

# Experience-based approach to successful heap leach pad design



In the current economic climate, heap leaching can be an attractive and cost effective means of recovering metals, explains **Terry Mandziak**, Associate Consultant, SRK (US) and **David Pattinson**, Principal Consultant Minerals Processing, SRK Consulting (UK). While heap leaching typically has lower recovery rates than conventional milling, the lower capital and operating costs allow lower ore grades to be economically processed and generate a positive cash flow that can be used to fund and develop other projects.

**H** heap leaching has been applied to a number of different ores containing metals including gold, silver, copper, nickel, zinc and uranium. The ore can be processed as coarse rock, normally referred to as a dump leach, or as a crushed ore in a heap leach. The reagents used and the chemistry of leaching are metal specific, but the basic principles are similar to all ore types.

At first glance, heap leaching can appear to be an extremely simple technology; however, without the proper characterisation, engineering and design, a heap leach pad (HLP) can face significant issues that can affect the overall economic viability of the project. It is important that each part of the circuit is designed to meet the specific requirements of the ore being leached. Characterising the foundation conditions and materials used in construction reduces the risk in the HLP design, but developing and implementing a robust ore characterisation and testing program can minimise the risk of a detrimental effect on

the financial performance to the project.

The purpose of this paper is to present a lessons-learned approach to items that should be considered in the evaluation and design of a heap leach project.

## BASIC FEATURES OF A HEAP LEACH OPERATION

A schematic of a typical heap leaching circuit is shown in Figure 1, with the main components being:

- ore materials processing and handling systems which includes crushing, conveying and stacking equipment;
- agglomeration of the ore (if needed) to stabilise the finer fractions and initiate the leaching kinetics;
- a lined HLP to provide containment of the stacked ore during the leaching process;
- solution irrigation systems to apply leach solution to the heap including pumps, piping and solution distribution systems;

