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DAFTAR PUSTAKA

Abbas, S., Zulfiqar, S., Arshad, M., Khalid, N., Hussain, A., & Ahmed, I. (2025). Molecular characterization of heavy metal-tolerant bacteria and their potential for bioremediation and plant growth promotion. *Frontiers in Microbiology, 16*, 1644466. doi:https://doi.org/10.3389/fmicb.2025.1644466

Abd, R. (2024). Exploring the Unseen: Novel Microbes and Their Impact on Biogeochemical Cycling. *Hosts and Viruses, 11*, 45-55. doi:https://dx.doi.org/10.17582/journal.hv/2024/11.45.55

Abdi, O., & Kazemi, M. (2015). A review study of biosorption of heavy metals and comparison between different biosorbents. *Journal of Materials and Environmental Science, 6*(5), 1386-1399.

Abegunde, S., Idowu, K., Adejuwan, O., & Adeyemi-Adejolu, T. (2020). A review on the influence of chemical modification on the performance of adsorbents. *Resources, Environment and Sustainability, 1*, 100001. doi:https://doi.org/10.1016/j.resenv.2020.100001

Abidin, H., Davies, R., Kusuma, M. A., & Deguchi, T. (2009). Subsidence and uplift of Sidoarjo (East Java) due to the eruption of the Lusi mud volcano (2006–present). *Environmental Geology, 57*, 833–844. doi:10.1007/s00254-008-1363-4

Abraham, W. (2010). Megacities as Sources for Pathogenic Bacteria in Rivers and Their Fate Downstream. *International Journal of Microbiology, 2011*(1), 798292. doi:https://doi.org/10.1155/2011/798292

Abrahim, G., & Parker, R. (2008). Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. *Environmental Monitoring and Assessment, 136*, 227–238. doi:https://doi.org/10.1007/s10661-007-9678-2

Afonso, A., Gomes, I., Saavedra, M., Simões, L., & Simões, M. (2023). Drinking-water isolated Delftia acidovorans selectively coaggregates with partner bacteria and facilitates multispecies biofilm development. *Science of The Total Environment, 875*, 162646. doi:https://doi.org/10.1016/j.scitotenv.2023.162646

Aguilar-Paredes, A., Valdés, G., & Nuti, M. (2020). Ecosystem Functions of Microbial Consortia in Sustainable Agriculture. *agronomy, 10*, 1902. doi:doi:10.3390/agronomy10121902

Agustawijaya, D., Karyadi, K., & Krisnayanti, B. S. (2017). Rare earth element contents of the Lusi mud: An attempt to identify the environmental origin of the hot mudflow in East Java – Indonesia. *Open Geosciences,, 9*(1), 689-706. doi:https://doi.org/10.1515/geo-2017-0052

Ahmed, S., Kumar, P., Rozbu, M., Chowdhury, A., Nuzhat, S., Rafa, N., . . . Mofijur, M. (2022). Heavy metal toxicity, sources, and remediation techniques for contaminated water and soil. *Environmental Technology & Innovation, 25*, 102114. doi:https://doi.org/10.1016/j.eti.2021.102114

Ahn, J., Lee, S., Kim, J., Kim, M., Song, J., & Weon, H. (2016). Dynamics of bacterial communities in rice field soils as affected by different long-term fertilization

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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practices. *Journal of Microbiology, 54*(11), 724-731. doi:10.1007/s12275-016-6463-3

Aissaoui, H., Chaptal, M., Thomas, V., Louvel, D., Adenis, A., & Alsibai, K. (2021). Case Report: Gold Miner's Lung: A Case of Chronic Hypersensitivity Pneumonia in Amazonian Forest. *Frontiers in Tropical Diseases, 2*, 685248. doi:https://doi.org/10.3389/fitd.2021.685248

Akoto, R., & Anning, A. (2021). Heavy metal enrichment and potential ecological risks from different solid mine wastes at a mine site in Ghana. *Environmental Advances, 3*, 100028. doi:https://doi.org/10.1016/j.envadv.2020.100028

Aksu, Z., Gönen, F., & Demircan, Z. (2002). Biosorption of chromium(VI) ions by Mowital®B30H resin immobilized activated sludge in a packed bed: comparison with granular activated carbon. *Process Biochemistry, 38*(2), 175-186. doi:https://doi.org/10.1016/S0032-9592(02)00053-5

Albaggar, A. (2014). *Investigation of bacterial community composition and abundance in a lowland arable catchment.* Norwich: School of Environmental Sciences, University of East Anglia.

Alcaraz, S. (2014). *Bacterial diversity and denitrifier communities in arable soils* (Vol. Thesis). Ontario: University of Waterloo.

Alfei, S., Marengo, B., & Zuccari, G. (2020). Oxidative Stress, Antioxidant Capabilities, and Bioavailability: Ellagic Acid or Urolithins? *Antioxidants, 9*(8), 707. doi:https://doi.org/10.3390/antiox9080707

Alfei, S., Schito, G., Schito, A., & Zuccari, G. (2024). Reactive Oxygen Species (ROS)-Mediated Antibacterial Oxidative Therapies: Available Methods to Generate ROS and a Novel Option Proposal. *International Journal of Molecular Sciences, 25*(13), 7182. doi:https://doi.org/10.3390/ijms25137182

Ali, M., Song, X., Ding, D., Wang, Q., Zhang, Z., & Tong, Z. (2022). Bioremediation of PAHs and heavy metals co-contaminated soils: Challenges and enhancement strategies. *Environmental Pollution, 295*, 118686. doi:https://doi.org/10.1016/j.envpol.2021.118686

Allison, S., & Martiny, J. (2008). Resistance, Resilience, and Redundancy in Microbial Communities. In N. A. Sciences, *In the Light of Evolution: Volume II: Biodiversity and Extinction.* Washington (DC): National Academies Press (US).

Alsterberg, C., Roger, F., Sundbäck, K., Juhanson, J., Hulth, S., Hallin, S., & Gamfeldt, L. (2017). Habitat diversity and ecosystem multifunctionality-The importance of direct and indirect effects. *Science advances, 3*(2), e1601475. doi:https://doi.org/10.1126/sciadv.1601475

Alsulaili, A., Elsayed, K., & Refaie, A. (2024). Utilization of agriculture waste materials as sustainable adsorbents for heavy metal removal: A comprehensive review. *Journal of Engineering Research, 12*(4), 691-703. doi:https://doi.org/10.1016/j.jer.2023.09.018

Amir, M. (2023). *Volume calculation and distribution of Sidoarjo mud using multi-temporal remote sensing imagery and TLS data.* Surabaya: Faculty of Civil, Planning, and Geo-Engineering, Sepuluh Nopember Institute of Technology .

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Anawar, H., & Chowdhury, R. (2020). Remediation of Polluted River Water by Biological, Chemical, Ecological and Engineering Processes. *Sustainability, 12*, 7017. doi:10.3390/su12177017

Andermann, T., Antonelli, A., Barrett, R., & Silberstro, D. (2022). Estimating Alpha, Beta, and Gamma Diversity Through Deep Learning. *Frontiers in Plant Science, 13*, 839407. doi:https://doi.org/10.3389/fpls.2022.839407

Andriyanov, P., & Kashina, D. M. (2024). Genomic analysis of multidrug-resistant Delftia tsuruhatensis isolated from raw bovine milk. *Frontiers in Microbiology, 14*, 1321122. doi:https://doi.org/10.3389/fmicb.2023.1321122

Anggarwal, M., Anand, P., Varshney, D., & Ates, B. (2025). Carriers of contamination: heavymetalsin Ganga Riversuspended particles. *Environmental Research Communications, 7*, 115015. doi:https://doi.org/10.1088/2515-7620/ae1c03

Angon, P., Islam, M., Shreejana, K., Das, A., Anjum, N., Poudel, A., & Suchi, S. (2024). Sources, effects and present perspectives of heavy metals contamination: Soil, plants and human food chain. *Heliyon, 10*(7), e28357. doi:https://doi.org/10.1016/j.heliyon.2024.e28357

ANZECC/ARMCANZ. (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality Paper No 4.* Canberra, ACT: Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand.

Aquisman, A., Assim, Z., Wahi, R., Kwabena, D., & Festus, W. (2019). Validation of the Atomic Absorption Spectroscopy (AAS) for Heavy Metal Analysis and Geochemical Exploration of Sediment Samples from the Sebangan River. *Advances in Analytical Chemistry, 9*(2), 23-33. doi:10.5923/j.aac.20190902.01

Arai, K., Basuki, A., & Harsono, T. (2012). Hot mudflow prediction area model and simulation based on Cellular Automata for LUSI mud plume at Sidoarjo in East Java. *Journal of Computational Science, 3*(3), 150-158. doi:https://doi.org/10.1016/j.jocs.2011.10.004

Ari, M., Scholz, K., Cieplik, F., & Al-Ahmad, A. (2025). Viable but non-cultivable state in oral microbiota: a critical review of an underexplored microbial survival strategy. *Frontiers in Cellular and Infection Microbiology, 15*, 533768. doi:https://doi.org/10.3389/fcimb.2025.1533768

Astuti, D., Adriyanti, A., Buditama, A., Nurmawati, A., Utami, L., & Sani. (2022). Morphology Characteristic Study of Adsorbent Prepared from Sidoarjo Hot Mud. *3rd International Conference Eco-Innovation in Science, Engineering, and Technology*, (pp. 247-253). doi:http://dx.doi.org/10.11594/nstp.2022.2736

Auvaria, S., & Munfarida, I. (2020). Analisis Daya Tampung Lingkungan (Beban Pencemaran Air) di Kawasan Porong Kabupaten Sidoarjo ex Penambangan Lapindo. *Jurnal Presipitasi, 17*(2), 104-112.

Ayilara, M., & Babalola, O. (2023). Bioremediation of environmental wastes: the role of microorganisms. *Frontiers in Agronomy, 5*, :1183691. doi:https://doi.org/10.3389/fagro.2023.1183691

Ayob, S., Othman, N., Altowayti, W., Khalid, F., Bakar, N., Tahir, M., & Soedjono, E. (2021). A Review on Adsorption of Heavy Metals from Wood-Industrial

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Wastewater by Oil Palm Waste. *Journal of Ecological Engineering, 22*(3), 249–265. doi:https://doi.org/10.12911/22998993/132854

Azaman, F., Juahir, H., Yunus, K., Azid, A., Kamarudin, M., Toriman, M., . . . Saudi, A. (2015). Heavy metal in fish: Analysis and human health-A Review. *Jurnal Teknologi, 77*(1), 61-69.

Azubuike, C., Chikere, C., & Okpokwasili, G. (2016). Bioremediation techniques–classification based on site of application: principles, advantages, limitations and prospects. *World Journal of Microbiology and Biotechnology, 32*, 180. doi:https://doi.org/10.1007/s11274-016-2137-x

Bagra, K., Bellanger, X., Merlin, C., Singh, G., Berendonk, T., & Klümper, U. (2023). Environmental stress increases the invasion success of antimicrobial resistant bacteria in river microbial communities. *Science of The Total Environment, 904*, 166661. doi:https://doi.org/10.1016/j.scitotenv.2023.166661

Bai, Y., Dai, Q., Guo, J., Fu, W., Yun, J., Wang, F., . . . Yang, G. (2025). Geobacter abundance in soil regulate by pH and iron-bearing minerals. *Frontiers in Ecology and Evolution, 13* , 1523532. doi:https://doi.org/10.3389/fevo.2025.1523532

Baker, N., Pilotto, F., Welti, E. O., & Palinauskas, V. (2025). Recovery or reorganisation? Long-term increases in riverine taxonomic and functional diversity are confounded by compositional dynamics. *Hydrobiologia, 852*, 1693–1715. doi:https://doi.org/10.1007/s10750-024-05665-5

Ballatori, N. (2002). Transport of Toxic Metals by Molecular Mimicry. *Environmental Health Perspectives, 110*(5), 689-694. doi:https://doi.org/10.1289/ehp.02110s5689

Barros, A., Raposo, D., Almeida, J., Jesus, H., Oliveira, M., Fernandes, C., . . . Santo-Ries, M. (2024). An integrated assessment of niche partitioning reveals mechanisms of coexistence between mesocarnivores. *Global Ecology and Conservation, 54*, e03116. doi:https://doi.org/10.1016/j.gecco.2024.e03116

Batley, G., & Simpson, S. (2008). Advancing Australia's Sediment Quality Guidelines. *Australian Journal of Ecotoxicology, 14*, 11-20.

Bauer, F., Knights, A., Hanley, M., Griffin, J., Foggo, A., Brown, A., & Firth, L. (2024). Topography-based modulation of environmental factors as a mechanism for intertidal microhabitat formation: A basis for marine ecological design. *Marine Pollution Bulletin, 202*, 116358. doi:https://doi.org/10.1016/j.marpolbul.2024.116358

Bauer, U., Poppinga, S., & Müller, U. (2020). Mechanical ecology – taking biomechanics to the field. *Integrative and Comparative Biology, 60*(4), 820–828. doi:https://doi.org/10.1093/icb/icaa018

Beal, J., Farny, N., Haddock-Angelli, T., Selvarajah, V., Baldwin, G., Buckley-Taylor, R., . . . Contributors, i. I. (2020). Robust estimation of bacterial cell count from optical density. *Communications biology, 3*(1), 512. doi:https://doi.org/10.1038/s42003-020-01127-5

Bekmukhamedova, N., & Mamiyev, M. (2023). Biosorbent ability of metals by microorganisms from the. *IOP Conf. Series: Earth and Environmental Science, 1142*, 012110. doi:10.1088/1755-1315/1142/1/012110

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Beltrán, J., Gualtero, J., Varón-López, M., Jaramillo-Paéz, C., & Pulido, X. (2025). Proteomic Analysis Reveals Proteins, Siderophores, and Exopolysaccharides Involved in Cd(II) Stress Response of the Heavy Metal-Tolerant Delftia lacustris B11CM Strain. *Journal of peptide science, 31*(11), e70060. doi:https://doi.org/10.1002/psc.70060

Benettayeb, A., Usman, M., Tinashe, C., Adam, T., & Haddou, B. (2022). A critical review with emphasis on recent pieces of evidence of Moringa oleifera biosorption in water and wastewater treatment. *Environmental Science and Pollution Research, 29*, 48185–48209. doi:https://doi.org/10.1007/s11356-022-19938-w

Berger, A., Harari, M., Gross, A., & Erez, A. (2024). Diversity loss in microbial ecosystems undergoing gradual environmental changes. *Cell Reports Sustainability, 1*(11), 100242. doi:https://doi.org/10.1016/j.crsus.2024.100242

Bhat, S., Maughan, H., Cameron, A., & Yost, C. (2022). Phylogenomic analysis of the genus Delftia reveals distinct major lineages with ecological specializations. *Microbial Genomics, 8*(9), 000864. doi:https://doi.org/10.1099/mgen.0.000864

Biggs, C., Yeager, L., Bolser, D., Bonsell, C., Dichiera, A., Hou, Z., . . . Erisman, B. (2020). Does functional redundancy affect ecological stability and resilience? A review and meta-analysis. *Ecosphere, 11*(7), e03184. doi:https://doi.org/10.1002/ecs2.3184

Bir, R., & Singh, M. (2020). Study of biosorption of heavy metals using agricultural and microbial biomass: a review. *Pollution Research, 39*, S153-S160.

Bosecker, K. (1997). Bioleaching: metal solubilization by microorganisms. *FEMS Microbiology Reviews, 20*(3-4), 591–604. doi:https://doi.org/10.1111/j.1574-6976.1997.tb00340.x

Bosnak, J. (2015). Soap Opera and Muddy Affairs in Indonesia. *Bijdragen tot de taal-, land- en volkenkunde / Journal of the Humanities and Social Sciences of Southeast Asia, 171*(4), 455-488. doi:https://doi.org/10.1163/22134379-17104002

Bôto, M., Magalhães, C., Perdigão, R., Alexandrino, D., Fernandes, J., Bernabeu, A., . . . Mucha, A. (2021). Harnessing the Potential of Native Microbial Communities for Bioremediation of Oil Spills in the Iberian Peninsula NW Coast. *Frontiers in Microbiology, 12*, 633659. doi:https://doi.org/10.3389/fmicb.2021.633659

Bravo, D., & Braissant, O. (2022). Cadmium-tolerant bacteria: current trends and applications in agriculture. *Letters in applied microbiology, 74*(3), 311-333. doi:https://doi.org/10.1111/lam.13594

Bridges, C., & Zalups, R. (2005). Molecular and ionic mimicry and the transport of toxic metals. *Toxicology and applied pharmacology, 204*(3), 274–308. doi:https://doi.org/10.1016/j.taap.2004.09.007

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon, 6*, e04691. doi: 10.1016/j.heliyon.2020.e04691

Broman, E., Sjöstedt, J., Pinhassi, J., & Dopson, M. (2017). Shifts in coastal sediment oxygenation cause pronounced changes in microbial community composition and associated metabolism. *Microbiome, 5*(1), 96. doi:https://doi.org/10.1186/s40168-017-0311-5

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Bruins, M., Kapil, S., & Oehme, F. (2000). Microbial Resistance to Metals in the Environment. *Ecotoxicology and Environmental Safety, 45*(3), 198-207. doi:https://doi.org/10.1006/eesa.1999.1860

Bui, X., Vo, T., Ngo, H., Guo, W., & Nguyen, T. (2016). Multicriteria assessment of advanced treatment technologies for micropollutants removal at large-scale applications. *Science of the Total Environment, 563-564*, 1050-1067. doi:http://dx.doi.org/10.1016/j.scitotenv.2016.04.191

Caballero, H., Campanello, G., & Giedroc, D. (2011). Metalloregulatory Proteins: Metal Selectivity and Allosteric Switching. *Biophysical chemistry, 156*(2-3), 103–114. doi:https://doi.org/10.1016/j.bpc.2011.03.010

Campillo-Cora, C., Rodríguez-Seijo, A., Pérez-Rodríguez, P., Fernández-Calviño, D., & Santás-Miguel, V. (2025). Effect of heavy metal pollution on soil microorganisms: Influence of soil physicochemical properties. A systematic review. *European Journal of Soil Biology, 124*, 103706. doi:https://doi.org/10.1016/j.ejsobi.2024.103706

