bearing ore', *Physicochemical Problems of Mineral Processing*, 54(3), pp.890-900.
- Kadarusman, A., Miyashita, S., Maruyama, S., Parkinson, C. D., and Ishikawa, A. (2004). 'Petrology, geochemistry and paleogeographic reconstruction of the East Sulawesi Ophiolite, Indonesia'. *Tectonophysics*, 392(1-4), 55-83.
- Korkmaz, K., (2014). Comparative study of high pressure and atmospheric acid leaching for the extraction of nickel and cobalt from refractory nickel laterit ores. Master's thesis, Middle East Technical University.
- Kovacheva-Ninova, V., Savov, G., Vassileva, V., Vutova, K., Petrov, E., and Petrov, D. (2018). 'Trends in the development of cobalt production'. *Electrotech. Electron*, 53, 849–894.
- Kursunoglu, S. and Kaya, M. (2016) 'Atmospheric pressure acid leaching of Caldag lateritic nickel ore', *International Journal of Mineral Processing*, 150, pp. 1–8. doi: <https://doi.org/10.1016/j.minpro.2016.03.001>.



Peningkatan Recovery Logam Kobalt dari Laterit Limonit dengan Bantuan Surfaktan CTAB pada Proses NAAL

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Lee, B.W., Alsenz, R., and Ignatiev, A. (1978), 'Surface structures of the two allotropic phases of cobalt', *The American Physical Society*, 17(4).

Levenspiel, O. (1999). 'Chemical reaction engineering 3rd edition', John Wiley and Sons: New York.

Li, J.H., Li, Y.Y., Zheng, S., Xiong, D.L., Chen, H., Zhang, Y.F., (2015). 'Research review of laterit nickel ore metallurgy', *Nonferrous Metals Science and Engineering*, 6(1), 35-40.

Li, L., Qu, W., Zhang, X., Lu, J., Chen, R., Wu, F., and Amine, K. (2015). 'Succinic acid-based leaching system: a sustainable process for recovery of valuable metals from spent Li-ion batteries'. *Journal of Power Sources* 282, 544-551. <https://doi.org/10.1016/j.jpowsour.2015.02.073>

Li, G., Rao, M., Jiang, T., Huang, Q., and Peng, Z., (2011), 'Leaching of limonitic laterit ore by acidic thiosulfate solution', *Minerals Engineering*, 24, 859–863.

Lintjewas, L., Setiawan, I. and Kausar, A. al (2019) 'Profil Endapan Nikel Laterit di Daerah Palangga, Provinsi Sulawesi Tenggara', *Riset Geologi dan Pertambangan*, 29(1), pp. 91-104. doi: <https://doi.org/10.14203/risetgeotam2019.v29.970>.

Liu, K., Chen, Q., and, Hu, H., (2009), 'Comparative leaching of minerals by sulphuric acid in a Chinese ferruginous nickel laterit ore', *Hydrometallurgy* 98, 281–286.

Liu, K., Chen, Q., Hu, H., Yin, Z., and, Wu, B., (2010). 'Pressure Acid Leaching of a Chinese Laterit Ore Containing Mainly Maghemite and Magnetite', *Hydrometallurgy* 104, 32-38.

Liu, P., Huang, R., Tang, Y., (2019). 'Comprehensive understandings of rare earth element (REE) speciation in coal fly ashes and implication for REE extractability'. *Environ. Sci. Technol.* 53, 5369–5377. <https://doi.org/10.1021/acs.est.9b00005>

Luo, J., Li, G., Rao, M., Peng, Z., Zhang, Y. and Jiang, T., (2015). 'Atmospheric leaching characteristics of nickel and iron in limonitic laterit with sulfuric acid in the presence of sodium sulfite'. *Minerals Engineering*, 78, pp.38-44.

M. H., Khajavi, L. T., and Dreisinger, D. B. (2017). 'Extraction of nickel and cobalt from nickeliferous limonitic laterit ore using borax containing slags'. *International Journal of Mineral Processing*, 167, 27–34. <https://doi.org/10.1016/j.minpro.2017.07.012>

Ma, B., Wang, C., Yang, W., Yang, B., Zhang, Y., (2013). 'Selective pressure leaching of Fe (II)-rich limonitic laterit ores from Indonesia using nitric acid'. *Minerals Engineering*, 45, pp.151-158.

