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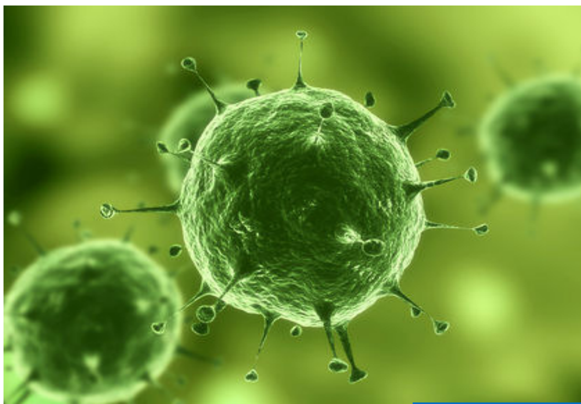
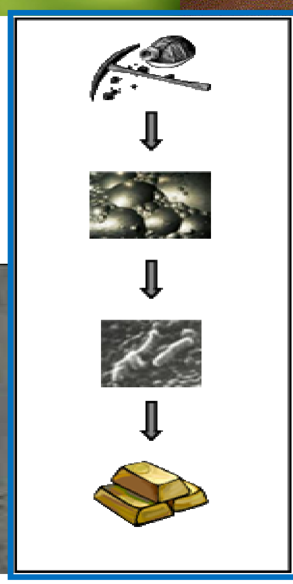
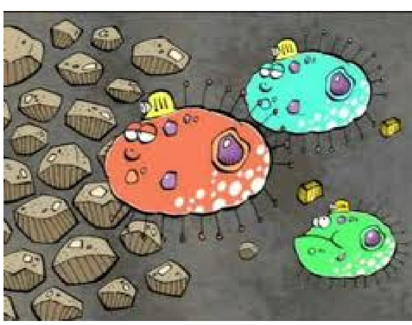
NEWS LETTER







BIOMINING

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ENVIS Newsletter on Environmental Biotechnology is a half-yearly publication, publishes articles related to the thematic area of the ENVIS Centre. Popular or easily intelligible expositions of new or recent developments are welcome

Manuscripts should be typewritten (font should be Times New Roman and font size ought to be 12) on one side of the paper in double spacing with maximum of 6-8 typed pages

Figures and typed table should be in separate pages and provided with title and serial numbers. The exact position for the placement of the figures and tables should be marked in the manuscript.

Articles should be sent to

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EDITORIAL

Biomining is the extraction of specific metals from their ores through biological means usually bacteria. Although it is a new technique used by the mining industry to extract minerals such as copper, uranium and gold from their ores but now a days, biomining occupies an increasingly important place among the available mining technologies. Today biomining is no longer a promising technology but an actual economical alternative for treating specific mineral ores. Traditional extractions involve many expensive steps such as roasting and smelting, which requires sufficient concentrations of elements in ores while low concentrations are not a problem for bacteria because they simply ignore the waste which surrounds the metals, attaining extraction yields of over 90% in some cases.

In this newsletter (Vol. no. 21). We have attempted to discuss the Biomining

(S. C. Santra)

IN THIS ISSUE:

BIOMINING

Biomining is a method of extracting minerals and metals from their parent ores using naturally occurring biological processes. The practice requires none of the environmentally damaging processes found in conventional refinement methods and instead relies entirely on the natural interaction of biological organisms.

Microorganisms are used to leach out the minerals, rather than the traditional methods of extreme heat or toxic chemicals, which have a deleterious effect on the environment. This technology is also environmentally friendly as it generates minimal amount of pollutants. It is a very low capital, low operational cost, and a low energy input process. It has the added benefit of mining low grade ore and/or mine tailings. It is used to recover the various types of minerals from ore using microorganism. Biomining method is cheap, reliable and efficient method of mineral recovery. Using biotechnology efficiency of biomining can be increased by using genetically modified microorganisms. Biomining is done in two steps known as bioleaching and biooxidation. Biomining is also known as microbial leaching or as biooxidation. It provides such a green technology to exploit mineral resources. Physical-chemical processes utilized in conventional mining technologies necessitate large amounts of energy for roasting/smelting and produce harmful gaseous emissions such as sulfur dioxide; biomining will help eliminate these problems. Furthermore, the tailings generated by biomining operation are less chemically active. The biological activity these tailings would support is reduced to a minimum as they have already been bioleached. The modest nutritional requirements and the irrigation needed to support the select microbial life in a heap or the tank reactors are indeed less expensive than the enormous cost associated with pryometallurgical processes.

Biomining has a long history, although the early miners did not know that microbes were involved. The use of microorganisms to extract copper has its roots deep in antiquity. It is not clear to what extent microbial activity was used to extract copper by eighteenth-century in Welsh miners at Anglesey (North Wales), but it is certain that microbes played a role in even earlier activities at the Rio Tinto mine. Romans recovered silver and copper from a deposit located in the Seville province in the south of Spain, which later became known as the Rio Tinto mine. The Rio Tinto (Red River) obtained its name from the red color imparted to the water by the high concentration of ferric iron. This dissolved ferric iron (and the less easily seen dissolved copper) is due to natural microbial activity. From earliest records the Rio Tinto has been known as a river devoid of fish and with water that is undrinkable.

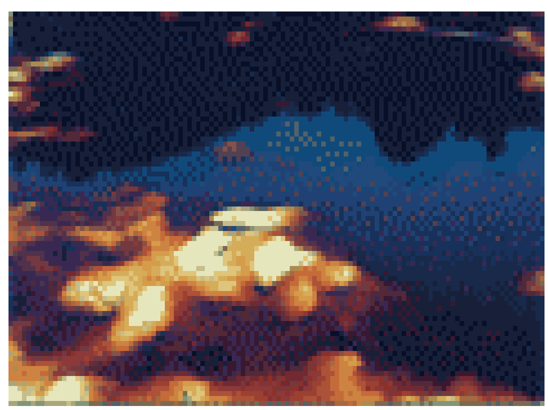

Figure: 1 The Rio Tinto acidic river (±pH 2.3) is red owing to high concentrations of dissolved ferric iron resulting from natural microbially mediated mineral decomposition.