Campillo-Cora, C., Rodríguez-Seijo, A., Pérez-Rodríguez, P., Fernández-Calviño, D., & Santás-Miguel, V. (2025). Effect of heavy metal pollution on soil microorganisms: Influence of soil physicochemical properties. A systematic review. *European Journal of Soil Biology, 124*, 103706. doi:https://doi.org/10.1016/j.ejsobi.2024.103706

Capdevila, D., Edmonds, K., & Giedroc, D. (2017). Metallochaperones and metalloregulation in bacteria. *Essays in Biochemistry, 61*(2), 177-200. doi:https://doi.org/10.1042/EBC20160076

Cardoso, A., Dias, C., de Moura, C., Ferreira, J., Rodrigues, E., Macêdo, E., . . . Viegas, B. (2024). Use of Bayesian Methods in the Process of Uranium Bioleaching by Acidithiobacillus ferrooxidans. *Applied Sciences, 14*(1), 109. doi:https://doi.org/10.3390/app14010109

Carlson, H., Price, M., Callaghan, M., Aaring, A., Chakraborty, R., Liu, H., . . . Deutschbauer, A. (2019). The selective pressures on the microbial community in a metal-contaminated aquifer. *The ISME Journal, 13*, 937–949. doi:https://doi.org/10.1038/s41396-018-0328-1

Castellani, M., Vecchia, A. B., Natale, R., Piaser, E., Lastrucci, L., Coppi, A., & Villa, P. (2023). Genetic drift versus natural selection affecting the evolution of spectral and functional traits of two key macrophytes: Phragmites australis and Nuphar lutea. *Freshwater Biology, 68*(10), 1739-1750. doi:https://doi.org/10.1111/fwb.14162

Chaerun, S., Winarko, R., & Yushandiana, F. (2023). Biohydrometallurgy: paving the way for a greener future of mineral processing in Indonesia - A mini review. *Current Research on Biosciences and Biotechnology, 5*(1), 299-307. doi:https://doi.org/10.5614/crbb.2023.5.1/8KIZ3AOE

Chandrangsu, P., Rensing, C., & Helmann, J. (2017). Metal homeostasis and resistance in bacteria. *Nature Reviews Microbiology, 15*, 338-350. doi:https://doi.org/10.1038/nrmicro.2017.15

Chaudhary, P., Xu, M., Ahamad, L., Chaudhary, A., Kumar, G., Adeleke, B., . . . Fayssal, S. (2023). Application of Synthetic Consortia for Improvement of Soil Fertility,

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Pollution Remediation, and Agricultural Productivity: A Review. *Agronomy, 13*(3), 643. doi:https://doi.org/10.3390/agronomy13030643

Che, S., Wang, J., Zhou, Y., Yue, C., Zhou, X., Xu, Y., . . . Yang, M. (2024). The adsorption and fixation of Cd and Pb by the microbial consortium weakened the toxic effect of heavy metal-contaminated soil on rice. *Chemical Engineering Journal, 497*, 154684. doi:https://doi.org/10.1016/j.cej.2024.154684

Chen, F., Koh, X., Tang, M., Gan, J., & Lau, S. (2021). Microbiological assessment of ecological status in the Pearl River Estuary, China. *Ecological Indicators, 130*, 108084. doi:https://doi.org/10.1016/j.ecolind.2021.108084

Chen, H., Lei, L., Li, Z., Zhou, H., Cheng, H., Chen, Z., . . . Wang, Y. (2024). Redundancy and resilience of microbial community under aniline stress during wastewater treatment. *Science of The Total Environment, 951*, 175822. doi:https://doi.org/10.1016/j.scitotenv.2024.175822

Chen, P., & He, C. (2008). Selective recognition of metal ions by metalloregulatory proteins. *Current Opinion in Chemical Biology, 12*(2), 214-221. doi:https://doi.org/10.1016/j.cbpa.2007.12.010

Cheng, H., Liu, G., Shen, Y., Liu, Y., Wan, L., Yang, S., . . . Su, X. (2024). An assessment of soil microbial community environmental stress in alpine marginal ecosystems using microbial indicators. *Ecological Indicators, 158*, 111542. doi:https://doi.org/10.1016/j.ecolind.2023.111542

Chojnacka, K. (2010). Biosorption and bioaccumulation – the prospects for practical applications. *Environment International, 36*(3), 299-307. doi:https://doi.org/10.1016/j.envint.2009.12.001

Chojnacka, K., & Mikulewicz, M. (2014). Bioaccumulation. In P. Wexler, *Encyclopedia of Toxicology (Third Edition)* (pp. 456-460). Academic Press. doi:https://doi.org/10.1016/B978-0-12-386454-3.01039-3

Chu, D. (2018). Effects of heavy metals on soil microbial community. *IOP Conf. Series: Earth and Environmental Science*, 012009. doi:10.1088/1755-1315/113/1/012009

Chukwu, E., & Gulser, C. (2025). Morphological, physiological, and anatomical effects of heavy metals on soil and plant health and possible remediation technologies. *Soil Security, 18*, 100178. doi:https://doi.org/10.1016/j.soisec.2025.100178

Ciptawati, E., Dzikrulloh, M., Septiani, M., Rinata, V., Rokhim, D., Fauziyyah, N., & Sribuana, D. (2022). Analisis Kandungan Mineral dari Lumpur Panas Sidoarjo sebagai Potensi Sumber Silika dan Arah Pemanfaatannya. *Indonesian Journal of Chemical Analysis, 5*(1), 18-28. doi:10.20885/ijca.vol5.iss1.art3

Cordoso, P., Pinto, R., Lopes, T., & Figueira, E. (2024). How Bacteria Cope with Oxidative Stress Induced by Cadmium: Volatile Communication Is Differentially Perceived among Strains. *Antioxidants, 13*(5), 565. doi:https://doi.org/10.3390/antiox13050565

Cremin, K., Jones, B., Teahan, J., Meloni, G., Perry, D., Zerfass, C., . . . Unwin, P. (2020). Scanning Ion Conductance Microscopy Reveals Differences in the Ionic Environments of Gram-Positive and Negative Bacteria. *Analytical Chemistry, 92*(24), 16024–16032. doi:https://doi.org/10.1021/acs.analchem.0c03653

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Custido, M., Espinoza, C., Peñaloza, R., Peralta-Ortiz, T., Sánchez-Suárez, H., Ordinola-Zapata, A., & Vieyra-Peña, E. (2022). Microbial diversity in intensively farmed lake sediment contaminated by heavy metals and identification of microbial taxa bioindicators of environmental quality. *Scientific Reports, 12*, 80. doi:https://doi.org/10.1038/s41598-021-03949-7

da Costa, A., & Duta, F. (2001). Bioaccumulation of copper, zinc, cadmium and lead by Bacillus sp., Bacillus cereus, Bacillus sphaericus and Bacillus subtilis. *Brazilian Journal of Microbiology, 32*, 1-5.

Da Costa, C., Colin, Y., Debret, M., Copard, Y., Gardes, T., Jacq, K., . . . Berthe, T. (2023). Shifts in sediment bacterial communities reflect changes in depositional environments in a fluviatile context. *Science of The Total Environment, 885*, 163890. doi:https://doi.org/10.1016/j.scitotenv.2023.163890

Dagdag, E., Sukoso, R. A., & Leksono, A. (2015). Analysis of Heavy Metals in Sediment of Lapindo Mud, Sidoarjo, East Java. *International Journal of ChemTech Research, 8*(11), 358-363.

Daims, H., & Wagner, M. (2018). Microbe of The Month: Nitrospira. *Trends in Microbiology, 26*(5), 462-463. doi:https://doi.org/10.1016/j.tim.2018.02.001

Dann, L., Smith, R., Jeffries, T., McKerral, J., Fairweather, P., Oliver, R., & Mitchell, J. (2016). Persistence, loss and appearance of bacteria upstream and downstream of a river system. *Marine and Freshwater Research, 68*(5), 851-862. doi:https://doi.org/10.1071/MF16010

Danouche, M., El Ghachtouli, N., & El Arroussi, H. (2021). Phycoremediation mechanisms of heavy metals using living green microalgae: physicochemical and molecular approaches for enhancing selectivity and removal capacity. *Heliyon, 7*(7), e07609. doi:https://doi.org/10.1016/j.heliyon.2021.e07609

Davidova, S., Milushev, V., & Satchanska, G. (2024). The Mechanisms of Cadmium Toxicity in Living Organisms. *Toxics, 12*(12), 875. doi:https://doi.org/10.3390/toxics12120875

Davies, R., Mathias, S., Swarbrick, R., & Tingay, M. (2011). Probabilistic longevity estimate for the LUSI mud volcano, East Java. *Journal of the Geological Society, London,, 168*, 517–523. doi:10.1144/0016-76492010-129

Davies, R., Swarbrick, R., Evans, R., & Huuse, M. (2007). Birth of a mud volcano: East Jawa, 29 May 2006. *GSA Today, 7*(2). doi:10.1130/GSAT01702A.1

De Coster, Q., & Rademakers, R. (2023). NanoPack2: population-scale evaluation of long-read sequencing data. *Bioinformatics, 39*(5), btad311. doi:https://doi.org/10.1093/bioinformatics/btad311

Degen, R., Aune, M., Blihm, B., Cassidy, C., Kędra, K., Kraan, C., . . . Zuschin, M. (2018). Trait-based approaches in rapidly changing ecosystems: A roadmap to the future polar oceans. *Ecological Indicators, 91*, 722-736. doi:https://doi.org/10.1016/j.ecolind.2018.04.050

Dell'Anno, F., Rastelli, E., Tangherlini, M., Corinaldesi, C., Sansone, C., Brunet, C., . . . Dell'Anno, A. (2021). Highly Contaminated Marine Sediments Can Host Rare Bacterial Taxa Potentially Useful for Bioremediation. *Frontiers in microbiology, 12*, 584850. doi:https://doi.org/10.3389/fmicb.2021.584850

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
Ardine Rahma Sarita, Prof. Dr. rer. nat. Andhika Puspito Nugroho, S.Si., M.Si.; Prof. Dr. Endah Retnaningrum, S.Si.,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Díaz, J., Serrano, J., & Leiva, E. (2018). Bioleaching of Arsenic-Bearing Copper Ores. *Minerals, 8*(5), 215. doi:https://doi.org/10.3390/min8050215

Díaz, S., Lavorel, S., de Bello, F., Quétier, F., Grigulis, K., & Robson, T. (2007). Incorporating plant functional diversity effects in ecosystem service assessments. *PNAS, 104*(52), 20684 –20689. doi:https://doi.org/10.1073/pnas.0704716104

Dincă, L., Grenni, P., Onet, C., & Onet, A. (2022). Fertilization and Soil Microbial Community: A Review. *Applied Sciences, 12*(3), 1198. doi:https://doi.org/10.3390/app12031198

Dixit, M., Ghoshal, D., Lal Meena, A., Ghasal, P., Rai, A., Choudhary, J., & Dutta, D. (2024). Changes in soil microbial diversity under present land degradation scenario. *Total Environment Advances, 10*, 200104. doi:https://doi.org/10.1016/j.teadva.2024.200104

Dixit, M., Ghoshal, D., Lal Meena, A., Ghasal, P., Rai, A., Choudhary, J., & Dutta, D. (2024). Changes in soil microbial diversity under present land degradation scenario. *Total Environment Advances, 10*, 200104. doi:https://doi.org/10.1016/j.teadva.2024.200104

Docherty, K., Borton, H., Espinosa, N., Gebhardt, M., Gil-Loaiza, J., Gutknecht, J., . . . Gallery, R. (2015). Key Edaphic Properties Largely Explain Temporal and Geographic Variation in Soil Microbial Communities across Four Biomes. *PLoS ONE, 10*(11), e0135352. doi:https://doi.org/10.1371/journal.pone.0135352

Dominguez-Benetton, X., Varia, J., Pozo, G., Modin, O., Heijne, A., Fransaer, J., & Rabaey, K. (2018). Metal recovery by microbial electro-metallurgy. *Progress in Materials Science, 94*, 435-461. doi:https://doi.org/10.1016/j.pmatsci.2018.01.007

Donald, A., Raphael, P., Olumide, O., & Amarachukwu, O. (2022). Environmental Heavy Metal Pollution: Physicochemical Remediation Strategies to the Rescue. *Journal of Environment Pollution and Human Health, 10*(2), 31-45. doi:10.12691/jephh-10-2-1

Dong, Y., Wu, S., Deng, Y., Wang, S., Fan, H., Li, X., . . . Zhuang, X. (2021). Distinct Functions and Assembly Mechanisms of Soil Abundant and Rare Bacterial Taxa Under Increasing Pyrene Stresses. *Frontiers in Microbiology, 12*, 689762. doi:https://doi.org/10.3389/fmicb.2021.689762

Dragosits, M., & Mattanovich, D. (2013). Adaptive laboratory evolution – principles and applications for biotechnology. *Microbial cell factories, 12*, 64. doi:https://doi.org/10.1186/1475-2859-12-64

Duffus, J. (2002). "Heavy Metals" - A Meaningless Term. *Pure and Applied Chemistry, 74*, 793-807.

Duncan, A., deVries, N., & Nyarko, K. (2018). Assessment of Heavy Metal Pollution in the Sediments of the River Pra and Its Tributaries. *Water, Air, & Soil Pollution, 229*, 272. doi:https://doi.org/10.1007/s11270-018-3899-6

Durland, J., & Ahmadian-Moghadam, H. (2022, September 19). *Genetics, Mutagenesis*. Retrieved February 9, 2025, from StatPearls: https://www.ncbi.nlm.nih.gov/books/NBK560519/

Eisenhauer, N., Mueller, K., Ebeling, A., FGleixner, G., Huang, Y., Madaj, A., . . . Isbell, F. (2024). The multiple-mechanisms hypothesis of biodiversity–stability

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

relationships. *Basic and Applied Ecology, 79*, 153-166. doi:https://doi.org/10.1016/j.baae.2024.07.004

Eivazihollagh, A., Svanedal, I., Edlund, H., & Norgren, M. (2019). On chelating surfactants: Molecular perspectives and application prospects. *Journal of Molecular Liquids, 278*, 688-705. doi:https://doi.org/10.1016/j.molliq.2019.01.076

Ekawati, J., & Sulistyowati, E. (2021). The Vulnerability of Settlements in The Areas Impacted by Lapindo Mudflow Disaster, Sidoarjo. *IOP Conf. Series: Earth and Environmental Science, 830*, 012035. doi:10.1088/1755-1315/830/1/012035

Ekawati, J., Hardiman, G., & Pandelaki, E. (2020). Analysis of GIS-Based Disaster Risk and Land Use Changes in The Impacted Area of Mudflow Disaster Lapindo. *IOP Conf. Series: Earth and Environmental Science, 409*, 012032. doi:10.1088/1755-1315/409/1/012032

Elfidasari, D., Ismi, L., & Sugoro, I. (2020). Heavy metal concentration in water, sediment, and Pterygoplichthys pardalis in the Ciliwung River, Indonesia. *AACL Bioflux, 13*(3), 1764-1778.

Elgarahy, A., Elwakeel, K., Mohammad, S., & Elshoubaky, G. (2021). A critical review of biosorption of dyes, heavy metals and metalloids from wastewater as an efficient and green process. *Cleaner Engineering and Technology, 4*, 100209. doi:https://doi.org/10.1016/j.clet.2021.100209

Ewoti, O., Davy, S., Song, S., Mboene, R., Ladibé, P., Djiala, M., . . . Nola, M. (2023). Impact of heavy metal residues on the diversity of bacteria isolated from a few water points in areas of agricultural activity. *GSC Biological and Pharmaceutical Sciences, 23*(3), 060-074.

Fahrudin, F., Santosa, S., & Sareda. (2020). Toleransi logam berat timbal (Pb) pada bakteri indigenous dari air laut Pelabuhan Paotere, Makassar. *Aquatic Science & Management, 8*(1), 8-14.

Fan, T., Chen, Y., Wang, Y., Fang, W., Pan, J., Li, C., . . . Zhang, L. (2022). Aquatic Microbial Community Characteristics and Influencing Factors in Urban Landscape Rivers. *Polish Journal of Environmental Studies, 31*(6), 5661-5673. doi:10.15244/pjoes/152239

Fan, Y., Chen, K., Dai, Z., Peng, J., Wang, F., Liu, H., . . . Cao, W. (2024). Land use/cover drive functional patterns of bacterial communities in sediments of a subtropical river, China. *Science of The Total Environment, 947*, 174564. doi:https://doi.org/10.1016/j.scitotenv.2024.174564

FAO. (1999). *Soil salinity assessment - Methods and interpretation of electrical conductivity measurements.* Rome: Food and Agriculture Organization of the United Nations.

FAO. (2019). *Standard operating procedure for soil organic carbon: Walkley-Black method, Titration and colorimetric method.* Rome: Food and Agriculture Organization of the United Nations.

FAO. (2021a). *Standard operating procedure for soil pH determination.* Rome: Food and Agriculture Organization of the United Nations.

FAO. (2021b). *Standard operating procedure for soil nitrogen - Kjeldahl method.* Rome: Food and Agriculture Organization of the United Nations.

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

FAO. (2021c). *Standard operating procedure for soil available phosphorus, Bray I and Bray II method.* Rome: Food and Agriculture Organization of the United Nations.

FAO. (2023). *Standard operating procedure for soil moisture content by gravimetric method.* Rome: Food and Agriculture Organization of the United Nations.

