Heap Leaching and the Water Environment – Does Low Cost Recovery Come at a High Environmental Cost?

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Abstract

Heap leaching is a processing technology with low operating costs and is being increasing considered for the treatment of marginal grade metalliferous ores.

However, heap leach facilities significantly modify the site water balance and pose a risk of process water loss to the receiving environment. Historic mismanagement of heap leach operations has caused widespread environmental damage, and civil society and regulators may therefore regard heap leaching with caution. Heap leach facilities may also prove challenging to regulate in terms of mining environmental legislation since they function as processing facilities during operation but become *in situ* waste facilities on closure.

Key words: Heap leaching, metallurgical processing, mine waste facility, operating cost, environmental impact, water balance, legislation

Introduction

Companies are looking to optimise economic benefit from their existing investments and are therefore considering opportunities for cost-effective processing of low grade metalliferous ores that would otherwise be discarded as 'mineralised waste'. Heap leaching is a hydrometallurgical technique that often has lower operational costs than more conventional processing technologies and is increasingly being considered both in the design of new mines and the expansion of existing operations.

However, there are several well documented examples of heap leach facilities such as Summitville in Colorado where poor design and/or mismanagement have resulted in extensive environmental damage, particularly to the water environment, downstream ecosystems and users. Heap leaching may therefore considered to be a processing technology with a 'bad reputation', and is regarded with caution (and sometimes outright hostility) by both regulators and civil society. In the gold sector, scepticism about the environmental acceptability of heap leaching is compounded by the use of cyanide - an exceptionally emotive chemical – as the reagent to liberate gold from the ore.

This paper will examine the potential environmental impacts of heap leaching and examine whether this often controversial processing technology can be managed in an environmentally responsible manner, or whether low cost processing comes at an unacceptably high environmental cost.

What is heap leaching?

Heap leaching is a hydrometallurgical process whereby ore is stacked onto an impermeable base and 'irrigated' with a process solution that liberates the product from the ore and mobilises it into solution. The 'pregnant' solution is then intercepted at the base of the heap leach pad via a series of underdrains and transferred via solution channels to process solution ponds. The pregnant solution is treated according to the specific processing requirements of the commodity, and the 'barren' solution is circulated back for reuse in the circuit: thus, the process reagents are maintained within a closed process water circuit (Kappes, 2002). Heap leaching is seldom (if ever) a 'stand alone' technology and is only the first stage of the metals beneficiation process. The product generated by a heap leach facility is a 'pregnant' solution which must be further beneficiated into a saleable product in another processing facility - for example through an elution and electrowinning circuit in a gold context – and thus, heap leach facilities are functionally linked to a 'conventional' metallurgical plant elsewhere.

Operational and environmental advantages of heap leaching

Heap leaching can be a low cost means of treating low grade metalliferous ores, especially where the orebody is oxidised. Because heap leaching facilities have lower operational costs than conventional hydrometallurgical plants, heap leaching provides a potentially economic method of treating ores that might otherwise not be processed. It could therefore be argued that in the absence of low cost treatment options such as heap leaching, many low grade ores could not be economically processed:

thus, failure to treat low grade ore due to lack of low cost processing alternatives could result in a range of unacceptable economic, socio-political and environmental impacts, as discussed below.

Optimal exploitation of the orebody

High metals prices have prompted mining companies to consider treating previously uneconomic ore. Where the company has already incurred the capital expense of developing mine infrastructure, the consequence of not processing marginal grade ore because of uneconomic conventional processing costs is that the company does not reap maximum benefit from its investment. Another consequence of a company's failure to exploit the full potential of an orebody (by not mining low grade ore) is diminished taxation revenue for the host nation: this is particularly topical in an era of growing 'resource nationalism' throughout the developing world, where there is a political imperative for mining companies to demonstrate that the orebody has been exploited to its full potential.

Reduced requirement to dispose of low grade ore as mineralised waste

Failure to process low grade ore results in greater volumes of this material having to be disposed of as waste rock. This has negative economic implications for the company in terms of costs relating to the handling and disposal of larger amounts of mineralised waste. Larger waste rock dumps may also result in a greater magnitude and/or extent of environmental impacts associated with mineralised waste disposal (such as land sterilisation, metals leaching and acid drainage) and could also negatively influence the financial provision for closure due to the increased size of waste rock facilities requiring rehabilitation in order to meet the site's agreed closure criteria.

Optimised reagent usage

Heap leaching can result in more efficient reagent usage than some conventional metallurgical processes, as the process chemicals are retained within a closed circuit and recirculated for use (thus reducing the requirement for reagent 'top up' to maintain the leach solution at effective process concentrations).

