PVC-lined copper leach pads in Chile

By Mark E. Smith

Copper heap leaching began in Chile a century ago and has been commonly used since the 1970s. Chile is the leading producer of copper followed by the United States, and while conventional milling remains the primary source of production. heap leaching continues to increase in its share of production (Smith, 1992).

Copper heap leaching in Chile uses an estimated 3 million square meters of geomembranes annually for the base liner, plus a large additional amount for liners between ore lifts. Until 1994, PVC geomembranes have not been used in this application. This has been the sole domain of polyethylene, mostly 1.5 mm thick HDPE (Smith, 1994). Prior to 1994, there were no PVC-lined copper leach pads.

In recent years a problem unique to copper heap leaching has been discovered. All of the Chilean copper mines are in the north, in or near the Atacama Desert. The local soils generally contain salts that are soluble in the acidic leach solution. These salts are primarily gypsum. The typical site in Northern Chile contains about 5 percent soluble salts, but this can range in concentration from 1 percent to 30 percent.

When a copper leach pad liner develops a leak, the percolating solution can dissolve the salts and cause localized differential settlement In extreme cases, numerical modeling has predicted biaxial strains of 20 percent Sites with high concentrations of acid-soluble salts require the use of a highly flexible geomembrane such as polyvinyl chloride (PVC) or very low density polyethylene (VLDPE). With Union Carbide's withdrawal from the geomembrane market, we have lost VLDPE as an option.

Why not PVC?

It is not clear why PVC has been excluded, but it is likely related to the common practice, especially in South American mining, of continuing with products that have been successful in previous projects. Further, there has not been a compelling reason to vary from the successful use of HDPE.

The mechanical requirements, such as puncture resistance and tensile strength, are identical to gold heap leaching, where PVC geomembranes have been used in a number of successful applications. The only significant difference between gold and copper leaching is the chemistry of the lixivant. While gold leaching uses an alkaline cyanide solution. copper uses a sulfuric acid solution at a pH around 2. In addition, trace organics (kerosene) from the process plant are in the solutions. **Table 1** presents typical copper pregnant leach solution (PLS) chemistry. Tests using EPA method 9090 have shown that PVC behaves well in contact with this solution (Smith, Orman and Queja 1995).

Designers now are faced with the issue of soluble salts, while operators are looking for ways to cut costs and streamline operations. The latter has lead to some interesting developments in the way heaps are stacked.

Table 1
Typical Copper PLS Chemistry

pH	1.7 - 2.0
Acid Content (H_2SO_4)	1 -2%
Kerosene	75 mg/l avg

Concurrent stacking technology

One of the major costs of a leach-pad liner system is the protective cover layer over the geomembrane. The purpose of this layer is to protect the geomembrane from damage by the large equipment used to stack the heap and from falling rock particles. This layer may not need to provide drainage when the permeability of the ore enhanced with drain pipes provides adequate drainage.

At the Blackhawk gold mine in Goldfields, Nev., and at the Lo Aquirre and El Lince copper mines in Chile, new methods of stacking were developed in the 1980s. In both methods the protective cover layer is omitted. At Blackhawk the ore is stacked with a conveyor-stacker operating over movable, protective panels isolating the rubber tires from the liner. Lo Aquirre and El Lince sequence the liner such that the stacker is working ahead of the leading edge of the deployed liner. In this method, the base liner is deployed concurrently with the stacking of the heap, as shown in **Figure 1.**

With the "El Lince method," the heap is stacked with a radial stacking conveyor system. The supports for the stacker are typically 5 to 10 meters from the toe of the advancing face of the heap. The liner system is deployed in rolls in the same direction that the radial stacker retreats. Each time the stacker retreats (usually about 5 meters at a time), the rolls of geomembrane are advanced and then seamed by mine personnel. This occurs daily.

In the following manner, however, heavy equipment is never working over the liner. After the first ore lift is fully leached, the process is repeated on top of that lift, using either no liner or a very thin liner, depending on metallurgical criteria The equipment then is isolated from the base liner by 2 to 8 meters of ore, reducing the loads to very low levels.

Mine personnel deploy the liner on a daily basis for the life of the project. Because the geomembrane installation will not be done by professional installers, seaming must be as simple as possible.

