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Biomining & Bioleaching

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Introduction

- Biomining is the broad term that describes the extraction of specific metals from their ores through biological means, usually microorganisms.
- It is an alternative to more traditional physical-chemical methods of mineral processing.
- The application of biomining processes predates by centuries the understanding of the role of microorganisms in metal extraction.
- However, the modern era of biomining began with the discovery of the bacterium *Thiobacillus ferrooxidans*.



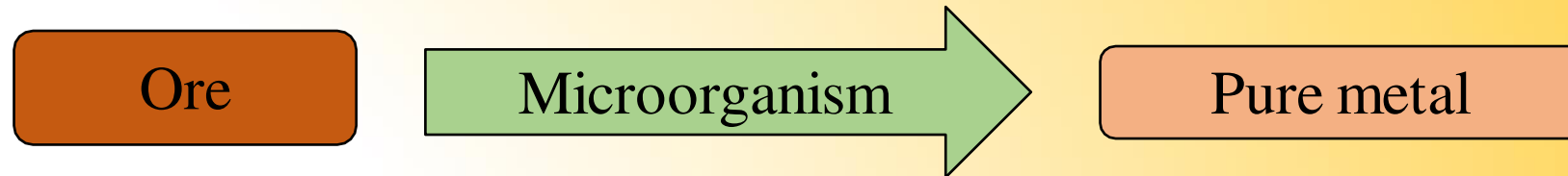
Fig.: Microscopic image of *Thiobacillus ferrooxidans*

Introduction

- Biomining encompasses two processes:

1. Bioleaching: Bioleaching is the process by which metals are dissolved from ore bearing rocks using microorganisms.

- Bioleaching is also called microbial leaching.



2. Biooxidation: Biooxidation is a process by which the recovery of a metal is enhanced by microbial decomposition of the mineral, but the target metal is not necessarily solubilized.

- In bioleaching the desired metal is leached from the ore. In biooxidation, the undesired metals and other compounds are leached away from the ore.

Microorganisms Used in Bioleaching

The most commonly used microorganisms in bioleaching are:

- *Thiobacillus thiooxidans*
- *Thiobacillus ferrooxidans*

Other microorganism:

- *Sulfolobus* – Ca, As
- *Saccharomyces cerevisiae* – Cu, Pb, Sn
- *Penicillium simplicissium* - Cr

Chemistry of Bioleaching

- *Thiobacillus thiooxidans* and *T. ferrooxidans* have always been found to be present on the leaching dump.
- The species of *thiobacillus* is most extensively studied gram –ve bacteria which derives energy from oxidation of Fe^{2+} .
- The reaction mechanisms are of two types, i.e.,
 - Direct bacterial leaching (Contact leaching)
 - Indirect bacterial leaching

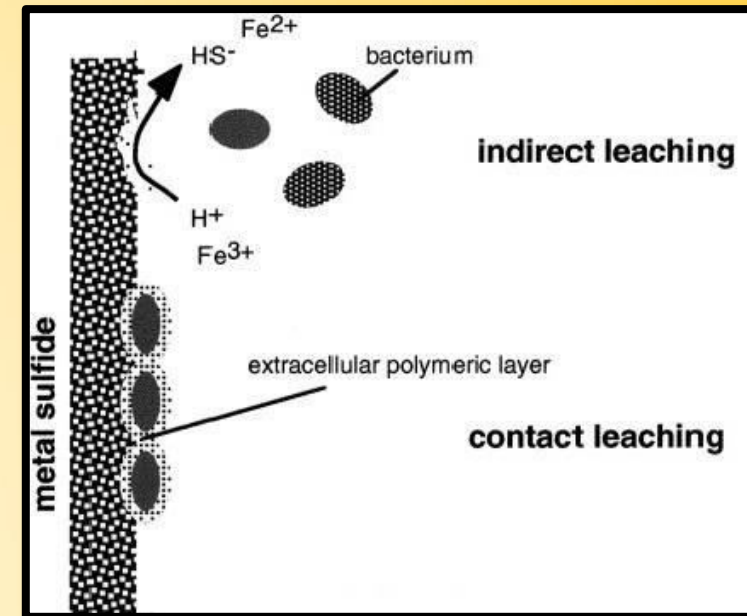
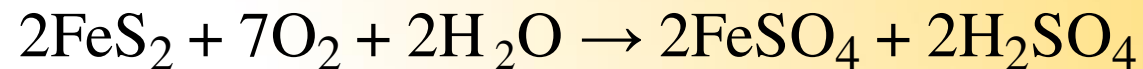