Fashola, M., Anagun, O., & Babalola, O. (2023). Heavy metal pollution: Toxic effects on bacterial cells. *Authorea*. doi:10.22541/au.168690270.01555938/v1

Faur-Brasquet, C. K., & Le Cloirec, P. (2002). Removal of metal ions from aqueous solution by adsorption onto activated carbon cloths: adsorption competition with organic matter. *Carbon, 40*(13), 2387-2392. doi:https://doi.org/10.1016/S0008-6223(02)00117-3

Feria-Cáceres, P., Penagos-Velez, L., & Moreno-Herrera, C. (2022). Tolerance and Cadmium (Cd) Immobilization by Native Bacteria Isolated in Cocoa Soils with Increased Metal Content. *Microbiology Research, 13*(3), 556-573. doi:https://doi.org/10.3390/microbiolres13030039

Fitriani, D., Agustine, E., Kirana, K., Meiliani, T., Rofifah, S., Chicilia, N., . . . Tamuntuan, G. (2025). Assessing Cisanti Lake Sediments as Environmental Quality Indicators in the Upstream of the Citarum River. *Indonesian Physical Review, 8*(3), 734-744. doi:https://doi.org/10.29303/ipr.v8i3.490

Fletcher, L., C, S., Farrell, C., Buckley, T., Pellegrini, M., & Sack. (2022). Testing the association of relative growth rate and adaptation to climate across natural ecotypes of Arabidopsis. *New Phytologist, 236*(2), 413-432. doi:https://doi.org/10.1111/nph.18369

Flouty, R., & Estephane, G. (2012). Bioaccumulation and biosorption of copper and lead by a unicellular algae Chlamydomonas reinhardtii in single and binary metal systems: A comparative study. *Journal of Environmental Management, 111*, 106-114. doi:https://doi.org/10.1016/j.jenvman.2012.06.042

Fonseca, C., & Ganade, G. (2001). Species functional redundancy, random extinctions and the stability of ecosystems. *Journal of Ecology, 89*(1), 118-125. doi:https://doi.org/10.1046/j.1365-2745.2001.00528.x

Fonti, V., Dell'Anno, A., & Beolchini, F. (2016). Does bioleaching represent a biotechnological strategy for remediation of contaminated sediments? *Science of The Total Environment, 563-564*, 302-319. doi:https://doi.org/10.1016/j.scitotenv.2016.04.094

Fowler, S., Toth, C., & Gieg, L. (2016). Community Structure in Methanogenic Enrichments Provides Insight into Syntrophic Interactions in Hydrocarbon-Impacted Environments. *Frontiers in microbiology, 7*, 562. doi:https://doi.org/10.3389/fmicb.2016.00562

Frémion, F., Bordas, F., Mourier, B., Lenain, J., Kestens, T., & Courtin-Nomade, A. (2016). A. Influence of dams on sediment continuity: A study case of a natural metallic contamination. *Science of The Total Environment, 547*, 282-294. doi:https://doi.org/10.1016/j.scitotenv.2016.01.023

Fu, S., Iqbal, B., Li, G., Alabbosh, K., Khan, K., Zhao, X., . . . Du, D. (2024). The role of microbial partners in heavy metal metabolism in plants: a review. *Plant Cell Reports, 43*, 111. doi:https://doi.org/10.1007/s00299-024-03194-y

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
Ardine Rahma Sarita, Prof. Dr. rer. nat. Andhika Puspito Nugroho, S.Si., M.Si.; Prof. Dr. Endah Retnaningrum, S.Si.,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Fuentes, S., Barra, B., Caporaso, J., & Seeger, M. (2015). From Rare to Dominant: a Fine-Tuned Soil Bacterial Bloom during Petroleum Hydrocarbon Bioremediation. *Applied and environmental microbiology, 82*(3), 888-896. doi:https://doi.org/10.1128/AEM.02625-15

Gadd, G. (2009). Biosorption: critical review of scientific rationale, environmental importance and significance for pollution treatment. *Journal of Chemical Technology & Biotechnology, 84*(1), 13–28. doi:https://doi.org/10.1002/jctb.1999

Gadd, G., & Griffiths, A. (1978). Microorganisms and Heavy Metal Toxicity. *Microbial Ecology, 4*(4), 303-317.

Galand, P., Lucas, S., SK, F., Peru, E., Pruski, A., Vétion, G., . . . Guizien, K. (2016). Disturbance Increases Microbial Community Diversity and Production in Marine Sediments. *Frontiers in microbiology, 7*, 1950. doi:https://doi.org/10.3389/fmicb.2016.01950

Galan-Freyle, N., Aranguren-Diaz, Y., Ospina-Maldonado, S., Chapuel-Aguillon, P., Pertuz-Peña, M., Hernandez-Rivera, S., & Pacheco-Londoño, L. (2025). Exploring cadmium bioaccumulation and bioremediation mechanisms and related genes in soil microorganisms: a review. *Environmental Science and Pollution Research, 32*, 20215-20231. doi:https://doi.org/10.1007/s11356-025-36802-9

Gałązka, A., & Grządziel, J. (2016). The Molecular-Based Methods Used for Studying Bacterial Diversity in Soils Contaminated with PAHs (The Review). In M. Larramendy, & S. Soloneski, *Soil Contamination - Current Consequences and Further Solutions* (pp. 85-104). InTech.

Gallardo-Navarro, O., Aguilar-Salinas, B., Rocha, J., & Olmedo-Álvarez, G. (2024). Higher-order interactions and emergent properties of microbial communities: The power of synthetic ecology. *Heliyon, 10*(14), e33896. doi:https://doi.org/10.1016/j.heliyon.2024.e33896

Garbisu, C., & Alkorta, I. (2003). Basic concepts on heavy metal soil bioremediation. *The European Journal of Mineral Processing and Environmental Protection, 3*(1), 58-66.

Garnier, C., Mounier, S., & Benaïm, J. (2004). Influence of dissolved organic carbon content on modelling natural organic matter acid–base properties. *Water Research, 38*(17), 3685-3692. doi:https://doi.org/10.1016/j.watres.2004.05.019

Gautam, R., Mudhoo, A., Lofrano, G., & Chattopadhyaya, M. (2014). Biomass-derived biosorbents for metal ions sequestration: Adsorbent modification and activation methods and adsorbent regeneration. *Journal of Environmental Chemical Engineering, 2*(1), 239-259. doi:https://doi.org/10.1016/j.jece.2013.12.019

Gauthier, P., Norwood, W., Prepas, E., & Pyle, G. (2014). Metal–PAH mixtures in the aquatic environment: A review of co-toxic mechanisms leading to more-than-additive outcomes. *Aquatic Toxicology, 154*, 253-269. doi:http://dx.doi.org/10.1016/j.aquatox.2014.05.026

Genchi, G., Sinicropi, M., Lauria, G., Carocci, A., & Catalano, A. (2020). The Effects of Cadmium Toxicity. *International journal of environmental research and public health, 17*(11), 3782. doi:https://doi.org/10.3390/ijerph17113782

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Gerber, U., Hübner, R., Rossberg, R., Krawczyk-Bärsch, E., & Merroun, M. (2018). Metabolism-dependent bioaccumulation of uranium by Rhodosporidium toruloides isolated from the flooding water of a former uranium mine. *PLoS ONE, 13*(8). doi:https://doi.org/10.1371/journal.pone.0201903

Gerenfes, D., & Teju, E. (2018). Determination of Some Selected Heavy Metals in Water, Oreochromis niloticus and Labeobarbus intermedius Samples from Abaya and Chamo Lakes. *Journal of Natural Sciences Research, 8*(21), 85-95.

Ghaed, S., Shirazi, E., & Marandi, R. (2013). Biosorption of Copper Ions by Bacillus and Aspergillus Species. *Adsorption Science & Technology, 31*(10), 869-890.

Gholami, S., Dimde, M., Braatz, D., Müller, J., Haag, R., & Wagner, O. (2020). Reusable biopolymer based heavy metal filter as plant protection for phytoremediation. *Environmental Technology & Innovation, 19*, 101005. doi:https://doi.org/10.1016/j.eti.2020.101005

Giakoumatos, S., & Kopsidas, O. (2022). Biomass as adsorbent – A depollution cost effective material in a promising market. *IOP Conf. Series: Earth and Environmental Science, 1123*, 012070. doi:10.1088/1755-1315/1123/1/012070

Gibbons, S., & Gilbert, J. (2015). Microbial diversity — exploration of natural ecosystems and microbiomes. *Current opinion in genetics & development, 35*, 66–72. doi:https://doi.org/10.1016/j.gde.2015.10.003

Godoy-Lozano, E., Escobar-Zepeda, A., Raggi, L., Merino, E., Gutierrez-Rios, R., Juarez, K., . . . Pardo-Lopez, L. (2018). Bacterial Diversity and the Geochemical Landscape in the Southwestern Gulf of Mexico. *Frontiers in Microbiology, 9*, 2528. doi:https://doi.org/10.3389/fmicb.2018.02528

Golzar-Ahmadi, M., Bahaloo-Horeh, N., Pourhossein, F., Norouzi, F., Schoenberger, N., Hintersatz, C., . . . Kaksonen, A. (2024). Pathway to industrial application of heterotrophic organisms in critical metals recycling from e-waste. *Biotechnology Advances, 77*, 108438. doi:https://doi.org/10.1016/j.biotechadv.2024.108438

Gómez-Aguilar, D., Rodríguez-Miranda, J., & Salcedo-Parra, O. (2022). Fruit Peels as a Sustainable Waste for the Biosorption of Heavy Metals in Wastewater: A Review. *Molecules, 27*(7), 2124. doi:https://doi.org/10.3390/molecules27072124

Goswami, A., Adkins-Jablonsky, SJ, Filho, M., Shilling, M., Dawson, A., . . . Morris, J. (2023). Heavy Metal Pollution Impacts Soil Bacterial Community Structure and Antimicrobial Resistance at the Birmingham 35th Avenue Superfund Site. *Microbiology spectrum, 11*(2), e0242622. doi:https://doi.org/10.1128/spectrum.02426-22

Goswami, M., Bhattacharyya, P., Mukherjee, I., & Tribedi, P. (2017). Functional Diversity: An Important Measure of Ecosystem Functioning. *Advances in Microbiology, 7*, 82-93. doi:http://dx.doi.org/10.4236/aim.2017.71007

Gregory, T. (2009). Understanding Natural Selection: Essential Concepts and Common Misconceptions. *Evolution: Education and Outreach, 2*, 156–175. doi:https://doi.org/10.1007/s12052-009-0128-1

Guo, Y., Cheng, S., Fang, H., Yang, Y., Li, Y., Shi, F., & Zhou, Y. (2023). Copper and cadmium co-contamination affects soil bacterial taxonomic and functional

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

attributes in paddy soils. *Environmental Pollution, 329*, 121724. doi:https://doi.org/10.1016/j.envpol.2023.121724

Guo, Y., Jin, J., Lu, Y., Lin, Y., Liu, Q., & Li, Z. (2024). Bacterial diversity loss weakens community functional stability. *Applied Soil Ecology, 202*, 105536. doi:https://doi.org/10.1016/j.apsoil.2024.105536

Gupta, A., Gupta, R., & Singh, R. (2016). Microbes and Environment. In R. Singh, *Principles and Applications of Environmental Biotechnology for a Sustainable Future* (pp. 43–84). Springer Singapore. doi:https://doi.org/10.1007/978-981-10-1866-4_3

Gupta, S., Graham, D., Sreekrishnan, T., & Ahammad, S. (2023). Exploring the impacts of physicochemical characteristics and heavy metals fractions on bacterial communities in four rivers. *Journal of Environmental Management, 325*(A), 116453. doi:https://doi.org/10.1016/j.jenvman.2022.116453

Haferburg, G., & Kothe, E. (2007). Microbes and metals: interactions in the environment. *Journal of Basic Microbiology, 47*(6), 453-467. doi:https://doi.org/10.1002/jobm.200700275

Haidar, Z., Fatema, K., Shoily, S., & Sajib, A. (2023). Disease-associated metabolic pathways affected by heavy metals and metalloid. *Toxicology Reports, 10*, 554-570. doi:https://doi.org/10.1016/j.toxrep.2023.04.010

Hajiagha, M., & Kafil, H. (2023). Efflux pumps and microbial biofilm formation. *Infection, Genetics and Evolution, 112*, 105459. doi:https://doi.org/10.1016/j.meegid.2023.105459

Hammond, M., & Kolasa, J. (2019). The Long and Short of Biodiversity: Cumulative Diversity and Its Drivers. *Diversity, 11*(3), 41. doi:https://doi.org/10.3390/d11030041

Handoko, L., Rifa'i, A., Yasufuku, N., & Ishikura, R. (2015). Physical properties and mineral content of Sidoarjo mud volcano. *Procedia Engineering, 125*, 324 – 330. doi:10.1016/j.proeng.2015.11.070

Haque, M., Jewel, M., & Sultana, M. (2019). Assessment of physicochemical and bacteriological parameters in surface water of Padma River, Bangladesh. *Applied Water Science, 9*, 10. doi:https://doi.org/10.1007/s13201-018-0885-5

Harris, R. (2025). Response and Functional Adaptation of Rhizosphere Microbial Communities to Cadmium Stress in Rice. *Ecological Conservation and Restoration, 1*(1), 25-34.

He, H., Dang, L., Yang, Q., Chen, R., Yang, J., Li, J., . . . Dai, J. (2025). Cadmium toxicity on communities of ammonia-oxidizing microorganisms. *PeerJ, 13*, e18829. doi:http://doi.org/10.7717/peerj.18829

Helmann, J. (2014). Specificity of Metal Sensing: Iron and Manganese Homeostasis in Bacillus subtilis. *Journal of Biological Chemistry, 289*(41), 28112-28120. doi:https://doi.org/10.1074/jbc.R114.587071

Helmann, J., Soonsanga, S., & Gabriel, S. (2007). Metalloregulators: Arbiters of Metal Sufficiency. In D. Nies, & S. Silver, *Molecular Microbiology of Heavy Metals* (Vol. 6, pp. 37-71). Berlin, Heidelberg: Springer. doi:https://doi.org/10.1007/7171_2006_073

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Herawati. (2007). *Analisis Resiko Lingkungan Aliran Air Lumpur Lapindo ke Badan Air.* Semarang: Program Studi Magister Ilmu Lingkungan.

Hernandez, D., David, A., Menges, E., Seacry, C., & Afkhami, M. (2021). Environmental stress destabilizes microbial networks. *The ISME Journal, 15*(6), 1722-1734. doi:https://doi.org/10.1038/s41396-020-00882-x

Hidayati, D., Ismail, B., Shuhaimi-Othman, M., & Sulaiman, N. (2018). Chemical Composition of a Mud Volcano LUSI and the Health Risk Involved based on the Air Quality Index that Occurred as a Result of Disastrous Gas Exploration Drilling Activities in Sidoarjo, Indonesia. *Sains Malaysiana, 47*(8), 1665–1674. doi:http://dx.doi.org/10.17576/jsm-2018-4708-05

Hidayati, D., Sulaiman, N., Ismail, B., Shuhaimi-Othman, M., & Bellard, M. (2017). Evaluation of the Effect of Sidoarjo Mud on Aquatic Life Using Chromatophores and the Microstructure of Fish Scales. *Sains Malaysiana, 46*(3), 373–380. doi:http://dx.doi.org/10.17576/jsm-2017-4603-03

Hnatush, S., Moroz, O., Yavorska, G., & Borsukevych, B. (2018). Sulfidogenic and metal reducing activities of Desulfuromonas genus bacteria under the influence of copper chloride. *Biosystems Diversity, 26*(3), 218-226. doi:https://doi.org/10.15421/011833

Hochstein, M., & Sudarman, S. (2010). Monitoring of LUSI Mud-Volcano - a Geo-Pressured System, Java, Indonesia. *Proceedings World Geothermal Congress 2010,* (pp. 25-29). Bali.

Hodgson, R., Cando-Dumancela, C., Davies, T., Dinsdale, E., Doane, M., Edwards, R., . . . Breed, M. (2026). Contrasting Microbial Taxonomic and Functional Colonisation Patterns in Wild Populations of the Pan-Palaeotropical C4 Grass, Themeda triandra. *Plant, cell & environment, 49*(1), 209–225. doi:https://doi.org/10.1111/pce.70205

Hu, J., Wan, L., Wang, Y., Dai, K., Butterbach, -B. K., & Lin, S. (2025). The Decrease of Soil Microbial Community Diversity and Network Complexity Results in the Increase of Soil-Borne Diseases With Monocultural Years in Greenhouse Tomato Production Systems. *Environmental microbiology reports, 17*(4), e70165. doi:https://doi.org/10.1111/1758-2229.70165

Huang, C., Liang, C., Yang, T., Chen, J., & Wang, W. (2021). Shift of bacterial communities in heavy metalcontaminated agricultural land during a remediation process. *PLoS ONE, 16*(7), e0255137. doi:https://doi.org/10.1371/journal.pone.0255137

Huang, H., Lin, Y., Yang, Z., Qu, K., Li, Z., Lu, G., . . . Yao, Y. (2024). Transformation of Heavy Metals by periphyton. *E3S Web of Conferences, 561*, 02031. doi:https://doi.org/10.1051/e3sconf/202456102031

Huang, M., Pan, J., & Zheng, L. (2001). Removal of heavy metals from aqueous solutions using bacteria. *Journal of Shanghai University, 5*, 253-259. doi: https://doi.org/10.1007/s11741-996-0035-4

Ibrahim, U., Kawo, A., & Yahya, S. (2021). Physicochemical and molecular characterization of heavy metal–tolerant bacteria isolated from soil of mining sites in Nigeria. *Journal of genetic engineering & biotechnology, 19*(1), 152. doi:https://doi.org/10.1186/s43141-021-00251-x

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
Ardine Rahma Sarita, Prof. Dr. rer. nat. Andhika Puspito Nugroho, S.Si., M.Si.; Prof. Dr. Endah Retnaningrum, S.Si.,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Idris, M., Umaru, D., Aliyu, A., & Musa, I. (2021). Atomic Absorption Spectroscopy Analysis of Heavy metals in water at Daura Gypsum Mining Site, Yobe State, Nigeria. *Journal for Foundations and Applications of Physics, 8*(2), 227-234.

Igiri, B., Okuduwa, S., Idoko, G., Akabuogu, E., Adeyi, A., & Ejiogu, I. (2018). Toxicity and Bioremediation of Heavy Metals Contaminated Ecosystem from Tannery Wastewater: A Review. *Journal of toxicology, 2018*, 2568038. doi:https://doi.org/10.1155/2018/2568038

Ilyas, S., Kim, M., & Lee, J. (2017). Integration of microbial and chemical processing for a sustainable metallurgy. *Journal of Chemical Technology & Biotechnology, 93*(2), 320-332. doi:https://doi.org/10.1002/jctb.5402

Imamovic, M., Horozic, E., Salkovic, V., Pasalic, A., & Hadzic, N. (2023). Metal complexes as potential agents for neutralizing free radicals: a review of in vitro studies. *Acta Medica Saliniana, 52*(1-2). doi:10.5457/618

Imran, I., Khan, A., Kamal, A., Alrefaei, A., & Zaman, W. (2025). Utilization and Characterization of Microbes for Heavy Metal Remediation. *Polish Journal of Environmental Studies, 34*(2), 1179-1190. doi:https://doi.org/10.15244/pjoes/186937

Inglezakis, V., Zorpas, A., Loizidou, M., & Grigoropoulou, H. (2005). The effect of competitive cations and anions on ion exchange of heavy metals. *Separation and Purification Technology, 46*(3), 202-207. doi:https://doi.org/10.1016/j.seppur.2005.05.008

Insafitri. (2009). Impact of Lapindo Mud Dumping Water in Madura Strait East Java. *Jurnal Kelautan, 2*(1), 165-179.

