Mining for gold and copper using biohydrometallurgy

Biohydrometallurgy is an application in mining which uses biology to aid metallurgy (as the name suggests). In its natural state a metal such as copper is found combined with other elements in the mineral chalcopyrite1. A bacterium is then used to form the compound copper sulphate (CuSO4), which in turn can be treated chemically to obtain pure copper. This microbiological mining process is used only with low-grade ores and currently accounts for 10%2 of copper production worldwide. Copper can be extracted from its ores by using bacteria.

This is done by, firstly the low-grade copper ore and also the tailings (left from an earlier traditional mine) are stacked up where the ground has been made impermeable. The ground is then sprayed with the acidic leaching solution (Thiobaccillus ferro oxidans and Thiobaccillusthio-oxidans 3). This solution is used because the bacteria used, thrive in acidic conditions and they also don't need any organic material on which to feed. The bacteria require Fe3+ ions, or S2- ions, oxygen and carbon dioxide. The bacterium may also need bacterial nutrients containing nitrogen and phosphorus.

The result is that the bacteria transfer the insoluble sulphide minerals into a solution of Cu2+, Fe2+, Fe3+ and SO42 – ions. The process would be carried on impermeable base layer on the ground to prevent ions leaking into the ground below it. As it is impermeable it is easier to drain the solution with copper ions. The bacteria are able to " extract" the copper ions from its ore because the bacteria obtain the energy they need to live by oxidising ions such as S2-.

These ions are present in copper minerals and when they are oxidised, the copper ions are released into a solution. After it is drained, the next stage is when copper (Cu^{2+}) ions are removed from the solution by ligand exchange solvent extraction which leaves other ions in the solution. The copper is removed by bonding to a ligand, which is a large molecule consisting of a number of smaller groups each possessing a lone pair. The ligand (L) is dissolved in an organic solvent such as kerosene and shaken with the solution producing this reaction: $Cu^{2+}(aq) + 2LH(organic)$ -; $CuL_2(organic) + 2H^+(aq)$The ligand donates electrons to the copper, producing a complex – a central metal atom (copper) bonded to 2 molecules of the ligand.

Because this complex has no charge, it is no longer attracted to polar water molecules and dissolves in the kerosene, which is then easily separated from the solution. Because the initial reaction is reversible, and therefore not a displacement reaction, it is determined by pH. Adding concentrated acid reverses the equation, and the copper ions go back into an aqueous solution. Then the copper is passed through an electro-winning process to increase its purity: an electric current is passed through the resulting solution of copper ions. Because copper ions have a 2+ charge, they are attracted to the negative cathodes and collect there.

The copper can also be concentrated and separated by displacing the copper with Fe from scrap iron: $Cu^{2+}(aq) + Fe(s)$ -; $Cu(s) + Fe^{2+}(aq)$The electrons lost by the iron are taken up by the copper. Copper is the oxidising agent (it accepts electrons), and iron is the reducing agent (it loses electrons). The left over leaching solution flows into an open pond, where T. ferro oxidans catalyses oxidation of the remaining Fe^{2+} ions to Fe^{3+} ions.

This process of oxidation recharges the leaching solution, which is pumped back to the top of the pile for the cycle to begin again. Gold could also be extracted in a similar way, using bacteria. Fifteen to thirty percent4 of the world's gold reserves are trapped in refractory minerals such as chalcopyrite. Firstly the refractory sulphide concentrate (from the minerals) was treated with the thermophillic bacterium Sulpholobus acidocalderius.

These bacteria then catalysed the oxidation of the encapsulating sulphide minerals by dioxygen, under fixed aqueous conditions at 70 o C. Cyanidation of the final and resulting extract led to a breakthrough, in which the gold recovered increased from 10% to 100%5. Then a mixed culture of moderately thermophillic bacteria from certain samples was introduced. This culture became effective over a wide range of conditions such as temperatures, pH, water salinity and arsenic concentration.

Researchers found out that the bacteria worked best at 46 oC (if the temperature is to high, enzymes building the bacteria cell will be denatured due to a higher temperature) and in solutions with a pH of between 0. 5 and 1. 5. These greatly enhanced the percentage of gold extracted.

This new process has many advantages and disadvantages. One of the main advantages of this process is that it cost much less than the traditional method. Mining copper by the traditional method can cost between $130 and $200 per tonne. The introduction of Biohydrometallurgy rapidly reduces the cost to around $70 per tonne.

The result is that one tonne of mined copper typically results in two tonnes of sulphur dioxide being pumped into the atmosphere whereas biological extraction avoids this. Another advantage is that this biological process of mining has no environmental problems associated with it. This is because the whole process is biological apart from in the copper extraction where Electro winning is used where the ions are separated. The main disadvantages of Biohydrometallurgy are that it is slow, requiring decades rather than years, and methods for breaking ores into small enough particles for efficient extraction are not yet available. Already, biological methods are economically feasible for low-grade ores that elude conventional methods, but further technological innovations may make them competitive in more situations. Also the mining industry have not yet taken on this new process because there is a general lack of familiarity with the technology – there are few trained biohydrometallurgists and few commercial success.

The industry is also concerned with the reliability of this biological process because of the length of time it occurs in. Bacterial leaching is used as a secondary process in the extraction of copper because the process is to slow and uneconomic because less money is made. Also when using the traditional method when extracting copper, more copper can be obtained from the ore. The bacterial process of extracting gold is used as a primary process (secondary process is the traditional method) because the research and technology has been developed fast. More economic because more gold is produced so more money to be made. There is also a low cost of running the plants.

Also the whole process is more feasible and economically competitive with the conventional process. For a new process for bacterial leaching to become commercial the government and political powers must approve and also regulate a new process and may need to provide funding. A Political power may need to hold an enquiry into the effects of this new technology to check if it is mandatory and safe. Thus granting permission for the new technology to go ahead. SummaryThis type of bacterial chemistry in order to obtain metal from its ore is a new technology but the industry is still yet to recognise it.

Its main advantage is it cheap and mostly environmentally friendly compared to traditional methods. This type of process will lead us into the future.