COMPARISON OF SPRAY AND DRIP LEACHING SYSTEMS

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Introduction

Methods and research findings related to leaching of agricultural lands are applicable to heap leaching in mining. Water is used as the basic carrier and efficient use of the leaching solution is important. In both agriculture and mining, the solution moves in response to the same physical laws.

Probably the greatest difference between agriculture and mining leaching is the chemistry of the leaching solution and its potential effect on safety and the environment. But particle and pore sizes of the mediums are also different, and this affects the way water moves through them.

Leaching is used in agriculture to remove undesirable salts; in mining it is used is to retrieve metals. Toxicity and wind drift of the leaching solution are usually not a problem in agriculture, but in leaching of ore, they are.

The purpose of this paper is to compare and evaluate the characteristics of heap leaching with a commonly used spray system and an Ore'Max drip system being newly introduced for this application. The Ore'Max drip system is referred to by name in this report because all drip systems will not perform in the same manner when used for leaching purposes.

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PROCEDURE

A spray system and an Ore'Max drip system were installed on the Rochester Mine near Lovelock, Nevada in 1986. They were operated during 1986 and 1987 when measurements and observations of their effectiveness in heap leaching were made. Characteristics of the two systems that are important to the leaching process are compared and conclusions are presented based on these comparisons. Layouts of these systems are shown in figures 1 and 2.

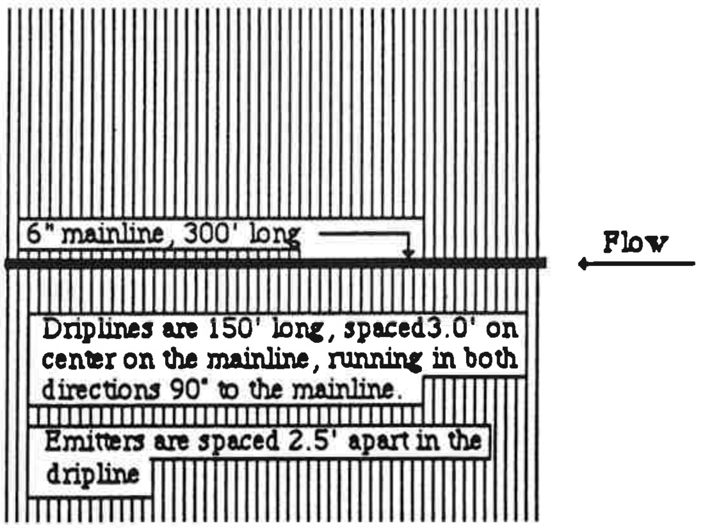

Figure 1. Layout of Ore'Max drip system.

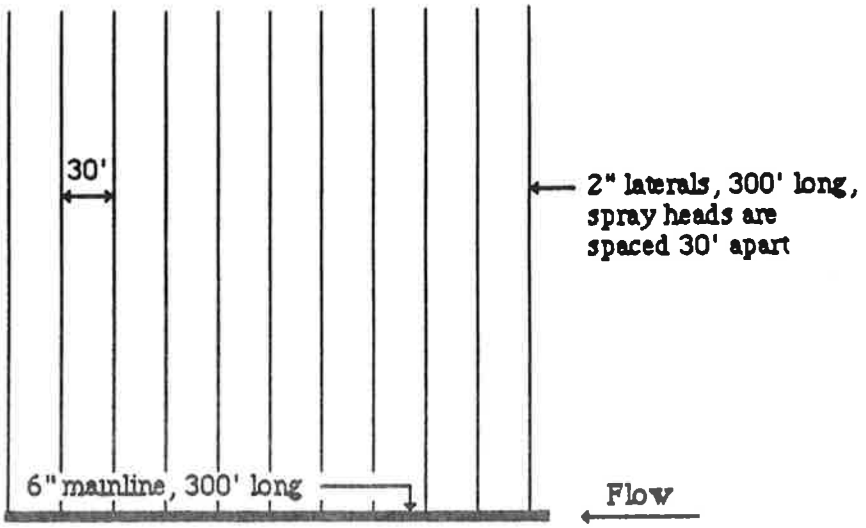

Figure 2. Layout of spray system.