Ma, B., Wang, C., Yang, W., Yang, B., Zhang, Y., (2013). 'Selective pressure leaching of Fe (II)-rich limonitic laterit ores from Indonesia using nitric acid', *Minerals Engineering* 45, 151–158.

Ma, B., Yang, W., Pei, Y., Wang, C. and Jin, B., (2017). 'Effect of activation pretreatment of limonitic laterit ores using sodium fluoride and sulfuric acid on water leaching of nickel and cobalt'. *Hydrometallurgy*, 169, pp.411-417.

Marsh, E., E. and Anderson, E., D. (2011) Ni-Co laterit deposits, U.S. Geological Survey Open-File Report 2011-1259

Marsh, E.E., Anderson, E.D. and Gray, F., (2013). Nickel-cobalt laterits: a deposit model (No. 2010-5070-H). US Geological Survey.

McDonald, R.G. and Whittington, B.I., (2008). 'Atmospheric acid leaching of nickel laterits review: Part I. Sulphuric acid technologies.' *Hydrometallurgy*, 91(1-4), pp.35-55.

Meng, F., Liu, Q., Kim, R., Wang, J., Liu, G., and Ghahreman, A. (2020). 'Selective recovery of valuable metals from industrial waste lithium-ion batteries using citric



acid under reductive conditions: Leaching optimization and kinetic analysis'.

Hydrometallurgy 191, 105160. <https://doi.org/10.1016/j.hydromet.2019.105160>

Miettinen, V., Mäkinen, J., Kolehmainen, E., Kravtsov, T., and Rintala, L., (2019). 'Iron control in atmospheric acid laterit leaching'. *Minerals*, 9(7), 1–13. <https://doi.org/10.3390/min9070404>

Mokoena, K., Mokhahlane, L.S. and Clarke, S., (2022). 'Effects of acid concentration on the recovery of rare earth elements from coal fly ash'. *International Journal of Coal Geology*, 259, p.104037.

Mubarok, M.Z., and Fathoni, M. W. (2016) 'Studi kinetika pelindian bijih nikel limonit dari pulau halmahera dalam larutan asam nitrat', *Metalurgi*, 31(1), pp.59-68.

Özbaş, E. E., Gökçe, C. E., Güneysu, S., Özcan, H. K., Sezgin, N., Aydin, S., and Balkaya, N. (2013). 'Comparative metal (Cu, Ni, Zn, total Cr, and Fe) removal from galvanic sludge by molasses hydrolysate'. *Journal of Chemical Technology & Biotechnology* 88, 2046-2053. <https://doi.org/10.1002/jctb.4066>

Permanadewi, S. (2017). 'Cebakan Nikel Laterit di Pulau Gag, Kabupaten Raja Ampat, Provinsi Papua Barat'. *Buletin Sumber Daya Geologi* 12(1), pp.55-70.

Picazo-Rodriguez, N.G., Toro, N., Román, M.R.G., Soriano, D.A.T., Madrid, F.M.G., Jamett, I., Gálvez, E. and Cedillos, J.G.M., (2023). 'Cobalt Metal: Overview of Deposits, Reserves, Processing, and Recycling'

Prasetyo, P. and Ronald, N. (2011) 'Masih terbukanya peluang penelitian proses caron untuk mengolah nikel laterit kadar rendah di Indonesia', *Majalah Metalurgi*, 26, pp. 3544.

Ribeiro, P.P.M., de Souza, L.C.M., Neumann, R., dos Santos, I.D. and Dutra, A.J.B., (2020). 'Nickel and cobalt losses from laterit ore after the sulfation-roasting-leaching processing'. *Journal of Materials Research and Technology*, 9(6), pp.12404-12415.

Rudnick, R. L., and Gao, S. (2013). 'Composition of the Continental Crust. In Treatise on Geochemistry'. (Second Edition, pp. 1–51). Elsevier.