At Lo Aquirre and El Lince, the liner was a very thin (0.2 to 0.3 mm) low den-

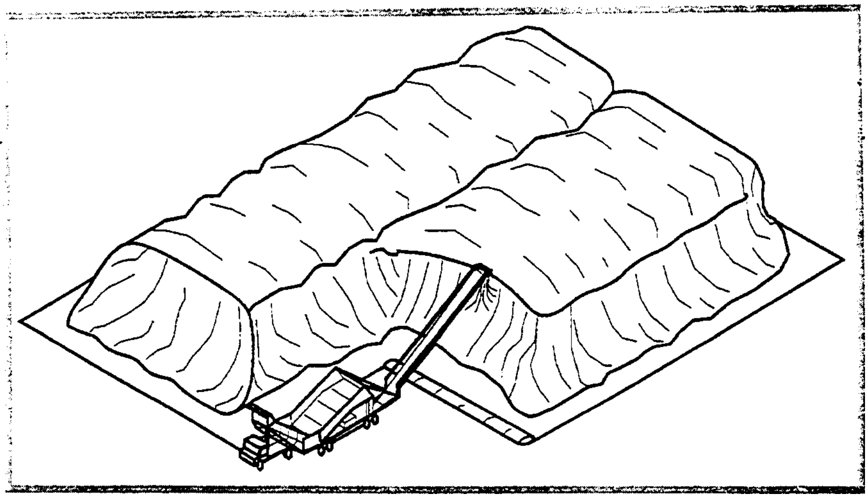

Figure 1. Concurrent heap stacking

sity polyethylene (LDPE). Selected for cost and availability, LDPE satisfies the desire to stay in the polyethylene group. Seams are formed by a sewn shingle-lap joint because of the difficulty in heat fusing such thin material. Leakage rates in excess of 1.5 percent of the process flow rates, however, resulted in important economic and environmental concerns (Smith, 1993).

Modernization

In 1993, the author was approached by two separate mining companies to apply the concurrent stacking technology while using a modem liner system. After considerable operations and capital cost studies, a liner system using PVC geomembranes was selected for both Chilean projects. This system is shown in **Figure 2.** Ultimate heap heights range from 12 to 50 meters.

Geomembrane thicknesses of 0.75 to 1.0 mm were selected, based on the relative quality of the bedding and the fine particle size of the ore to be placed over the geomembrane. Thicknesses in the range of 0.5 to 1.25 mm (20 to 50 mm) may be appropriate in other circumstances.

The bedding layers were constructed by carefully working the natural soils, locally called Chusca, using a combination of steel drum rollers, motor graders and manual labor for rock removal.

The crushed ore, 12 to 19 mm in maximum particle size, is placed directly over the geomembrane by use of the radial stacker. The stacker works at a height of about 4 meters, but the ore rolls down the face of the heap and the impact on the liner is minimal.

Perforated pipes are installed concurrently with liner deployment to aid drainage and to control the hydraulic head over the geomembrane.

The leach pads and ore heaps at both projects went into construction in mid-1994, and one was in production by year-end. The concurrent liner deployment and heap stacking methodology is working as planned, with the expected fine-tuning and procedural optimization.

A third project, in pre-feasibility studies in 1994, may incorporate a PVC-lined conventional leach pad. PVC is being considered because of the salt-induced differential settlement potential in the foundation.

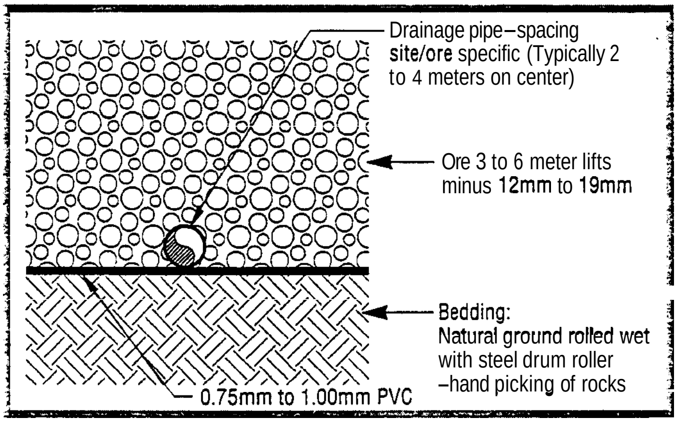

Figure 2. Leach pad liner system

Significance

While not all copper heap-leach projects lend themselves to the concurrent stacking technology, up to one-third do. With these two projects in production, PVC should become an acceptable product for both concurrent and conventional stacking. As of this writing, at least one other copper project in Chile and one in the United States are considering PVC for their leach pads. Both projects are direct results of the successful application at the first projects and both will use conventional stacking technology.

These projects have demonstrated two important items. First, they have given designers the ability to select PVC geomembranes for copper projects when the engineering constraints so dictate, with fewer pre-existing industry biases against this material or the absence of successful case histories. Second, they demonstrate that concurrent stacking technology can be successfully implemented while using an engineered liner system.

These factors allow engineers more opportunity to optimize their liner designs, which should result in cost and performance benefits to the mine owners. This is especially important considering the increasing need for flexible liners and the loss of VLDPE as a design option.