OBSERVATIONS AND DISCUSSION

Capital and Installation Costs

Capital investments for the two systems used to cover the two 90,000 square foot panels, each 20 feet deep, are shown in Tables 1 and 2 . Pumps, pipelines, and other equipment outside the panel boundaries are not included.

Table 1. Capital costs for drip system covering 90,000 square foot panel.

Item	Amount	Unit	Total Cost
6" pipe with coupler and spline	300	feet	$2277.00
6" end cap	1	each	26.56
6" valve	1	each	290.00
drip hose	30,000	feet	4620.00
figure 8 drip hose end	200	each	30.00
0.5" adapter, thread to barb	200	each	60.00
		Total Capital Cost	$7303.56

Table 2. Capital costs for spray system covering a 90,000 square foot panel.

Item	Amount	Unit	Cost
2" pipe with coupler & spline	3000	feet	$4590.00
6" pile with coupler & spline	300	feet	2277.00
6" x 6" x 2" tee	10	each	1253.00
6" end cap	1	each	26.56
2" end cap	10	each	86.40
spray heads	100	each	364.00
pressure regulators	100	each	448.00
6" valve	1	each	290.00
2" valves	10	each	574.20
		Total Capital Cost	$9909.16

The average cost for the spray system was 11.0 cents per square foot. The average cost for the Ore'Max drip system was 8.1 cents per square foot, a savings of 2.9 cents per square foot .

Installation time favored the spray system; 36 man-hours versus 42 for the Ore-Max drip system. Man-hours required for various installation activities are shown for each system in Table 3.

Drilling and taping the 6-inch mainline of the drip system are performed only once during the life of the mainline. It was done prior to installation with non-priority labor. The 2-inch laterals of the spray system were fitted with spray heads and pressure regulators prior to installation of that system. All lines of both systems were flushed to remove debris that accumulated during the installation process.

Table 3. Time required to install and remove leaching systems on a 90,000 sq.ft .panel.

Type of system	Activity	Man-hours
Ore-Max	Layout and connect 300' of 6" mainline with one flushing and one 6" shut-off valve	12
	Layout 30,000' of drip line connected to header	18
	Removal	12
	Total man-hours for drip system	42
Spray	Layout and connect 300' of 6" mainline pipe with 6" x 6" x 2" Tee every 30', and one 6" valve	12
	Layout 9000' of 2" pipe with spray heads	12
	Removal of system	12
	Total man-hours for spray system	36

Maintenance

Maintenance and monitoring requirements of the two systems were quite different. The Spray heads threw solution into the air where it was subject to evaporation and drift. When spray fell on the panel surface, pipes, and spray heads, scale formed due to evaporation, precipitation, and the natural scaling tendency of the caustic cyanide solution. This caused the Spray heads to function unevenly and sometimes stick, spraying solution mostly in one direction. This in turn resulted in ponding, very uneven distribution of the leaching solution, and uneven leaching of the panel.

In addition, falling spray from the spray heads had many large droplets with sufficient energy to move and compact the fines into the larger pores of the crushed ore. The addition of scale to these fines caused cementation of the fines and reduced the pore size in the ore so that its surface permeability was less than the rate that water was applied. This resulted in surface ponding.

The spray heads required replacement and acid washing to remove the scale. Replacement of spray heads required shut down of the spray line and wearing of a full isolation suit by the operator for protection from the cyanide solution. The spray system required constant monitoring to minimize the number of stuck spray heads.

Evaporation caused formation of scale around emitters of the Ore'Max system and in the last two rings inside the emitter wall when a heavy rain upset the chemistry of the leaching solution. The scale was usually broken clean by pinching the discharge end of the emitter with pliers. When build-up was such that this did not solve the problem, the emitter was replaced in less than 2 minutes without shutting the system down. The field work required wearing only rubber gloves for protection. Less than 1 percent of the emitters scaled up during the observation period.

The effect of scale formation was not nearly as critical with the Ore'Max system as it was with the spray system. Scale formation at the emitters did not cause reduction of porosity, erosion, ponding, or washouts. The monitoring requirement for the drip system was therefore considerably reduced.

Surface Coverage

Surface coverage from the spray system should be 100 percent of the surface area. Considerable overlap of spray patterns is required to obtain reasonably uniform application of the leaching solution to the panel surface. It would seem logical that with uniform application to the panel surface, vertically solution movement in the ore should also be uniform. But this is not necessarily true as the ore is not homogeneous.