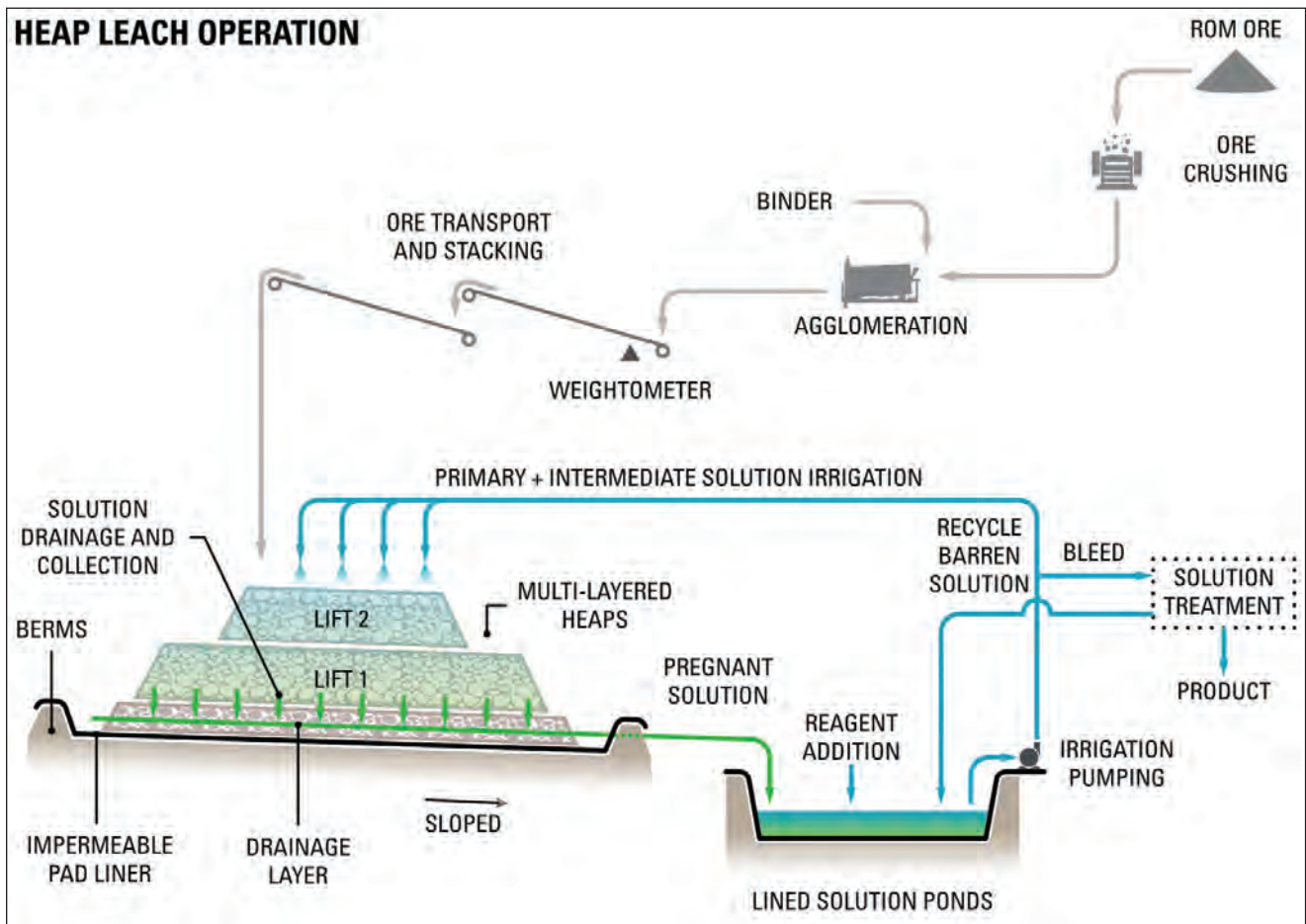


Figure 1 Typical Heap Leach Circuit

- solution collection system that includes a coarse drainage layer with network of solution collection pipes installed over the liner system/under the ore, and an external solution collection system to route pregnant solution to the solution collection ponds;
- solution collection ponds including pregnant, intermediate and barren solution ponds for collecting and managing the recirculation of solutions to the HLP and as holding ponds, prior to pumping to metals recovery circuits;
- emergency ponds to collect solution arising from extreme events, such as design rainfall events or power outages;
- reagent preparation and addition systems; and
- metals recovery circuits. These are specific to the metal(s) being recovered, e.g. carbon adsorption columns for gold, zinc precipitation for silver, solvent extraction and electrowinning (SX/EW) for copper, sulphide precipitation for complex ores of nickel zinc and copper.

#### DESIGN CRITERIA

Prior to starting, a set of design criteria should be developed that considers regulatory (environmental and permitting), production, processing, climatological, design and closure items. For conceptual level designs, it is acceptable to make assumptions on key design criteria, and the authors have found that circulating a brief and concise set of design criteria, along with listing references to the data source (industry standard, site specific test work, etc), can greatly aid in defining the level of confidence for specific design criteria items, and flag up additional work programs to decrease the uncertainty reflected in the design.

#### Characterisation Program

The purpose of characterisation is to develop an understanding of the ore, subsurface geotechnical and geologic conditions and construction materials to be used in the HLP. Often, the project timeline is compressed or funding requirements are limited, reducing the schedule and scope to sufficiently characterise not only the heap leach facility itself, but also the ore material.

#### Sampling and Metallurgical Program

A metallurgical testing program should always be developed and performed on representative samples of the ore. The samples selected should represent the range of mineralogy and varying metal grades in the deposit expected across the life cycle of the mining operation. In addition to testing of representative samples, variability testing should also be performed to establish how the range of ore mined and placed on the HLP will vary - from not only a mineralogical perspective - but a geotechnical (primarily fines content) perspective as well. Ideally, all samples should be selected in consultation with the geology specialists, metallurgists, heap leach pad designer and mining engineers, as this results in a HLP with a higher likelihood of success, based on the authors' experience.

Core samples are typically used for smaller scale testing such as bottle rolls and laboratory column tests, where the sample requirements are up to a few hundred kilograms. For larger diameter/height column tests or pilot heap testing, bulk samples obtained by excavation will be required, resulting in significant costs that are often underestimated.