How Biomining Works?

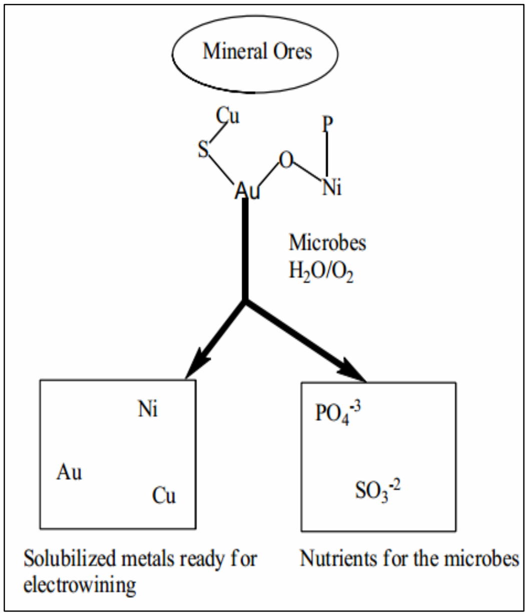

Figure: 2 A Schematic of Biomining

Types of Biomining

1. Stirred Tank Biomining
2. Bioheaps
3. In- situ Bioleaching

1. Stirred Tank Biomining:-

This method is used for leaching from substrates with high mineral concentration. Special types of stirred tank bioreactors lined with rubber or corrosion resistant steel and insulated with cooling pipes or cooling jackets are used for this purpose. *Thiobacillus* is commonly used bacteria. Since it is aerobic the bio reactor is provided with an abundant supply of oxygen throughout the process provided by aerators, pumps and blowers. This is multistage process consisting of large number of bio-reactors connected to each other. The substrates moves from one reactor to another and in the final stage it is washed with water and treated with a variety of chemicals to recover the mineral.

The name is fairly self-explanatory, as the process requires constructing large aerated tanks that are generally arranged in a series. So that runoff from one tank serves as raw material for the next. In this way, the reactor can operate in continuous flow mode, with fresh ore being added to the first tank while the runoff from the final tank is removed and treated. The ore being processed is generally crushed to a very small particle size to ensure that the solids remain suspended in the liquid medium. Mineral nutrients in the form of $(NH_4)_2SO_4$ and KH_2PO_4 are also added to the tanks to ensure maximal microbial density is maintained.

Due to extremely high cost of stirred tank reactors, they are only used for highly valuable minerals or materials. For gold extraction for example, this technique is usually used when the ore body contains high concentration of arsenopyrite (AsFeS).

Figure: 3 Stirred tank Biooxidation

2. Bioheaps :-

Bioheaps are large amount of low grade ore and effluents from extraction processes that contain trace amounts of minerals. Such effluents are usually stacked in the large open space heaps and treated with microorganisms to extract the minerals. Bioheaps are also called biopiles, biomounds and biocells. They are also used for biodegradation of petroleum and chemical wastes. The low grade ore are crushed and acid treated ore is then agglomerated so that the finer particles get attached to the coarser ones and then treated with the water and effluent liquid. This is done to optimize moisture content in the ore bacteria that is inoculated along with the liquid. The ore is then stacked in the large heaps of 2-10m feet high with aerating tube to provide air supply to the bacteria thus promoting bio oxidation.

Figure: 4 Gold Acres heap leach pad showing side slopes of the test region. The plastic pipes visible were used to supply the leach solution via drip and spray irrigators

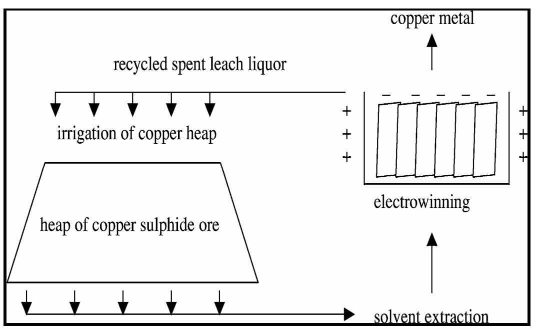

Figure: 5 Heap leaching of copper-containing ore.

3. In- situ Bioleaching :-

In this method the mineral is extracted directly from the mine instead of collecting the ore and transferring to an extracting facility away from the site of the mine. In-situ biomining is usually done to extract trace amounts of minerals present in the ores after a conventional extraction process is completed. The mine is blasted to reduce the ore size and to increase permeability and is then treated with water and acid solution with bacterial inoculums. Air supply is provided using pipes or shafts. Biooxidation takes place in-situ due to growing bacteria and results in the extraction of mineral from the ore.

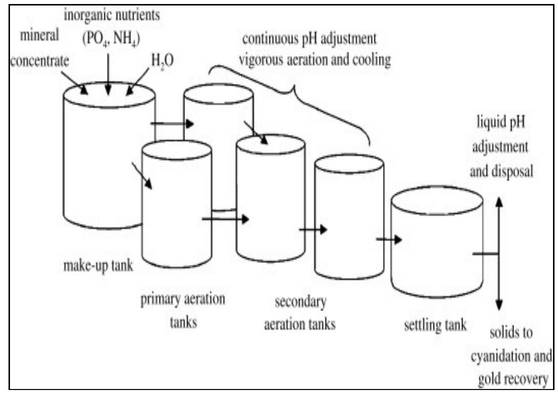

Figure: 6 Typical continuous-flow biooxidation process for pretreatment of gold-bearing arsenopyrite concentrate

Figure: 7 Bioleaching tanks

Process of recovery of metals through biomining

Minerals are recovered from ores by the microorganisms mainly by two mechanisms: (a) Oxidation and (b) Reduction.

