KEYS TO SUCCESSFUL GOLD HEAP LEACHING

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ABSTRACT

Heap leaching is widely applied in the gold industry. It appears to be a deceptively simple technology, which has led to many failed projects, especially in the early days of gold heap leaching in the 1970a and 80s when numerous small to medium sized projects were launched by small companies with limited technical support. This paper identifies the main causes of failure and presents practically oriented keys to overcome past mistakes, learn from past successes, and develop a successful operation.

INTRODUCTION

Heap leaching is widely applied to oxidized, weathered, and nonreactive sulphidic gold ores. It is typically used for low grade deposits. However, it is also sometimes applied to small higher grade deposits or remote or politically high risk locations to minimize capital cost. Heap bio-oxidation pre-treatment has found limited application for low grade refractory ores. Heap leaching applications include both ROM and crushed ore. Both Permanent and on-off systems are employed. It can be a stand-alone operation or a satellite to flotation and/or CIP facilities to treat low grade ore zones.

Heap leaching appears to be a deceptively simple technology and this has led to numerous failed projects, especially in the early days of gold heap leaching in the 1970s and 80s when numerous projects were launched by small companies with limited technical support. In 1979 Kappes, Cassiday and Associates stated that of twenty-two heap leach projects surveyed, 50% were failures(1), and twenty years later In 1999 they reported that the failure rate remained similar(2).

Typical factors in failed gold heap leaching projects include:

- Poor percolation.
- Longer than projected ramp-up times.
- Longer than projected leach cycle times.
- Lower than projected recoveries.
- Poor drainage of leach solution from heaps.

The prime causes for poor performance include:

- Insufficient and/or non-representative sampling of the deposit.
- Inadequate understanding of the mineralogy.
- Inadequate or unsuitable metallurgical testwork program.
- Failure to identify and design for impurities such as soluble copper.
- Insufficient scale-up factors.
- Poor leach pad design and/or construction.
- Unsuitable stacking methods.
- Poor operating procedures and process control.
- Lack of, or inexperienced, technical support.
- Inexperienced operation staff.
- Attempts to cut corners to save money and/or time.

This paper presents some keys to avoiding mistakes of the past and developing a successful operation. It focuses on procedures, concepts and strategies rather than specific technical criteria.

BUILD A SOUND FOUNDATION WITH WELL PLANNED DRILLING AND SAMPLING

Metallurgical testwork is a **big consumer** of diamond drill core, and the drilling program must be designed accordingly. Drill chips can be usefully used for initial bottle roll testwork to determine maximum gold extraction potential, but core is needed for the subsequent column testwork which comprises most of the program.

The diamond drill diameter should be maximized. It is far better to pay the extra cost than to find out too late that the core is too small for testing the crush size required to achieve adequate liberation of the gold.

The presence of potentially key constituents such as visible coarse gold, clays and copper minerals should be noted during core logging.

Recently drilled core samples should be selected wherever possible for metallurgical testwork. Older core should only be used when there is limited oxidation and/or degradation. Sulphide core should be protected from oxidation by storing in a freezer.

Samples should be drawn only from zones **which are likely to be mined**, based on grade and intercept thickness.

Early metallurgical input is needed to specify an assay suite for the subsequent drilling program to avoid later backtracking. In addition to gold and silver, it may be necessary to track potentially key impurity elements such as copper, iron, sulphur, arsenic, antimony and mercury.

Early mineralogical input should also be provided to identify potential metallurgical issues.

Geological, mineralogical and assay data should be used to define potential ore types, ie those which may have different metallurgical characteristics. **If in doubt, include it!** The number of ore types can always be reduced as testwork progresses.

SYSTEMATIC TESTWORK IS ESSENTIAL

Being **systematic** is key to successful testwork. The temptation to take **short cuts should be resisted**, as it is one of the common contributors to past failures. A phased approach should be adopted, with increasingly tall column tests and increasing levels of detail. **Bench marking** against industry experience with similar ore deposits is highly recommended.

The mineralogy of each potential ore type should be carefully assessed to identify the gold and silver minerals, predict the crush size needed for liberation and identify key impurities and gangue minerals.