Irawati, W., Riak, S., Sopiah, N., & Sulistia, S. (2017). Heavy metal tolerance in indigenous bacteria isolated from the industrial sewage in Kemisan River, Tangerang, Banten, Indonesia. *Biodiversitas, 18*(4), 1481-1486. doi:10.13057/biodiv/d180426

Ishikuri, S., & Hattori, T. (1985). Formation of Bacterial Colonies in Successive Time Intervals. *Applied and Environmental Microbiology, 49*(4), 870-873.

Istadi, B., Pramono, G., Sumintadireja, P., & Alam, S. (2009). Modeling study of growth and potential geohazard for LUSI mud volcano: East Java, Indonesia. *Marine and Petroleum Geology, 26*, 1724–1739. doi:10.1016/j.marpetgeo.2009.03.006

Istadi, B., Wibowo, H., Sunardi, E., Hadi, S., & Sawolo, N. (2012). Mud Volcano and Its Evolution. In I. Dar, *Earth Sciences* (pp. 375-434). InTech. doi:10.5772/24944

Jadaa, W., & Mohammed, H. (2023). Heavy Metals – Definition, Natural and Anthropogenic Sources of Releasing into Ecosystems, Toxicity, and Removal Methods – An Overview Study. *Journal of Ecological Engineering, 24*(6), 249–271. doi:https://doi.org/10.12911/22998993/162955

Jahanirad, M., Nasrabadi, T., & Karbassi, A. (2023). Role of Salinity and Oxidation-Reduction Potential in Mobility of Heavy Metals in Suspended Sediments at Estuarine Zone. *Pollution, 9*(2), 756-765. doi:http://doi.org/10.22059/POLL.2022.350296.1672

Jan, A., Azam, M., Siddiqui, K., Ali, A., Choi, I., Mohd, Q., & Haq, R. (2015). Heavy Metals and Human Health: Mechanistic Insight into Toxicity and Counter Defense

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

System of Antioxidants. *International Journal of Molecular Sciences, 16*(12), 29592-29630. doi:https://doi.org/10.3390/ijms161226183

Jansson, J., & Hofmockel, K. (2018). The soil microbiome — from metagenomics to metaphenomics. *Current Opinion in Microbiology, 43*, 162-168. doi:https://doi.org/10.1016/j.mib.2018.01.013

Javanbakht, V., Alavi, S., & Zilouei, H. (2014). Mechanisms of heavy metal removal using microorganisms as biosorbent. *Water Science & Technology, 69*(9), 1775–1787. doi:https://doi.org/10.2166/wst.2013.718

Jayaramaiah, R., Martins, C., Egidi, E., Macdonald, C., Wang, J., Liu, H., . . . Singh, B. (2025). Soil function-microbial diversity relationship is impacted by plant functional groups under climate change. *Soil Biology and Biochemistry, 200*, 109623. doi:https://doi.org/10.1016/j.soilbio.2024.109623

Jeyakumar, P., Debnath, C., Vijayaraghavan, R., & Muthuraj, M. (2023). Trends in Bioremediation of Heavy Metal Contaminations. *Environmental Engineering Research, 28*(4), 220631. doi:DOI: https://doi.org/10.4491/eer.2021.631

Jian, J., Feng, S., Xu, Y., Jia, M., Huang, H., Zheng, X., . . . Xu, H. (2025). Bacterial community assembly processes mediate soil functioning under cadmium stress in the agroecosystem. *Journal of Hazardous Materials, 494*, 138496. doi:https://doi.org/10.1016/j.jhazmat.2025.138496

Jiang, X., Ma, H., Zhao, Q., Xin, C., & Chen, B. (2021). Bacterial communities in paddy soil and ditch sediment under rice-crab co-culture system. *AMB Express, 11*, 163. doi:https://doi.org/10.1186/s13568-021-01323-4

Jiao, N., Song, X., Yin, D., & Deng, X. (2022). Diversity and structure of the microbial community in rhizosphere soil of Fritillaria ussuriensis at different health levels. *PeerJ, 10*, e12778. doi:https://doi.org/10.7717/peerj.12778

Jie, S., Li, M., Gan, M., Zhu, J., Yin, H., & Liu, X. (2016). Microbial functional genes enriched in the Xiangjiang River sediments with heavy metal contamination. *BMC Microbiology, 16*, 179. doi:https://doi.org/10.1186/s12866-016-0800-x

Jin, Y., Luan, Y., & Ning, Y. W. (2018). Effects and Mechanisms of Microbial Remediation of Heavy Metals in Soil: A Critical Review. *Applied Science, 8*(8), 1336. doi:https://doi.org/10.3390/app8081336

Joensuu, M., Pilditch, C., Harris, R., Hietanen, S., Pettersson, H., & Norkko, A. (2017). Sediment properties, biota, and local habitat structure explain variation in the erodibility of coastal sediments. *Limnology and Oceanography, 63*(1), 173-186. doi:https://doi.org/10.1002/lno.10622

Johnson, H., Cho, H., & Shoudharym, M. (2019). Bacterial Heavy Metal Resistance Genes and Bioremediation Potential. *Computational Molecular Bioscience, 9*(1), 1-12. doi:https://doi.org/10.4236/cmb.2019.91001

Johnson, O., Tobler, R., Schmidt, J., & Huber, C. (2023). Fluctuating selection and the determinants of genetic variation. *Trends in Genetics, 39*(6), 491-504. doi:https://doi.org/10.1016/j.tig.2023.02.004 4

Jomova, K., Alomar, S., Nepovimova, E., Kuca, K., & Valko, M. (2024). Heavy metals: toxicity and human health effects. *Archives of Toxicology*. doi:https://doi.org/10.1007/s00204-024-03903-2

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Jomova, K., Makova, M., Alomar, S., Alwasel, S., Nepovimove, E., Kuca, K., . . . Valko, M. (2022). Essential metals in health and disease. *Chemico-Biological Interactions, 367*, 110173. doi:https://doi.org/10.1016/j.cbi.2022.110173

Jones, C., Labonté, J., Haygood, L., Torres, M., Boharmann, G., Lyons, T., & Riedinger, N. (2025). Impacts on Sedimentary Microbial Communities Related to Temporal Changes in Trace Metal Concentrations. *Geobiology, 23*(4), e70027. doi:https://doi.org/10.1111/gbi.70027

Jordan, M., Wang, J., Capdevila, D., & Giedroc, D. (2020). Multi-metal nutrient restriction and crosstalk in metallostasis systems in microbial pathogens. *Current Opinion in Microbiology, 55*, 17-25. doi:https://doi.org/10.1016/j.mib.2020.01.010

Juliastuti, S., Baeyens, J., Creemers, C., Bixio, D., & Lodewyckx. (2003). The inhibitory effects of heavy metals and organic compounds on the net maximum specific growth rate of the autotrophic biomass in activated sludge. *Journal of Hazardous Materials, 100*(1-3), 271-283. doi:https://doi.org/10.1016/S0304-3894(03)00116-X

Jurburg, S., & Salles, J. (2015). Functional Redundancy and Ecosystem Function — The Soil Microbiota as a Case Study. *InTech*. doi:http://dx.doi.org/10.5772/58981

Kaduková, J., & Virčíková, E. (2005). Comparison of differences between copper bioaccumulation and biosorption. *Environment International, 31*(2), 227-232. doi:https://doi.org/10.1016/j.envint.2004.09.020

Kanamarlapudi, S., Chintalpudi, V., & Muddada, S. (2018). Application of Biosorption for Removal of Heavy Metals from Wastewater. In J. Derco, & B. Vrana, *Biosorption.* InTech. doi:http://dx.doi.org/10.5772/intechopen.77315

Kapahi, M., & Sachdeva, S. (2019). Bioremediation Options for Heavy Metal Pollution. *Journal of Health and Pollution, 9*(24), 191203. doi:https://doi.org/10.5696/2156-9614-9.24.191203

Kara, I., Kremser, K., Wagland, S., & Coulon, F. (2023). Bioleaching metal-bearing wastes and by-products for resource recovery: a review. *Environmental Chemistry Letters, 21*, 3329–3350. doi:https://doi.org/10.1007/s10311-023-01611-4

Karnwal, A. (2024). Unveiling the promise of biosorption for heavy metal removal from water sources. *Desalination and Water Treatment, 319*, 100523. doi:https://doi.org/10.1016/j.dwt.2024.100523

Keeney, D., & Poulin, R. (2007). Functional Richness, Functional Evenness, and Use of Niche Space in Parasite Communities. *The Journal of Parasitology, 93*(1), 216–219.

Khan, Z., Elahi, A., Bukhari, D., & Rehman. (2022). Cadmium sources, toxicity, resistance and removal by microorganisms-A potential strategy for cadmium eradication. *Journal of Saudi Chemical Society, 26*(6), 101569. doi:https://doi.org/10.1016/j.jscs.2022.101569

Khatri, N., & Tyagi, S. (2015). Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in Life Science, 8*(1), 23–39. doi:https://doi.org/10.1080/21553769.2014.933716

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Kicińska, A., Pomykała, R., & Izquierdo-Diaz, M. (2022). Changes in soil pH and mobility of heavy metals in contaminated soils. *European Journal of Soil Science, 73*(1), e13203. doi:https://doi.org/10.1111/ejss.13203

Kılıç, Z., Atakol, O., Aras, S., Cansaran-Duman, D., & Emregul, E. (2014). Biosorption properties of zinc(II) from aqueous solutions by Pseudevernia furfuracea (L.) Zopf. *Journal of the Air & Waste Management Association, 64*(10), 1112–1121. doi:https://doi.org/10.1080/10962247.2014.926299

Kim, B., Shin, J., Guevarra, R., Lee, J., Kim, D., Seol, K., . . . Isaacson, R. (2017). Deciphering Diversity Indices for a Better Understanding of Microbial Communities. *Journal of Microbiology and Biotechnology, 27*(12), 2089–2093. doi:https://doi.org/10.4014/jmb.1709.09027

Kinuthia, G., Ngure, V., Beti, D., Lugalia, R., Wangila, A., & Kamau, L. (2020). Levels of heavy metals in wastewater and soil samples from open drainage channels in Nairobi, Kenya: Community health implication. *Scientific Report, 10*, 8434. doi:http://doi.org/10.1038/s41598-020-65359-5

Knight, C., Nicolith, O., Griffiths, R., Goodall, T., Jones, B., Weser, C., . . . de Vries, F. (2024). Soil microbiomes show consistent and predictable responses to extreme events. *Nature, 636*, 690–696. doi:https://doi.org/10.1038/s41586-024-08185-3

Knotek-Smith, H., Deobald, L., Ederer, M., & Crawford, D. (2003). Cadmium stress studies: media development, enrichment, consortia analysis, and environmental relevance. *Biometals, 16*(2), 251–261. doi:https://doi.org/10.1023/a:1020617013927

Koleff, P., KJ, G., & Lennon, J. (2003). Measuring beta diversity for presence–absence data. *Journal of Animal Ecology, 72*(3), 367-382. doi:https://doi.org/10.1046/j.1365-2656.2003.00710.x

Kondakindi, V., Pabbati, R., Erukulla, P., Maddela, N., & Prasad, R. (2024). Bioremediation of heavy metals-contaminated sites by microbial extracellular polymeric substances – A critical view. *Environmental Chemistry and Ecotoxicology, 6*, 408-421. doi:https://doi.org/10.1016/j.enceco.2024.05.002

Kong, D., Xu, L., Dai, M., Ye, Z., Ma, B., & Tan, X. (2024). Deciphering the functional assembly of microbial communities driven by heavy metals in the tidal soils of Hangzhou Bay. *Environmental Pollution, 360*, 124671. doi:https://doi.org/10.1016/j.envpol.2024.124671

Kou, B., He, Y., Wang, Y., Qu, C., Tang, J., Wu, Y., . . . Yu, T. (2023). The relationships between heavy metals and bacterial communities in a coal gangue site. *Environmental Pollution, 322*, 121136. doi:https://doi.org/10.1016/j.envpol.2023.121136

Kowalska, J., Mazurek, R., Gąsiorek, M., & Zaleski, T. (2018). Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination–A review. *Environmental Geochemistry and Health, 40*, 2395–2420. doi:https://doi.org/10.1007/s10653-018-0106-z

Krisnayanti, B., & Agustawijaya, D. (2014). Characteristics of Lusi mud volcano and its impacts on the Porong River. *Journal of Degraded and Mining Lands Management, 1*(4), 207-210. doi:10.15243/jdmlm.2014.014.207

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Kubier, A., Wilkin, R., & Pichler, T. (2019). Cadmium in soils and groundwater: A review. *Applied geochemistry : journal of the International Association of Geochemistry and Cosmochemistry, 108*, 1–16. doi:https://doi.org/10.1016/j.apgeochem.2019.104388

Kulbat, E., & Sokołowska, A. (2017). The occurrence of heavy metals and metal-resistant bacteria in water and bottom sediments of the Straszyn reservoir (Poland). *E3S Web of Conferences, 22*, 00093. doi:10.1051/e3sconf/20172200093

Kumar, M., Shekhar, S., Kumar, R., Kumar, P., Govarthanan, M., & Chaminda, T. (2023). Drinking water treatment and associated toxic byproducts: Concurrence and urgence. *Environmental Pollution, 320*, 121009. doi:https://doi.org/10.1016/j.envpol.2023.121009

Kumari, S., Devi, M., Thakur, K., Minhas, B., Bhatt, A., & Kaushik, N. (2024). Impact of Anthropogenic Activities on Microbial Diversity and Soil Health. In R. Bhatia, & A. Walia, *Advancements in Microbial Biotechnology for Soil Health* (Vol. 50, pp. 227-248). Singapore: Springer. doi:https://doi.org/10.1007/978-981-99-9482-3_11

Kuppan, N., Padman, M., Mahadeva, M., Srinivasan, S., & Devarajan, R. (2024). A comprehensive review of sustainable bioremediation techniques: Eco friendly solutions for waste and pollution management. *Waste Management Bulletin, 2*(3), 154-171. doi:https://doi.org/10.1016/j.wmb.2024.07.005

Kurm, V., van der Putten, W., Weidner, S., Geisen, S., Snoek, B., Bakx, T., & Hol, G. H. (2019). Competition and predation as possible causes of bacterial rarity. *Environmental Microbiology, 21*(4), 1356-1368. doi:https://doi.org/10.1111/1462-2920.14569

Kushkevych, I., Procházka, V., Vítězová, M., Dordević, D., Abd El-Salam, M., & Rittmann, S. (2024). Anoxygenic photosynthesis with emphasis on green sulfur bacteria and a perspective for hydrogen sulfide detoxification of anoxic environments. *Frontiers in microbiology, 15*, 1417714. doi:https://doi.org/10.3389/fmicb.2024.1417714

Laaraj, M., Brahim, Y., Mesnage, V., Bensalem, F., Lahmidi, I., Miyeh, M., . . . Benaabidate, L. (2025). Heavy Metal Contamination of Sediments in the Inaouène Watershed (Morocco): Indices, Statistical Methods, and Contributions to Sustainable Environmental Management. *Sustainability, 17*(10), 4668. doi:https://doi.org/10.3390/su17104668

Lai, H., Ding, X., Cui, M., Zheng, J., Chen, Z., Pei, J., & Zhang, J. (2023). Mechanisms and influencing factors of biomineralization based heavy metal remediation: A review. *Biogeotechnics, 1*(3), 100039. doi:https://doi.org/10.1016/j.bgtech.2023.100039

Lauretp, L., Cianciaruso, M., & Samia, D. (2015). Functional diversity: an overview of its history and applicability. *Natureza & Conservação, 13*(2), 112-116. doi:https://doi.org/10.1016/j.ncon.2015.11.001

Ledin, M. (2000). Accumulation of metals by microorganisms — processes and importance for soil systems. *Earth-Science Reviews, S1*(1-4), 1-31. doi:https://doi.org/10.1016/S0012-8252(00)00008-8

Lee, K., Archer, S., Kansour, M., & Al-Mailem, D. (2024). Bioremediation of oily hypersaline soil via autochthonous bioaugmentation with halophilic bacteria and

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

archaea. *Science of The Total Environment, 922*, 171279. doi:https://doi.org/10.1016/j.scitotenv.2024.171279

Leferve, E., Bossa, N., Wiesner, M., & Gunsch, C. (2016). A review of the environmental implications of in situ remediation by nanoscale zero valent iron (nZVI): Behavior, transport and impacts on microbial communities. *Science of The Total Environment, 565*, 889-901. doi:https://doi.org/10.1016/j.scitotenv.2016.02.003

Legras, G., Loiseau, N., & Gaertner, J. (2018). Functional richness: Overview of indices and underlying concepts. *Acta Oecologica, 87*, 34-44. doi:https://doi.org/10.1016/j.actao.2018.02.007

Lennon, J., den Hollander, F., Wilke-Berenguer, M., & Blath, J. (2021). Principles of seed banks and the emergence of complexity from dormancy. *Nature Communications, 12*, 4807. doi:https://doi.org/10.1038/s41467-021-24733-1

Li, C., Quan, Q., Gan, Y., Dong, J., Fang, J., Wang, L., & Liu, J. (2020). Effects of heavy metals on microbial communities in sediments and establishment of bioindicators based on microbial taxa and function for environmental monitoring and management. *Science of The Total Environment, 749*, 141555. doi:https://doi.org/10.1016/j.scitotenv.2020.141555

Li, J., Wang, W., Li, X., Liu, S., Xu, X., Yinglan, A., & Ren, S. (2024). Heavy metals in the continuous river−estuary−sea system of the Yellow River Delta, China: Spatial patterns, potential sources, and influencing factors. *Marine Pollution Bulletin, 209*(Part B), 117247. doi:https://doi.org/10.1016/j.marpolbul.2024.117247

Li, Q., Wang, Y., Li, Y., Li, L., Tang, M., HU, W., . . . Ai, S. (2022). Speciation of heavy metals in soils and their immobilization at micro-scale interfaces among diverse soil components. *Science of The Total Environment, 825*, 153862. doi:https://doi.org/10.1016/j.scitotenv.2022.153862