(a) Oxidation

The microorganisms like *Thiobacillus ferroxidans* and *T. thioxidans* are used to release iron and sulfur respectively. *T. ferroxidans* oxidize ferrous ion to ferric ion.

$$4Fe + O_2 + 4H = Fe + 2H_2O$$

(b) Reduction

Bacteria like *Desulfovibro desulfuricans* play an active role in reduction of sulfates which results in the formation of hydrogen sulfides.

$4H_2 + H_2SO_4 \rightarrow H_2S + 4H_2O$

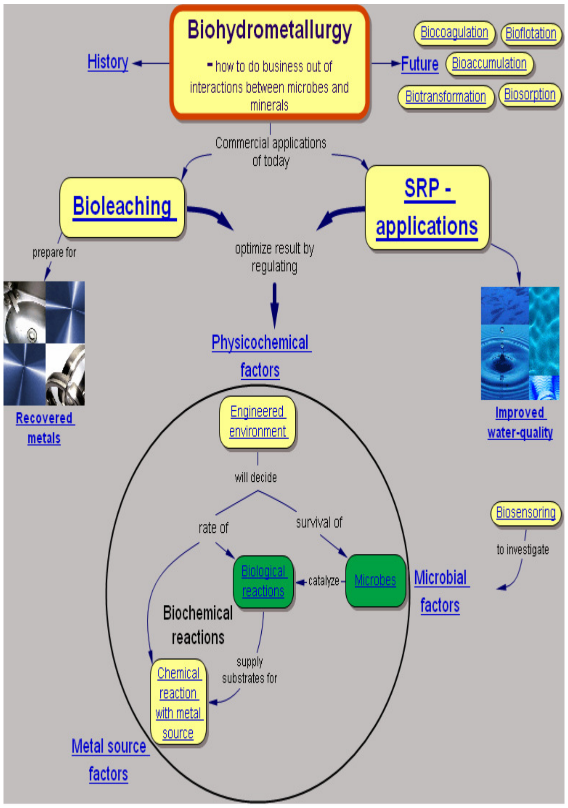

Figure: 8 Hydrometallurgy and biotechnology

Biological tools use for biomining:

A variety of mineral oxidizing bacteria readily found can easily oxidize iron and sulfur containing minerals. These include the iron- and sulfuroxidizing *Acidithiobacillus ferrooxidans* (previously, *Thiobacillus ferrooxidans*), the sulfur-oxidizing *Acidithiobacillus thiooxidans* (previously *Thiobacillus thiooxidans*) and *Acidithiobacillus caldus* (previously, *Thiobacillus caldus*) and the iron-oxidizing *Leptospirillum ferrooxidans* and *Leptospirillum ferriphilum.*

Several species of fungi can be used for biomining. Fungal strains *Aspergillus niger* and *Penicillium simplicissimum* were able to mobilize Cu, Sn, Al, Ni, Pb and Zn. Similarly, 'Phytomining' is based on the tendency of some plant species to bioaccumulate excessive amounts of metals from their host rock. The plants, called hyperaccumulators are grown on highly mineralized soils or post-mine lands and their yield (bio-ore) is used as a pure metal source. Compared to the bacterial mining, these technologies are not so popular primarily because of the longevity of these processes and so their unprofitability.

Microbes useful for biomining operations

There are wide varieties of bacteria with varying capabilities existing on earth. Therefore, it is essential to identify precisely the types that can perform biooxidation/ bioleaching effectively.

Thiobacillus ferrooxidans is a chemophilic, moderately thermophilic bacteria which can produce energy from oxidation of inorganic compounds like sulfur and iron. It is the most commonly used bacteria in biomining. Several other bacteria such as: *T. thioxidans, Thermothrix thiopara, Sulfolobus acidocaldarius* and *S. brierleyi* are also widely used to extract various minerals.

Thermothrix thiopara is an extremely thermophilic bacteria that can survive very high temperatures between 60-75^{o}C and is used in extraction of sulfur. Techniques like genetic engineering and conjugation are used to produce bacteria with desired characteristics to increase the rate of biooxidation thus increasing the mineral yield through biomining. It is also important to identify biomining bacteria present in colonies of other bacteria.

Characteristics of bacteria used in biomining:

Bacteria are most suitable microorganism for the extraction of minerals from low grade ores. The characteristics of the bacteria used in bio-mining are:

1. Bacteria which are thermophilic that is bacteria which can survive at high temperature are selected for biomining, as mineral extraction involves the high temperature procedures.

2. Bacteria which are chemophilic, as biomining uses both strong acid and alkalis.

3. Autotropic bacteria are selected for biomining. (Bacteria, which has the ability to produce energy from inorganic compounds through photosynthesis or chemosysnthesis).

4. Bacteria which have the capacity to form biofilms are selected for biomining purpose.

Important bacteria involving in biomining:

<u>ACIDITHIOBACILLUS</u>

Biomining bacteria belonging to this genus were previously included in the genus *Thiobacillus*. As a result of 16S rRNA sequence analysis, it became clear that the genus *Thiobacillus* included sulfur-oxidizing bacteria that belonged to α-, β-, and γ-divisions of the Proteobacteria. To solve this anomaly, the genus *Thiobacillus* was subdivided and a new genus, *Acidithiobacillus*, was created to accommodate the highly acidophilic members of the former genus. These members include *Acidithiobacillus ferrooxidans(At. ferrooxidans)* (previously *Thiobacillus ferrooxidans*), *At. thiooxidans* (previously *T. thiooxidans*), and *At. caldus* (previously *T. caldus*). These bacteria appear to be ubiquitous and have been isolated from sites that provide a suitable environment for their growth (such as sulfur springs and acid mine drainage) from many regions throughout the world.

