Bioleaching: A Game Changing Technology in the Tailings Reclamation Industry

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Bioleaching technology developed by BacTech Mining Corporation employs the use of naturally occurring bacteria, harmless to both humans and the environment, to liberate precious and base metals from difficult to treat ores and concentrates. The registered trademark for BacTech's technology is "BACOX". BacTech is one of only two companies worldwide to have successfully commercialized its gold bioleach technology and has supplied technology to mining operations to aid metals extraction since 1994. By virtue of having no direct competition, the Company is the leader in the base metal bioleach arena and, with a successful demonstration of the technology in Cobalt, Ontario, will hold a significant advantage over late entries to the field.

Historically, liberation of metals has been achieved by smelting, or burning, of sulphide ores or concentrates. Concentration of metal sulphides into a smaller mass is often performed prior to smelting or bioleaching, as these are the more expensive parts of an overall operation, and it is cheaper to treat smaller tonnages of material. Although economically efficient, smelting produces noxious $S0_2$ emissions that create acid rain. Bioleaching produces no offensive gases as it is a hydrometallurgical form of treatment.

There are often many deleterious elements such as arsenic associated with sulphide minerals and these often report to the flue gases in smelting. Bioleaching has a further environmental attribute by effectively stabilizing any arsenic present and producing a stable end product for tailings disposal. BacTech has successfully licensed its proprietary gold bioleaching technology on three separate occasions, of which two plants are still operational. The Company is now turning its focus to adapt bioleaching to a range of different sulphide hosted base metals. Although the bioleach segment for treating sulphide-based base metals is similar to gold, there is considerable work still to be done on the up front (concentrate) and back end (metals recovery). The only effective way to answer these questions is through the operation of a demonstration plant in the Cobalt area of Northern Ontario.

Put simply, bioleaching uses naturally occurring bacteria in reactors (tanks) to oxidize sulphides. The key is that by providing the bacteria with optimal operating and living conditions in reactors, they are capable of oxidizing metal encapsulated in sulphides in as little as 5-6 days, as opposed to many years in their natural habitat. This is a common residence time in a commercial bioleach plant and the control of this and other parameters, such as the particle size of feed, are relatively simple and readily managed by operators with the correct training.

There exist numerous opportunities, both in Canada and abroad, where bioleaching can be employed to reprocess existing tailings deposits left behind by miners. These deposits have two things in common. First is the presence of sulphide minerals deemed to be too difficult to process at the time of mining. These sulphides oxidize naturally over time creating sulphuric acid in the process, also known as acid mine drainage ("AMD"). Second, the tailings tend to be older, therefore the liberation technology used at the time would not be as efficient as that which is used today, resulting in economic grades of various metals trapped in these sulphide tailings. In essence, its is these residual metals that allow BacTech to pursue its goal of rehabilitating acid generating mine tailings, while receiving compensation from the resale of captured metals in the tailings.

Sustainable Development Focus

The benefits of using bioleaching as a liberation technology are numerous, but for this discussion, we will focus on the neutralization of arsenic from mine tailings. As stated earlier, the historical approach to treating refractory, arsenic ores has been accomplished using smelting and/or roasting. This entails subjecting the sulphide ore to intense heat, whereby the sulphides are burned off, leaving the desired metals for recovery. A side effect of burning sulphides is the creation of arsenic trioxide (As_20_3) which is partially released into the atmosphere. Identification of this issue has led to the institution of strict limits on the amount of arsenic that can be burned through a mineral treatment process. The general industry rule is that smelters cannot treat concentrates that contain more than 5% arsenic, and they are also subject to a total tonnage limit that can be produced in a given year.

Since bioleaching works in the absence of heat, there are no arsenic trioxide gases produced through the process. In fact, bioleaching can treat concentrates with much higher levels of arsenic than what would be allowed using a pyrometallurgical process. Concentrates produced from tailings in the Cobalt region regularly return assays for arsenic of over 10%, thereby eliminating them from consideration for smelting. Bioleaching, given access to a ready supply of iron, either internally generated or through the addition of pyrite from external tailings, can handle much higher levels of arsenic for neutralization. Despite the Cobalt tails having reasonable levels of iron present, only a portion of the iron will be soluble. As a molar ratio of at least 3:1 of iron to arsenic is required for the formation of stable ferric arsenate, it will be necessary to add iron as pyrite or pyrhotite to the bioleach process. Such sources of iron do exist in the region and we are aiming to identify such materials with residual precious metals such that they will help offset the cost of their own oxidation in the bioleach process.