Li, X., Sun, M., Zhang, L., Finlay, R., Liu, R., & Lian, B. (2022). Widespread bacterial responses and their mechanism of bacterial metallogenic detoxification under high concentrations of heavy metals. *Ecotoxicology and Environmental Safety, 246*, 114193. doi:https://doi.org/10.1016/j.ecoenv.2022.114193

Li, Y., Ma, K., Song, W., Zhou, J., Liu, X., Wang, M., & Tu, Q. (2023). Environmental heterogeneity and dispersal limitation simultaneously determine the spatial scaling of different microbial functional groups. *Science of The Total Environment, 885*, 163854. doi:https://doi.org/10.1016/j.scitotenv.2023.163854

Li, Y., Wei, S., Chen, X., Dong, Y., Zeng, M., Yan, C., . . . Jiao, R. (2023). Isolation of cadmium-resistance and siderophore-producing endophytic bacteria and their potential use for soil cadmium remediation. *Heliyon, 9*(7), e17661. doi:https://doi.org/10.1016/j.heliyon.2023.e17661

Liang, C., Wu, H., Chen, J., & Wei, Y. (2023). Mechanistic insights into the interfacial adsorption behaviors of Cr(VI) on ferrihydrite: Effects of pH and naturally coexisting anions in the environment. *Ecotoxicology and Environmental Safety, 249*, 114474. doi:https://doi.org/10.1016/j.ecoenv.2022.114474

Liao, M., Luo, Y., Zhao, X., & Huang, C. (2005). Toxicity of cadmium to soil microbial biomass and its activity: Effect of incubation time on Cd ecological dose in a paddy soil. *Journal of Zhejiang University. Science. B, 6*(5), 324-330. doi:https://doi.org/10.1631/jzus.2005.B0324

UNIVERSITAS GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Linnane, E., Haddad, S., Melle, F., Mei, Z., & Fairen-Jimenez, D. (2022). The uptake of metal–organic frameworks: a journey into the cell. *Chemical Society Reviews, 51*, 6065-6086. doi:10.1039/D0CS01414A

Lisafitri, Y., & Kardena, E. (2023). Progress and Challenges of Biological Leaching of Heavy Metal in Coal Ash from a Power Plant. *Journal of Engineering and Technological Sciences, 55*(1), 79-90. doi:10.5614/j.eng.technol.sci.2023.55.1.8

Liu, B., Yang, C., Wan, X., Chen, S., Tao, Y., Li, Q., . . . Wang, X. (2025). Microbial Community Restructuring and Functional Response in Giant Duckweed (Spirodela polyrhiza) Fronds Driven by Cadmium Stress. *Microorganisms, 13*(11), 2423. doi:https://doi.org/10.3390/microorganisms13112423

Liu, M., Chen, J., Sun, X., Hu, Z., & Fan, D. (2019). Accumulation and transformation of heavy metals in surface sediments from the Yangtze River estuary to the East China Sea shelf. *Environmental Pollution, 245*, 111-121. doi:https://doi.org/10.1016/j.envpol.2018.10.128

Liu, X., Mei, S., & Salles, J. (2023). Inoculated microbial consortia perform better than single strains in living soil: A meta-analysis. *Applied Soil Ecology, 190*, 105011. doi:https://doi.org/10.1016/j.apsoil.2023.105011

Liu, Y., Gao, T., Wang, X., Fu, J., Zuo, M., Yang, Y., . . . Chang, G. (2022). Effects of heavy metals on bacterial community surrounding Bijiashan mining area located in northwest China. *Open Life Sciences, 17*(1), 40-54. doi:https://doi.org/10.1515/biol-2022-0008

Liu, Y., Tie, B., Li, Y., Lei, M., Wei, X., Liu, X., & Du, H. (2018). Inoculation of soil with cadmium-resistant bacterium Delftia sp. B9 reduces cadmium accumulation in rice (Oryza sativa L.) grains. *Ecotoxicology and Environmental Safety, 163*, 223-229. doi:https://doi.org/10.1016/j.ecoenv.2018.07.081

Liu, Z., Wu, Y., Lei, C., Liu, P., & Gao, M. (2012). Chromate reduction by a chromate-resistant bacterium, Microbacterium sp. *World Journal of Microbiology and Biotechnology, 28*, 1585–1592. doi:https://doi.org/10.1007/s11274-011-0962-5

Locey, K., Fisk, M., & Lennon, J. (2016). Microscale Insight into Microbial Seed Banks. *Frontiers in Microbiology, 7*, 2040. doi:https://doi.org/10.3389/fmicb.2016.02040

Logue, J., Findlay, S., & Comte, J. (2015). Editorial: Microbial Responses to Environmental Changes. *Frontiers in Microbiology, 6*, 1364. doi:https://doi.org/10.3389/fmicb.2015.01364

Ludwig. (2016). Noncoding DNA Evolution: Junk DNA Revisited. In R. Kliman, *Encyclopedia of Evolutionary Biology* (pp. 124-129). Academic Press. doi:https://doi.org/10.1016/B978-0-12-800049-6.00168-2

Lukačišinová, M., Novak, S., & Paixão, T. (2017). Stress-induced mutagenesis: Stress diversity facilitates the persistence of mutator genes. *PLoS computational biology, 13*(7), e1005609. doi:https://doi.org/10.1371/journal.pcbi.1005609

Luque, V. (2016). Drift and Evolutionary Forces: Scrutinizing the Newtonian Analogy. *Theoria, 31*(3), 397-410. doi:10.1387/theoria.14943

Lv, J., Yuan, R., & SQ, W. (2021). Water diversion induces more changes in bacterial and archaeal communities of river sediments than seasonality. *Journal of*

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Environmental Management, 293, 112876. doi:https://doi.org/10.1016/j.jenvman.2021.112876

Lynch, M., Ackerman, M., Cout, J., Long, H., Sung, W., Thomas, W., & Foster, P. (2016). Genetic drift, selection and the evolution of the mutation rate. *Nature Reviews Genetics, 17*, 704-714. doi:https://doi.org/10.1038/nrg.2016.104

Lyons, T., Tino, C., Fournier, G., Anderson, R., Leavitt, W., Konhauser, K., & Stüeken, E. (2024). Co-evolution of early Earth environments and microbial life. *Nature Reviews Microbiology, 22*, 572–586. doi:https://doi.org/10.1038/s41579-024-01044-y

Maret, W. (2024). The Extracellular Metallometabolome: Metallophores, Metal Ionophores, and Other Chelating Agents as Natural Products. *Natural Product Communications, 19*(8), 1-23. doi:https://doi.org/10.1177/1934578X24127170

Maron, P., Sarr, A., Kaisermann, A., Lévêque, J., Mathieu, O., Guigue, J., . . . Ranjard, L. (2018). High Microbial Diversity Promotes Soil Ecosystem Functioning. *Applied and Environmental Microbiology, 84*(9), e02738-17. doi:https://doi.org/10.1128/AEM.02738-17

Martin, E., Feit, B., Requier, F., Friberg, H., & Jonsson, M. (2019). Chapter Three - Assessing the resilience of biodiversity-driven functions in agroecosystems under environmental change. In *Advances in Ecological Research* (pp. 59-123). doi:https://doi.org/10.1016/bs.aecr.2019.02.003

Marzuki, I., Ahmad, R., Kamaruddin, M., Asaf, R., Armus, R., & Siswanty, I. (2021). Performance of cultured marine sponges-symbiotic bacteria as a heavy metal bio-adsorption. *BIODIVERSITAS, 22*(12), 5536-5543.

Mason, N., Mouillot, D., Lee, W., & WIlson, J. (2005). Functional richness, functional evenness and functional divergence: the primary components of functional diversity. *Oikos, 111*(1), 112-118. doi:https://doi.org/10.1111/j.0030-1299.2005.13886.x

Massoud, R., & Khosravi-Darani, K. (2023). Role of microorganisms in bio-removal of heavy metals. *Journal of Human, Health and Halal Metrics, 4*(1), 48-57. doi:https://doi.org/10.30502/jhhhm.2023.380103.1065

Mathivanan, K., Chandirika, J., Vinothkanna, A., Yin, H., Liu, X., & Meng, D. (2021). Bacterial adaptive strategies to cope with metal toxicity in the contaminated environment – A review. *Ecotoxicology and Environmental Safety, 226*, 112863. doi:https://doi.org/10.1016/j.ecoenv.2021.112863

Matlock, B. (2019). *Differences in bacterial optical density measurements between UV-Visible spectrophotometers.* Wilmington, DE USA: Thermo Fisher Scientific.

Mavrommati, M., Daskalaki, A., Papanikolaou, S., & Aggelis. (2022). Adaptive laboratory evolution principles and applications in industrial biotechnology. *Biotechnology Advances, 54*, 107795. doi:https://doi.org/10.1016/j.biotechadv.2021.107795

Mawarda, P., Le Roux, X., van Elsas, J., & Salles, J. (2020). Deliberate introduction of invisible invaders: A critical appraisal of the impact of microbial inoculants on soil microbial communities. *Soil Biology and Biochemistry, 148*, 107874. doi:https://doi.org/10.1016/j.soilbio.2020.107874

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Mazzini, A., & Etiope, G. (2017). Mud volcanism: An updated review. *Earth-Science Reviews, 168*, 81–112. doi:http://dx.doi.org/10.1016/j.earscirev.2017.03.001

Mazzini, A., Svensen, H., Akhmanov, G., Aloisi, G., Planke, S., Malthe-Sørenssen, A., & Istadi, B. (2007). Triggering and dynamic evolution of the LUSI mud volcano, Indonesia. *Earth and Planetary Science Letters*, 375-388. doi:10.1016/j.epsl.2007.07.001

Merchant, A., & Spatafora, G. (2014). A role for the DtxR family of metalloregulators in gram-positive pathogenesis. *Molecular oral microbiology, 29*(1), 1-10. doi:https://doi.org/10.1111/omi.12039

Mi, Q., Wu, Y., Cai, H., Xu, Z., Guan, R., Fan, X., & Guo, J. (2025). Effects of Long-Term Heavy Metal Pollution on Microbial Community Structure in Soil. *Toxics, 13*(9), 806. doi:https://doi.org/10.3390/toxics13090806

Michael-Igolima, U., Abbey, S., & Ifelebuegu, A. (2022). A systematic review on the effectiveness of remediation methods for oil contaminated soils. *Environmental Advances, 9*, 100319. doi:https://doi.org/10.1016/j.envadv.2022.100319

Micó, A., Recatalá, L., Peris, M., & Sánchez, J. (2006). Assessing heavy metal sources in agricultural soils of an European Mediterranean area by multivariate analysis. *Chemosphere, 65*(5), 863-872. doi:https://doi.org/10.1016/j.chemosphere.2006.03.016

Milenković, N., Damjanovic, M., & Ristic, M. (2005). Study of Heavy Metal Pollution in Sediments from the Iron Gate (Danube River), Serbia and Montenegro. *Polish Journal of Environmental Studies, 14*(6), 781-787.

Minata, Z., Rokhim, D., Nenohai, J., Agustina, N., Islamiyah, K., Ronggopuro, B., & Utomo, Y. (2024). The Potential and Carrying Capacity of Lusi Sidoarjo Island as An Education and Conservation-Based Tourism. *Journal of Natural Resources and Environmental Management, 14*(1), 13-24. doi:http://dx.doi.org/10.29244/jpsl.14.1.13

Miranda, L., Ayoka, G., Egodawatta, P., & Goonertilleke, A. (2022). Adsorption-desorption behavior of heavy metals in aquatic environments: Influence of sediment, water and metal ionic properties. *Journal of Hazardous Materials, 421*, 126743. doi:https://doi.org/10.1016/j.jhazmat.2021.126743

Mishra, A., & Gupta, S. (2021). Analysis of Heavy Metal in Industrial Soil Through Atomic Absorption Spectroscopy and its Relationship with Some Soil Properties. *Journal of Materials & Metallurgical Engineering, 11*(2), 29-37.

Misra, S., Kumar, A., Pathak, K., Kumar, G., & Virmani, T. (2024). Role of Genetically Modified Microorganisms for Effective Elimination of Heavy Metals. *BioMed Research International, 2024*, 9582237. doi:https://doi.org/10.1155/2024/9582237

Mitra, S., Chakraborty, A., Tareq, A., Emran, T., Nainu, F., Khusro, 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), 101865. doi:https://doi.org/10.1016/j.jksus.2022.101865

Moldovan, A., Török, A., Kovacs, E., Cadar, O. M., & Micle, V. (2022). Metal Contents and Pollution Indices Assessment of Surface Water, Soil, and Sediment from the

UNIVERSITAS GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Arieș River Basin Mining Area, Romania. *Sustainability, 14*(13), 8024. doi:https://doi.org/10.3390/su14138024

Monira, M., & Mostafa, M. (2023). Heavy Metals in Agricultural Soil and Their Impacts on Rice Production and Human Health: A Review. *Asian Journal of Applied Science and Technology, 7*(2), 204-216. doi:https://doi.org/10.38177/ajast.2023.7222

Mora, C., Contreras, J., Villarreal, M., Martínez, J., Delgado, E., Roldan, H., . . . Jaquez, D. (2025). Identification of microorganisms at different times in a bioleaching process for the recovery of gold and silver from minerals in oxide form. *Heliyon, 11*(2), e41878. doi:https://doi.org/10.1016/j.heliyon.2025.e41878

Morawska-Płoskonka, J., & Niklińska, M. (2013). Effects of Soil Moisture and Nickel Contamination on Microbial Respiration Rates in Heavy Metal-Polluted Soils. *Polish journal of environmental studies, 22*(5), 1411-1418.

Moreira, V., Cravo-Laureau, C., de Carvalho, A., Baldy, A., Bidone, E., Sabadini-Santos, E., & Duran, R. (2023). Microbial indicators along a metallic contamination gradient in tropical coastal sediments. *Journal of Hazardous Materials, 443*(Part B), 130244. doi:https://doi.org/10.1016/j.jhazmat.2022.130244

Motta-Romero, H., Perez-Donado, C., Auchtung, J., & Rose, D. (2023). Toxicity of cadmium on dynamic human gut microbiome cultures and the protective effect of cadmium-tolerant bacteria autochthonous to the gut. *Chemosphere, 338*, 139581. doi:https://doi.org/10.1016/j.chemosphere.2023.139581

Mouchet, M., Villéger, S., Mason, N., & Mouillot, D. (2010). Functional diversity measures: an overview of their redundancy and their ability to discriminate community assembly rules. *Functional Ecology, 24*(4), 867-876. doi:https://doi.org/10.1111/j.1365-2435.2010.01695.x

Mouillot, D., Villéger, S., Parravicini, V., Kulbicki, M., Arias-González, J., Bender, M., . . . Bellwood, D. (2014). Functional over-redundancy and high functional vulnerability in global fish faunas on tropical reefs. *PNAS, 111*(38), 13757-13762. doi:https://doi.org/10.1073/pnas.1317625111

Muhammad, M., Batool, S., Hivare, V., Li, W., Waheed, A., & Sinha, D. (2024). Chapter 1 - Bioremediation techniques—classification, principles, advantages, limitations, and prospects. In J. Parray, & W. Li, *Microbiome-Assisted Bioremediation: Rehabilitating Agricultural Soils* (pp. 1-23). Academic Press. doi:https://doi.org/10.1016/B978-0-443-21911-5.00003-9

Mujahid, A., & Dickert, F. (2016). 5 - Molecularly Imprinted Polymers: Principle, Design, and Enzyme-Like Catalysis. In L. SJ, S. P. Cao, & A. Turner, *Molecularly Imprinted Catalysts* (pp. 79-101). Elsevier. doi:https://doi.org/10.1016/B978-0-12-801301-4.00005-0

Muller, G. (1969). Index of Geoaccumulation in Sediments of The Rhine River. *Geo Journal, 2*(3), 108-118.

Mustapha, M., & Halimoon, N. (2015). Screening and isolation of heavy metal tolerant bacteria in industrial effluent. *Procedia Environmental Sciences, 30*, 33-37.

Nagarajan, R., Eswaramoorthi, S., Anandkumar, A., & Ramkumar, M. (2023). Geochemical fractionation, mobility of elements and environmental significance of

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

surface sediments in a Tropical River, Borneo. *Marine Pollution Bulletin, 192*, 115090. doi:https://doi.org/10.1016/j.marpolbul.2023.115090

Nalatambi, S. (2009). Determination Of Metals In Tap Water Using Atomic Absorption Spectrometry: A Case Study In Bandar Sunway Residential Area. *Sunway Academic Journal, 6*, 33-46.

Narla, A., Hwa, T., & Murugan, A. (2025). Dynamic coexistence driven by physiological transitions in microbial communities. *Proceedings of the National Academy of Sciences of the United States of America, 122*(16), e2405527122. doi:https://doi.org/10.1073/pnas.2405527122

Nemerow, N., & Sumitomo, H. (1970). Part A - Pollution Index for Benefit Analysis. In EPA, *Benefits of Water Quality Enhancement* (16110 DAJ 12/70 ed., pp. 1-36). Environmental Protection Agency / Water Quality Office.

Newsome, L., & Falagán, C. (2021). The Microbiology of Metal Mine Waste: Bioremediation Applications and Implications for Planetary Health. *GeoHealth, 5*(10), e2020GH000380. doi:https://doi.org/10.1029/2020GH000380

Nie, Y., Zhao, J., Tang, Y., Guo, P., Yang, Y., Wu, X., & Zhao, F. (2016). Species Divergence vs. Functional Convergence Characterizes Crude Oil Microbial Community Assembly. *Frontiers in Microbiology, 7*, 01254. doi:https://doi.org/10.3389/fmicb.2016.01254

Niehaus, L., Boland, I., Liu, M., Chen, K., Fu, D., Henckel, C., . . . Momeni, B. (2019). Microbial coexistence through chemical-mediated interactions. *Nature Communications, 10*, 2052. doi:https://doi.org/10.1038/s41467-019-10062-x

Nizamani, M., Hughes, A., Qureshi, S., Zhang, Q., Tarafder, E., Das, D., . . . Zhang, Z. (2024). Microbial biodiversity and plant functional trait interactions in multifunctional ecosystems. *Applied Soil Ecology, 201*, 105515. doi:https://doi.org/10.1016/j.apsoil.2024.105515

Njoku, K., Akinyede, O., & Obidi, O. (2020). Microbial Remediation of Heavy Metals Contaminated Media by Bacillus megaterium and Rhizopus stolonifer. *Scientific African, 10*, e00545. doi:https://doi.org/10.1016/j.sciaf.2020.e00545

Nnaji, N., Anyanwu, C., Miri, T., & Onyeaka, H. (2024). Mechanisms of Heavy Metal Tolerance in Bacteria: A Review. *Sustainability, 16*(24), 11124. doi:https://doi.org/10.3390/su162411124

Nonić, M., & Šijačić-Nikolić, M. (2020). Genetic Diversity: Sources, Threats, and Conservation. In F. W. Leal, A. Azul, L. Brandili, L. Lange Salvia, & T. Wall, *Life on Land. Encyclopedia of the UN Sustainable Development Goals* (pp. 421–435). Springer, Cham. doi:https://doi.org/10.1007/978-3-319-95981-8_53

Nuruddin, M., Hasbi, A., & Abdullah, M. (2015). Sidoarjo mud: creating worth from waste. In J. Miralles i Garcia, & C. Brebbia, *Ecosystems and Sustainable Development X* (pp. 309-315). WIT Press.