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THE FIRST PVC-LINED COPPER LEACH PADS

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Introduction

Copper heap leaching has been common since the 1970s, but it became a major component of commercial production in the early 1980s. Chile is the leading producer of copper followed by the U.S., and while conventional milling remains the primary source of production, heap leaching continues to increase in its share of production (Smith, 1992).

In Chile it has been estimated that copper heap leaching consumes 3 million square meters of geomembranes annually for the base liner, plus a large additional amount for liners between lifts of ore. However, until 1994 PVC geomembranes have not been used in this application; this has been the sole domain of polyethylene, mostly 1.5mm (60 mil) thick high density polyethylene (HDPE) (Smith, 1994).

In recent years a problem unique to copper heap leaching has been discovered. All of the Chilean copper mines are in the North, in or near the Atacama desert. The local soils generally contain salts that are soluble in the acidic leach solution, ranging in concentration from 1 to 30 percent by dry weight.

When a copper leach pad liner develops a leak, the percolating solution can dissolve the salts and cause localized differential settlement. Numerical modeling has predicted biaxial strains on the order of 20% in certain cases. These sites require the use of a highly flexible geomembrane and all but preclude the use of HDPE.

Why Not PVC?

It is not clear why PVC has been excluded, but it is likely related to the common practice, especially in mining, of doing what has been done before.

The mechanical requirements are identical to gold heap leaching, where PVC geomembranes have enjoyed successful applications. The only significant difference between these processes is the chemistry of the lixivant. While gold leaching uses an alkaline cyanide solution in the pH range of 9 to 11, copper leaching uses dilute sulphuric acid at a pH around 2. In addition, trace organics (kerosene) from the process plant are in the solutions. Table 1 presents typical PLS chemistry. Tests using EPA method 9090 procedures have shown that PVC behaves well in contact with this solution (Smith & Orman, 1994).

Concurrent Stacking Technology

One of the major costs of a leach pad liner is the **engineered** protective cover layer over the geomembrane. The purpose of this is to protect the geomembrane from damage by the large equipment used to stack the heap. This layer generally does not need to provide drainage because the permeability of the ore - enhanced with drain pipes - provides adequate drainage.

pH	**1.7 -** 2.0
Acid Content	**1 - 2 %**
Kerosene	***50 - 200*** **mg/l** (*75* **mg/l** avg.)

Table 1
Typical PLS Chemistry

In the U.S. at the Blackhawk gold mine in Goldfields, Nevada, and at the Lo **Aquirre** and El Lince copper mines in Chile, a new method of stacking was developed in the 1980s. In this method, the base liner is deployed concurrently with the stacking of the heap, as shown in Figure 1.

The heap is stacked with a radial stacking conveyor system. The supports for the stacker are typically 5 to 10 meters from the toe of the advancing face of the heap. The liner system is deployed in rolls in the same direction that the radial stacker retreats. Each time the stacker retreats, usually about 5 meters at a time, the rolls of geomembrane are advanced and seamed by mine personnel.