Tap water can be used for initial leach testwork, but site water should be used for subsequent testwork phases. Thus it is important to identify, sample and analyze potential site water as early as feasible – for example saline water may be beneficial for clayey ores

The optimum crush size should be determines **as early as possible** as it can impact the future drilling and sampling program. If a very coarse crush size or ROM material is indicated, it will have a major impact on sample requirements and the size of the leach columns.

R**ealistic** commercial leach conditions should always be used for the column tests in order to obtain meaningful performance data and provide a suitable basis for scale-up, plant design and performance projection.

If fines and/or clays are present, percolation tests should be carried out before committing to column tests. In the event of inadequate percolation, additional tests should be carried out after agglomerating with various quantities of cement and/or lime to determine the optimum conditions.

Final column tests must be at the **full projected lift height**. This can lead to relatively long test duration especially for slow leaching ores. Final testwork should be carried out on composites related to the projected mine plan.

The question of pilot scale tests is often a thorny issue, and may be influenced by non technical considerations such as corporate policy or financial institution requirements. In fact, a well designed tall column program with comprehensive orebody coverage **may provide more security** than larger scale pilot work, which is usually limited to only a relatively small portion of the ore. A very large test heap is needed to reliably project commercial performance due to the need to minimize the impact of the side slopes.

Impurities which can potentially affect the process should be identified early and the test program designed accordingly. Copper, for example, occurs in various forms, some of which consume cyanide (eg oxides and secondary sulphides) and others may result in lower recovery (eg gold locked in primary sulphides). The presence of soluble copper minerals may require the addition of a cyanide recovery step or the use of ion exchange resin instead of carbon for gold recovery.

If refractory gold is present heap bioleaching testwork may have to be considered, in which case an alternative lxiviant to cyanide may be needed.

Parallel economic studies and risk analyses should be undertaken for each phase of testwork to provide a basis for decision making about the future of the project. The studies should cover **all other aspects of the project** including ore reserve estimation, mining, water availability, climatic, environmental, decommissioning and long term monitoring, logistic, social and political issues.

BE CONSERVATIVE IN SCALE-UP

Conservative safety factors should be applied to testwork data for leach recovery, leach cycle time and reagent consumption. Unfortunately there are no universally accepted industry standard procedures so scale-up is generally based on industry experience with similar ore deposit. Generally the recovery is lower and the leach cycle time is **1.5 to 3 times longer** than the corresponding column test figure, depending on the ore characteristic. For example In Figure 1, the commercial cycle time is more than twice the column time.

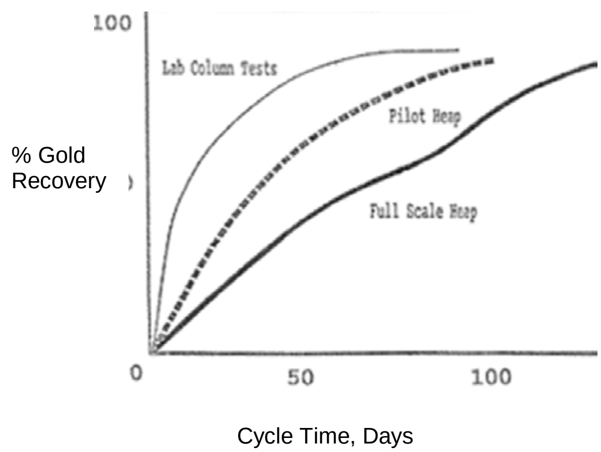

Figure 1: Comparative leach curves for columns, pilot heap and commercial heap[3]

Interestingly, the commercial cycle time in Figure 1 is longer than the 10,000 t test heap, so that designing from the test heap data would have resulted in underestimating the required leach time. A much larger test heap would have been required to simulate commercial performance.

LAY A SOUND FOUNDATION WITH GOOD PAD DESIGN

The services of a suitably experienced group to design and construct the pad is a wise investment. The “do it yourself” approach to save money has led to **disastrous results** in the past. Once in operation, fixing pad problems is difficult and likely to be very costly in loss of production.

