GEOTECHNICAL ISSUES in NICKEL LATERITE HEAP LEACHING[i]

By M.E. Smith, PE, GE and M.L. Steemson, PhD, RPEQ[ii]

INTRODUCTION

Owing to the potential for comparatively low capital costs and lower cut-off grades, heap leaching has been proposed as an alternative for nickel laterites by a number of recent projects, including European Nickel's Çaldağ project in Turkey and Acoje project in the Philippines, Vale's Piauí project in Brazil and Metallica Minerals' Nornico project in Australia, among others. Indeed, most new nickel projects are investigating heap leaching as an option for at least a portion of the production. Extensive development work was undertaken by BHP Billiton, who applied acid agglomeration to a range of nickel laterite ores, including limonites, saprolites and fine clay-bearing ores. They also introduced the concept of two-stage heap leaching. The impetus for heap leaching in these projects has been from experience developed over many years in copper and gold; however, nickel laterite projects involve unique issues which need to be considered. The current paper discusses some of these issues related to the geotechnical aspects of nickel laterite heap leaching.

Heap Permeability

Maximum sustainable irrigation rates are directly related to permeability and thus a key issue applicable to all laterite and saprolite deposits is the low permeability of the ore and its sensitivity to heap height. With nickel laterites this is further complicated by dissolution of up to 30% of the solids and the related destruction of the permeability-enhancing agglomerates. Therefore, ore permeability testing should include both fresh agglomerate and leached residues or ripios (representing the lowest permeability) over a range of simulated heap or lift heights. In several recent testing programs including column metallurgical tests followed by geotechnical analyses, ripios samples reported permeability values consistent with sustainable irrigation rates of 5 to 10 $L/m^2/hr$ with maximum lift heights of 4 to 8 m. Higher irrigation rates or thicker lifts would have resulted in fully saturated heaps, surface ponding, slope instability and high susceptibility to liquefaction. Within these ranges of lift thicknesses and irrigation rates, unsaturated permeability testing generally suggested a high degree of saturation by the end of the leach cycle, which also affects slope stability and liquefaction potential. These data further suggest that multi-stack heap drainage would be significantly impaired, thus indicating the need for thin interlift liners and drainage systems between each lift, as is common in oxide copper heap leaching.

A key point in interpreting metallurgical column leach data in terms of permeability has been that small columns generally are optimistic in terms of drainage properties. This is caused by a number of factors, ranging from lower ore densities to bridging along the column walls to solution channelling. In one case a sample was leached in a small diameter clear plastic column. The laboratory reported sustainable irrigation rates of up to 100 $L/m^3/hr$ though the ore was a limonite. Visual inspection of the column showed that most of the solution had followed channels along the column-ore interface. Larger columns (e.g, nominally 1,000mm diameter), properly loaded, tend to report more realistic drainage information and there is good correlation between performance in these columns, geotechnical testing and actual heap performance.

Heap Construction

Either multi-stacking (conventional heap) and dynamic (on/off pad) heaps are both appropriate for nickel laterites, depending on site and ore factors. During several project trade-off studies both multi-stacking and dynamic heaps were found to have similar initial capital costs and similar life-of-project NPVs. Thus, the decision between these two technologies will often be driven by factors other than economics. Generally speaking, the relative advantages of each approach can be summarized as:

- Leach cycles: short, well defined leach cycles tend to favor dynamic heaps.
- Land availability: dynamic heaps require more total land because of the ripios disposal.

- Ripios disposal & closure: a combined dump (with ripios from a dynamic heap and plant residue) can be smaller and thus less expensive to close than two separate dumps.
- Water balance: a dynamic heap requires a larger total area (heap plus ripios dump) and thus collects more rain water, but the water from the ripios dump can be easier to divert from process than from a larger multi-stack heap.
- Traffic support capacity of leached ore: supporting the stacker over the prior lifts of leached ore is a key limitation for a multi-stack system with lateritic ore.
- Risk factors can vary considerable between the two approaches, and it is often a risk analysis that leads to the final selection.