Metallurgical testwork, such as bottle roll and column tests, is performed to establish the optimum particle size and metal extraction, the time required for leaching (kinetics) and recovery, reagent requirements and consumptions, the heap height and irrigation rate, the number of leaching stages and the potential build-up of impurities. On one project, the optimum crush size was changed after issuing the feasibility study, which had a major impact on the overall project schedule and economics. For bio-heap applications, the bacteria requirements, nutrients and air addition rates have to be established. For the more complex systems, the thermodynamics of the heaps and the chemistry has to be studied.

Using the test results from the laboratory without scaling as the basis for the design of a large scale application can result in large differences between laboratory and commercial results. Depending on the experience with similar ores, options include reducing recovery rates/factoring kinetic rates, performing large scale column tests which are closer in height to the proposed heap, and, if possible, large scale pilot heaps which are more representative in terms of physical performance of a full scale HLP. On several gold projects, reducing the column recovery by 5% and applying a scaling factor of three from the column leach cycle to represent the field leach cycle, has been a reasonable approach.

The metallurgical program should also characterise the reaction chemistry of the ore to ensure that the metals are extracted efficiently and that metals are not re-precipitated within the heap, thus becoming non-recoverable. On one project, vanadium was being leached as a secondary product and the client was developing a QA/QC program to include this in the reserve estimate and economic model, however, during the column testing program, no vanadium was being recovered. Post-leaching studies found that the metal had dissolved, but was re-precipitating in the ore.

As with any test results, careful interpretation of the data generated from any program is necessary to ensure that the effect of all variables are established and that correct interpolation of results is made from the smaller scale to the full scale plant design.

#### *Ore Characterisation Program (Geotechnical)*

Often, metallurgical laboratories will measure the maximum flow rate in the column sample, however, since the column height does not usually represent the lift height or the ultimate ore height, this test represents the upper 1 or 2 m of a lift. Once the optimum crush size and leaching parameters have been identified and selected from the metallurgical testing, ore percolation testing should be performed. Representative samples should be tested under the design ore height (normal load), and the authors recommend that the ore should typically be a minimum of one to two orders of magnitude more permeable than the solution application rate to allow for air flow within the heap and the variability in the fines content of the ore.

The percolation test apparatus consists of a thick-walled cell in which an ore sample is placed and subjected to conditions that simulate the loads and leaching conditions that would occur in the heap leach pad. The ore is placed in a cell located in a load frame. A hydraulic jack is used to apply a normal load to the sample, corresponding to specified ore lift heights. Displacement measurements are taken at two

points on opposite sides of the specimen, at each of the loading sequences during the test. These displacements are averaged and used to calculate percent consolidation and densities at each stage of the test. Solution (water) is applied to the top of the sample and allowed to percolate through the sample and collected through an outflow port at the base of the cell. The objective is to determine if the inflow rates remain the same as the outflow rates, in order to maintain unsaturated flow conditions (no build-up of excess head), as void ratios decrease as a result of additional loading of the material.

#### *Heap Leach Pad Characterisation Program*

To develop an understanding of the subsurface conditions and “borrow sources” used to construct the HLP proper, a field investigation program is performed to characterise the foundation and construction materials. (NB “Borrow sources” are areas identified where material can be taken to fill indentations, build berms or bunded walls, use for the base layers of the pad, etc). The field investigation typically consist of test pits and boreholes used to develop the soil and rock depths and profiles, and provide disturbed and undisturbed samples that can be used in a laboratory testing program. This information can also be supplemented with geophysics.

Laboratory testing typically includes index testing, such as gradation and “Atterberg limits”, used to develop the materials classification and relative consistency, and can be correlated with published data. Site specific water content, compaction, durability, permeability and shear strength testing is also performed, for use in the design.

(NB The “Atterberg limits” are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes distinct changes in behavior and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behavior of a soil is different, and consequently so are its engineering properties.)

When evaluating the geomembrane liner to be used, interface shear strength and liner load testing should be performed using the materials that will be specified for construction. Depending on the stability factor of safety analysis, smooth or textured High Density Polyethylene (HDPE) or Linear Low Density Polyethylene (LLDPE) may be used in the design and construction.