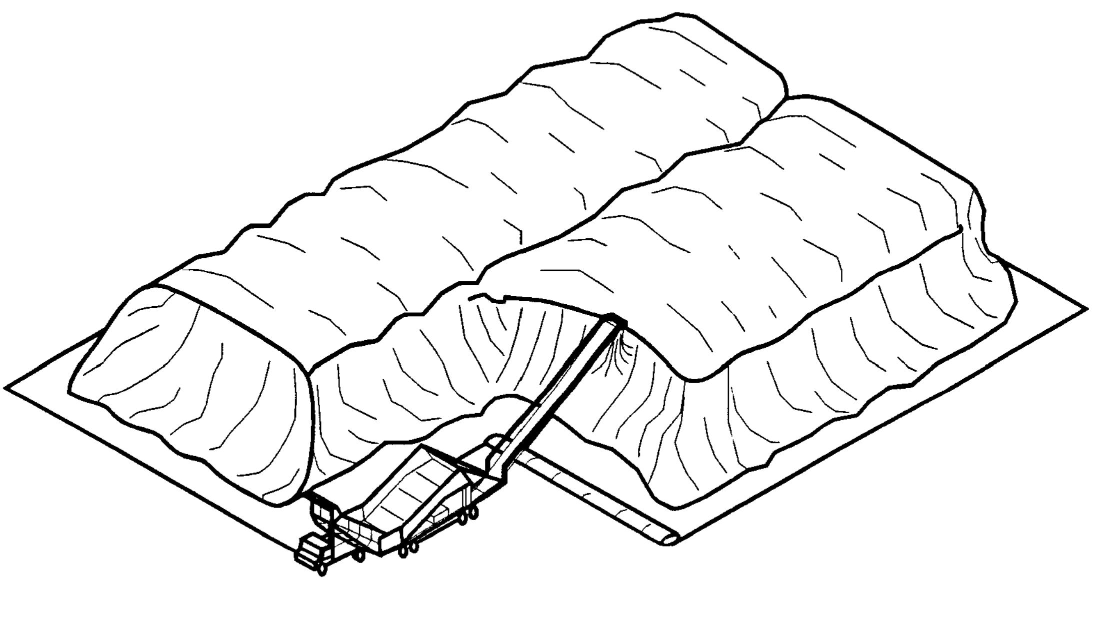

Figure 1
Concurrent Heap Stacking

In this manner there is never heavy equipment working over the liner. After the first lift is fully leached, the process is repeated on top, using either no liner or a thinner liner. The equipment is then isolated from the liner by 4 to 8 meters of ore, reducing the loads to very low levels.

Because the liner must be deployed on nearly a daily basis for the life of the project, the mine personnel do this job. This means that the geomembrane installation won't be done by professional installers and seaming must be as simple as possible.

At Lo Aquirre and El Lince the selected liner was very thin (0.2 to **0.3mm)** low density polyethylene (LDPE). LDPE was apparently selected for cost and availability. Seams are formed by a sewn shingle-lap joint because of the difficulty in heat fusing such thin material. However, leakage rates in excess of 1.5% of the process flow rates resulted, causing importance economic and environmental concerns (Smith, 1993).

Modernization

In 1993 the author was approached by two separate mining companies to apply the concurrent stacking technology but use a modern liner system.

After considerable operations and cost studies a liner system using PVC geomembranes was selected for both Chilean projects. This system is shown in Figure 2.

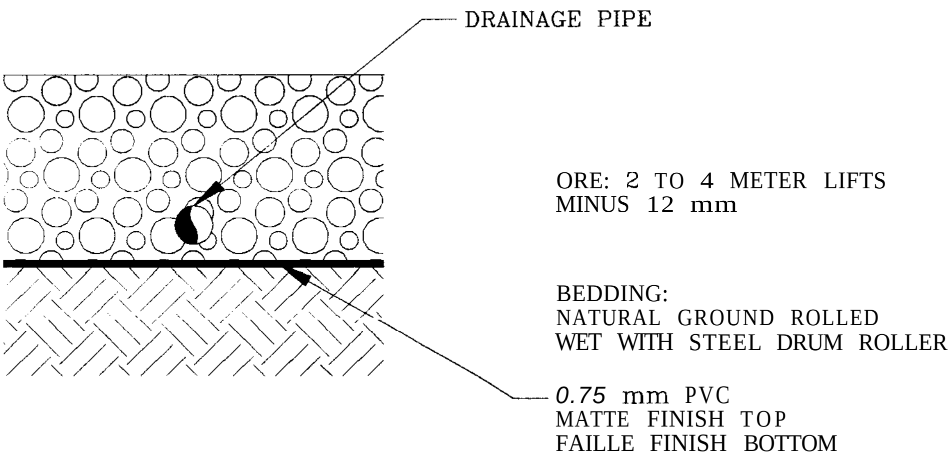

Figure 2
Leach Pad Liner System

A geomembrane thickness of **0.75mm** (30 mil) was selected for both cases because of the relative quality of the bedding and the fine particle size to be placed over the geomembrane. However, thicknesses in the range of 0.5 to **1.25mm** (20 to **50mm)** may be appropriate in other circumstances.

The bedding layer was constructed by carefully working the natural soils, using a combination of steel drum rollers, motor graders and manual labor for rock removal.

The crushed ore, 10 to 12mm in maximum particle size, is placed directly over the geomembrane by use of the radial stacker. The stacker works at a height of about 4 meters, but the ore rolls down the face of the heap and the impact on the liner is minimal.

Perforated pipes are installed concurrently with liner deployment to aid drainage and control the hydraulic head to less than **300mm** over the geomembrane.

Performance

The leach pads and ore heaps at both projects went into construction in July and August of 1994, and one was in production by October 1994. The concurrent liner deployment and heap stacking methodology is working basically as planned, with the expected fine-tuning and procedural optimization.

Significance

While not all copper heap leach projects lend themselves to the concurrent **stacking** technology, an important percentage do. With these two projects in production, **PVC** should become an acceptable product for both concurrent and conventional **stacking.** In fact, as of this writing at least one other copper project in Chile and one in the U.S. are planning on **PVC** for it's leach pads: both are direct results of the successful application at the first projects and both will use conventional stacking technology.

These projects have given designers the ability to select **PVC** geomembranes for copper projects when the engineering constraints so dictate, without pre-existing industry biases against this material or the absence of successful case histories. This gives engineers more ability to do their job in an optimal manner, and this should result in cost and performance benefits to the mine owners.

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