Microbial Alchemy using bacteria to mine precious metals

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Introduction

With increase in industrialization along with population growth, the demand of metals has dramatically increased and is likely to go up further in years to come.

It necessitates the need for innovative and economical ways of recovering metals from low-grade deposits.

Large stockpiles of low and lean grade ores exist but the recovery of metals from them using conventional techniques is very expensive and leads environmental problem.

Ores with low metal content are not suitable for direct smelting but it is possible to extract metals economically using the activity of microorganisms which decompose a variety of mineral deposit and bring the revolution in mining industry.

Microbial Alchemy

Alchemy: a seemingly magical process of transformation, creation or combination.

Microbial Alchemy: transforming metals from something that has no value into a solid, precious and valuable metal with the help of microorganisms.

Biomining

Biomining is the extraction of specific metals from their ores through biological means usually bacteria or microorganism.

Microbial recovery of metals is sometimes called “microbial mining” or “biohydrometallurgy”.

Biomining is a biotechnological process implemented at industrial scale to extract base metals from sulfidic ores.

Current scenario

Currently, biomining accounts for about 25% and 5% of the world production of Cu and Au, respectively.

In India, first time bioleaching technology being used for silica magnesite by using *Bacillus Licheniformis* developed (The Bose Institute, Calcutta, collaboration with the Department of Biotechnology).

Industries carry out **biomining** in India: Hindustan Copper Limited (New Delhi)

Bioleaching plants: 1.) The Bruhat Bangalore Mahanagara Palike (BBMP) 2.) GHMC (Greater Hyderabad Municipal Corporation)

Mining mechanism

Microorganisms involved in biomining gain energy by breaking down minerals into their constituent elements.

Thiosulfate mechanism

For oxidation of acid insoluble metal sulfides such as pyrite and molybdenite. In this solublization is through ferric iron attack on acid insoluble metal sulphides

Polysulfide mechanism

For acid soluble metal sulfides such as chalcopyrite, galena. In this solublization of acid soluble metal sulfide through combined attack by ferric ions and protons.

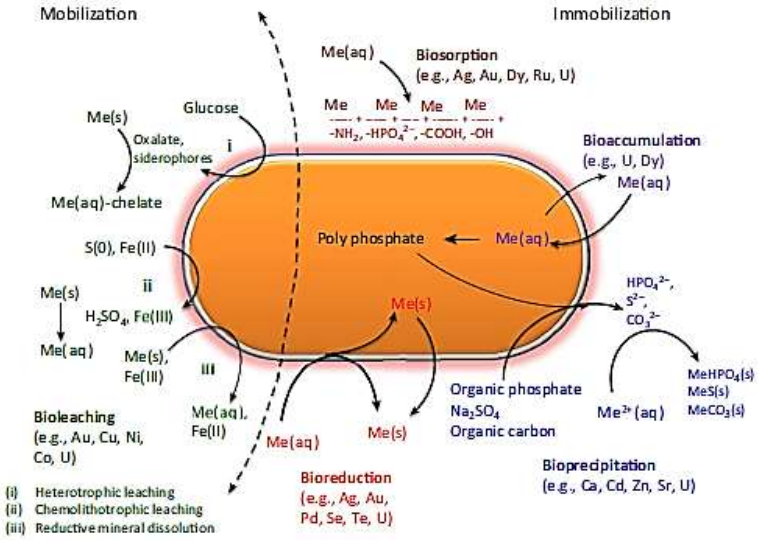

Figure: Microbe–Metal Interactions Depicting Different Mechanisms of Metal Solubilization and Immobilization Used for Bio-recovery.

Bioleaching

The conversion of an insoluble metal (usually a metal sulphide, e.g., CuS, NiS, ZnS) into a soluble form (usually the metal sulphate, e.g., $CuSO_4$, $NiSO_4$, $ZnSO_4$) because of various activities of microorganisms.

Mechanism of bioleaching

Direct bioleaching:

Physical contact between the bacterial cell and the mineral sulfide surface,
The oxidation to sulfate takes place via enzymatically catalysis.

$$4FeS_2 + 14O_2 + 4H_2O \xrightarrow{\text{bacteria}} 4FeSO_4 + 4H_2SO_4 \quad (1)$$

$$4FeSO_4 + O_2 + 2H_2SO_4 \xrightarrow{\text{bacteria}} 2Fe_2(SO_4)_3 + 2H_2O \quad (2)$$

Indirect bioleaching:
Bacteria produce strong oxidizing agents (ferric iron and sulfuric acid) helps in oxidation of soluble iron or soluble sulfur respectively.

Ferric iron or sulfuric acid, being powerful oxidizing agents react with metals and extract them.

$$4FeSO_4 + O_2 + 2H_2SO_4 \longrightarrow 2Fe_2(SO_4)_3 + 2H_2O$$

Microorganism involved in biomining

The most commonly used microorganisms for bioleaching are *Thiobacillus ferrooxidans* ,*Thiobacillus thiooxidans*

- Use ferrous iron and reduced sulphur compounds as electron donors and fix carbon dioxide.
- Produce sulphuric acid (acidophiles).
- Work synergistically and improve the extraction of metals from the ores.

➢ A combination of two bacteria *Leptospirillum ferrooxidans* and *Thiobacillus organoparpus* can effectively degrade pyrite (FeS_2) and chalcopyrite ($CuFeS_2$). The individual organisms alone are of no use in extracting metals.
➢ *Pseudomonas aeruginosa* mining low grade uranium ore
❑ Certain fungi have also found use in bioleaching.

- *Aspergillus niger* can extract copper and nickel
- *Aspergillus oryzae* is used for extracting gold.
- *Rhizopus arrhizus* is also effective for extracting uranium

Factors affecting bioleaching

Physicochemical

Temperature : Affects leaching rate, microbial composition and activity (30-50^{0}C)

pH :Needs to be low to obtain fastest leaching rates and to keep ferric iron and metals in solution (2.3-3.5)

Oxygen : Electron acceptor needed in chemical and biological oxidation

Microbiological

Microbial diversity : Mixed cultures tend to be more robust and efficient than pure

Population density : High population density tends to increase the leaching rate

Metal tolerance : High metal concentrations may be toxic to metals

References (if any)

1. Hamidian, H., Rezai, B., Milani, S., Vahabzade, F., and Shafaie, S. (2009). Microbial leaching of uranium ore. *Asian Journal of Chemistry*, *21*(8), 5808-5820.
2. Nancharaiah, Y. V., Mohan, S. V., and Lens, P. N. L. (2016). Biological and bioelectrochemical recovery of critical and scarce metals. *Trends in biotechnology*, *34*(2), 137-155.
3. Siddiqui, M. H., Kumar, A., Kesari, K. K., and Arif, J. M. (2009). Biomining -a useful approach toward metal extraction. *American-Eurasian Journal of Agronomy*, *2*(2), 84-88.
4. Wang, Y., Li, K., Chen, X., and Zhou, H. (2018). Responses of microbial community to pH stress in bioleaching of low grade copper sulfide. *Bioresource technology*, *249*, 146-153.
5. Zhang, X., Feng, Y. L., and Li, H. R. (2016). Enhancement of bio-oxidation of refractory arsenopyritic gold ore by adding pyrolusite in bioleaching system. *Transactions of Nonferrous Metals Society of China*, *26*(9), 2479-2484.
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