#### **PAD TYPES**

Selecting and designing a pad type that does not adequately address the permitting, construction, operational and closure requirements can result in a facility that not only does not provide the flexibility to address changes encountered in operations, but is also costly and cannot be fully optimised. Therefore, early in the design process, the type of heap leach pad selected should consider such site conditions as available area (footprint), topography (terrain slopes), climate (temperature and precipitation), foundation conditions (slope stability), environmental (permitting and design requirements), and closure (long-term maintenance). Metallurgical properties such as leach cycle time, recovery, ore permeability/percolation and the agglomeration requirements of the crushed ore play a significant role in the pad selection process.



Figure 2 Typical reusable HLP

Typically, the following three HLP configurations are considered.

#### *Dedicated*

The dedicated pad involves the preparation and placement of ore on a continually expanding pad (either vertically and/or horizontally). Following leaching, the ore is left in place. Subsequent re-leaching or washing (rinsing) and treatment, if required, may be undertaken. The advantages of such pads include:

- o can accommodate variable ore production rates and different leach cycle durations;
- o involves a relatively simple liner that is in essence “loaded” only once, but needs to be designed for the maximum ore height;
- o can be expanded vertically or horizontally (if allowed for in the original design);
- o on-going pad extensions can be funded through revenue;
- o requires a durable ore; and
- o can use interlift liners to improve solution recovery.

The disadvantages of such pads include:

- o requires a large area;
- o requires relatively flat to gently sloping topography;
- o requires a relatively dry climate to maintain a near-zero water balance, or the implementation of measures to shed or divert precipitation without collecting it; and
- o needs a large pond storage capacity to hold extreme precipitation runoff due to the potentially large pad area.

#### *Reusable*

The reusable HLP, often referred to as an on-off or dynamic HLP, involves the construction of a series of cells onto which the prepared ore is loaded, leached, rinsed and chemically treated (if necessary) prior to disposal. After the ore has been leached, it needs to be removed in order to make room for the placement of fresh ore. A typical reusable HLP is shown in Figure 2.

Conveyors and/or stackers may be used to load the ore onto the pad and, in some cases truck loading can be used. Unloading of the spent ore may be performed with bucket-wheel excavators and conveyors or, alternatively, loaders and trucks, however, the loads imposed on the liners and drains by the loading and unloading equipment are usually the key factors affecting the design of liners and drains. Depending on the washing or detoxification methods used, the ore may still need to be placed within an area that has a barrier system of some type, referred to as a Spent Ore Facility (SOF), and any recovered solution collected. The difference between the SOF and the re-usable HLP is that the spent ore is typically designed for stability (which may include an elevated phreatic surface), while the re-usable HLP is designed for stability, percolation and leaching of the ore. (NB “Phreatic” is a term relating to solution or water level. In a dedicated HL where the ore remains in place, it is necessary to consider its long-term stability taking in to account the phreatic surface of the water (or the level of water) that will exist in the heap.)

The following are some advantages of reusable pads relative to “permanent” pads further described below:

- o occupies a relatively small footprint, and corresponding pond volume and area;
- o easier to maintain a “zero water balance” because of the smaller area on to which precipitation falls, and hence becomes part of the pad water balance;
- o needs ore with consistent properties/characteristics; and
- o pad cost per tonne decreases with each subsequent use.

Disadvantages relative to larger “permanent” pads include:

- o requires double handling of ore material;
- o the leach cycle and leaching characteristics must be predictable and preferably short;
- o provides limited flexibility regarding varying the duration of leaching or increased production rate as the pad is difficult to expand due to infrastructure (piping, conveyors, etc.);

- o requires a durable liner that can withstand the repeated placement and removal of ore;
- o spent ore needs to be drained down to a water content that allows for double handling of the ore, and needs to be placed in spent ore area (which can require some type of containment); and
- o not amenable to ore “maturing” for later re-leaching. In other words, once the ore is removed from the heap leach facility, the opportunity to re-leach the material is lost, unless the spent ore facility is constructed with a containment system along with irrigation and solution recovery system.

The size of the pads and the number of pad cells are dictated both by the rate at which ore is produced and by the duration of the leach cycle required for optimum metal extraction.

### Valley

The valley method involves the preparation and placement of ore behind a retaining structure which is usually an earthen embankment. The ore is leached in place, with subsequent lifts progressing up the slope. The majority of the ore remains in contact with the leach solution during operation. At completion of leaching, the ore is rinsed, left in place, and the facility reclaimed.