In addition to the avoidance of $S0_2$ airborne emissions, bioleaching converts the arsenic present in the tailings into ferric arsenate ($FeAsO_4$), which is a stable end product and safe for disposal. According to Ontario Regulation 558, as long as the ferric arsenate remains stable under the Toxicity Characteristic Leaching Procedure (EPA Test method 1311), the material is classified as non-hazardous (classification number P012; ON1096) and able to be disposed of in a non-hazardous waste site. Our bioleach plants in the gold industry treat multiple types of arsenical concentrates and readily achieve the Ontario Regulation 558 criteria. We also routinely monitor any ferric arsenate produced according to the TCLP protocol to ensure the material remains stable.

Technological Feasibility

A major benefit of bioleaching is its unique way of solving an old problem. As stated earlier, the historical method for treating mine concentrates or sulphides was with a pyrometallurgical solution.

Smelting and roasting do an admirable job of releasing metal from sulphides, but do so at the expense of creating detrimental air pollution. Bioleaching is the leader in the emerging field of hydrometallurgy or extracting metal using liquid processes. There are numerous technologies that are being developed using a hydromet process, but only BacTech and Gold Fields have successfully commercialized their gold bioleach processing technologies to date. BacTech intends to apply its proven technology to base metal extraction and arsenic remediation. An example of an alternative hydromet process to bioleaching is pressure leaching, in which high temperatures and pressures are used to "crack-open" sulphides. However, these processes are expensive and complicated, using sophisticated equipment requiring a high skill level, making it difficult to train local people as operators. The high cost of a pressure leaching operation also makes it more vulnerable to low metal prices, making the long term viability of pressure oxidation more questionable in these times of economic uncertainty. A common theme for many environmental applications of bioleaching technology is the inability to make a high enough grade of concentrate containing sufficient metal value to sustain an expensive treatment process such as pressure leaching -- or if a high grade concentrate can be made, then only a small proportion of the metals can be collected into the concentrate, making a potential remediation operation ineffective, as much of the metal value and harmful elements such as arsenic are still left in the original feed material. As bioleaching is able to process lower grades of concentrate, this makes the operation far more amenable to remediation applications, as the concentrate can recover more of the metal value and harmful elements if there is less emphasis on the need to meet a specific criteria for the grade of concentrate to be produced. A common query for any arsenic treatment process relates to the stability of the final arsenic product and it's fate overtime in the environment. The stability of the final ferric arsenate product has never been an issue at our arsenical gold projects nor to the best of our knowledge has it been a concern at any of our competitor's sites, making a total of 20 projects worldwide since 1986. Over this time a variety of sources of published literature confirms the stability of the final products from commercial bioleach plants. One such reference entitled "Neutralisation of Bioleach Liquors" by Nyombolo et al of Mintek South Africa (a quality accredited world class research facility) tested the stability of ferric arsenate precipitates over a 7 year period and concluded the following : "For all of the tests, the very long-term trend is for an improvement in arsenic stability. Precipitates that are stable initially tend to remain stable, and those that exhibit some instability in the first few years appear to gain in stability after about two years. This is a very encouraging finding, and indicates that fears that a decrease in stability could occur over the long term are unfounded."

The best way to determine BacTech's ability to stand behind its research and development capabilities is to review the path taken by the Company to arrive at its current position.

• Bioleach technology first investigated at King's College, London, England for the elimination of sulphur from coal in the mid 1980s
• Technology, still in its infancy, migrates to Perth, Australia, in the late 1980s, where it is funded privately
• 1994: A public company, Gold Mines of Australia, builds the first BacTech bioleach plant at the Youanmi Mine in Western Australia. Bioleaching provides additional mine life of three years processing refractory arsenic gold concentrates from the mine. The mine was closed in 1997 due to low gold prices,

but BacTech had its first successful commercial application.

• 1998: A public company, Allstate Mining, licenses and installs the 2nd BacTech bioleach plant to process refractory arsenic ore from the Beaconsfield Mine in Tasmania (Australia). The mine is now in its 11th year of continuous operation.

• 2000: A Chinese company, Shandong Tarzan Biogold Co. Ltd. ("Biogold"), licenses and installs a bioleach plant capable of treating 100 tonnes of concentrate per day from mines both in China and abroad, demonstrating the diversity of the technology for treating non-homogenous feeds from various metallurgical backgrounds. Recently, the current owner, Sino Gold Mining Limited, doubled the capacity of the current plant to 200 tonnes per day.

• 2001: Industrias Peñoles S.A. de C.V. ("Peñoles"), the world's largest silver producer, contributed USD$5 million to build a demonstration plant in suburban Monterrey, Mexico, to test the technology's ability to treat dirty or complex base metal concentrates. The findings of the study proved the benefits of bioleaching with respect to (a) neutralizing deleterious elements in the concentrate, and (b) eliminating costly transportation of concentrates to smelters, thereby reducing the environmental footprint left by smelting and truck haulage usage. It should be noted that since 2001, research and development carried out by BacTech has led to many improvements to our technology, and what exists today is considerably different to what was used at that time.