Early consideration should be given to the choice between permanent heaps and on-off (dynamic) pads. Factors to consider include available site area and topography, projected leach cycle time, projected permeability of the heap, potential stability of agglomerates, overall heap stability, climate, environmental issues, decommissioning and long term monitoring.

The leach pad should be carefully located to achieve suitable slope to promote good solution drainage, while minimizing the required earthworks and avoiding underground water resources. Characterization of the pad foundation conditions requires a **thorough geotechnical investigation**, and proper ground and underliner preparation are essential to minimize settlement and avoid liner punctures from both economic and environmental viewpoints.

Phreatic head is the depth of solution in the base of the heaps during leaching. It needs to be minimized to avoid the risks of blanketing the lower portion of the heap and jeopardizing hydraulic stability. This is achieved by providing adequate ground slope, carefully prepared and placed overliner of coarse competent crushed rock or gravel and the use of pipes to assist drainage. The movement of mobile equipment and foot traffic should only be allowed **on the overliner** to avoid damage to the plastic liner itself.

Process control and leach solution sampling procedures need to be considered at the pad design stage. For example berms are useful for reducing cross flow and mixing of leach solution in the heaps which can make it difficult to monitor the performance of individual sections of the heaps

Geotechnical tests should be undertaken to determine heap stability and maximum allowable heap height. This is especially important when agglomeration is included.

SELECT THE RIGHT HEAP BUILDING METHOD

Selection of the heap building method is another key issue which can have a **major impact** on the success or failure of a project. A thorough assessment of possible methods is required, and the selection must not be made on economics alone. Other important factors to consider include(4):

- Particle size – ie ROM, coarse crush, fine crush.
- Ore characteristics – ie fines content, hardness, moisture content.
- Avoidance of segregation of coarse and fines which causes channelling.
- Careful handling of agglomerates to avoid breakdown which can cause percolation problems.
- Keeping foot and vehicular traffic off heap surface to minimize compaction.
- Ore transport distances.
- Number and height of lifts.
- Flexibility for limited or irregular heap surface area.
- Climatic conditions.
- Ore throughput.

An example of wrong selection is running trucks on the top of heaps when processing finely crushed ore, especially when agglomerated. This will generally result in compaction of the surface and **serious percolation problems**. The use of trucks is generally limited to ROM or competent coarse ore.

SPRAYS OR DRIPPERS

Even distribution of leach solution is a prerequisite for maximizing recovery and maintaining target gold concentration in the leach solution for downstream processing. Although both sprays and drippers can theoretically achieve this, their suitability is affected by particle size, leach solution composition climate, water make-up availability and environmental issues. Drippers are particularly favoured when evaporation must be minimized or for subsurface solution application for cold weather operation. Fortunately it is usually feasible to change from one to the other with minimum operational impact.

Before finalizing the selection and system design, it is prudent to obtain input from experienced suppliers and visit comparable operations.

WINNING OR LOSING CAN DEPEND ON COMMISSIONING AND RAMP-UP

Adopt a **conservative approach** to pre-production mining and heap building schedule. Extra leach area should always be available to hedge against percolation problems or slower than predicted leach rates during commissioning. Check the actual experience of other operations treating similar ore types.

If the mine plan is changed significantly subsequent to the testwork program, the ore grade, mineral composition and impurity levels should be reviewed to determine whether the plant design and/or performance projections will be affected. If so, carry out additional testwork before going ahead with the revised mine plan.

Provide additional people available to monitor the leaching performance during commissioning - the regular operating crew is generally too busy “fighting fires”! The additional people can focus on recalibrating the leaching model with actual data and optimizing operating procedures and process controls

If crushing and heap building is carried out by a contractor, the operating team should provide close supervision, especially in the early stages. The contractor cannot be expected to have process knowledge and is likely to be **working to different priorities**.

Management must ensure that the heads of the geological, mining and metallurgical groups must talk to each other daily. Successful heap leaching has to be a **team effort**. Locating them in adjoining offices is a good strategy. A **“we and they” culture is a sure recipe for failure**!