Advantages of valley pads include:

- o can be used in steep terrain;
- o can operate in a wide range of climatic conditions;
- o can accommodate extended leach durations;
- o usually does not involve a separate pregnant pond;
- o can expand vertically or horizontally (if allowed for in original design); and
- o can use interlift liners to improve solution recovery. (NB Essentially it is like building a second pad on top of an old one. This is sometimes done in valley or dump situations as the size of the operations are usually large and the grades in ore are low. The interlift liner would prevent solution passing in to a spent ore layer. It would reduce the time taken for the PLS to appear in the piping. If there is no interlift liner, the solution would have to pass through all the ore (including spent material) and the time for PLS to appear would increase.)

Disadvantages include:

- o expansion capability can be restricted;
- o solution inventory (from both a metals and water balance consideration);
- o complex leaching model;
- o requires a durable ore;
- o requires a high integrity liner to deal with the high normal loads and hydraulic heads;
- o involves an engineered retaining structure; and
- o the great height may lead to specific consideration of slope stability - both static and dynamic (earthquake-induced instability).

### PAD LINERS (CONTAINMENT)

The ability to contain ore and solution is the heart of the HLP. The selection and design of the containment system requires a good understanding of the subsurface conditions, borrow and construction materials, and the loading (both ore height and construction equipment) that will be applied. Key parameters in selecting the

geomembrane type and liner configuration are the potential liner leakage rates, shear strength and corresponding impacts on slope stability calculations, and potential for differential settlement. (NB The objective is to have zero leakage rates but in reality there will always be very, very small amounts of leakage. The pads can cover vast areas and it is unlikely that there will not be some imperfection in a liner, a weld or an inconsistency in a clay layer. The design has to minimise these to levels that do not affect the environment.)

The HLP is designed with a pad liner system to provide containment of the ore and solution. This is required not only as a permitting and regulatory requirement, but collecting and recirculating the process solution is desired from an economics perspective. Several different liner configurations are typically used to contain process solution:

- single liners consisting of a clay liner or a geomembrane, placed on a prepared surface;
- double liner consisting of two single liners, an upper (primary) liner and a lower (secondary) liner, typically separated by a drainage medium (granular or synthetic); and
- composite liner consisting of a geomembrane placed over a low permeability soil liner.

The composite liner is the most common containment system in heap leach facilities. Geomembrane materials, such as LLDPE and HDPE, are typically installed over a prepared and compacted low permeability clay soil. In some circumstances, where the local supply of clay soil is cost prohibitive or not readily available, a geosynthetic clay liner (GCL) is used in place of the low permeability clay soil, but this should be considered on a project specific basis.

### SLOPE STABILITY (PAD GEOTECHNICS)

The foundation conditions and construction material have to be characterised and incorporated into the design, as they have a significant impact on the slope stability. Most typically, however, the interface shear strength (shear strength between the low-permeability soil liner or GCL and geomembrane) governs the factor of safety calculations. Therefore, the evaluation and selection of the materials used in the construction of the composite liner system need to be carefully considered, weighed against such options as slope recontouring to shallow foundation grades or over excavating lower-strength materials and replacing with a higher-shear strength controlled fill, installation of textured geomembrane and/or shear berms.

Another critical item in assessing the overall HLP stability is considering adjacent facilities, such as waste rock dumps or mine pits. Characterising pre- and post-mining groundwater and surface water conditions are important in the stability assessment, since changing conditions, resulting in the groundwater levels being elevated or discharging surface water up-gradient to the HLP, can also have an adverse effect on the overall HLP stability.

### SOLUTION MANAGEMENT

Since metals are recovered in the leach solution, the management or application and recovery of this solution is critical to the overall heap leach economics.



### Heap Irrigation

Barren leach solution is pumped to the ore surface and distributed across the area under leach. Effective heap leaching requires an even distribution of solution through the ore at a slow and consistent rate, otherwise preferential flow paths can be created which short circuit or bypass sections of unleached ore. Typical irrigation systems used are:

- sprinklers or wobbler type distributors when the liquid is released as a fan of water drops and total coverage is achieved by careful spacing of multiple sprinkler heads; and
- drip emitters where the solution is distributed as small droplets emanating from a network of small perforated pipes placed directly on the top and side slopes of the ore.