Potential environmental impacts of heap leaching

Environmental concerns associated with heap leach facilities revolve primarily around failure to contain process solutions within the heap leach circuit and their potential release into the receiving surface and subsurface environment, with resultant impacts on the health of people, livestock and ecosystems.

Impacts on the project water balance

The construction of heap leach facilities can significantly influence the mine water balance in terms of both the volume of water to be managed and the potential for transfer of water between catchments.
The heap leach component of the mine water system must be operated as a closed water circuit under normal operating conditions: in certain jurisdictions, it may be possible for an operation to secure permits to treat and discharge excess stormwater from leach pads, although this is likely to require persuasive motivation based on extensive investigations to identify, quantify and mitigate the possible impact on the downstream catchment(s) within acceptable limits. The large size of many heap leach facilities requires the retention of enormous volumes of wash down water after storm events: for example, the world's largest heap leach complex at the Yanacocha mine in Peru comprises five active heap leach facilities that will have a pad surface area in excess of $2.7km^2$ once the Carachugo Stage 9 and Cerro Yanacocha Stage 4 facilities are completed, and the pad area is set to more than double with the development of the proposed La Quinua/Cerro Negro heap leach facility (Smith, undated).

Impacts of potential exposure to process solution on people, livestock and wildlife

The concentration of the process chemicals used in the heap leach circuit is similar to that in conventional minerals processing facility. However, the heap leach infrastructure is spread over a much larger area than a metallurgical plant, over which it is much harder to achieve effective access control for people, livestock and wildlife. Allied to this, the process solution is often exposed to the environment in open solution trenches and process ponds rather than being contained in process vessels with limited access, thus posing a much greater threat to animal – for example, in 2001 alone, AngloGold reported 554 bird fatalities at its Yatela heap leach facility in Mali through ingestion of cyanide-bearing process solution (Anglogold Ashanti, 2004). There may also be potential risks to worker health and safety associated with the windblown dispersion of process solution droplets from the leach pad, particularly from facilities using spray (as opposed to trickle) irrigation, although these are likely to be limited in aereal extent.

Beyond the immediate confines of the heap leach pad, there is potential for process solution release from the leach pad circuit to deteriorate water quality in the receiving environment, sometimes to the point of compromising its beneficial use. Such releases from a process water circuit that should operate as a closed system with no losses to the surface or subsurface environment can result from inadequate design of seepage and overflow containment facilities, poor construction and/or poor management of the heap leach water balance.

Costs associated with pollution control and closure

Heap leaching is a low cost processing technology in the operational phase, but the potentially high costs – and often extended time frame - associated with the wash down, closure and rehabilitation of spent heap leach pads is often overlooked. The often onerous engineering and financial requirements required to meet the operation's commitments to pollution control and rehabilitation/closure may not be recognised at a feasibility stage, particularly by companies who have not previously undertaken heap leaching projects. Thus, companies who are attracted to this technology because of the low operating cost – but have not fully factored in broader environmental costs - may find that they have significantly underbudgeted for these activities.

Civil society perceptions of heap leaching

Extensive water contamination resulting from poorly designed and/or managed heap leach operations such as Summitville and the Kendall Mine in Montana has left civil society sceptical about the environmental acceptability of heap leaching and the effectiveness of the environmental controls that are in place at such facilities. Stakeholders express particular concern over the potential for process solutions to escape from the mine water circuit and to impact on the surface and groundwater environment, thus posing a risk to humans, livestock, wildlife and aquatic ecosystems, as well as potentially compromising the beneficial use of water for downstream users. In 1998, a citizen's initiative to phase out open pit cyanide leach mining in Montana was voted into law via a state-wide referendum (Montana Environmental Information Centre, 1999), although it should be noted that the motivation was focused as much on objections to the use of cyanide as concerns about heap leaching.

Legislative and governance issues

Given its controversial reputation, much of the mining-related legislation worldwide remains surprisingly silent on the issue of heap leaching and the environmental controls required to responsibly manage this activity: this is even the case in jurisdictions such as Colorado in the United States which have had negative previous experiences of poorly designed and/or managed heap leach facilities. In Africa, where over 30 nations have updated their mining legislation (and associated environmental regulations) since 1990, it is still rare to find specific reference to heap leaching in mining or environmental legislation (even though many of the deeply-weathered orebodies – particularly in the tropical zone - could potentially be processed by heap leaching in the future) and even very recent pieces of legislation such as the South African Minerals and Petroleum Resources Development Act which came into force in 2004 contains no reference to this processing technology.