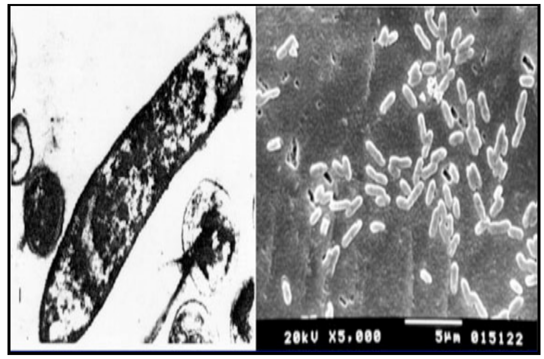

Figure: 9 *Acidithiobacillus bacteria*

Acidithiobacillus ferrooxidans:

This was the first bacterium discovered that was capable of oxidizing minerals. Nutritionally, typical *At. ferrooxidans* isolates are considered obligate autotrophs. They are also able to grow on formic acid. For many years *At. ferrooxidans* was considered to be the most important microorganism in biomining processes that operate at 40°C or less. It is currently understood that *At. ferrooxidans* is not favored in situations in which the ferric iron content is much higher than the ferrous iron (high-redox potential), such as found in continuously operating stirred tank reactors operating under steady-state conditions.

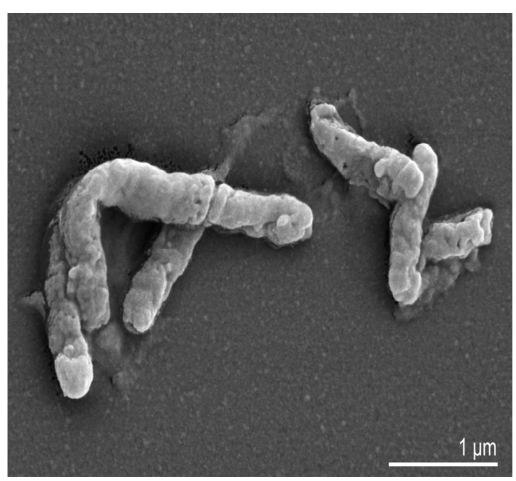

Figure: 10 *Thiobacillus ferrooxidans*

LEPTOSPIRILLUM

Bacteria of this genus are similar to Acidithiobacilli in that they are also highly acid-tolerant (optimum pH ~1.5–1.8), gram-negative, Chemolithoautrotrophic bacteria. Based on 16S rRNA sequence data, they are not members of the Proteobacteria but belong to the division Nitrospira. The Leptospirilli is that they are capable of using only ferrous iron as an electron donor. The Leptospirilli have a high affinity for ferrous iron and unlike *At. ferrooxidans*, their ability to oxidize ferrous iron is not inhibited by ferric iron.

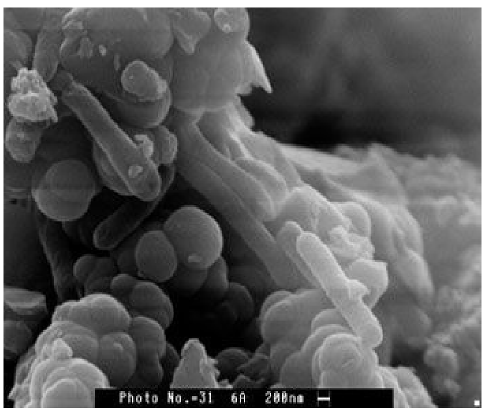

Figure: 11 *Leptospirillum bacteria*

ACIDIPHILIUM

Acidiphilium are acid-tolerant, gram-negative heterotrophs rather than iron- or sulfur-oxidizing autotrophs. As such, they are not primarily involved in mineral decomposition. They are included because they have been detected in a batch bioreactor and are frequently found growing near bacteria such as *At. ferrooxidans*, where they are believed to feed on the organic waste products produced by the iron and sulfur oxidizers. Indeed strains of Acidiphilium are sometimes so closely associated with *At. ferrooxidans* that they have been difficult to separate.

Acidiphilium are able to produce bacteriochlorophyll-a but are not able to grow using light as their sole energy source. One species, *Acidiphilium acidophilum* (previously *Thiobacillus acidophilus*), is unique among members of the genus in that it is able to grow autotrophically using reduced inorganic sulfur, heterotrophically using a variety of carbon sources, or mixotrophically using both organic and inorganic carbon.

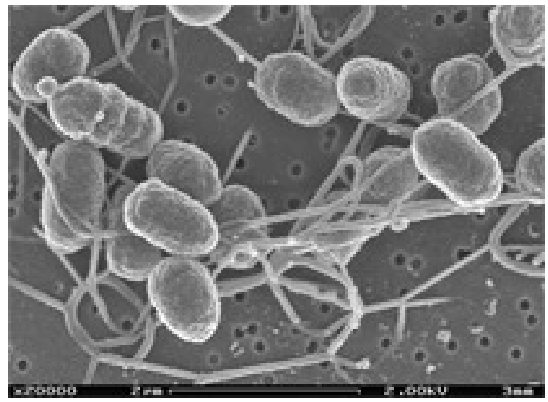

Figure: 12 *Acidiphilium bacteria*

SULFOBACILLUS & RELATIVES

Sulfobacilli are moderately thermophilic (40°–60°C), endospore-forming, gram-positive bacteria that have been isolated from heaps of mineral waste and of biomining operations. These bacteria are able to grow autotrophically or heterotrophically. When growing autotrophically they use ferrous iron, reduced inorganic sulfur compounds, or sulfide minerals as electron donors.