Similar application rates can be achieved for either option, but drip emitters can have lower evaporative losses and, if necessary, can be buried just below the surface of the ore. This can be of particular benefit in arid environments or when makeup water is expensive.

The surface of the stacked heap should be prepared, typically by ripping or a small grader, prior to laying the solution distribution systems.

The irrigation system should be designed to allow for solution application to specific parts of the heap and incorporate flow measurement instrumentation at suitable points in individual heap sections.

The layout of a typical irrigation system is shown in Figure 3.

### Solution Collection

Solution that percolates through the ore reports to the solution collection system, typically comprised of a piping network covered in a free draining, granular drainage system. This solution collection system gravity drains to the HLP edge, where it is connected into a piping system that conveys pregnant solution to the solution ponds. Typical heap solution collection pipes are shown in Figure 4 and 5.

The solution collection system not only provides a direct connection from the leached ore to the solution ponds, it also reduces the “phreatic” surface within the ore and affects the overall slope stability. The design is therefore very important and should:

- be rated to take the load on the pipework from construction and operational equipment, in addition to the ultimate ore height;
- be sized for upset conditions and provide sufficient flow capacity to account for pipe deformation;
- be designed with a minimum gradient to allow efficient drainage via gravity flow;
- be sub-divided into individual piping networks to facilitate monitoring of specific sections of the heap; and
- provide solution sample points to monitor grade.

### WATER BALANCE

Water is a key resource that typically needs to be brought in from offsite and water management, either the supply of makeup water or the release of excess solution, is an important variable in permitting. A water balance model is usually developed to estimate the overall water requirement (identifying if the pad is a net water consumer or if excess water is generated) and to size the solution

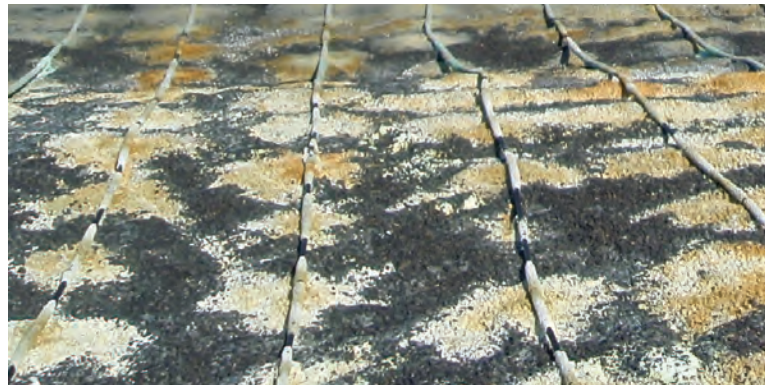


Figure 3 Typical solution irrigation pipework

ponds. The water balance should be performed for the entire mine life and include critical times, such as ramp up or the start of leaching when the largest make-up water requirement occurs, and closure when the largest excess water condition occurs. The water balance should also consider upset conditions, such as extreme wet and dry periods to develop sensitivities.

An Excel spreadsheet is typically used to simulate the pad loading (including ore loading, lined pad and pond areas), track inflows (such as rainfall, application solution, drain down, etc) and outflows (such as pad and pond evaporation, wet-up of ore, etc). The water balance can be performed using average monthly data (deterministic) or statistical data (probabilistic), and is simply a mass balance, in which the solution inflows and outflows are modelled:

$$\text{Change in Storage} = \text{Inflows} - \text{Outflow}$$

Inflows considered in a water balance should include:

- Leach solution. This is the unit application rate, usually expressed in litres per hour per square metre, multiplied by the area under leach.
- Precipitation. This is the precipitation event (both incremental and design storm event) multiplied by the pad and pond surface area. Depending on the site location and climatological conditions, snowfall may occur, therefore a snowmelt distribution may need to be developed to account for the winter snow falls and spring and summer melts.
- Surface water inflows. These should be zero when diversions are properly constructed around the perimeter of the heap leach facility and ponds.