Nwaehiri, U., Akwukwaegbu, P., & Nwoke, B. (2020). Bacterial remediation of heavy metal polluted soil and effluent from paper mill industry. *Environmental Analysis Health and Toxicology, 35*(2), e2020009. doi:https://doi.org/10.5620/eaht.e2020009

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Nygymetova, A., Sadvakasova, A., Zaletova, D., Kossalbayev, B., Bauenova, M., Wang, J., . . . Allakhverdiev, S. (2025). Development and Transfer of Microbial Agrobiotechnologies in Contrasting Agrosystems: Experience of Kazakhstan and China. *Plants, 14*(14), 2208. doi:https://doi.org/10.3390/plants14142208

Ogbonna, D., & Obande, O. (2018). Physico-chemical and Microbiological Characteristics of a River Mud as substrate for Biological Generation of Electricity in the Niger Delta, Nigeria. *Microbiology Research Journal International, 25*(2), 1-14. doi:https://doi.org/10.9734/MRJI/2018/44112

Ogola. (2025). Wastewater-driven nutrient enrichment restructures viral community assembly, host interactions, and ecological function along the Nakivubo–Lake Victoria interface in Uganda. *Science of The Total Environment, 993*, 180002. doi:https://doi.org/10.1016/j.scitotenv.2025.180002

Olaniran, A., Balgobind, A., & Pillay, B. (2013). Bioavailability of Heavy Metals in Soil: Impact on Microbial Biodegradation of Organic Compounds and Possible Improvement Strategies. *International journal of molecular sciences, 14*(5), 10197–10228. doi:https://doi.org/10.3390/ijms140510197

Olawale, S. (2021). Biosorption of heavy metals from aqueous solutions: an insight and review. *International Journal of Ground Sediment & Water, 14*, 835-891. doi:10.5281/zenodo.4957836

Oleńska, E., Małek, W., Swiecicka, I., Wójcik, M., Thijs, S., & Vangronsveld, J. (2025). Bacteria Under Metal Stress-Molecular Mechanisms of Metal Tolerance. *International journal of molecular sciences, 26*(12), 5716. doi:https://doi.org/10.3390/ijms26125716

Osburn, E., Yang, G., Rillig, M., & Strickland, M. (2023). Evaluating the role of bacterial diversity in supporting soil ecosystem functions under anthropogenic stress. *ISME Communications, 3*, 66. doi:https://doi.org/10.1038/s43705-023-00273-1

Osei-Owusu, J., Heve, W., Duker, R., Aidoo, O., Larbi, L., Edusei, G., . . . Ninsin, K. (2023). Assessments of microbial and heavy metal contaminations in water supply systems at the University of Environment and Sustainable Development in Ghana. *Sustainable Chemistry for the Environment, 2*, 100015.

Osman, D., Foster, A., Chen, J., Svedaite, K., Steed, J., Lurie-Luke, E., . . . RObinson, N. (2017). Fine control of metal concentrations is necessary for cells to discern zinc from cobalt. *Nature Communications, 8*, 1884. doi:https://doi.org/10.1038/s41467-017-02085-z

Otte, J., Blackwell, N., Soos, V., Rughöft, S., Maisch, M., Kappler, A., . . . Schmidt, C. (2018). Sterilization impacts on marine sediment---Are we able to inactivate microorganisms in environmental samples? *FEMS Microbiology Ecology, 94*(12), fiy189. doi:https://doi.org/10.1093/femsec/fiy189

PacBio. (2022). *Amplification of bacterial full-length 16S gene with barcoded primers.* PacBio.

Pagnucco, G., Overfield, D., Chamlee, Y., Shuler, C., Kassem, A., Opara, S., . . . Tiquia-Arashiro, S. (2023). Metal tolerance and biosorption capacities of bacterial strains isolated from an urban watershed. *Frontiers in microbiology, 14*, 1278886. doi:https://doi.org/10.3389/fmicb.2023.1278886

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Pamungkas, B., & Shofwan, M. (2023). Sebaran Pencemaran Air Sumur di Kawasan Bencana Lumpur. *Sustainable Agricultural Technology Innovation, 1*(1), 250-256.

Pan, Y., Xie, J., Yan, W., Zhang, T., & Chen, C. (2022). Response of microbial community to different land-use types, nutrients and heavy metals in urban river sediment. *Journal of Environmental Management, 321*, 115855. doi:https://doi.org/10.1016/j.jenvman.2022.115855

Pande, V., Pandey, S., Sati, D., Bhatt, P., & Samant, M. (2022). Microbial Interventions in Bioremediation of Heavy Metal Contaminants in Agroecosystem. *Frontiers in microbiology, 13*, 824084. doi:https://doi.org/10.3389/fmicb.2022.824084

Pandey, J., & Singh, R. (2017). Heavy metals in sediments of Ganga River: up- and downstream urban influences. *Applied Water Science, 7*, 1669–1678. doi:https://doi.org/10.1007/s13201-015-0334-7

Pang, Y., Wang, J., Dai, S., Zhang, W., Wang, X., Zhang, X., & Huang, Z. (2025). Functional redundancy enables a simplified consortium to match the lignocellulose degradation capacity of the original consortium. *Environmental Research, 264*(Part 2), 120373. doi:https://doi.org/10.1016/j.envres.2024.120373

Parades-Aguilar, J., Calderon, K., Agustin-Salazar, S., Cerruti, P., Ambrogi, V., Gamez-Meza, N., & Medina-Juarez, L. (2024). Isolation and identification of metallotolerant bacteria with a potential biotechnological application. *Scientific Reports, 14*, 3663. doi:https://doi.org/10.1038/s41598-024-54090-0

Peña-Guzmán, C., Otálvaro-Álvarez, Á., & Jiménez-Ariza, T. (2024). Use of oilseed crops biomass for heavy metal treatment in water. *Oil Crop Science, 9*(3), 177-186. doi:https://doi.org/10.1016/j.ocsci.2024.07.001

Peng, Y., Xu, H., Shi, J., Wang, Z., Lv, J., Li, L., & Wang, X. (2024). Soil microbial composition, diversity, and network stability in intercropping versus monoculture responded differently to drought. *Agriculture, Ecosystems & Environment, 365*, 108915. doi:https://doi.org/10.1016/j.agee.2024.108915

Permyakov, E. (2021). Metal Binding Proteins. *Encyclopedia, 1*(1), 261-292. doi:https://doi.org/10.3390/encyclopedia1010024

Pham, V., Kim, J., Chang, S., & Chung, W. (2022). Bacterial Biosorbents, an Efficient Heavy Metals Green Clean-Up Strategy: Prospects, Challenges, and Opportunities. *Microorganisms, 10*, 610. doi:https://doi.org/10.3390/microorganisms10030610

Philppot, L., Griffiths, B., & Langenheder, S. (2021). Microbial Community Resilience across Ecosystems and Multiple Disturbances. *Microbiology and molecular biology reviews : MMBR, 85*(2), e00026-20. doi:https://doi.org/10.1128/MMBR.00026-20

Pi, H., & Helmann, J. (2017). Ferrous Iron Efflux Systems in Bacteria. *Metallomics : integrated biometal science, 9*(7), 840–851. doi:https://doi.org/10.1039/c7mt00112f

Planavsky, N., Crowe, S., Fakhraee, M., Beaty, B., Reinhard, C., Mills, B., . . . Konhauser, K. (2021). Evolution of the structure and impact of Earth's biosphere. *Nature Reviews Earth & Environment, 2*, 123–139. doi:https://doi.org/10.1038/s43017-020-00116-w

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Ardine Rahma Sarita, Prof. Dr. rer. nat. Andhika Puspito Nugroho, S.Si., M.Si.; Prof. Dr. Endah Retnaningrum, S.Si.,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Plazinski, W., & Rudziński, W. (2011). Biosorption of Heavy Metal Ions: Ion-Exchange versus Adsorption and the Heterogeneity of Binding Sites. *Adsorption Science & Technology, 29*(5), 479-486. doi:https://doi.org/10.1260/0263-6174.29.5.479

Plumb, R. (1981). *Procedures for Handling and Chemical Analysis of Sediment and Water Samples.* Vicksburg: Environmental Laboratory US Army Engineer Waterways Experiment Station.

Plumlee, G., Casadevall, TJ, Wibowo, H., Rosenbauer, R., Johnson, C. B., . . . Morman, S. (2008). *Preliminary Analytical Results for a Mud Sample Collected from the LUSI Mud Volcano, Sidoarjo, East Java, Indonesia.* U.S. Geological Survey Open.

Pohl, C. (2007). *Lapindo Brantas and The Mud Volcano Sidoarjo.* Friends of the Earth International. Friends of the Earth Europe.

Prapagdee, B., & Watcharamusik, A. (2009). Adaptive and cross-protective responses against cadmium and zinc toxicity in cadmium-resistant bacterium isolated from a zinc mine. *Brazilian journal of microbiology, 40*(4), 838-845. doi:https://doi.org/10.1590/S1517-838220090004000014

Pratap, J., & Krishnan, K. (2024). A Systematic Review on Microbial Bioremediation and Nanobioremdiation of Toxic Heavy Metals Pollution. *Letters in Applied NanoBioScience, 13*(4), 156. doi:https://doi.org/10.33263/LIANBS134.156

Priya, A., Gnanasekaran, L., Dutta, K., Rajendran, S., Balakrishnan, D., & Soto-Moscoso, M. (2022). Biosorption of heavy metals by microorganisms: Evaluation of different underlying mechanisms. *Chemosphere, 307*(4), 135957. doi:https://doi.org/10.1016/j.chemosphere.2022.135957

Prokkola, H., Nurmesniemi, E., & Lassi, U. (2020). Removal of Metals by Sulphide Precipitation Using Na2S and HS−-Solution. *ChemEngineering, 4*(3), 51. doi:https://doi.org/10.3390/chemengineering4030051

Prosser, J., & Martiny, B. (2020). Conceptual challenges in microbial community ecology. *Philosophical Transactions of The Royal Society B, 375*, 20190241. doi:http://dx.doi.org/10.1098/rstb.2019.0241

Prtchey, O., & Gaston, K. (2006). Functional diversity: back to basics and looking forward. *Ecology letters, 9*(6), 741–758. doi:https://doi.org/10.1111/j.1461-0248.2006.00924.x

Puckett, C., Ernst, R., & Barton, J. (2010). Exploring the Cellular Accumulation of Metal Complexes. *Dalton transactions (Cambridge, England : 2003), 39*(5), 1159-1170. doi:https://doi.org/10.1039/b922209j

Purnomo, T., & Soegiyanto. (2013). *Kajian Penggunaan Typha latifolia (L) Sebagai Fitoremediator Logam Berat Pada Lahan Pertanian yang Tercemar Lumpur Lapindo Sebagai Model Mekanisme Penyerapan Logam Berat Secara Hayati.* Laporan Penelitian Fundamental.

Qi, Q., Hu, C. L., Wang, X., Tang, C., Dai, Z., & Xu, J. (2022). Contamination with multiple heavy metals decreases microbial diversity and favors generalists as the keystones in microbial occurrence networks. *Environmental Pollution, 306*, 119406. doi:https://doi.org/10.1016/j.envpol.2022.119406

Qi, Q., Hu, C., Lin, J., XH, W., Tang, C., Dai, Z., & Xu, J. (2022). Contamination with multiple heavy metals decreases microbial diversity and favors generalists as the

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

keystones in microbial occurrence networks. *Environmental Pollution, 306*, 119406. doi:https://doi.org/10.1016/j.envpol.2022.119406

Qiu, J., Bai, J., Wang, Y., Zhai, Y., Zhang, X., Xu, Y., & Wang, Y. (2024). Cadmium contamination decreased bacterial network complexity and stability in coastal reclamation areas. *Journal of Hazardous Materials, 476*, 134896. doi:https://doi.org/10.1016/j.jhazmat.2024.134896

Qu, C., Chen, W., Hu, X., Cai, P., Chen, C., Yu, X., & Huang, Q. (2019). Heavy metal behaviour at mineral-organo interfaces: Mechanisms, modelling and influence factors. *Environment International, 131*, 104995. doi:https://doi.org/10.1016/j.envint.2019.104995

Qu, F., & Zheng, W. (2024). Cadmium Exposure: Mechanisms and Pathways of Toxicity and Implications for Human Health. *Toxics, 12*(6), 388. doi:https://doi.org/10.3390/toxics12060388

Rabow, S., Soares, M., & Rousk, J. (2022). Can heavy metal pollution induce soil bacterial community resistance to antibiotics in boreal forests? *Journal of Applied Ecology, 60*, 237-250. doi:10.1111/1365-2664.14322

Raeside, C., Gaffé, J., Deatherage, D., Tenaillon, O., Briska, A., Ptashkin, R., . . . Schneider, D. (2014). Large Chromosomal Rearrangements during a Long-Term Evolution Experiment with Escherichia coli. *mBio, 5*(5), e01377-14. doi:https://doi.org/10.1128/mbio.01377-14

Rafeeq, H., Afsheen, N., Rafique, S., Arshad, A., Intisar, M., Hussain, A., . . . Iqbal, H. (2023). Genetically engineered microorganisms for environmental remediation. *Chemosphere, 310*, 136751. doi:https://doi.org/10.1016/j.chemosphere.2022.136751

Rahman, Z., & Singh, V. (2018). Assessment of heavy metal contamination and Hg-resistant bacteria in surface water from different regions of Delhi, India. *Saudi Journal of Biological Sciences, 25*, 1687-1695.

Rahman, Z., & Singh, V. (2018). Assessment of heavy metal contamination and Hg-resistant bacteria in surface water from different regions of Delhi, India. *Saudi Journal of Biological Sciences, 25*, 1687–1695. doi:http://dx.doi.org/10.1016/j.sjbs.2016.09.018

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*, 775-805. doi:https://doi.org/10.3390/waste1030046

Ramon, P., Galand, P., & Logares, R. (2025). Microbial functional diversity and redundancy: moving forward. *FEMS Microbiology Reviews, 49*, fuae031. doi:https://doi.org/10.1093/femsre/fuae031

Rao, M., & Larsen, T. (2010). Ecological Consequences of Extinction. *Lessons in Conservation, 3*, 25-53.

Rasheela, A., Khalid, M., Abumaali, D., Alatalo, J., & Ahmed, T. (2024). Impact of Abiotic Stressors on Soil Microbial Communities: A Focus on Antibiotics and Their Interactions with Emerging Pollutants. *Soil Systems, 9*(1), 2.

UNIVERSITAS GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Ren, Q., Liu, J., Wei, Y., Luo, Z., Wu, T., & Chai, B. (2024). Microbial functional taxa promote soil multifunctionality in naturally restoring subalpine meadows. *Global Ecology and Conservation, 56*, e03313. doi:https://doi.org/10.1016/j.gecco.2024.e03313

Rendón-Castrillón, L., Ramírez-Carmona, M., Ocampo-López, C., & Gómez-Arroyave, L. (2023). Bioleaching Techniques for Sustainable Recovery of Metals from Solid Matrices. *Sustainability, 15*(13), 10222. doi:https://doi.org/10.3390/su151310222

Richards, J. (2011). *Report Into The Past, Present, and Future Social Impacts of Lumpur Sidoarjo*. Humanitus Sidoarjo Fund. Humatitus.

Ricotta, C., Bacaro, G., Maccherini, S., & Pavoine, S. (2022). Functional imbalance not functional evenness is the third component of community structure. *Ecological Indicators, 140*, 109035. doi:https://doi.org/10.1016/j.ecolind.2022.109035

Rocca, J., Simonin, M., Blaszczak, J., Ernakovich, J., Gibbons, S., Midani, F., & Washburne, A. (2019). The Microbiome Stress Project: Toward a Global Meta-Analysis of Environmental Stressors and Their Effects on Microbial Communities. *Frontiers in Microbiology, 9*, 3272. doi:https://doi.org/10.3389/fmicb.2018.03272

Roșca, M., Diaconu, M., Hlihor, R., Cozma, P., Silva, B., Tavares, T., & Gavrilescu, M. (2024). Evaluation of Microbial Biosorbents for Efficient Cd(II) Removal from Aqueous Solutions. *Water, 16*(24), 3660. doi:https://doi.org/10.3390/w16243660

Rudolph, M., Karlstrom, L., & Manga, M. (2011). A prediction of the longevity of the Lusi mud eruption, Indonesia. *Earth and Planetary Science Letters, 308*, 124–130. doi:10.1016/j.epsl.2011.05.037

Sadeghi, S., Petermann, B., Strffan, J., Brevik, E., & Gedeon, C. (2023). Predicting microbial responses to changes in soil physical and chemical properties under different land management. *Applied Soil Ecology, 188*, 104878. doi:https://doi.org/10.1016/j.apsoil.2023.104878

Saleem, M., Pierce, D., Wang, Y., Sens, D., Somji, S., & Garrett, S. (2024). Heavy Metal(oid)s Contamination and Potential Ecological Risk Assessment in Agricultural Soils. *Xenobiotics, 14*, 634-650.

Saleh, T. (2022). Chapter 3 - Kinetic models and thermodynamics of adsorption processes: classification. In T. Saleh. doi:https://doi.org/10.1016/B978-0-12-849876-7.00003-8

Salih, L., Rashed, R., & Muhammed, S. (2021). Evaluation of heavy metal content in water and removal of metals using native isolated bacterial strains. *BIODIVERSITAS, 22*(8), 3163-3174.