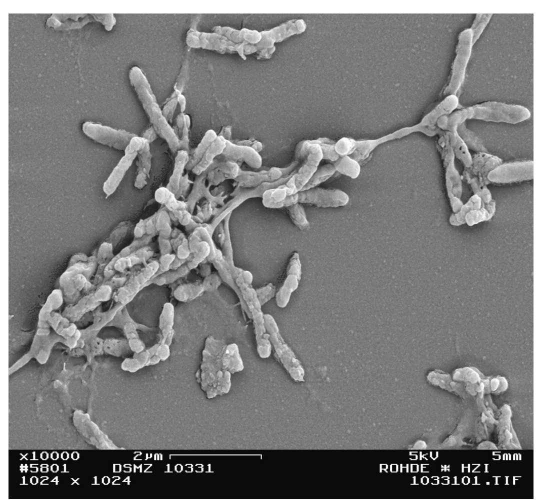

Figure: 13 *Acidimicrobium ferrooxidans.*

However, their ability to fix CO_2 appears to be poor. To grow strongly, they require elevated levels of CO_2 in the atmosphere, small quantities of yeast extract, or close association with heterotrophic iron-oxidizing bacteria such as *Acidimicrobium ferrooxidans.*

FERROPLASMA & RELATIVES

These organisms are pleomorphic in shape, and lack cell walls. *Ferroplasma acidiphilum* was isolated from a pilot plant bioreactor treating arsenopyrite/pyrite in Kazakstan. It oxidizes ferrous iron but not sulfur and appears to be obligatory aerobic. The archeaon is mesophilic, growing optimally at 33°C with an upper limit of 45°C. It has an optimum pH for growth of 1.7 and a lower limit of about 1.3. A closely related mixotrophic archeaon, *Ferroplasma acidarmanus*, was isolated from acid mine drainage. Similar archaea have been isolated from commercial bioreactors also treating an arsenopyrite/pyrite concentrate operating at 40°C at the Fairview mine in Barberton, South Africa.

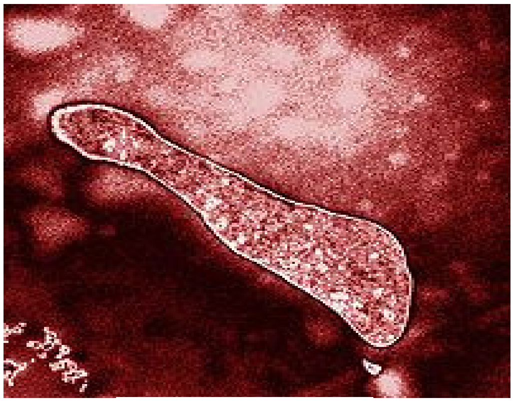

Figure: 14 *Ferroplasma acidiphilum*

SULFOLOBUS

These are obligatory autotrophic archaea grow by oxidizing ferrous iron, reduced inorganic sulfur compounds, or sulfide ores. *S. metallicus* is thermophilic. It is very capable of oxidizing minerals such as arsenopyrite and chalcopyrite,

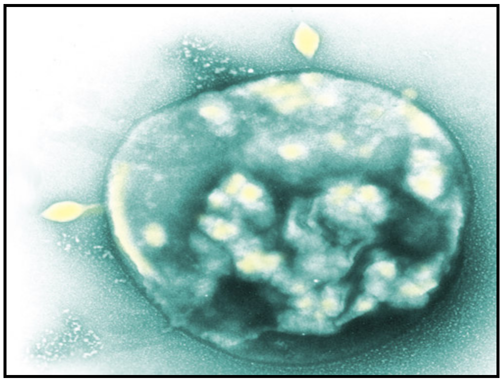

Figure: 15 *Sulfolobus metallicus*

METALLOSPHAERA

These archaea are aerobic iron- and sulfur-oxidizing chemolithotrophs that are also able to grow on complex organics such as yeast extract or casamino acids but not sugars. The species most frequently described in the context of mineral sulfide oxidation is *Metallosphaera sedula*. *M. sedula* has been reported to grow at pH 1.0 - 4.5 and is able to oxidize a variety of minerals at temperatures of 80°-85°C. Metallosphaera-like organisms have been reported to be potentially the most efficient at high-temperature bioleaching of recalcitrant chalcopyrite ores.

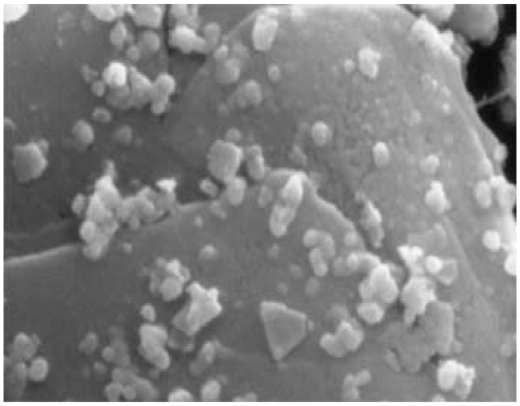

Figure: 16 *Metallosphaera sedula*

ACIDIANUS

There are several species of this group of archaea that oxidize minerals, although the industrial potential of this group is thought to be less promising than that of Sulfolobus and Metallosphaera. *Acidianus* *brierleyi* can grow autotrophically by oxidizing ferrous iron or sulfur, or grow heterotrophically on complex organic substrates. The optimum temperature is 70°C and the optimum pH is 1.5–2.0. *Acidianus infernus* and *Ad. ambivalens* are obligate chemolithotrophs that can grow either aerobically or anaerobically by the oxidation or reduction of inorganic sulfur compounds. *Ad. infernus* has an optimum temperature of 90°C and an optimum pH of 2.0.

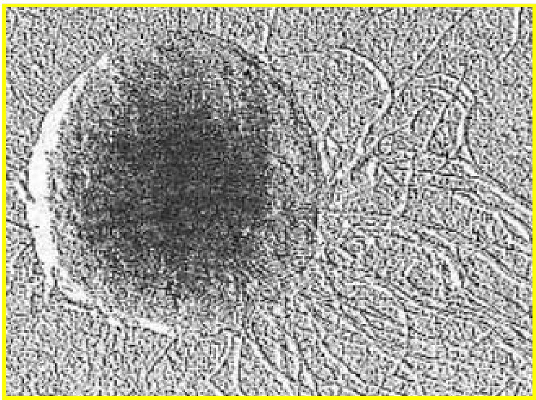

Figure: 17 *Acidianus bacteria*

Metals recovered in biomining processes

For many years biomining was thought to be a technology for the recovery of metals from low-grade ores, but today is being used as main process for recovery of copper and as important pretreatment step for gold recovery in their respective mining processes.