Fig.: Direct and indirect bioleaching

Chemistry of Bioleaching

Direct Bacterial Leaching

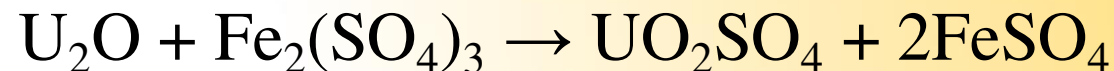
- In this process, a physical contact exist between bacteria and ores and oxidation of mineral takes place through enzymatically catalysed steps.
- Example: pyrite is oxidised to ferric sulphate



Chemistry of Bioleaching

Indirect bacterial leaching

- In this process the microbes are not in direct contact with minerals, but bacteria produces strong oxidising agents such as ferric ion and sulfuric acid on oxidation of soluble iron or soluble sulfur respectively.
- For indirect bioleaching, acidic environment is absolutely essential in order to keep ferric iron and other metals in solution.
- Acidic environment maintained by oxidation of iron, sulfur, metal sulphides or by dissolution of carbonate ions.
- Example: Bioleaching of uranium



Direct bioleaching:

Direct enzymatic attack on the minerals by microorganisms. Certain bacteria (e.g., *T. ferrooxidans*) can transfer electrons (coupled with ATP) from iron or sulfur to oxygen.

These organisms can obtain energy from the oxidation of Fe^{2+} to Fe^{3+} or from the oxidation of sulfur to sulfate.

Indirect bioleaching:

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

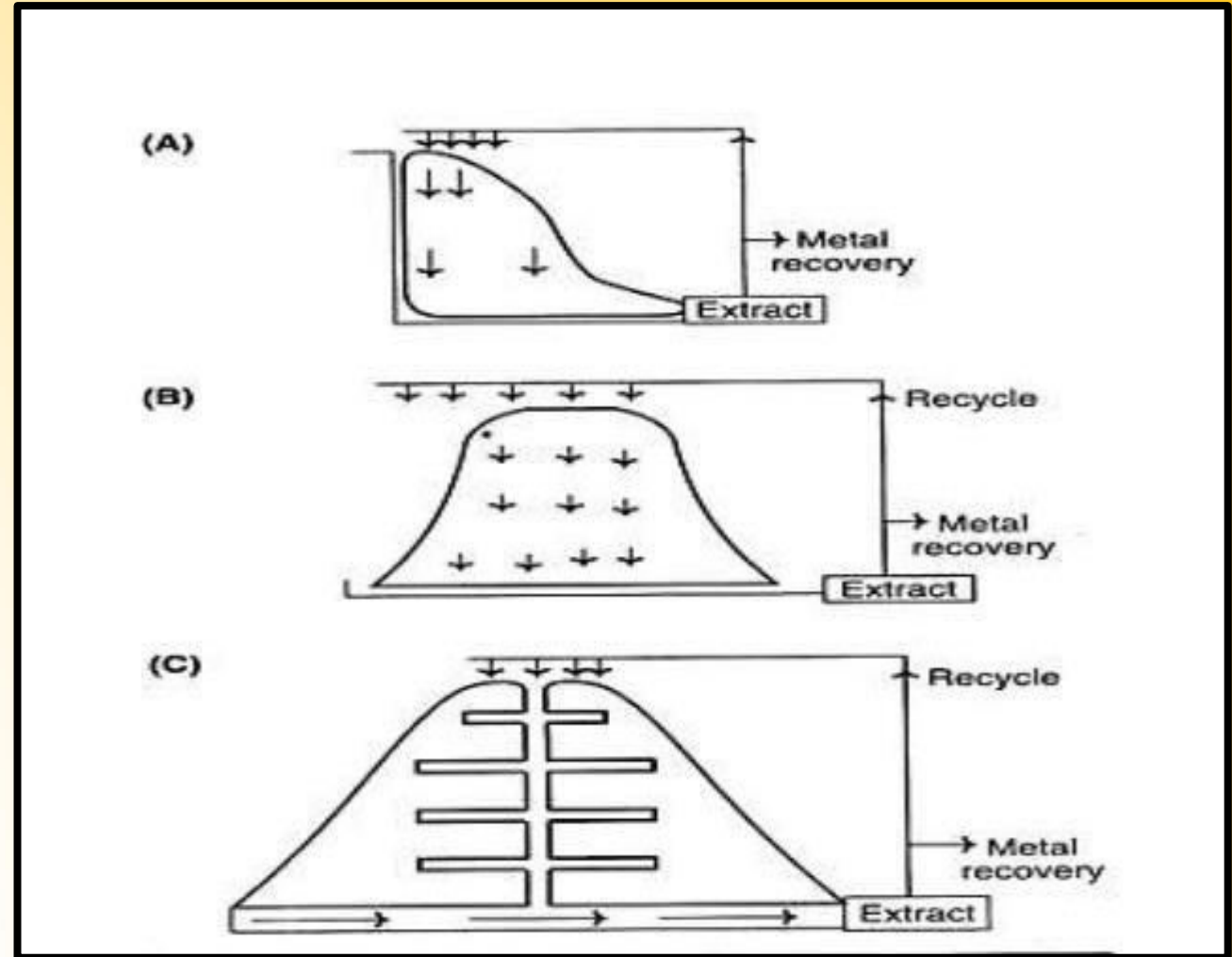
Ferric iron or sulfuric acid, being powerful oxidizing agents react with metals and extract them.