Even though we are comfortable with the application of our technology for gold, there remain some technical barriers in base metals that we hope to address through the demonstration plant in Cobalt, Ontario. The bacteria will attack sulphides both in gold and base metal applications. The major differences in the technologies occur in the upstream and downstream processes that complete the process chain. In gold, most arsenopyrites are floated to produce a suitable concentrate for bioleaching. Our findings, to date, for producing a base metal concentrate from Cobalt tails show that floatation and gravity can be used either independently or in concert with one another. This can be attributed to the unique nature of the metallurgy in the Cobalt camp, where different tails produce different responses to different methods of concentration . The goal in all cases, obviously, is to capture as much metal, including the arsenic, into a concentrate that provides enough value to make the operation commercially viable. To date, we have had a good response from test work for gravity and flotation concentration and would expect most tails in the Cobalt region to respond well to either gravity or flotation either independently or in combination. The commercial facility is most likely to use both concentration techniques in tandem. However, test work into concentration methods will be ongoing through the demonstration as new deposits are presented for reclamation.

Conversely, assuming the accomplishment of metal recovery goals and determination of the viability of bioleaching, the resulting concentrates we will be presented with may give downstream challenges for producing physical metal. There are two basic paths we can follow once we have successfully put the base metals into a soluble state. First we can plate Cobalt and nickel through the use of solvent extraction, electrowinning ("SX-EW"), a known finishing step in various base metal operations worldwide. The drawback is that SX-EW is a costly technology from a capital point of view, and could have a negative impact on the project's IRR. The associated silver would be recovered using standard recovery methods, as it remains with the residues of bioleaching. Second, we can produce a cobalt/nickel precipitate which would be sold to an appropriate buyer. This may end up being difficult, as the market for such a product could be limited. Therefore, an important goal of the demonstration plant is to not only show that a high reclamation of arsenic complemented by a high recovery of metals is consistently achievable, but that high product qualities of all the final entities are also sustainable over a reasonable time frame of operation. The mission of the demonstration plant is to create the highest added value for the environment in terms of mine waste remediation, while showing that a meaningful revenue stream is likely to be created for a larger commercial venture for sale of metal products.

Since bioleaching is an intermediate step in base metal extraction, we will constantly monitor technological advancements in both upstream and downstream applications. Clearly the technical objective of operating the demonstration plant is to provide the design information for a larger commercial facility capable of treating different tails from the Cobalt region. We believe that the majority of the 18Mt of regional tails could be processed in a commercial facility that will adopt a broad design envelope to cater for variations in tails characteristics. Our plant in China was designed using a similar strategy for being able to treat "unknown" arsenical gold ores from a variety of origins. Bioleaching lends itself to this type of strategy and copes with greater fluctuations in feed types than smelting or pressure leaching processes. Available information suggests a similarity in the mineralogy exists for the different cobalt tails, which is helpful for our concentrator design. In the commercial treatment scenario, each of these tails would be sampled and tested in the laboratory prior to reclamation and processing in the commercial facility to ensure that the arsenic can be extracted/stabilized and the metal values recovered. This is similar to the strategy currently employed in our plant in China where samples are sent for testing prior to establishment of contracts for treatment. In the nine years of operation of the plant in China it has been very rare for a concentrate to be rejected as un-amenable to processing.

BacTech has always protected its intellectual property through the application of process patents in countries where deemed necessary. Since bacteria are naturally occurring, we cannot apply for any protection on them as entities but can apply for patents relating to their application. This project is very likely to result in advances to our base metal bioleach technology and we will apply for patents as appropriate. However what we have found is that the art of bioleaching is made up of 50% process patent and 50% know-how. To illustrate this statement, we look to our operation in China which has been in continuous production since 2001. In the seven year interval, no less than four bioleach plants have sprung up in China in an attempt to replicate BacTech's technology, none of which are operational today. Upon further investigation by Dr. Paul Miller of BacTech, it was his finding that, although the outward appearance of the plant appeared to be remarkably similar to the Biogold plant, the inner workings were not capable of producing the desired outcome. We are confident that the technology will be compromised in the future in China. With this in mind, we sold our gold technology to a third party in early 2008, but we continue to own the base metal intellectual property. The only other successful installation in China uses technology supplied by Gold Fields of South Africa who are our only commercial competitor in gold bioleach technology. As mentioned previously, we have no commercial competitors in the field of base metal bioleaching.