Santos, A.L.A., Becheleni, E.M.A., Viana, P.R.M., Papini, R.M., Silvas, F.P.C., and Rocha, S.D.F. (2020) 'Kinetics of atmospheric leaching from a brazilian nickel laterit ore allied to redox potential control'. doi: <https://doi.org/10.1007/s42461-020-00310-w>

Saputra, F., Fadli, A., and Amri, A. (2016). Kinetika Reaksi pada Sintesis Hidroksiapatit dengan Metode Presipitasi. *Jom FTEKNIK*, 3(1), 1–6.

Sheikh, I. (2016) 'Cobalt Poisoning: A Comprehensive Review of the Literature', *Journal of Medical Toxicology and Clinical Forensic Medicine*, 2(2). doi: <https://doi.org/10.21767/2471-9641.100017>.

Sidhu PS., Gilkes RJ, Cronell RM., Posner A M., Quirk JP. (1981) 'Dissolution of Iron Oxides and Oxyhydroxides in Hydrochloric and Perchloric Acids'. *Miner.* 29, 269-276.

Sonule, B. B., Kulkarni, A. N., Kakde, N. K., Madrewar, K.T. (2023). 'Comparative analysis of pyrometallurgy, hydrometallurgy and Bio-Hydro-Metallurgy for extraction of metals from e-waste', *International Journal of Research Publication and Reviews*, 4(10), pp. 1970-1977

Stanković, S., Stopić, S., Sokić, M., Marković, B. and Friedrich, B., (2020). 'Review of the past, present, and future of the hydrometallurgical production of nickel and cobalt from laterit ores', *Metallurgical and Materials Engineering*, 26(2), pp. 199-208. doi: <https://doi.org/10.30544/513>.

Stopić, R. and Friedrich, G. (2016) 'Hydrometallurgical processing of nickel lateritic ores', *Vojnotehnicki Glasnik.Military Technical Courier*, 40, pp. 1033-1047.



Sufriadin (2013) ‘Mineralogy, geochemistry and leaching behavior of Soroako nickeliferous laterit deposits, Sulawesi, Indonesia’, Disertasi Fakultas Teknik Geologi, Universitas Gadjah Mada.

Sun, C., Xu, L., Chen, X., Qiu, T., and Zhou, T. (2018). ‘Sustainable recovery of valuable metals from spent lithium-ion batteries using DL-malic acid: Leaching and kinetics aspect’. *Waste Management and Research* 36, 113-120. <https://doi.org/10.1177/0734242X17744273>

Syafrizal, M. N. (2009) ‘Morphology and geologic structure control of nickel laterit deposition: case study nickel laterit deposite in the Gee Island and Pakal Island, East Halmahera, North Maluku’, International Conference Earth Science and Technology.

Tonggiroh, A. and Mustafa, M. (2012) Analisis pelapukan serpentin dan endapan nikel laterit daerah pallangga kabupaten Konawe selatan Sulawesi Tenggara, *Prosiding*, 6.

Vignes, A. (2013) Extractive Metallurgy 1, *Extractive Metallurgy 1*. doi: 10.1002/9781118618974.

Wahab, W., Deniyatno, D., Saranga, M. and Supriyatna, Y.I., (2022). ‘Kinetics study of leaching ore nickel laterit using hydrochloric acid in atmosphere pressure’. *Riset Geologi dan Pertambangan*, 32(1), pp.14-26.

Wang, B., Guo, Q., Wei, G., Zhang, P., Qu, J., and Qi, T., (2012). ‘Characterization and atmospheric hydrochloric acid leaching of a limonitic laterit from Indonesia’. *Hydrometallurgy*, 129–130, 7–13. <https://doi.org/10.1016/j.hydromet.2012.06.017>

Wang, D., Zhang, Y., and Duan, B. (2018) ‘Preparation of Mo-Cu composite by rapid microwave infiltration’, *Nonferrous Metals Science and Engineering*, 9(3), pp.11-16. doi: <https://doi.org/10.13264/j.cnki.yjsjx.2018.03.003>

Wang, Z., Dai, S., Zou, J., French, D., Graham, I.T., (2019). ‘Rare earth elements and yttrium in coal ash from the Luzhou power plant in Sichuan, Southwest China: Concentration, characterization and optimized extraction’. *Int. J. Coal Geol.* 203, pp. 1–14. <https://doi.org/10.1016/j.coal.2019.01.001>.