OPERATING STRATEGY IS ALL IMPORTANT TO PROFITABILITY

The initial process control model must necessarily be based on metallurgical testwork. It is vital to validate and amend it as soon as real operating data becomes available.

Heap leaching is generally slow to respond to process changes such as reagent addition or irrigation rate, especially for multiple lift operations. Failure to allow for this “flywheel effect” can lead to overcorrection and “chasing your tail”. One of the early priorities is to develop expertise in this key aspect of heap management.

Always be ready for **unexpected changes** in ore characteristics. Having at least one panel of fresh ore is good insurance for maintaining target production.

If testwork reveals ore types with significantly difference metallurgical responses, consider segregating them for separate process control and monitoring. Also, consider developing a “quick leach test” to assist with classifying ore types.

FORWARD PLANNING IS KEY TO PROFITABLE OPERATION

Forward planning should not be allowed to suffer because of short term problems. A co-operative strategy should be developed to optimize long term mining and processing to maximize profitability, which should be regularly reviewed in the light of fluctuations in the gold price. A key component is to carry out on going column leach tests for designated future ore zones.

Anticipate dilution due to rainfall based on site climatic records. Counter-measures include:

- Covering the heaps with “raincoats”.
- Protecting agglomerates with shade cloth or a layer of crushed rock or gravel.
- Countering dilution by increasing lixiviant addition, switching to fresh ore panels, or accommodating a higher flow of diluted solution flow by incorporating flexibility into product recovery circuit design.
- Providing suitably sized emergency ponds for temporary storage of excess solution.

Figure 2: Typical Use of “Raincoats”(5)

Likewise, in cold climates, adopt strategies such as:

- Thermal covers over heaps to prevent freezing.
- Carrying out stacking and/or leaching only in warmer months.
- Using trucks for ore transport and heap building instead of conveyors/stackers (for ROM or coarse competent crushed ore only).
- Heating of heap feed solution.
- Using of drippers buried below frost level with a layer of ore during coldest period, then leaching the top layer during warmer weather.
- By-passing ponds during cold weather.
- Insulating and heat tracing piping.
- Installing floating covers on ponds, or using insulated covered tanks instead of ponds.

CONCLUSIONS

Heap leaching appears to be a deceptively simple technology, and this has led to numerous failed projects. Keys to avoiding mistakes of the past and developing a successful project include:

- Build a sound foundation with well planned drilling and sampling.
- Use samples only from zones which are likely to be mined.
- Benchmark against other projects treating similar ore deposits.
- Draw samples only from zones which are likely to be mined.
- Carefully assess mineralogy to identify the gold and silver minerals and predict the crush size needed for liberation and gangue minerals.
- Identify potential Impurities early; if an additional process step is needed, include it in the test program.
- Carry out a systematic phased testwork program; start with potential ore types based on chemical analysis and mineralogy and consolidate as the program progresses.
- Carry out final column tests at the full projected lift height.
- Undertake economic studies and risk analyses for each phase of testwork, to provide a basis for decision making about the future of the project.
- Be conservative in scale-up.
- Select the right heap building method.
- Lay a sound foundation with good pad design, obtain experienced input and resist the temptation to “do it yourself”.
- Adopt a conservative approach to pre-production mining, heap building schedule and ramp-up time.
- Provide close supervision if crushing and heap building is carried out by a contractor, especially in the early stages
- Achieve even distribution of leach solution.
- Have additional people available to monitor leaching performance during commissioning.
- Validate and amend testwork based performance model with actual data as soon as it becomes available.
- Do not allow forward planning to suffer because of short term problems.
- Insist on a team effort between various disciplines.
- Always be ready for unexpected changes in ore characteristics; having at least one panel of fresh ore is good insurance for maintaining target production.
- Consider segregating different ore types for separate process control and monitoring, and develop a “quick leach test” for classifying ore types.
- Anticipate dilution due to rainfall based on site climatic records and develop countermeasures.
- Adopt cold weather operating strategies where appropriate.

Finally, learn from others’ successes and mistakes, don’t try to “re-invent the wheel” and resist the temptation to “cut corners”.

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