Sani, S., & Haris, A. (2022). A microbial technology approach using bioleaching for low grade metals extraction - a review. *IOP Conf. Series: Earth and Environmental Science, 1103*, 012019. doi:10.1088/1755-1315/1103/1/012019

Santangelo, J., Johnson, M., & Ness, R. (2018). Modern spandrels: the roles of genetic drift, gene flow and natural selection in the evolution of parallel clines. *Proceedings of the Royal Society B, 285*, 20180230. doi:http://dx.doi.org/10.1098/rspb.2018.0230

Saputro, R., Suhardjono, & Juwono, P. (2021). Analysis of Carrying Capacity of the Porong River Caused by Sidoarjo Mud Disposal. *Civil and Environmental Science Journal, 4*(2), 92-201. doi:https://doi.org/10.21776/ub.civense.2021.00402.9

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Sarkar, A., McInroy, C., Harty, S., Raulo, A., Ibata, N., Valles-Colomer, M., . . . Moeller, A. (2024). Microbial transmission in the social microbiome and host health and disease. *Cell, 187*(1), 17-43. doi:https://doi.org/10.1016/j.cell.2023.12.014

Sarkodie, E., Jiang, L., Li, K., Yang, J., Guo, Z., Shi, J., & Deng, Y. (2022). A review on the bioleaching of toxic metal(loid)s from contaminated soil: Insight into the mechanism of action and the role of influencing factors. *Frontiers in Microbiology, 13*, 1049277. doi:https://doi.org/10.3389/fmicb.2022.1049277

Sawolo, N., Sutriono, E., Istadi, B., & Darmoyo, A. (2009). The LUSI mud volcano triggering controversy: Was it caused by drilling? *Marine and Petroleum Geology, 26*, 1766–1784. doi:10.1016/j.marpetgeo.2009.04.002

Sayol, F., Cooke, R., Pigot, A., Blackburn, T., Tobias, J., Steinbauer, M., . . . Faurby, S. (2021). Loss of functional diversity through anthropogenic extinctions of island birds is not offset by biotic invasions. *Science advances, 7*(46), eabj5790. doi:https://doi.org/10.1126/sciadv.abj5790

Sazykin, I., Khmelevtsova, L., Azhogina, T., & Sazykina, M. (2023). Heavy Metals Influence on the Bacterial Community of Soils: A Review. *Agriculture, 13*, 653. doi:https://doi.org/10.3390/agriculture13030653

Segretin, A., Cazón, J., & Donati. (2017). Bioaccumulation and Biosorption of Heavy Metals. In E. Donati, *Heavy Metals in the Environment.* Boca Raton: CRC Press. doi:https://doi.org/10.1201/b22013

Sexton, J., Clemens, M., Bell, N., Hall, J., Fyfe, V., & Hoffmann, A. (2024). Patterns and effects of gene flow on adaptation across spatial scales: implications for management. *Journal of Evolutionary Biology, 37*(6), 732–745. doi:https://doi.org/10.1093/jeb/voae064

Shade, A. (2023). Microbiome rescue: directing resilience of environmental microbial communities. *Current Opinion in Microbiology, 72*, 102263. doi:https://doi.org/10.1016/j.mib.2022.102263

Shahid, M., Pourrut, B., Dumat, C., Nadeem, M., Aslam, M., & Pinelli, E. (2014). Heavy-metal-induced reactive oxygen species: phytotoxicity and physicochemical changes in plants. *Reviews of environmental contamination and toxicology, 232*, 1-44. doi:https://doi.org/10.1007/978-3-319-06746-9_1

Sheeba, V., Anas, A., Jasmin, C., Vincent, M., & Parameswaran, P. (2020). Response of particle-associated bacteria to long-term heavy metal contamination in a tropical estuary. *World Journal of Microbiology and Biotechnology, 36*, 65. doi:https://doi.org/10.1007/s11274-020-02842-1

Sheela, A., Letha, J., Sabu, J., Jobin, T., & Justus, J. (2014). Effect of Nutrients on Bioaccumulation of Heavy Metals in a Tropical Urban Coastal Lacustrine System. *Water Environment Research, 88*(6), 513-523.

Shoemaker, W., & Lennon, J. (2018). Evolution with a seed bank: The population genetic consequences of microbial dormancy. *Evolutionary applications, 11*(1), 60–75. doi:https://doi.org/10.1111/eva.12557

Sholehhudin, M., Susanto, B., Adriyani, R., & Laksono, D. (2019). Heavy Metals Contamination in Groundwater Around Sidoarjo Mud Vulcano Area, East Java Indonesia. *Malaysian Journal of Medicine and Health Sciences, 15*(3), 86-89.

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Sigma Aldrich. (n.d.). *Cleaning Laboratory Glassware.* Sigma Aldrich.

Simon, A., & Coop, G. (2024). The contribution of gene flow, selection, and genetic drift to five thousand years of human allele frequency change. *Proceedings of the National Academy of Sciences of the United States of America, 121*(9), e2312377121. doi:https://doi.org/10.1073/pnas.2312377121

Simpson, S., Batley, G., Chariton, A., Stauber, J., King, C., Chapman, J., . . . Maher, W. (2005). *Handbook for Sediment Quality Assessment.* Bangor, NSW: CSIRO.

Singh, A., Sharma, A., Verma, R., Chopade, R., Pandit, P., Nagar, V., . . . Sankhla, M. (2022). Heavy Metal Contamination of Water and Their Toxic Effect on Living Organisms. In D. Junqueira Dorta, & D. Palma de Oliveira, *The Toxicity of Environmental Pollutants.* IntechOpen. doi:http://dx.doi.org/10.5772/intechopen.105075

Singh, S., Paswan, S., Kumar, P., Singh, R., & Kumar, L. (2023). Chapter 14 - Heavy metal water pollution: an overview about remediation, removal and recovery of metals from contaminated water. In S. Shukla, S. Kumar, S. Madhav, & P. Mishra, *Metals in Water: Global Sources, Significance, and Treatment* (pp. 263-284). Woodhead Publishing. doi:https://doi.org/10.1016/B978-0-323-95919-3.00018-5

Singh, V., Singh, N., Rai, S., Kumar, A., Singh, A., Singh, M., . . . Mishra, V. (2023). Heavy Metal Contamination in the Aquatic Ecosystem: Toxicity and Its Remediation Using Eco-Friendly Approaches. *Toxics, 11*(147). doi:https://doi.org/10.3390/toxics11020147

Siregar, A., Sulistyo, I., & Prayogo, N. (2020). Heavy metal contamination in water, sediments and Planiliza subviridis tissue in the Donan River, Indonesia. *Journal of Water and Land Development, 45*(IV-VI), 157-164. doi:https://DOI.org/10.24425/jwld.2020.133057

Slavin, Y., Asnis, J., Häfeli, U., & Bach, H. (2017). Metal nanoparticles: understanding the mechanisms behind antibacterial activity. *Journal of nanobiotechnology, 15*(1), 65. doi:https://doi.org/10.1186/s12951-017-0308-z

Smith, D., & Nordberg, M. (2015). Chapter 2 - General Chemistry, Sampling, Analytical Methods, and Speciation. In G. Nordberg, B. Fowler, & M. Nordberg, *Handbook on the Toxicology of Metals (Fourth Edition)* (pp. 15-44). Academic Press. doi:https://doi.org/10.1016/B978-0-444-59453-2.00002-0

Sojka, M., & Jaskula, J. (2022). Heavy Metals in River Sediments: Contamination, Toxicity, and Source Identification—A Case Study from Poland. *International Journal of Environmental Research and Public Health, 19*(17), 10502. doi:https://doi.org/10.3390/ijerph191710502

Song, J., Shen, Q., Wang, L., Qiu, G., Shi, J., Xu, J., . . . Liu, X. (2018). Effects of Cd, Cu, Zn and their combined action on microbial biomass and bacterial community structure. *Environmental Pollution, 243*(Part A), 510-518. doi:https://doi.org/10.1016/j.envpol.2018.09.011

Song, Y., Wang, P., Li, G., & Zhou, D. (2014). Relationships between functional diversity and ecosystem functioning: A review. *Acta Ecologica Sinica, 34*(2), 85-91. doi:https://doi.org/10.1016/j.chnaes.2014.01.001

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Sonone, S., Jadhav, S., Sankhla, M., & Kumar, R. (2021). Water Contamination by Heavy Metals and their Toxic Effect on Aquaculture and Human Health through Food Chain. *Letters in Applied NanoBioScience, 10*(2), 2148-2166. doi:https://doi.org/10.33263/LIANBS102.21482166

Sprocati, A., Alisi, C., Segre, L., Tasso, F., Galletti, M., & Cremisini, C. (2006). Investigating heavy metal resistance, bioaccumulation and metabolic profile of a metallophile microbial consortium native to an abandoned mine. *Science of The Total Environment, 366*(2-3), 649-658. doi:https://doi.org/10.1016/j.scitotenv.2006.01.025

Sreedevi, P., Suresh, K., & Jiang, G. (2022). Bacterial bioremediation of heavy metals in wastewater: A review of processes and applications. *Journal of Water Process Engineering, 48*, 102884. doi:https://doi.org/10.1016/j.jwpe.2022.102884

Srinidhi, P., Kumar, A., & Irene, A. (2025). Investigating Heavy Metal Stress On Microbial Populations: Adaptations And Growth Responses. *International Journal of Creative Research Thoughts, 13*(8), g874-g883.

Srivastava, N., Gupta, B., Gupta, S., Danquah, M., & Sarethy, I. (2019). Chapter 6 - Analyzing Functional Microbial Diversity: An Overview of Techniques. In S. Das, & H. Dash, *Microbial Diversity in the Genomic Era* (pp. 79-102). Academic Press. doi:https://doi.org/10.1016/B978-0-12-814849-5.00006-X

Stajković-Srbinović, O., Delić, D., Rasulić, N., Kuzmanović, D., Houšková, B., Sikirić, B., & Mrvić, V. (2017). Microorganisms in soils with high nickel and chromium concentrations in Western Serbia. *Polish Journal of Environmental Studies, 26*(4), 1663-1671.

Stefanidis, K., Oikonomou, A., Dimitrellos, G., Tsoukalas, D., & Papastergiadou, E. (2023). Beyond taxonomic diversity patterns – investigating how α and β components of macrophyte functional diversity respond to environmental gradients in lotic ecosystems of Greece. *Frontiers in Plant Science, 14*, 1204383. doi:https://doi.org/10.3389/fpls.2023.1204383

Su, Z., Li, X., Xi, Y., Xie, T., Liu, Y., Liu, B., . . . Zhang, C. (2022). Microbe-mediated transformation of metal sulfides: Mechanisms and environmental significance. *Science of The Total Environment, 825*, 153767. doi:https://doi.org/10.1016/j.scitotenv.2022.153767

Sulaymon, A., Ebrahim, S., & M-Ridha, M. (2014). Competitive biosorption of Pb(II), Cr(III), and Cd(II) from synthetic wastewater onto heterogeneous anaerobic biomass in single, binary, and ternary batch systems. *Desalination and Water Treatment, 52*, 5629–5638. doi:10.1080/19443994.2013.813008

Sun, Z., Zhang, W., Sun, H., Wang, J., Chen, Q., & Yuan, C. (2023). Organic matter addition promotes Cd immobilization in alkaline paddy soils. *2*(36). doi:https://doi.org/10.1007/s44246-023-00072-2

Sveen, T., Viketoft, M., Bengtsson, J., Strengbom, J., Lejoly, J., Buegger, F., . . . Bahram, M. (2025). Functional diversity of soil microbial communities increases with ecosystem development. *Nature Communications, 16*, 10408. doi:https://doi.org/10.1038/s41467-025-66544-8

Syhabuddin, T., Ekaputri, J., Maulana, M., Soemitro, R., Petrus, H., & Chikako, F. (2024). One part method for making geopolymer paste using flocculated sidoarjo mud.

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Archives of Metallurgy and Materials, 69(4), 1401-1406. doi:https://doi.org/10.24425/amm.2024.151406

Taha, A., Hussien, W., & Gouda, S. (2023). Bioremediation of Heavy Metals in Wastewaters: A Concise Review. *Egyptian Journal of Aquatic Biology & Fisheries, 27*(1), 143-166.

Taketani, R., Dini-Andreote, F., Beier, S., & Fernandez, C. (2021). Editorial: Advancements in the Understanding of Anthropogenic Impacts on the Microbial Ecology and Function of Aquatic Environments. *Frontiers in Microbiology, 12*, 820697. doi:https://doi.org/10.3389/fmicb.2021.820697

Tan, R., Lee, C., Pichika, M., Cheng, S., & Lam, K. (2022). PH Responsive Polyurethane for the Advancement of Biomedical and Drug Delivery. *Polymers, 14*(9), 1672. doi:https://doi.org/10.3390/polym14091672

Tan, Y., Zhang, R., Liu, Z., Li, B., & Yuan, Y. (2022). Microbial Adaptation to Enhance Stress Tolerance. *Frontiers in microbiology, 13*, 888746. doi:https://doi.org/10.3389/fmicb.2022.888746

Tang, H., Xiang, G., Xiao, W., Yang, Z., & Zhao, B. (2024). Microbial mediated remediation of heavy metals toxicity: mechanisms and future prospects. *Frontiers in Plant Science, 15*, 1420408. doi:https://doi.org/10.3389/fpls.2024.1420408

Tang, Y., Yu, G., Zhang, X., Wang, Q., Ge, J., & Liu, S. (2018). Changes in nitrogen-cycling microbial communities with depth in temperate and subtropical forest soils. *Applied Soil Ecology, 124*, 218-228. doi:https://doi.org/10.1016/j.apsoil.2017.10.029

Tanikawa, W., Sakaguchi, M., Wibowo, H., Shimamoto, T., & Tadai, O. (2010). Fluid transport properties and estimation of overpressure at the Lusi mud volcano, East Java Basin. *Engineering Geology, 116*, 73-85. doi:10.1016/j.enggeo.2010.07.008

Tayang, A., & Songachan, L. (2021). Microbial bioremediation of heavy metals. *Current Science, 120*(6), 1013-1025.

Thermo Scientific. (2024). *Bacterial Growth Curves: Analysis through OD_{600} measurements.* Thermo Fisher Scientific.

Thompson, I., van der Gast, C., Ciric, L., & Singer, A. (2005). Bioaugmentation for bioremediation: the challenge of strain selection. *Environmental Microbiology, 7*(7), 909-915. doi:https://doi.org/10.1111/j.1462-2920.2005.00804.x

Tilman, D. (2001). Functional Diversity. In S. Levin, *Encyclopedia of Biodiversity (Second Edition)* (pp. 587-596). Academic Press. doi:https://doi.org/10.1016/B978-0-12-384719-5.00061-7

Timková, I., Sedláková-Kaduková, J., & Pristaš, P. (2018). Biosorption and Bioaccumulation Abilities of Actinomycetes/Streptomycetes Isolated from Metal Contaminated Sites. *Separations, 5*(4), 54. doi:https://doi.org/10.3390/separations5040054

Tingay, M. (2010). Anatomy of the 'Lusi' Mud Eruption, East Java. *ASEG Ectended Abstract, 1*, 1-6. doi:10.1081/22020586.2010.12042009

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Tingay, M., Heidbach, O., Davies, R., & Swarbrick, R. (2008). Triggering of the Lusi mud eruption: Earthquake versus drilling initiation. *Geology, 36*(8), 639–642. doi:https://doi.org/10.1130/G24697A.1

Tomova, I., Stoilova-Disheva, M., Lazarkevich, I., & Vasileva-Tonkova, E. (2015). Antimicrobial activity and resistance to heavy metals and antibiotics of heterotrophic bacteria isolated from sediment and soil samples collected from two Antarctic islands. *Frontiers in Life Science, 8*(4), 348–357. doi:http://dx.doi.org/10.1080/21553769.2015.1044130

Trinh, H., Lee, S., Nguyen, T., & Park, H. (2025). Contribution of the microbial community to operational stability in an anammox reactor: Neutral theory and functional redundancy perspectives. *Bioresource Technology, 419*, 132029. doi:https://doi.org/10.1016/j.biortech.2024.132029

Ueki, T., & Lovley, D. (2022). Desulfovibrio vulgaris as a model microbe for the study of corrosion under sulfate-reducing conditions. *mLife, 1*(1), 13-20. doi:https://doi.org/10.1002/mlf2.12018

Vaishampayan, P., Probst, A., La Duc, M., Bargoma, E., Benardini, J., Andersen, G., & Venkateswaran, K. (2013). New perspectives on viable microbial communities in low-biomass cleanroom environments. *The ISME journal, 7*(2), 312-324. doi:https://doi.org/10.1038/ismej.2012.114

Van Rossum, T., Ferretti, P., Maistrenko, O., & Bork, P. (2020). Diversity within species: interpreting strains in microbiomes. *Nature reviews. Microbiology, 18*(9), 491–506. doi:https://doi.org/10.1038/s41579-020-0368-1

Van Ruijven, J., & Berendse, F. (2009). Diversity enhances community recovery, but not resistance, after drought. *Journal of Ecology, 98*(1), 81-86. doi:https://doi.org/10.1111/j.1365-2745.2009.01603.x

Vera, M., Schippers, A., Hedrich, S., & Sand, W. (2022). Progress in bioleaching: fundamentals and mechanisms of microbial metal sulfide oxidation – part A. *Applied Microbiology and Biotechnology, 106*, 6933–6952. doi:https://doi.org/10.1007/s00253-022-12168-7

Victorino, L., & Bessa, L. (2018). Microbial Diversity: The Gap between the Estimated and the Known. *Diversity, 10*(2), 46. doi:https://doi.org/10.3390/d10020046

Vighi, M., & Billa, S. (2013). Ecotoxicology: The Challenges for the 21st Century. *Toxics, 1*(1), 18-35. doi:https://doi.org/10.3390/toxics1010018

Visco, P., Allen, R., Majumdar, S., & Evans, M. (2010). Switching and Growth for Microbial Populations in Catastrophic Responsive Environments. *Biophysical journal, 98*(7), 1099–1108. doi:https://doi.org/10.1016/j.bpj.2009.11.049

Vo, P., Danaee, S., Hai, H., Huy, L., Nguyen, T., Nguyen, H., . . . Ralph, P. (2024). Biomining for sustainable recovery of rare earth elements from mining waste: A comprehensive review. *Science of The Total Environment, 908*, 168210. doi:https://doi.org/10.1016/j.scitotenv.2023.168210

Volesky, B. (2007). Biosorption and me. *Water Research, 41*(18), 4017-4029. doi:https://doi.org/10.1016/j.watres.2007.05.062

UNIVERSITAS
GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Vondráčková, S., Hejcman, M., Tlustoš, P., & Száková, J. (2013). Effect of Quick Lime and Dolomite Application on Mobility of Elements (Cd, Zn, Pb, As, Fe, and Mn) in Contaminated Soils. *Polish Journal of Environmental Studies, 22*(2), 577-589.