Biomining of Copper:

Biomining of copper demands conversion of water-insoluble copper sulfides to water soluble copper sulfates. Copper ores such as chalcocite (Cu_2S) or covellite (CuS) are crushed, acidified with sulfuric acid and agglomerated in rotating drums to bind fine material to courser particles before piling in heaps. The heaps are then irrigated with an iron- which percolates through the heap and bacteria growing on the surface of the ore and in solution catalyze the release of copper.

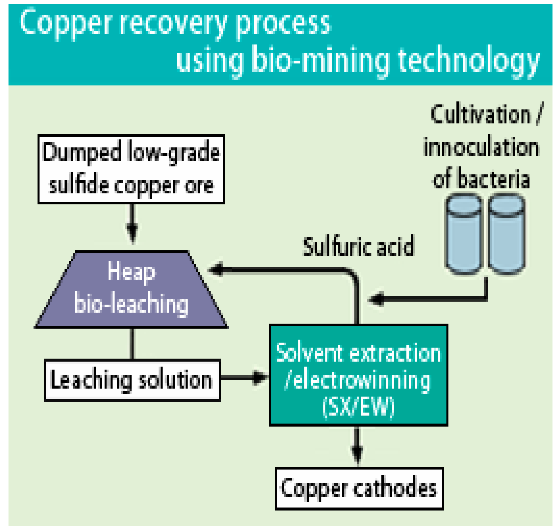

Figure: 18 Copper recovery process using bio-mining

Gold and Silver Leaching:

Today's microbial leaching of refractory precious metal ores to enhance gold and silver recovery is one of the most promising applications. Gold is obtained through bioleaching of arsenopyrite/pyrite ore and its cyanidation process. Silver is more readily solubilized than gold during microbial leaching of iron sulfide.

Biooxidation of refractory gold ores to extract gold is carried out by a commercial procedure called BIOX developed by GENCOR S.A Ltd Johannesburg South Africa in an effort to replace existing procedures which posed severe pollution problems. The BIOX process had several advantages over existing procedures including lower cost.

Figure: 19 Process of gold discharge

Uranium Recovery:

Uranium leaching is more important than copper, although less amount of uranium is obtained than copper. For getting one uranium, a thousand tones of uranium ore must be handled. *In situ* uranium leaching is gaining vast acceptance. However, uranium leaching from ore on a large scale is widely practiced in the USA, South Africa, Canada and India.

Figure: 20 Process of uranium recovery

Silica Leaching:

Magnesite, bauxite, dolomite and basalt are the ores of silica. Mohanty et al (1990) in India isolated *Bacillus licheniformis* from magnesite ore deposits. Later it was shown to be associated with bioleaching, concomitant mineralysis and silican uptake by the bacterium. It was concluded that silican uptake was restricted adsorption of bacterial cell surface rather than internal uptake through the membrane.

Biomining of other minerals:

Recent technological developments have helped to make possible the recovery of oil. Using microorganisms is one such technique to improve the recovery process hence called "Microbially Enhanced Oil Recovery" (MEOR). It was discovered in 1926 that microorganisms can be used in the petroleum industry to enhance oil recovery, but the concept became popular only after the1950s. Microbes can enhance the recovery of petroleum products directly or indirectly.

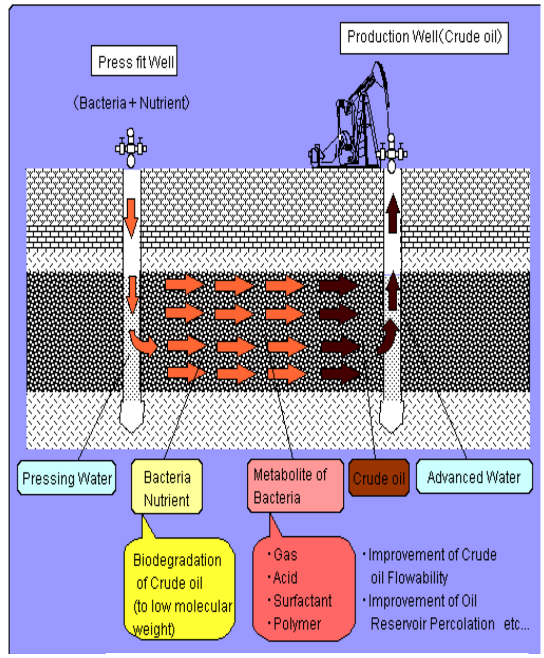

Figure: 21 Process of Microbial Enhanced Oil Recovery

Factors effecting biomining:

Success of biomining and efficiency in recovery of minerals depends on various factors

(a) Choice of Bacteria -

This is the most important factor that determines the success of bioleaching. Suitable bacteria that can survive at high temperatures, acid concentrations, high concentrations of heavy metals, remain active under such circumstances, are to be selected to ensure successful bioleaching.

(b) Crystal Lattice Energy -

This determines the mechanical stability and degree of solubility of the sulfides. The sulfide ores with lower crystal lattice energy have higher solubility, hence, are easily extracted into solution by the action of bacteria.

(c) Surface Area -

Rate of oxidation by the bacteria depends on the particle size of the ore. The rate increases with reduction in size of the ore and vice-versa.

(d) Ore Composition -

Composition of ore such as concentration of sulfides, amount of mineral present, and the extent of contamination, has direct effect on the rate of bio-oxidation.

(e) Acidity -

Biooxidation requires a pH of 2.5-3 for maximum results. The rate of biooxidation decreases significantly if the pH is not in this range since the activity of acidophilic bacteria is reduced.

(f) Temperature -

The bacteria used in biomining are either mesophilic or thermophilic. Optimum temperature is required for biooxidation to proceed at a fast rate. Optimum temperature range for a given bacteria is between 25-35 °C depending on the type of ore being selected. The rate of biooxidation is reduced significantly if the temperature is above or below the optimum temperature.

(g) Aeration -

The bacteria used in biomining are aerobic thus require an abundant supply of oxygen for survival and growth. Oxygen can be provided by aerators and pipes. Mechanical agitation is also an effective method to provide continuous air supply uniformly and also to mix the contents.