Wanta, K.C., Tanujaya, F.H., Susanti, R.F., Petrus, H.T.B.M., Perdana, I., Astuti, W., (2018). ‘Studi Kinetika Proses Atmospheric Pressure Acid Leaching Bijih Laterit Limonit Menggunakan Larutan Asam Nitrat Konsentrasi Rendah’. *Jurnal Rekayasa Proses*, 12(2), 77–84. <https://doi.org/10.22146/jrekpros.35644>

Weert, G. and Shang, Y., (1993). ‘Iron control in nitrate hydrometallurgy by (auto) decomposition of iron (II) nitrate’. *Hydrometallurgy*, 33(3), pp.255-271.

Weert, G.V., and Boering, M., (1995) ‘Selective pressure leaching of zinc and manganese from natural and man-made spinels using nitric acid’, *Hydrometallurgy* 39 (1– 3), 201–213.

Weston, D., (1974). ‘Hydrometallurgical treatment of nickel, cobalt and copper containing materials’. US Patent 3,793,430.

Xiao, J., Ding, W., Peng, Y., Chen, T., Zou, K., and Wang, Z. (2020) ‘Extraction of nickel from garnierite laterit ore using roasting and magnetic separation with calcium chloride and iron concentrate’, *Minerals*, 10(352). doi: 10.3390/min10040352.

Xie, Y.-D., Xiong, W.-L., Yu, J.-X., Tang, J.-Q., and Chi, R.-A. (2018). ‘Recovery of copper from metallurgical sludge by combined method of acid leaching and biosorption’. *Process Safety and Environmental Protection* 116, 340-346. <https://doi.org/10.1016/j.psep.2018.02.017>

Yagi, S., and Kunii, D., (1955). 5th Symposium (International) on Combustion, Reinhold, New York, 231



- Zhang, P., Guo, Q., Wei, G., Meng, L., Han, L., and Qu, J. (2015) 'Extraction of metals from saprolitic laterit ore through pressure hydrochloric-acid selective leaching', *Hydrometallurgy*, 157, pp. 149–158. doi: <https://doi.org/10.1016/j.hydromet.2015.08.007>.
- Zhang, P., Qiang, G., Jingkui, Q., and Tao, Q. (2020) 'Leaching Ni and Co from Saprolitic Laterit Ore by Employing Atmospheric Acid Leaching Solution with High Concentration of FeCl₃ at Mild Conditions', *Russian Journal of Non-Ferrous Metals*, 61(1), pp. 42–48. doi: <https://doi.org/10.3103/S1067821220010113>.
- Zhang, P., Sun, L., Wang, H., Cui, J., and Hao, J. (2019) 'Surfactant-assistant atmospheric acid leaching of laterit ore for the improvement of leaching efficiency of nickel and cobalt', *Journal of Cleaner Production*, 228, pp. 1–7. doi: <https://doi.org/10.1016/j.jclepro.2019.04.305>.
- Zhao, C., Cai, Y., Ning, Z., Wang, G., Kang, S., Zhang, C. and Zhai, Y., (2017). 'Recovery of MgO from laterit nickel slag through roasting by ammonium sulfate'. *Journal of Central South University (Science and Technology)*, 48(8), pp.1972-1978.
- Zhao, Y., Gao, J., Yue, Y., Peng, B., Que, Z., Guo, M., and Zhang, M. (2013) 'Extraction and separation of nickel and cobalt from saprolite laterit ore by microwave-assisted hydrothermal leaching and chemical deposition', *International Journal of Minerals, Metallurgy and Materials*, 20(7), pp. 612–619. doi: <https://doi.org/10.1007/s12613-013-0774-8>.
- Zhou, F., Zhang, L., Wang, Z., Zhang, Y. and Chi, R., (2023). 'Effect of surfactant addition on leaching process of weathered crust elution-deposited rare earth ores with magnesium sulfate'. *International Journal of Mining Science and Technology*, 33(8), pp.1045-1053.
- Zhou, F., Zhang, L., Wang, Z., Zhang, Y. and Wu, X., (2022). 'Application of surfactant for improving leaching process of weathered crust elution-deposited rare earth ores'. *Journal of Rare Earths*.