When the solution is applied to the panel surface, and there is a good mixture of particle sizes on the surface so that the macro pores are well bridged, the solution infiltrates and travels through the ore almost entirely in the small capillary pores forming continuous films around the particles, not in the large open pores where gravitational forces dominate. In fact water will avoid entering the larger pores until the capillary pores are nearly saturated.

As solution occupies the capillary pores and forms films around the ore particles, solution moves in all directions from wet to dry, or in more exact terms, from low tensions to high tensions. In concentrations of very fine particles and extremely small pores, the rate of movement in all directions is slow but nearly uniform because the gravitational influences are almost nonexistent. In a medium composed of nearly all large pores such as found in sand, gravity has a significant influence and the wetted pattern under emitters is elongated vertically.

Pore size distribution of the ore therefore influences both the entrance, and movement of solution in both the vertical and horizontal directions. Finer particles reduce the amount of large pore space but increase the leaching effectiveness of the solution as it moves through the panel by increasing the capillary channels and the solution-particle contact.

The ore at the Rochester mine is crushed to 80 per cent less than 3/8 of an inch, and 5 percent less than 200 mesh. The net application rate of the solution to the panel surface was 0.24 gallons per hour per square foot. There was no ponding or runoff from the panel under the Ore-Max system.

Heap Permeability

Permeability of a heap during the leaching operation is a major factor in obtaining maximum recovery of metal. The agglomeration of high clay ores improved permeability and made their processing effective. The method of applying the leaching solution, as stated earlier, can significantly influence the porosity of the heap near the surface, the solution movement through it, and the resultant removal of gold and silver.

Droplets from spray systems were large. This was desirable as it reduced wind drift and evaporation, but when the drops struck the panel surface, they washed the finer particles into pores where they collected, reoriented, and reduced the surface intake rate to less than the rate that the solution was being applied. This resulted in solution ponding on the surface of the heap.

The leaching solution from the spray heads was saturated with carbonate and bicarbonate ions when it impacted the surface. Calcium carbonate scale that was formed was from 2 to 6 inches thick and had a hardness comparable to concrete. When these conditions developed, it was necessary to rip the panel.

Droplets from emitters fall from 0 to 10 inches compared to as much as 120 inches from spray heads. A small amount of washing occurred at the point of impact under the emitters. However, this area was only a few inches in diameter and the surface of the heap remained near its original permeability throughout the leach cycle.

Under the drip system, the leaching solution and the salts in the solution moved from the point of impact, where low tension values existed, through capillary migration to drier areas where higher tension values existed. Gravity had a slight but minor influence in the smaller capillary pores but increased to cause more vertical movement in the larger capillary pores. The surface of the heap remained near its original permeability throughout the leach cycle. The calcium carbonate scale and other evaporative salts remained near the surface without influencing the permeability of the heap.

Ponding, Overspraying, and Washouts

Maximum spacing of emitters is controlled by the infiltration rate and capillary conductivity of the heap. Because the crushed ore is not homogeneous, theoretical calculations for determining spacings are of little value. Satisfactory spacings can be determined most reliably in the field by observing the lateral and vertical movement of the solution in ore under the discharge from a single emitter. To make this observation, a trench is dug across the middle of the wetted area after a few hours of leach solution application from an emitter. The shape of the wetted cone can then be observed. It is desirable to make more than one observation because of the non-homogeneous nature of the crushed ore.

Using a spray system on the sides of a panel may result in (1) overspraying the solution beyond the ore or plastic panel barrier, and (2) washout of the sides if the application rate exceeds the infiltration rate of the panel. Infiltration rates of panel sides are considerably less than infiltration rates of panel tops because of the slope of the surface. Reducing application rates with the spray systems to control these problems can be difficult. But they are not serious with the drip system as the application rate can be controlled easily through emitter selection, emitter spacing, or line pressure, so that the physical limitations posed by the heap can be easily met.

At the Rochester mine, the sides of the panels were leached very satisfactorily with Ore-Max emitters. However, it was important to keep the application rate below the intake rate of the panel or washing would have occurred. There was no loss of solution by overspraying as the solution didn't travel laterally through the air.