(h) Solid-liquid Ratio –

The ratio of ore/sulfide to the leach solution (water + acid solution + bacterial inoculum) should be maintained at optimum level to ensure that biooxidation proceeds at maximum speed. The leach solution containing leached minerals should be removed periodically and replaced with new solution.

(i) Surfactants -

Adding small amounts of surfactants like Tween 20 to the leaching process increases the rate of biooxidation of minerals from sulfide ores. The surfactants decrease the surface tension of the leach solution, thus, wetting the ore and resulting in increased bacterial contact which ultimately increases the rate of biooxidation.

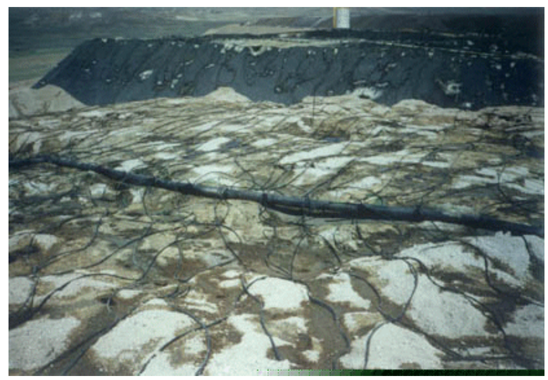

Figure: Top surface of sulfidic-refractory gold bioheap showing drip irrigation with water, sulfuric acid, and biomining microorganisms

Molecular Biology and Genomics of Biomining Organisms

The biomining organism that has been studied to the greatest extent by far is *At. ferrooxidans*. The 2.7-Mb genome of the ATCC23270-type strain has been almost completely sequenced by two organizations: Integrated Genomics, Chicago, and The Institute for Genomic Research. Many chromosomal genes and plasmids from related strains of *At. ferrooxidans* have been cloned and shown to be expressed and to function in laboratory strains of *Escherichia coli*. Most of this work has been recently reviewed. In addition, DNA has been transformed into several *At. ferrooxidans* isolates using conjugation and by electroporation into a single isolate. A recA mutant has been constructed by gene replacement, and the tools required to carry out molecular genetic studies as well as to modify the bacterium by genetic engineering are in place.

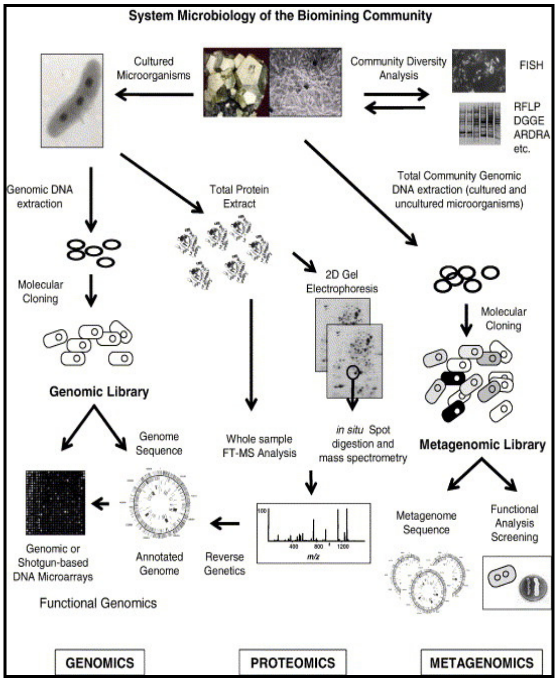

Figure: 22 Overview of the application of genomics, proteomics and metagenomics to biomining microorganisms.

Biomining - Environment Friendly Mining

The best method of sustaining the environment is such that returns back all the components (wastes) in a recyclable way so that the waste becomes useful and helps the biotic and abiotic relationship to maintain an aesthetic and healthy equilibrium that characterizes an ideal environment. The Biomining method is cheap, reliable, efficient and also environment friendly method of mineral recovery. Using biotechnology, efficiency of biomining can be increased by using genetically modified microorganisms.

Biomining contributes to sustainable development in the same way as all microorganism-mediated processes do. It uses existing organisms and mechanisms in nature. Traditional mining is an especially toxic process involving the use of chemicals like cyanide. Although the process of biomining does not yet completely eliminate the use of harmful chemicals, it allows for a lessened use, resulting in lower production costs of cleaning up the mining processes.

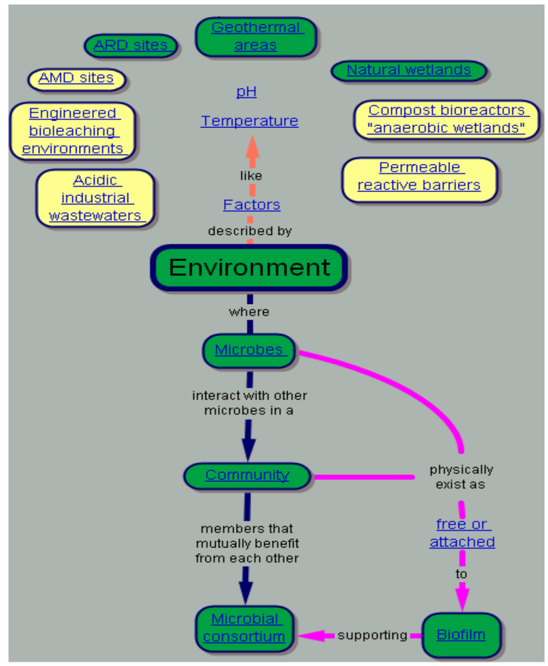

Figure: 23 Environment community interactions and microbes

Biotechnology and Biomining

Biomining uses naturally existing microorganisms to leach and oxidate. As well, studies of microorganism genomes are helping researchers to learn more about how microorganism biology works. This may lead to the genetic engineering of organisms for optimal biomining results.

