FACTFILE:
GCE ENVIRONMENTAL TECHNOLOGY

BIOHYDROMETALLURGY

Biohydrometallurgy

Learning outcomes

Students should be able to:

- define biohydrometallurgy as using bacteria to extract metals from low grade ore;
- understand that traditional metal smelting technologies are energy intensive and highly polluting;
- identify Thiobacillus ferrooxidans as bacteria capable of refining copper, zinc, lead and uranium;
- describe how suitable sites are identified and prepared for biorefining; and
- discuss advantages and disadvantages of biorefining in relation to traditional metal extraction methods.

Course Content

Biohydrometallurgy is also known as biorefining This is a process where bacteria are used to extract metal in commercial quantities from the leachate that has passed through an area of significant metal ion contamination.

It is a process which is different from bioremediation as the desired outcome is that sufficient metal will be recovered to make the process economically viable. Typically the technique is used on low grade ores such as mine tailings left behind from ore processing at an active or disused mine.

Traditional smelting of ore is very energy intensive and polluting.

The key steps in the process are;

- Ore is crushed mechanically in electrically driven grinders.
- The ore is roasted to drive out moisture.
- Thermal decomposition now occurs of Copper Carbonate or Copper Oxide in furnaces containing charcoal. Natural Gas is used to fire the furnaces. Carbon dioxide is released from the smelting process and from the burning gas.
- Thermal decomposition of copper ores containing sulphur. Again natural gas is used to fuel the furnace and oxygen is blown through the smelting ore. Sulphur dioxide (an Acid Rain contributor) is produced as a result. Carbon dioxide is released by the burning fuel gas.
- The ores refined by points 3 and 4 above are then purified by electrolysis. This involves large amounts of electricity.

Prior to the operation the following are considered:

- bio-prospecting for robust micro-organisms to enhance the leaching of low-grade ores, often the bacteria are already present at the mine site, or at sites elsewhere with similar conditions;
- identifying and characterising micro-organisms with special attributes using molecular biology methods;
- monitoring and influencing microbial populations to improve metal extractions, often by adding growth promoting additives to boost the bacteria already present;
- optimising whole-ore leaching for different minerals using a wide array of instrumented bioreactors, including columns where the tailings are filled in to bioreactors installed on site and the reactions are promoted under ideal conditions; and
- conducting preliminary test work on prospective heap-leach ores to characterise the metal content present.

A typical treatment regime for biomining might follow the steps below:

(i) the low grade ore and tailings, left from any earlier conventional mining, are piled up in an area, where the ground has been made permeable;

(ii) the pile is sprayed with a leaching solution that contains iron in the form of the Fe3+ ion, sulphate ions, (SO42-) and Thiobacillus ferrooxidans,' the sulphate ions in the leaching solution form sulphuric acid giving a suitable acidic solution essential for growth and activity of bacteria. This stage of the reaction may also occur in specially built reactors on site similar to those shown opposite in Uganda where cobalt is being extracted from mine tailings;

(iii) copper, released due to catalytic chemical reaction (facilitated by Thiobacillus ferrooxidans), is drained in the form of a solution;

(iv) the metal (copper) is then removed from the solution with the help of another solvent;

(v) the remaining leaching solution flows into an open pond, where Thiobacillus ferrooxidans catalyses a reaction that oxidises $Fe^{2}+$ into Fe^{+} ions and sulphide into sulphate ions, so that the leaching solution is now recharged;

(vi) the recharged leaching solution is pumped back to the top of the pile for the cycle to begin again;

(vii) the copper is eventually extracted from the solution using an 'electrowinning' process by passing electricity through the leachate solution. Copper is collected on the negative terminals; this process is costly and non biological. However 'bio-absorption filters' such as algae will be used in future to make the process entirely biological. Although this process will be energy dependent using electricity, traditional methods also use this step. Also the metal produced at this end step is very pure and of high value.

Pupil Activity

Create a flow map of this process of generating copper from mine tailings using *Thiobacillis ferrooxidans*. Add images where appropriate to clarify the process visually.

Site Preparation

Since the process involves passing acidified water through the mine tailings in an attempt to leach out the metal ions the following pre preparation activities are necessary prior to the extraction process:

- site is giving a suitable base with appropriate slope to allow desired fluid flow;
- site may need impervious membrane or lining depending on the risk of percolation to groundwater;
- tailings material is excavated, possible broken up, and stacked in heaps, or lifts;
- collection channel constructed to allow leachate collection;
- associated pumping, reactor vessels and pipe work needs built to allow circulation of leaching fluids and collection of leachate; and
- The final electrowinning(electrolysis) process may also be carried out on site, so these facilities would be built in advance;

Pupil Activity

Use the information in this fact file and in the link http://www.isca.in/rjrs/archive/v1i10/15.ISCA-RJRS-2012-329.pdf to produce a table of the advantages and disadvantages of biohydrometallurgy ove