Spacing of emitters should result in the wetted fronts meeting relatively close to the surface near the center between two emitters. If it is desired that the cones meet closer to the surface to reduce the volume of non-leached ore, this can be accomplished by placing the emitters closer together. However, this will increase the capital cost slightly.

At the Rochester mine, sampling revealed that contact of the wetted fronts between the two drip lines was 4 to 6 inches below the surface as shown in figure 3. Less than one percent of the total panel volume was not leached under this arrangement.

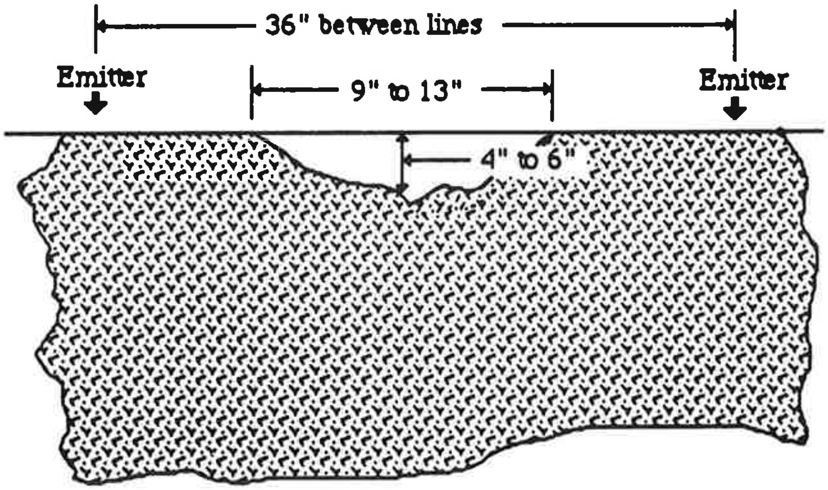

Figure 3. At the Rochester mine, the wetting fronts met 4 to 6 inches below the panel surface with the emitters on a 30" x 36" spacing.

Failing to provide 100 percent leaching of panels at the Rochester mine was not critical as panels are stacked on top of one another in 20 foot increments and any skipped areas are picked up during the next leaching.

Oxygen and Carbon dioxide concentration

One of the important advantages of the Ore'Max system over the spray irrigation during the leaching process was the tremendous reduction in the exposure of the leaching solution to the atmosphere. Increased exposure results in increased dissolved oxygen and carbon dioxide, increased evaporation, and increased heat loss. All of these effects are undesirable except increased dissolved oxygen.

Spraying the solution through the atmosphere results in saturating the solution with oxygen and carbon dioxide before it strikes the panel surface. The adsorbed carbon dioxide in solution reacts with the hydroxide ion in the solution forming bicarbonate and carbonate ions. This reaction lowers the pH and increases the consumption of lime. The solution then tends to scale the panel surface much more with the spray system than with the drip irrigation.

Evaluation of the solution applied at the Rochester mine with the drip system for dissolved oxygen showed the solution at the emitter discharge to contain 5 to 6 ppm of oxygen. The pregnant effluent collected at the central drainage well contained 7 to 8 ppm oxygen. The porosity of the heap allowed air to permeate the heap as the solution percolated through, resulting in more than enough dissolved oxygen in solution to dissolve gold and silver.

Evaporation of Solution

Evaporation of the solution under the spray system was significant. Loss of solution under atmospheric conditions of high temperatures, low humidity, and high winds, frequently experienced in desert conditions can result in evaporation and drift losses of 15 to 25 percent, and even higher under extreme conditions. Spray heads, having large drop sizes tend to reduce this loss but cannot come close to reaching the low losses associated with the Ore'Max drip system.

Exposure of the solution to the atmosphere from the drip system occurred only as the solution left the emitter, traveling 0 to 10 inches in the atmosphere, and from the wet soil surface around it. The wetted surface area under the drip system at the Rochester mine was one-third to one-half the total surface area of the panel, compared to the total surface area under the spray system.

Evaporation of the solution lowers solution temperature due to evaporative cooling. Solution traveling through the air reaches approximately wet bulb temperature within 10 feet of spray heads regardless of the solution temperature in the pipelines. This becomes a serious factor when air temperatures are below freezing.

