Biomining -A New approach for waste management

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Abstract

The waste generated by different categorical anthropogenic activities unlike mining, industrial waste, e -waste, etc., are causing serious threat to the environment. The constituents of the waste generated contain harmful toxic polycyclic aromatics which pose a direct threat to the environment as well as the human race. Heavy metal discharge from the solid waste accumulated in the dumping site gets cumulated in the soil and gets absorbed by the plants leading to biomagnifications in the food chain and substantially reaching the human body, leading to compromised health. An economic, environmentally sound and cost-effective approach 'Biomining' can be a powerful strategy for waste management. They transform toxic solid waste into nontoxic form and are sufficiently capable of catalysing mineral dissolution. It can be an absolute solution for mineral beneficiation to overcome environmental problems.

Keywords: Biomining, uses, waste management

Introduction

The necessity for improved technology to meet a person's everyday needs keeps replacing the older technology and automatically generates waste in a vast quantity (Vyas et al. 2022). Industrial garbage, municipal waste, and electronic waste are all having detrimental effects on the environment. Its management is the biggest challenge across the world. Electronic waste, rubbish dump, domestic waste, malleable waste produced from plastics and metals, wood, toppling construction sites all contribute in the generation of solid wastes (Das and Ghosh 2022).

Biomining is used for the recovery of several metals like copper, nickel, cobalt, zinc, uranium, and precious metals like gold and silver. Presently, biomining is also implemented in the recovery of metals from electronic waste such as voltaic substances like spend batteries, electrical appliances like refrigerator, television air conditioners, sound boxes, laptops, motherboards, which is serving as the fastest-growing waste around the globe. Extremophiles are microorganisms that thrive in an acidic pH range of 2.0–4.0 and aid in metal dissolution through acid secretion. Some known examples are *Leptospirillum ferrooxidans, Acidithiobacillus ferrooxidans, Acidithiobacillus thiooxidans, and Sulfolobus spp. Penicillium spp. and Aspergillus niger* fungal species are intensively studied for the biomining process (Kumar et al. 2022).

Biomining microorganisms play a crucial role by forming an association with the inorganic component of the solid waste and help in the recovery of metals, producing a minimum release of toxic effluents into the environment and are considered as a green technology. Biomining consists of two major steps for the recovery of metals from their respective sources. The first step involves bioleaching, which is escorted by thermophiles and chemolithotrophs that oxidize sulphur, where oxidation of metal sulphides at acidic pH takes place into metal ions (Pattanaik et al. 2020), followed by a conditioning step of bio-oxidation.

In bio-oxidation, microorganisms interact with a mineral matrix containing the target metal, allowing them to be exposed to the oxidation slag. In bio-oxidation, the metal remains in the more concentrated form. Metals are extracted by the action of ferric ion or acid during microbial solubilization, which involves both chemical and biological processes. Microorganisms are in charge of creating these leaching agents. It is known that a wide range of lithotrophic and organotrophic bacteria mediate these activities. Since the beginning of life, a significant part is played by the microorganisms in the production of minerals and the disintegration of the earth's crust (Gao et al. 2021). In the past, leaching of copper was done using microorganisms' having natural capacity for mineral breakdown without anyone even realizing that this process was mediated by microorganisms; it was purely empirical at the time. Five per cent of the world's gold was produced via biomining and copper production was up to 15% (Sana et al. 2021).

The recuperation of precious metals made possible by biomining will allow for the reclamation of solid wastes, as well as the opportunity to address public health and environmental quality issues related to pollution caused by solid wastes. It also emphasizes the regulatory bodies' duty to ensure that the biomined site has an appropriate lining system and design so that any further processing and municipal sewage wastewater treatment activities may be carried out with a minimal damage to the environment and public health (Mohan and Joseph 2020).

The interaction between the microorganisms and inorganic substances found in dumping site can be extremely important. The process of rock weathering enables the liberation of metals from minerals, and the reduction and oxidation of metals are all processes that depend heavily on the abundance of microorganisms in nature. The geochemical cycle of inorganic substances in nature also heavily relies on these microbial processes. Technical waste treatment applications may benefit from adapting these microbiological concepts and procedures. As a closed loop process with little effluent generation, the technique is also assumed to be an environment-friendly technique.