Types of Bioleaching

There are three commercial process used in bioleaching:

- Slope leaching
- Heap leaching
- In situ leaching

Fig.: Commercial bioleaching processes- (A) Slope leaching, (B) Heap leaching and (C) In-situ leaching



Slope Leaching

- Here the ores are first ground to get fine pieces and then dumped into large leaching dump.
- Water containing inoculum of *thiobacillus* is continuously sprinkled over the ore.
- Water is collected from the bottom and used to extract metals and generate bacteria in an oxidation pond.

Heap Leaching

- Here the ore is dumped into large heaps called leach heaps.
- Water containing inoculum of *thiobacillus* is continuously sprinkled over the ore.
- Water is collected from the bottom and used to extract metal and generate bacteria in an oxidation pond.

In-situ Bioleaching

- In this process the ore remains in its original position in the earth.
- Surface blasting of earth is done to increase the permeability of water.
- Water containing *thiobacillus* is pumped through drilled passage to the ores.
- Acidic water seeps through the rock and collects at the bottom.
- Again, water is pumped from bottom.
- Mineral is extracted and water is reused after generation of bacteria.

Copper Leaching

- Ores of copper from which copper is recovered are:
- Chalcocite (Cu_2S)
- Chalcopyrite (CuFeS_2)
- Covellite (CuS)
- Copper leaching is operated as simple heap leaching and in situ leaching process.
- Dilute sulphuric acid is percolated down through the pile.
- Liquid coming out of bottom of pile reach in mineral.
- Liquid is collected and transported to precipitation plant.
- Metal is precipitated and purified.

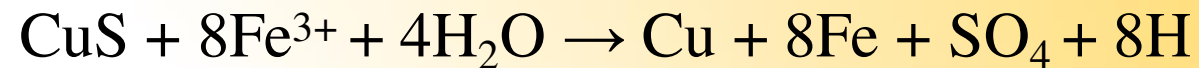
Copper Leaching

Reactions

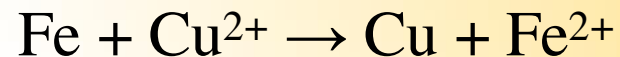
- Chalcocite is oxidized to soluble form of copper



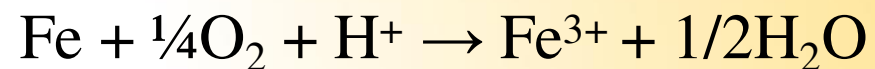
- Thereafter chemical reactions occur, i.e.



- Copper is removed.