Leaching with the spray system resulted in the formation of massive amounts of ice. The ice fields under spray heads at the Rochester mine in 1986 were 7 feet thick in some areas. A significant amount of solution was tied up as ice during the winter. An early spring thaw or warm rain can melt an ice field rapidly. The result can be serious if the process ponds are not sized to handle sudden increases in solution volume. Ice build-up on the panel surface results in non-uniform leaching rates. If the piping system freezes, the pipe system cannot be recovered until the ice melts.

Heat loss from the drip system application was significantly lower than heat loss from the spray application since the solution from the drip system was applied in large droplets and was in the atmosphere for such a short distance. The drip lines were laid underground for the winter season at the Rochester mine. They were installed three at a time behind three ripper-shanks at a depth of 2 to 3 feet. The crushed ore above the system will be leached when the panel above it is leached.

There were some drip lines at the Rochester mine which remained on the surface during the winter of 1986. The first half of each drip line maintained flow throughout the winter. The ends of those lines froze at night but resumed dripping during the warmer part of each day. A thin layer of ice formed on the surface around emitters. The amount of ice that formed was insignificant, but this may vary from year to year depending upon the severity of the weather. Snow tended to insulate the drip lines against radiant cooling. Snow melt first occurred along the drip lines.

Reagent losses occurred when solution was sprayed through the atmosphere. Sampling of the feed solution and a composite of the solution striking the panel surface revealed noticeable loss of sodium cyanide and reduction in pH. Sodium cyanide in spray can volatilize as hydrogen cyanide. Ultraviolet light also decomposes cyanide. The losses were directly related to the surface area of the solution exposed to the atmosphere.

Influence of Scale

The control of scale is very important in all mineral processing operations using water. The heap leaching of gold and silver by cyanide solution is very sensitive to scale formation. The scale that is formed is mainly calcium carbonate and is from lime used to maintain the pH above 10.5. Various companies sell a variety of scale-controlling reagents. Every operation's water chemistry is different. A reagent that works at one operation may not work well at another.

The formation of scale is influenced by the solution temperature, pressure differential, and surface area available for precipitation. The solubility of calcium carbonate is reduced by increasing the temperature or rapidly reducing the pressure of the solution.

Scale precipitation in pipelines can reduce the cross-sectional area of the pipelines, thus restricting solution flow. Scale can block the pores of activated carbon and can reduce the adsorption and desorption capabilities of activated carbon. Scale is removed from activated carbon by washing with nitric acid. Scale is removed from filter cloths used in Merrill-Crowe plants by washing with sulfamic acid.

As stated earlier, precipitation of scale on spray heads used in spray systems causes irregularities in spray patterns so that spray discharge is pointed mainly in one direction. This results in uneven application of the solution, washing of finer particles into the heap causing a reduction in intake rate and permeability, ponding, and possible runoff.

When scale forms on spray heads, they must be replaced or washed in acid. This requires that the spray line be shut down and the worker wear a full isolation suit to protect him from cyanide solution.

When scale forms on emitters, it accumulates at the discharge of emitters and can restrict flow from the emitter and the amount of leaching occurring under it. Since the emitter is on the surface of the panel, the scale can usually be removed by simply pinching the discharge end of the emitter with pliers.

Since the formation of scale on emitters results mostly from evaporation, a better way to control this problem may be to cover the emitter with a shallow layer of solids. Evaporation will then occur at the surface of the solids rather than the emitter. It is possible to provide this cover during installation of the Ore'Max system with an appropriately designed tool, particularly if the installation process is mechanized.

CONCLUSIONS

The following conclusions are made:

The Ore'Max drip system costs 25 percent less than the spray system.

The spray system requires 12 percent less installation labor than the Ore-Max system.

The Ore'Max system required less maintenance and less monitoring than the spray system.

There was considerably less scale and precipitation of calcium bicarbonate with the Ore'Max system. The scale that formed reduced the flow-rate only slightly rather than directing all discharge in one general direction resulting in ponding.

There was no ponding of the solution under the Ore-Max system

Surface permeability was much better under the Ore-Max system

Spacing of emitters on Ore'Max systems was controlled so that unleached ore in a 20 foot panel was less than one percent.

An Ore-Max system was installed to operate year around by burying it 2 to 3 feet below the surface. No ice formed on the panel surface.

Reagent losses were extremely small with the Ore'Max system as compared to losses from the spray system.