The mechanism basically involved in the process is mineral sulphides oxidation to the target metal ions and sulphate, and reaction is governed under the influence of microorganism, aerobically where O_2 serve as the terminal electron acceptor (Donati et al. 2016). Reaction involved in the process: (i) $MS(S) + 2O_2(g) \rightarrow MSO_4(ac)$. Acidophilic microorganisms with the ability to oxidize iron (II) and/or sulphur compounds in accordance with the following equations catalyse this reaction. (ii) $2Fe^{2+}(ac) + 1/2O_2(g) + 2H^+(ac) \rightarrow 2Fe^{3+}(ac) + H_2O$. (iii) $0.125S8(s) + 1\ 1/2O_2(g) + H_2O \rightarrow H_2SO_4(s)$. Only protons and iron (III) can dissolve metal sulphides during bioleaching procedures. Microorganisms exclusively play the role of replenishing iron (III) and/or protons in these currently established methods

Biomining as a New Aspect of Circularity of Waste Management

The "circular economy" approach of waste management, which includes not just managing trash but also its reuse and recycling, might help in the development of new companies and jobs while lowering emissions and enhancing the efficient use of natural resources (including energy, water, and materials). Biomining adheres to the core values of the circular economy by optimizing the recovery of recyclable materials. The ratio of soil to trash and excavation depth both affects how effective biomining is. The highest efficiency of biomining is implied by the depth of the excavation and the lowest soil-to-waste ratio (Bir et al. 2022). The most efficient resource recovery can be acquired only when the recovery of trash, which comprises recyclable, combustible, and non-combustible components, is taken into consideration. In the frame of reference of biomining, it puts into practise the core ideas of a circular economy model that uses sustainable waste management through reuse, recycling, and recovery, which is a shift from a linear economy, i.e. take-make-waste and accountable production of materials, and can satisfy the needs of raw materials for small-scale industries, such as small manufacturing industries, glass industries, plastic industries, etc., which can be advantageous with regard to environmental sustainability (Xavier et al. 2021).

Conclusion

Technology-based treatments which are economically viable and environment friendly are needed to address the harmful environmental effects of trash accumulation. The philosophy of "looking at waste as a resource and recycling it to retrieve the value of the waste" has significantly changed how solid waste is managed (SWM). The core of technical eco-innovations is automation of waste separation, retrieval, network optimization, digital information apps (increased efficiency by 40–85%), and modern techniques. The regulatory framework, which includes rule changes, new policies, plans, and smart city missions, is in charge of putting "technology advancements" into practice on a practical level and has demonstrated positive effects on society. The increase in bio-recovery efficiency of precious metals is essential for improving scaling-up potential because the majority of the discovered microbial technologies are created in laboratories.

References

Bir T, Banerjee S, Dutta A (2022). Legacy waste characterization: bio-mining solution for landfills and resource recovery towards circularity. In: International conference on chemical, bio and environmental engineering. Springer, Cham, pp 635–650

Das AP, Ghosh S (2022) Role of microorganisms in extenuation of mining and industrial wastes. Geomicrobiol J 39(3–5):173–175

Donati ER, Castro C, Urbieta MS (2016) Thermophilic microorganisms in biomining. World J Microbiol Biotechnol 32(11):1–8

Gao X, Jiang L, Mao Y et al (2021) Progress, challenges, and perspectives of bioleaching for recovering heavy metals from mine tailings. Adsorpt Sci Technol 7:2021

Kumar M, Kochhar N, Kavya IK et al (2022) Perspectives on the microorganism of extreme environments and their applications. Curr Res Microbial Sci 21:100134

Mohan S, Joseph CP (2020) Biomining: an innovative and practical solution for reclamation of open dumpsite. In: Recent developments in waste management: select proceedings of recycle 2018. Springer, Singapore, pp 167–178

Pattanaik A, Samal DP, Sukla LB, Pradhan D (2020) Advancements and use of OMIC technologies in the field of bioleaching: a review

Sana S, Neelam D, Gupta V et al (2021) An overview: application of microorganisms in bio-mining of metals (review article). Int J Pharm Biol Sci 11(1):01–08. https://doi.org/10.21276/ijpbs.2021.11.1.1

Vyas S, Prajapati P, Shah AV et al (2022) Opportunities and knowledge gaps in biochemical interventions for mining of resources from solid waste: a special focus on anaerobic digestion. Fuel 1(311):122625

Xavier LH, Giese EC, Ribeiro-Duthie AC, Lins FA et al (2021) Sustainability and the circular economy: a theoretical approach focused on e-waste urban mining. Resour Policy 74:101467