Figure 4 Typical underheap solution collection pipes



Figure 5 Typical solution collection channels and piping

Outflows considered in a water balance should include:

- Seepage. If the heap leach facility is lined, there should be no seepage losses.
- Ore Uptake/Wetting. This is the difference between the original ore water content and the drain down water content.
- Bleed Stream. Depending on the chemistry of the solution, a bleed stream may be necessary in which solution is removed from the system to decrease the concentrations of certain elements. (NB In some cases impurities or deleterious chemical species pass in to solution. If these are found to be too high then solution would be removed at a rate to balance the impurities coming in to the solution from the heap leach with the amount being removed in the bleed. The levels would be monitored as part of normal operation and the bleed adjusted accordingly. At the design stage, this would be modelled to make sure downstream processing is adequately sized. An example might be Si or Al in an acidic leach. If the levels in the HL solutions get too high they may start to affect the leaching performance. In this case, the treated solution is monitored to ensure that the levels of these elements are reduced before recirculation to the HL circuit. Another example might be Na or Cl. In these cases they are not precipitated and thus not removed by metals recovery processes. If recycled they will build up so it may be necessary to actively remove them before recycle, as an addition metals recovery circuit.)
- Evaporation. Evaporation losses are estimated by taking the incremental evaporation values multiplied as follows:
  - o The pond surface area. The pond surface area varies with the volume of water stored, and an estimate of the surface area available for evaporation would be based on a stage-storage/area curve;
  - o The HLP surface area. The pad area under leach would be estimated, along with an assumed evaporation factor, to account for the difference between ore surface evaporation and pan evaporation; and
  - o In the absence of evaporation data, an alternative approach, is to estimate a percentage loss from the circulated leach solution based on experience.
- Chemical reaction water requirements. Where the leaching reaction is complex and involves the removal of water from the system due to the formation of

compounds containing water, such as jarosite or metal hydrates, this should be evaluated through testwork and analysis of actual heap materials.

#### TEMPERATURE

Temperature is important. In cold climates such as Russia they find that the leaching rates for gold fall during the very cold winter months. They sometimes stop irrigation as it is ineffective.

In a sulphide heap leach, the oxidation usually generates heat and this has to be controlled. If bacteria is involved in the heap reactions, it has to be maintained within strict limits as high temperatures kill the bacteria and low temperature reduced their activity.

However, in heaps the temperature is “what it is” and does not have a significant affect – eg a gold HL in a warm climate.

#### ORE LOADING AND MATERIAL HANDLING

There are numerous methods by which ore can be placed on a heap leach facility, including using conveyor stacking, truck dumping or a combination thereof. The most appropriate method selected should consider the pad type and topography, ore properties, and project conditions and economics. For example, conveyors are typically used to load reusable heap leach facilities that can be designed to have flatter, more constant gradients, while trucks and/or conveyors can be used to load valley leach pads. Conveyors are also used to minimise the compaction of ore when placing ore in a retreating manner (on the top of a previously stacked and leached lift), as compared to conveyors stacking in an advance manner (on top of the lift being placed) and advance forward over the freshly placed material. If on top of leached material, you would stack backwards.

#### OPERATIONAL KINETICS

The kinetics of the HLP can be estimated from the metallurgical testing and reflected in the operating cost estimate used to calculate the project economics, however, maintaining optimal leaching kinetics during operations is critical. For example, small variances in the pH operating range for gold and copper heap leaching systems can have a large impact on recovery, which can take a long period of time to readjust. In one such project, the client implemented a reduction in lime addition to reduce short-term operational costs that resulted in a reduction in pH and a decrease in recovery that impacted gold recovery for a significant period of time.

In more complex heap leaching systems such as metal sulphide bio-heaps recovering copper, nickel, zinc, or gold, the bacterial requirements and corresponding chemical reactions are more complex. The reactions occurring in the heap affect the heat balance. In bacterial systems, the temperature needs to be maintained at acceptable levels to maintain the bacterial populations necessary for the leaching to occur, while the addition of air or oxygen needs to be monitored and controlled.