Wang, A., & Crowley, D. (2005). Global Gene Expression Responses to Cadmium Toxicity in Escherichia coli. *Journal of bacteriology*, *187*(9), 3259–3266. doi:https://doi.org/10.1128/JB.187.9.3259-3266.2005

Wang, C., Liu, D., & Bai, E. (2018). Decreasing soil microbial diversity is associated with decreasing microbial biomass under nitrogen addition. *Soil Biology and Biochemistry*, *120*, 126-133. doi:https://doi.org/10.1016/j.soilbio.2018.02.003

Wang, J., & Chen, C. (2006). Biosorption of heavy metals by Saccharomyces cerevisiae: A review. *Biotechnology Advances, 24*(5), 427-451. doi:https://doi.org/10.1016/j.biotechadv.2006.03.001

Wang, J., Fan, H., He, X., Zhang, F., Xiao, J., Yan, Z., . . . Li, R. (2021). Response of bacterial communities to variation in water quality and physicochemical conditions in a river-reservoir system. *Global Ecology and Conservation, 27*, e01541. doi:https://doi.org/10.1016/j.gecco.2021.e01541

Wang, J., Yang, Z., Wang, G., Shang, S., Tang, X., & Xiao, H. (2022). Diversity of epiphytic bacterial communities on male and female Sargassum thunbergii. *AMB Express, 12*(1), 97. doi:https://doi.org/10.1186/s13568-022-01439-1

Wang, K., Zhang, D., Xiong, J., Chen, X., Zheng, J., Hu, C., . . . Zhu, J. (2015). Response of Bacterioplankton Communities to Cadmium Exposure in Coastal Water Microcosms with High Temporal Variability. *Applied and environmental microbiology*, *81*(1), 231–240. doi:https://doi.org/10.1128/AEM.02562-14

Wang, L., Hu, C., & Shao, L. (2017). The antimicrobial activity of nanoparticles: present situation and prospects for the future. *International journal of nanomedicine, 12*, 1227–1249. doi:https://doi.org/10.2147/IJN.S121956

Wang, N., Wang, X., Chen, L., Liu, H., Wu, Y., Huang, M., & Fang, L. (2024). Biological roles of soil microbial consortium on promoting safe crop production in heavy metal(loid) contaminated soil: A systematic review. *Science of The Total Environment, 912*, 168994. doi:https://doi.org/10.1016/j.scitotenv.2023.168994

Wang, Q., Wang, C., Yu, W., Turak, A., Chen, D., Huang, Y., . . . Huang, Z. (2018). Effects of Nitrogen and Phosphorus Inputs on Soil Bacterial Abundance, Diversity, and Community Composition in Chinese Fir Plantations. *Frontiers in microbiology*, *9*, 1543. doi:https://doi.org/10.3389/fmicb.2018.01543

Wang, T., Zhang, Q., Qiao, Y., Jiang, Y., Xiao, F., Duan, J., & Zhao, X. (2024). Research progress on microbial adsorption of radioactive nuclides in deep geological environments. *Frontiers in Microbiology, 15*, 1430498. doi:https://doi.org/10.3389/fmicb.2024.1430498

Wang, X., Dai, Z., Zhao, H., Hu, L., Dahlgren, R., & Xu, J. (2023). Heavy metal effects on multitrophic level microbial communities and insights for ecological restoration of an abandoned electroplating factory site. *Environmental Pollution, 327*, 121548. doi:https://doi.org/10.1016/j.envpol.2023.121548

Wang, X., Wang, X., Wu, F., Zhang, J., Ai, S., & Liu, Z. (2023). Microbial community composition and degradation potential of petroleum-contaminated sites under

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

heavy metal stress. *Journal of Hazardous Materials, 457*, 131814. doi:https://doi.org/10.1016/j.jhazmat.2023.131814

Wang, Y., Selvamani, V., Yoo, I., Kim, T., & Hong, S. (2021). A Novel Strategy for the Microbial Removal of Heavy Metals: Cell-surface Display of Peptides. *Biotechnology and Bioprocess Engineering, 26*, 1-9. doi:https://doi.org/10.1007/s12257-020-0218-z

Wang, Z., Xu, J., Xu, Z., & Liu, X. (2024). Functional diversity and secondary production of macrofaunal assemblages can provide insights of biodiversity-ecosystem function relationships. *Environmental Sciences Europe, 36*, 62. doi:https://doi.org/10.1186/s12302-024-00889-7

Wen, O., Feng, S., Liang, J., Jia, P., Liao, B., Shu, W., . . . Yi, X. (2024). Heavy metal pollution in farmland soils surrounding mining areas in China and the response of soil microbial communities. *Soil Security, 17*, 100173. doi:https://doi.org/10.1016/j.soisec.2024.100173

Wen, X., Zhou, J., Zheng, S., Yang, Z., Lu, Z., Jiang, X. Z., . . . Chen, T. (2024). Geochemical properties, heavy metals and soil microbial community during revegetation process in a production Pb-Zn tailings. *Journal of Hazardous Materials, 463*, 132809. doi:https://doi.org/10.1016/j.jhazmat.2023.132809

Wesche, A., Guryler, J., Marks, B., & Ryser, E. (2009). Stress, Sublethal Injury, Resuscitation, and Virulence of Bacterial Foodborne Pathogens. *Journal of Food Protection, 72*(5), 1121-1138.

Westfall, F. (1999). Fossil Bacteria. In J. Seckbach, *Enigmatic Microorganisms and Life in Extreme Environments. Cellular Origin and Life in Extreme Habitats, vol 1* (pp. 73-88). Dordrecht: Springer. doi:https://doi.org/10.1007/978-94-011-4838-2_6

Wibowo, H., Prastisho, B., Prasetyadi, C., & Yudiantoro, D. (2018). The evolution of Sidoarjo hot mudflow (Lusi), Indonesia. *IOP Conference Series: Earth and Environmental Science, 212*, 012050. doi:10.1088/1755-1315/212/1/012050

Widder, S., Allen, R., Pfeiffer, T., Curtis, T., Wiuf, C., Sloan, W., . . . Groβkopf, T. (2016). Challenges in microbial ecology: building predictive understanding of community function and dynamics. *The ISME Journal, 10*, 2557-2568. doi:https://doi.org/10.1038/ismej.2016.45

Willis, A. (2019). Rarefaction, Alpha Diversity, and Statistics. *Frontiers in Microbiology, 10*, 2407. doi:https://doi.org/10.3389/fmicb.2019.02407

Wiryawan, A., Suntari, R., Kusuma, Z., & Syekhfani. (2019). Concentration of Some Metals in Water and Soil Samples at Some Locations near the Hotmud Flow at Porong Disaster Area, Sidoarjo, East Java, Indonesia. *IOP Conf. Series: Earth and Environmental Science, 217*, 012017. doi:10.1088/1755-1315/217/1/012017

Witkowska, D., Słowik, J., & Chilicka, K. (2021). Heavy Metals and Human Health: Possible Exposure Pathways and the Competition for Protein Binding Sites. *Molecules, 26*(19), 6060. doi:https://doi.org/10.3390/molecules26196060

Wood, D., Lu, J., & Langmead, B. (2019). Improved metagenomic analysis with Kraken 2. *Genome Biology, 20*, 202863748. doi:https://doi.org/10.1186/s13059-019-1891-0

UNIVERSITAS GADJAH MADA
**Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Wu, K., Qin, D., Qian, Y., & Liu, H. (2024). A new era of mutation rate analyses: Concepts and methods. *Zoological research, 45*(4), 767–780. doi:https://doi.org/10.24272/j.issn.2095-8137.2024.058

Xiao, L., Feng, L., Chen, X., Yao, J., Li, Y., & Feng, X. (2025). Screening and Characteristics of Cadmium-Tolerant Microorganisms in Soil Remediation. *Bulletin of environmental contamination and toxicology, 114*(3), 35. doi:https://doi.org/10.1007/s00128-024-03986-8

Xiao, Z., Duan, C., Li, S., Chen, J., Peng, C., Che, R., . . . Yu, Y. (2023). The microbial mechanisms by which long-term heavy metal contamination affects soil organic carbon levels. *Chemosphere, 340*, 139770. doi:https://doi.org/10.1016/j.chemosphere.2023.139770

Xie, S. (2024). Biosorption of heavy metal ions from contaminated wastewater: an eco-friendly approach. *Green Chemistry Letters and Reviews, 17*(1), 2357213. doi:https://doi.org/10.1080/17518253.2024.2357213

Xie, Y., Fan, J., Zhu, W., Amombo, E., Lou, Y., Chen, L., & Fu, J. (2016). Effect of Heavy Metals Pollution on Soil Microbial Diversity and Bermudagrass Genetic Variation. *Frontiers in Plant Science, 7*, 755. doi:https://doi.org/10.3389/fpls.2016.00755

Xu, M., Chen, A., Pan, Y., Zhao, T., & Chen, P. (2025). Microbially-driven mine restoration via functional redundancy: Mechanisms sustaining rhizospheric microbiome homeostasis in lianas. *Rhizosphere, 35*, 101150. doi:https://doi.org/10.1016/j.rhisph.2025.101150

Xu, Q., Jiang, D., Zhou, N., Kang, Y. L., Yang, C., Liu, X., . . . Liu, C. (2024). Community structure of soil microorganisms and endophytes of honeysuckle at different ecological niche specificities. *BMC Microbiology, 24*, 367. doi:https://doi.org/10.1186/s12866-024-03518-8

Xu, Q., Wu, B., & Chai, X. (2022). In Situ Remediation Technology for Heavy Metal Contaminated Sediment: A Review. *International Journal of Environmental Research and Public Health, 19*(24), 16767. doi:https://doi.org/10.3390/ijerph192416767

Yang, K., Kotak, H., & Haynes, C. (2022). Metal-organic ion transport systems. *Coordination Chemistry Reviews, 470*, 214705. doi:https://doi.org/10.1016/j.ccr.2022.214705

Yang, S., Liu, X., & Yang, G. (2023). Molecular-level insights into pH regulation of cation adsorption and exchange at clay particle edges. *Applied Clay Science, 232*, 106789. doi:https://doi.org/10.1016/j.clay.2022.106789

Yao, X., Zhang, J., Tian, L., & Guo, J. (2017). The effect of heavy metal contamination on the bacterial community structure at Jiaozhou Bay, China. *Brazilian Journal of Microbiology, 48*(1), 71-78. doi:http://dx.doi.org/10.1016/j.bjm.2016.09.007

Yi, J., Lo, L., Liu, H., Qian, P., & Cheng, J. (2021). Study of Heavy Metals and Microbial Communities in Contaminated Sediments Along an Urban Estuary. *Frontiers in Marine Science, 8*, 741912. doi:https://doi.org/10.3389/fmars.2021.741912

Yi, L., Gao, B., Liu, H., Zhang, Y., Du, C., & Li, Y. (2020). Characteristics and Assessment of Toxic Metal Contamination in Surface Water and Sediments Near a Uranium

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat Pada Lumpur Lapindo Sidoarjo, Jawa Timur
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Mining Area. *International Journal of Environmental Research and Public Health, 17*(2), 548. doi:https://doi.org/10.3390/ijerph17020548

Yin, K., Wang, Q., Lv, M., & Chen, .. L. (2019). Microorganism remediation strategies towards heavy metals. *Chemical Engineering Journal, 360*, 1553-1563. doi:https://doi.org/10.1016/j.cej.2018.10.226

Yu, C., Du, W., Meng, K., Chen, X., Zhang, H., & Xu, M. (2025). Exploring the potential ecological risks of cadmium accumulation in coastal sediments: implications for diversity, function, and assembly of fungal community. *Journal of Environmental Management, 395*, 127726. doi:https://doi.org/10.1016/j.jenvman.2025.127726

Yu, C., Zhu, Z., Meng, K., Zhang, H., & Xu, M. (2023). Unveiling the impact and mechanisms of Cd-driven ecological assembly and coexistence of bacterial communities in coastal sediments of Yellow Sea. *Journal of Hazardous Materials, 460*, 132309. doi:https://doi.org/10.1016/j.jhazmat.2023.132309

Yu, L., Yang, J., RF, Z., Zhou, J., Ding, F., Shao, C., & RK, G. (2023). Isolation of a novel multiple-heavy metal resistant Lampropedia aestuarii GYF-1 and investigation of its bioremediation potential. *BMC Microbiology, 23*, 330. doi:https://doi.org/10.1186/s12866-023-03093-4

Yu, X., Zhao, J., Liu, X., Sun, L., Tian, J., & Wu. (2021). Cadmium Pollution Impact on the Bacterial Community Structure of Arable Soil and the Isolation of the Cadmium Resistant Bacteria. *Frontiers in Microbiology, 12*, 698834. doi:https://doi.org/10.3389/fmicb.2021.698834

Yu, Z., Zeng, X., Cheng, X., Zhang, Q., & Zhang, K. (2025). Patterns and Environmental Drivers of Soil Microbial Succession. *Global Change Biology*, *31*(9), Global Change Biology. doi:https://doi.org/10.1111/gcb.70475

Zabochnicka-Świątek, M., & Krzywonos, M. (2014). Potentials of Biosorption and Bioaccumulation Processes for Heavy Metal Removal. *Polish Journal of Environmental Studies, 23*(2), 551-561.

Zadeh, P., Fermoso, F., Collins, G., Serrano, A., Mills, S., & Abram, F. (2023). Impacts of metal stress on extracellular microbial products, and potential for selective metal recovery. *Ecotoxicology and Environmental Safety, 252*, 114604. doi:https://doi.org/10.1016/j.ecoenv.2023.114604

Zampieri, B., Pinto, A., Schultz, L., de Oliveira, M., & de Oliveira, A. (2016). Diversity and Distribution of Heavy Metal-Resistant Bacteria in Polluted Sediments of the Araça Bay, São Sebastião (SP), and the Relationship Between Heavy Metals and Organic Matter Concentrations. *Environmental Microbiology, 72*, 582-594. doi:https://doi-org.ezproxy.ugm.ac.id/10.1007/s00248-016-0821-x

Zeglin, L. (2015). Stream microbial diversity in response to environmental changes: review and synthesis of existing research. *Frontiers in microbiology, 6*, 454. doi:https://doi.org/10.3389/fmicb.2015.00454

Zeglin, L. (2015). Stream microbial diversity in response to environmental changes: review and synthesis of existing research. *Frontiers in microbiology*, *6*, 454. doi:https://doi.org/10.3389/fmicb.2015.00454

Zhang, G., Liu, T., Li, H., Wang, Z., Huang, X., Yi, X., & Yan, D. (2022). Experimental Study on the Effects of Heavy Metal Pollution on Soil Physical Properties and

UNIVERSITAS GADJAH MADA
Karakterisasi Komunitas Bakteri Sungai Porong dan Potensinya Sebagai Agen Bioremediator Logam Berat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Microstructure Evolution. *Applied Science, 14*(5). doi:https://doi.org/10.3390/app14052022

Zhang, P., Yang, M., Lan, J., Huang, Y., Zhang, J., Huang, S., . . . Ru, J. (2023). Water Quality Degradation Due to Heavy Metal Contamination: Health Impacts and Eco-Friendly Approaches for Heavy Metal Remediation. *Toxics, 11*, 828. doi:https://doi.org/10.3390/toxics11100828

Zhang, T., & Zhang, H. (2022). Microbial Consortia Are Needed to Degrade Soil Pollutants. *Microorganisms, 10*(2), 261. doi:https://doi.org/10.3390/microorganisms10020261

Zheng, C., Shi, H., Wei, J., Cui, M., Lin, Z., Gao, Y., . . . Wen, Z. (2024). Evidence that spatial scale and environment factors explain grassland community assembly in woodland–grassland ecotones. *Ecology and Evolution, 14*(7), e11644. doi:https://doi.org/10.1002/ece3.11644

Zheng, M., Qi, X., Liu, Z., Wang, Y., Ren, Y., Li, Y., . . . Jia, T. (2025). Microbial taxonomic diversity and functional genes mirror soil ecosystem multifunctionality in nonferrous metal mining areas. *Journal of Hazardous Materials, 492*, 138149. doi:https://doi.org/10.1016/j.jhazmat.2025.138149

Zheng, X., Lin, H., Du, D., Li, G., Alam, O., Cheng, Z., . . . Li, J. (2024). Remediation of heavy metals polluted soil environment: A critical review on biological approaches. *Ecotoxicology and Environmental Safety, 284*, 116883. doi:https://doi.org/10.1016/j.ecoenv.2024.116883

Zhou, H., Wang, J., Shao, S., Yu, X., Kang, J., Qiu, G., . . . Shen, L. (2024). Comparison of biosorption behavior and mechanism of La3+, Sm3+, Y3+, Nd3+, Er3+ by Aspergillus niger and Bacillus sp. *Journal of Water Process Engineering, 59*, 104965. doi:https://doi.org/10.1016/j.jwpe.2024.104965

Zhu, P., Wang, Y., Jin, Y., Xiong, Y., Chen, G., & Ruan, F. (2024). Behaviour and mechanism of cadmium immobilization in contaminated soil by calcium carbide residue-enhanced MICP. *Scientific Reports, 14*, 25409. doi:https://doi.org/10.1038/s41598-024-75574-z

Zolgharnein, H., Azmi, M., Saad, M., Mutalib, A., & Mohamed, C. (2007). Detection of plasmids in heavy metal resistance bacteria isolated from the Persian Gulf and enclosed industrial areas. *Iranian Journal of Biotechnology, 4*, 232-239.

Zou, S., Liu, P., Wang, J., Lu, H., Zhang, Y., Wang, Y., & Li, B. (2025). Characterizing and tracing the heavy metals' spatial distribution in karst surface river affected by acid mine drainage. *Environmental Engineering Research, 30*(2), 240180. doi:https://doi.org/10.4491/eer.2024.180

Zymo Research. (n.d.). *ZymoBIOMICS™ DNA Miniprep Kit - DNA for microbiome or metagenome analyses.* Zymo Research.