Biotechnology or genetic engineering can be used to produce strains of bacteria which are resistant to heavy metals like mercury, cadmium and arsenic. These heavy metals slow the process of biomining. Therefore these heavy metal resistant bacteria can be efficiently used in biomining process.

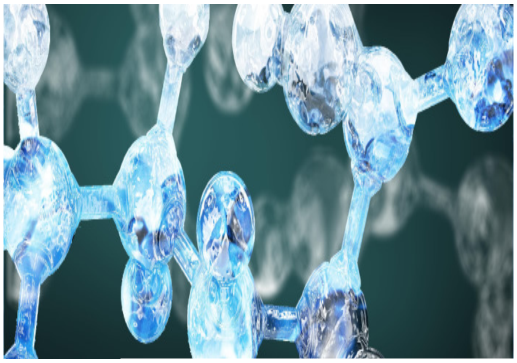

Figure: 24 Biotechnology– Bioanalysis Biomining from the mining center.

Current Research Areas in Biomining

Biomining is used by the mining industry to extract copper, uranium and gold from low grade ores but not for low grade manganese ore in industrial scale. The study of microbial genomes, metabolites and regulatory pathways provide novel insights to the metabolism of bioleaching microorganisms and their synergistic action during bioleaching operations. This will promote understanding of the universal regulatory responses that the biomining microbial community uses to adapt to their changing environment leading to high metal recovery. Possibility exists of findings ways to imitate the entire process during industrial manganese biomining endeavor.

There are continuing efforts to fully understand the basic biology of microorganisms, such as the *Thiobacillus ferrooxidans*. Researchers are seeking enhanced microbial performance in biomining processes through the identification of better indigenous strains and also through genetic engineering. However, because genetically engineered microorganisms need careful control and monitoring, they will not likely be available for commercial use for several years to come, and then only for controlled processes, like those possible in reactors.

Canadian researchers are also working on creating biomining conditions that will be optimal in the colder climates like Canada.

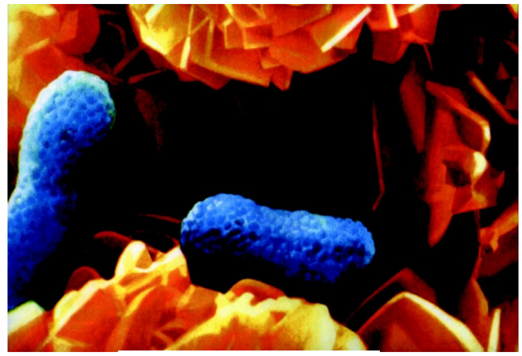

Figure: 25 Biomining made in Chile

Currently, 25 percent of all copper worldwide is produced through biomining. The process is used on a variety of other metals such as gold and uranium. Biomining is not yet a proven or profitable technology to apply to other metals such as zinc, nickel and cobalt.

Some advantages of biomining over traditional methods include reduced noxious gas production, and the elimination of toxic liquid waste produced as a result of chemical leaching. Biomining, however, is slower than traditional mining techniques and is not applicable to a wide variety of ores.

Figure: 26 Biomining technology

Biomining in India

Biomining is economically sound hydrometallurgical process with lesser environmental problem than conventional commercial application. However, it is an inter-disciplinary field involving metallurgy, chemical engineering, microbiology and molecular biology. It has tremendous practical application. In a country like India biomining has great national significance where there is vast unexploited mineral potential (Mogal and Desai, 1992).

The bioleaching technology of silica magnesite by using *Bacillus. Licheniformis* developed at Bose Institute, Calcutta, India is being used for the first time for commissioning a 5 billion tonnes capacity of pilot plant at Salem Works of Burn, Standard Co. Ltd, Tamil Nadu, in collaboration with the Department of Biotechnology, Govt. of India.

Hindustan Copper Limited is the sole integrated producer of primary copper in India. In the process of its multi-dimensional growth, HCL has been able to develop expertise in exploration, mining, beneficiation, smelting and refining of copper and recovery of by products such as Gold, Silver, Nickel Sulphate, Copper Sulphate, Selenium, Tellurium etc. The biomining technology not yet successfully introduced by HCL.

Figure: 28 Hindustan copper mining

Garbage bio-mining:

The Bruhat Bangalore Mahanagara Palike (BBMP) is exploring bio-mining as an answer to Bangalore's garbage woes. Bio-mining is clearing landfills by converting waste into compost, methane gas, bio-diesel and power.

GHMC (Greater Hyderabad Municipal Corporation) **i**n the Hyderabad city, the unique concept of bio-mining is being used to clear garbage heaps that have accumulated from years of solid waste dumping at Autonagar on city outskirts. More than 20 lakh tonnes of solid waste got collected at the dump yard, which became a matter of concern for the people living in nearby localities.

The GHMC has zeroed in on a private company, Bhavani Bio Organics, which offered to undertake bio-mining of the garbage mounds to make manure out of the waste at the 40-acre site. The company has been given a five-year contract, in which time, most of the solid waste is expected to be mined for manure.

Figure: 27 Garbage bio-mining

Future of biomining

Biomining or the "mining of the future". Indeed, it is much cheaper and greener than traditional mining - there are a lot fewer CO_2 emissions and carbon and water foot prints are lower than using conventional technology.

The future of biomining is challenging, as it offers advantages of operational simplicity, low capital and operating cost and shorter construction times that no other alternative process can provide. In addition, minimum environmental impact and the use of this technology in the mining industry are set to increase. Once commercial scale high-temperature processes have been designed, the variety of minerals that will become acquiescent to biomining will increase. Increased concern regarding the effect of mining on the environment is likely to improve the competitive advantage of microbially based metal recovery processes.

FORTHCOMING EVENTS		
Events	**Date**	**Place & Correspondence**
Conference on Myanmar Mining Investments	3-6 December 2012	Grand Copthorne Waterfront, Singapore http://www.myanmarmininginvestment.com
Ninth International Conference on Computational Fluid Dynamics in the Minerals and Process Industries	10-12 December 2012	MCEC, Melbourne, Australia, http://www.cfd.com.au

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