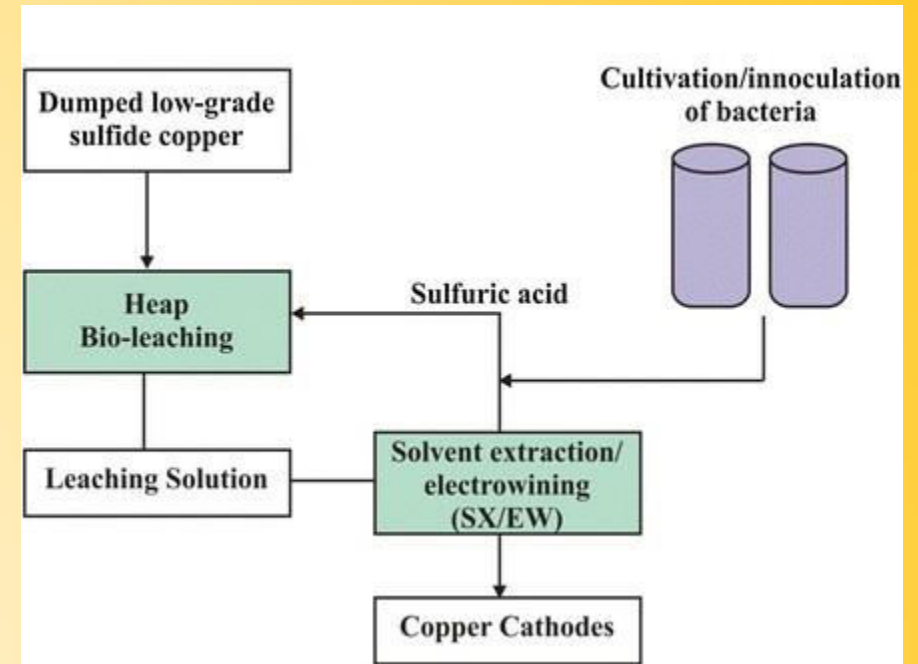
- Fe^{2+} is transferred to oxidation pond



Copper Leaching

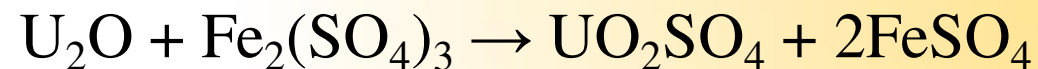
- Fe^{3+} ions produced by the oxidation of ore.
- It is pumped back to pile.
- Sulphuric acid is added to maintain pH.

Fig.: Copper recovery process using bio-mining technology



Uranium Leaching

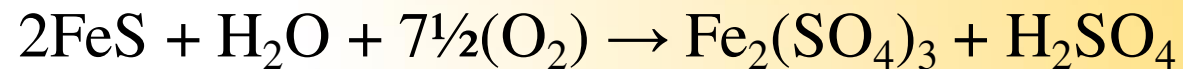
- Uranium is extracted when insoluble tetravalent uranium is oxidized with a hot $\text{H}_2\text{SO}_4/\text{FeSO}_4$ solution to make hexavalent uranium sulphate.
- pH required for the reaction is 1.5-3.5
- Temperature: around 35 degree C
- Following reaction take place in the process



Uranium Leaching

- Uranium leaching is an indirect process.
- When *T.ferrooxidans* are involved in uranium extraction, they do not directly attack on ore but on the iron oxidants.
- The pyrite reaction is used for the initial production of Fe

Reaction:



Gold and Silver Leaching

- Microbial leaching of refractory process metal ores to enhance gold and silver recovery is one of the promising applications.
- Gold is obtained through bioleaching of arsenopyrite/ pyrite.
- Silver is also obtained by bioleaching of arsenopyrite but it is more readily solubilized than gold during microbial leaching of iron sulphide.

Factors Affecting Bioleaching

Factors		Effects
1	Choice of bacteria	Suitable bacteria that can survive at high temperatures, acid concentrations, high concentrations of heavy metals, remaining active under such circumstances.
2	pH and temperature	Affects leaching rate, microbial growth
3	Population density	High population density tends to increase the leaching rate
4	Metal tolerance	High metal concentration may be toxic to microbes
5	Oxidation reactions and compositions activity	Needs to be low to obtain the fastest leaching rates and to keep ferric ions and metals in solution
6	Surface area	Rate of oxidation by the bacteria increases with reduction in size of the ore and vice-versa.

Benefits of Bioleaching

- Simple process.
- Inexpensive technique.
- No poisonous sulfur dioxide emission as in smelter.
- No need of high pressure and temperature.
- Ideal for low grade sulphide ores.
- Environment friendly process.

Disadvantages of Bioleaching

- Time consuming (takes 6-24 months or longer).
- Have a very low yield of minerals.
- Requires a large open area for treatment
- May have no process control.
- High risk of contamination.
- Inconsistent yield because bacteria can not grow uniformly.

Thank you . . .