Heap leach facilities are particularly difficult to categorise in terms of conventional metallurgical facilities. Heap leach pads are unique in that during their life cycle, they are transformed from operational metallurgical treatment facilities into process waste facilities on closure. This in *situ* metamorphosis in function does not occur in any other form of mineral beneficiation and is therefore unlikely to have been anticipated by (and thus catered for) by regulators that have had no previous experience of heap leaching processing.

It is true that the potential environmental impacts that could result from poor managed heap leach facilities are generally covered by existing environmental legislation, but usually in a generic manner such as impacts on the water environment or on biodiversity. Thus, the regulator needs to be knowledgeable enough about heap leaching to predict the potential environmental and socio-economic

impacts, invoke the relevant legislation and anticipate the management controls that will need to be implemented. This poses a particular problem in countries where heap leaching has not been previously undertaken and/or where there is poor capacity within the regulatory authorities that limits their ability to apply legislation outside the context of conventional metallurgical plants.
Voluntary industry initiatives such as the International Cyanide Management Code were originally developed for traditional gold plants and do not accommodate heap leaching as readily as more conventional forms of gold processing. Similarly, codes of practice to regulate the disposal of mine processing waste such as SANS 0286 in South Africa make no mention of heap leach operations. Even guidelines developed by the International Convention on Large Dams (ICOLD) which explicitly address other water-retaining mine waste facilities such as tailings dams do not specifically reference heap leach facilities, despite the fact that the heap leach solution ponds may be extremely large.

Discussion

So, does the low cost processing that heap leaching potentially offers come at an unacceptably high environmental cost? There is little doubt that the quality of design, construction and operational management employed at modern heap leach operations is a substantial improvement on their often problematic predecessors. Regulators' and civil society's concerns about heap leaching are often legitimate based on previous experience of unacceptable environmental impacts associated with such operations. The irony of such concern is that heap leaching is arguably the mode of minerals processing where companies should have the strongest economic imperative to impose the most stringent of environmental controls, particularly in the context of preventing solution losses from the process water circuit. The process solution - which poses the greatest environmental risk if mismanaged - contains the product: thus, any loss of process solution to the surrounding environment constitutes both a production and revenue loss, thus providing strong economic – as well as legal and moral - justification for the effective containment of process solution within the heap leach circuit.

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The ability of the heap leaching process to recover metals & other materials from low grade ores will likely continue to be a tool in the mining landscape.Â The heap leaching technology has seen substantial growth over the past few decades, becoming a key process in mining; NAUE, a group specializing in geosynthetic liners, assesses that over 30% of copper and gold produced each year is beneficiated via heap leaching, up from only about 3% decades earlier. Benefits of Heap Leaching. Largely due to the economic advantages it can offer, heap leaching has prevailed as the preferred approach to beneficiation in settings where the ore source is low grade, or has been considered uneconomic to process via other approaches. How does the form of a heap affect the recovery and solution grade? Under any given set of circumstances, what type of recovery can be expected before the leach solution quality drops below a critical limit? What recovery (quantifiable measure) can be expected? In recent years, the addition of an agglomeration drum has improved on the heap leaching process by allowing for a more efficient leach.Â Although heap leaching is a low cost-process, it normally has recovery rates of 60-70%. It is normally most profitable with low-grade ores. Higher-grade ores are usually put through more complex milling processes where higher recoveries justify the extra cost. The process chosen depends on the properties of the ore. The final product is cathode copper. Although heap leaching is a low cost-process, it normally has recovery rates of 60-70%. It is normally most profitable with low-grade ores.Â Environmental Concerns. Effectiveness. Heap leach mining works well for large volumes of low grade ores, as reduced metallurgical treatment (comminution) of the ore is required in order to extract an equivalent amount of minerals when compared to milling. The significantly reduced processing costs are offset by the reduced yield of usually approximately 60-70%. The amount of overall environmental impact caused by heap leaching is often lower than more traditional techniques.[citation needed] It also requires less energy consumption to use this method, which many consider to be an environmental alternative. Heap leaching, however, has a lower yield than conventional methods (10 to 20% less) and recovers a smaller net amount of uranium. Leaching efficiency can be improved by heating leach or wash solutions but the cost of heating a large heap using conventional heat sources would be prohibitive. A study is being made of a) the use of heated solutions in selected parts of the heap leaching process and b) the design, construction and operation of simple solar heaters to be used in conjunction with heap leaching. Studies are in progress on the effect of heating the solutions used in initial and late leaching and washing stages with various temperature increments.Â Leaching is defined as the transfer of a chemical species from the solid phase to the aqueous phase.