For both multi-stack and dynamic heaps, there are generally three approaches to stacking the heap:

- Retreat stacking with a conventional radial stacker, working over the previously leached lift (multi-stack heaps only).
- Advance stacking with a low-height radial stacker (a hybrid system using the simple equipment of the retreat stacker concept but working on top of the fresh lift).
- Advance stacking with a self-propelled tripper-stacker.

Plant Residue Management

Plant residue generally consists of three components: iron precipitates (the largest fraction), sulfates (gypsum, magnesium sulfate), and small quantities of other process sludges, and can be produced as conventional or thickened slurry, paste or filter cake. A number of authors have suggested that dry stacking of filtered tailings is the preferred method for all sites and all tailings streams when considering stability and environmental containment. Unfortunately, often the cost of producing filter cake is prohibitive. In most of the nickel heap leach operations studied by the authors, residue filtering was elected because of the process benefits (improved metal and acid recovery) and thus dry stacking of the residues has generally been selected for tailings disposal. Since the residues contain very high levels of sulphates and magnesium, low pH and often elevated manganese, an environmental containment system (base liner, drains, closure cap) will often be required unless good geologic containment and suitable climate factors are present. Because the shear strength of the residues will generally be very low and the material is susceptible to liquefaction, some method of stabilizing the final slopes will usually be needed. Analyses have indicated that combinations of small stabilizing buttresses and compaction of the exterior shell of the dump can achieve good stability as well as erosion protection, and often become part of the closure capping system. While the residue will usually have a low permeability, leachate will be produced by compression of the residue as well as normal leaching actions (especially in wet climates) and thus a system to collect and remove this water would generally be required.

A recent survey of tailings facilities found 122 modern dam failures. Some recent examples include: Omai (Guyana, 1995), El Porco (Bolivia, 1996), Las Frailes (Spain, 1998), and Zhen'an (China, 2006). Nickel leach residues differ from conventional tailings in that they are largely composed of chemical precipitates rather than ground rock. Though most of the projects studied plan on using filters, dry stacking dumps can have relatively high degrees of saturation and thus have the same problems as the ripios, but because the residue is chemical precipitates it lacks a granular media that creates shear strength and traffic support capacity. These residues also tend to have much lower permeabilities than ripios, often approaching that commonly specified for compacted clay liners. This makes the residue dumps highly prone to liquefaction in that the pore water cannot drain even under relatively slow loading conditions. In addition to having poor slope stability and very poor drainage properties, the residue can be prone to erosion.

High Rainfall & Raincoats

Most nickel laterites outside of Australia are found in tropical or sub-tropical climates characterized by both very high annual precipitation and intense peak storm events. This is not unique to nickel laterites, however, and a number of successful heap leach projects have been conducted in high rainfall climates, including: Central America, Myanmar, Ghana, Peru, Brazil and the Philippines. In such sites the proper management of rain and storm water can be a key driver. One of the techniques almost universally used to manage the high rainfall is the application of temporary geomembrane covers or "raincoats." A raincoat is placed over the heap, ripios or residue dump to shed rainwater from the system before it enters the process circuit. The covers provide several wet season improvements including: reduced surplus water and reduced water management issues; less dilution of process solutions for improved metal recovery; reduced reagent consumption in recirculated solutions; reduced likelihood of accidental spills due to excessive storm water accumulation or excessive flows in process solution channels or piping; and reduced damage to the surface of the heap and ore agglomerates caused by falling raindrops (impact damage) and sheet flow (erosion). Unlike semi-permanent to permanent covers used in other industries such as landfills, raincoats are generally used for short-term wet-season use, often with dry-season removal to aid in ore placement, irrigation network maintenance, and to encourage evaporation.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of BHP Billiton and European Nickel PLC who have been at the fore-front of the development of nickel laterite heap leach processing.

---

[i] First published in The Mining Record, May 2009

[ii] Mark Smith is Managing Director for Vector Engineering Inc., an Ausenco group company, Grass Valley, California, USA. smith@vectoreng.com. Mark Steemson is Senior Process Consultant for Vector Engineering, Inc, Brisbane, Australia. steemson@vectoreng.com