#### RISK ASSESSMENT

With any process, there are technical risks that need to be considered, addressed and mitigated in order to increase the likelihood that the project will meet or exceed the desired outcome. These risks change over the life of the project and work scopes need to be developed to reduce the uncertainty. There are numerous methods published for facilitating and



implementing a risk assessment. The important point is that a risk assessment is performed and that from SRK's experience in design, construction, operation and closure in the heap leach pad life cycle, the following technical risks should be considered in that assessment:

- Design/Study risks:
  - o Foundation slope failure.
  - o Ore slope failure.
  - o Metallurgical performance.
  - o Liner leakage.
  - o Poor solution recovery.
  - o Inaccurate costing/scheduling.
- Construction risks:
  - o Cost and schedule overruns.
  - o Construction Quality Assurance and Quality Control.
- Operational risks:
  - o Reduced metals recovery.
  - o Liner leakage.
  - o Water management issues due to extreme climatological conditions.
  - o Regulatory compliance.
- Closure risks:
  - o Cover stability.
  - o Solution management.

#### CONCLUSIONS AND RECOMMENDATIONS

The current economic climate and reduced access to investment is becoming the new norm that affects how a project advances. Owners are forced to implement cost savings or cost reduction measures in the engineering and studies phases, which can result in compartmentalisation of the project (advancing certain disciplines at different times) and pressures to skip conventional steps in the normal project development or toll-gating process (advancing from the conceptual or scoping study phase to feasibility design or final design).

From lessons learned from the design, construction and operation of numerous heap leach pads worldwide, SRK has the following technical recommendations to help in the development of a successful heap leach facility:

- Develop a site specific design that accounts for such site specific conditions as metallurgical, topography, climate, geotechnical, metallurgical, environmental and closure conditions.
- Develop a rigorous sampling and metallurgical characterization program that assesses the variability of the ore.
- Select the appropriate HLP type, containment, and ore loading system.
- Consider adjacent facilities and potential changes from closure conditions in the stability analysis.
- Select the appropriate solution management system, including irrigation, solution collection and water balance system that considers upset (extreme wet or dry) conditions.
- Monitor the operational kinetics against those used in the design process, and update with metallurgical testing performed during operations.
- Perform a risk assessment at numerous stages of the design process

In addition to the technical recommendations listed above, SRK also suggests that the design process includes the following:

- Account for construction and operational flexibility in the design.
- Benchmark with other projects.
- Follow a staged design process.
- Exceed minimum requirements.
- Design for the entire HLP Life Cycle.
- Implement a Peer Review Program.
- Define battery limits.
- Document the process to provide transparency and allow for regular reviews of key decisions.

Finally, metal price will always be a big factor in the economics of mining. The sensitivity to changing metal prices on HL economics, or any process for that matter, will be studied at the study phase. Nevertheless, the truth is that if it is a low-grade ore that is being considered for extraction and processing, HL is very likely to be a considerably cheaper option.

Terry Mandziak MSc, PE, Associate Consultant (Geotechnical Engineer) has more than 26 years of diversified professional experience in project coordination and project design mainly associated with geotechnical engineering for mining projects. His experience



includes the design and construction of heap leach and tailings facilities. His responsibilities typically include site selection, risk assessment, site investigation, laboratory analysis, slope stability assessment, data interpretation, costing analysis, and development of specifications, construction drawings, bid documents and construction programs. His project experience has included conceptual and final design engineering, preparation of construction documents, subcontractor selection, and construction management and supervision. Mandziak has worked on projects throughout the world, including North America, South America, Turkey, China and Africa. Mandziak has published an on-line course presenting the broader concepts about the design, construction, operation and closure of heap leach pads titled "Heap Leach Design" that can be found on EduMine at the following link: <http://www.edumine.com/courses/online-courses/heap-leach-design/>

David Pattinson PhD, MIMMM, CEng, has over 30 years' experience in the non-ferrous mining industry. Prior to joining SRK in 2005, he worked for more than 23 years in metallurgical and process plant design as part of an international engineering company and up to 2005 headed up the NF Process Design Group. He has been involved in feasibility studies, design, and commissioning in the UK, South America, Africa, the Middle East and Australia in numerous gold and base metal projects utilising whole ore and concentrate leaching, heap leaching and concentration. He has experience in a consultancy or project audit environment and reimbursable, EPCM and Lump sum type contract work.





# Mining World



Volume 12 | Issue 5 | October 2015



**KOMATSU**