THE VALUE OF GEOELECTRIC LEAK DETECTION SERVICES FOR THE MINING INDUSTRY[i]

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Abstract

The authors have performed an economic analysis of performing geoelectric leak location surveys on heap leach pads for gold and copper mining. Most likely average values for the input variables yielded benefit-to-cost ratios of 6.2 for gold mining and 5.6 for copper mining. The probability that the benefit-to-cost ratio for gold heap leaching would be greater than one was 97%, while the probability for copper was 96%. The benefit-to-cost ratios were determined by calculating the liner leakage rate and equivalent value of the lost solution versus the cost of performing a leak detection survey to find the leaks. Due to the large fluctuations in operating parameters for each heap leach site, a site-specific analysis would have to be performed to most accurately determine the benefit-to-cost ratio for a particular site, especially when leaching low grade ore, placing the liner on low permeability subgrade, or operating with low head. All monetary values presented herein are in US dollars.

Introduction

Geoelectric leak detection survey technology has been developed and applied over the past 20 years (Laine and Darilek, 1993). The largest area of application of this technology has been the waste containment industry. Up to the present, there has been little economic value placed on leak detection surveys due to the fact that the surveys have mainly been driven by environmental regulations. This paper intends to analyze the benefit-to-cost ratio of performing leak detection surveys on heap leach pads for gold and copper ore processing. The value of the surveys would be relative to the value of leachate solution lost through holes in the liner that would otherwise go undetected. To find the benefit-to-cost ratio, the value of solution lost throughout the life of the leach pad is compared to the cost of the survey.

Heap leaching is a mineral processing technology where piles of crushed ore are leached with chemical solutions to extract the desired metal. The leaching process takes place on leach pads, which are usually lined with a geomembrane overlain by a crushed rock drainage layer to facilitate the recovery of the leachate solution. The solution passes through the ore mass and dissolves the desired metal. The "pregnant leach solution"

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(PLS) is then recovered, the mineral is extracted, and the solution is then recycled back to the leach pile. The solvents used for gold and copper mining are cyanide and sulfuric acid, respectively. Heap leach pads generally do not undergo the same regulatory scrutiny as a solid or hazardous waste containment facility. In addition, most do not include a cushion geotextile on top of the liner to buffer the impact of rock placement on the liner. By performing a leak detection survey before leach pad operation, the PLS would not be lost through holes that would otherwise go undetected.

Background of Electric Leak Location Surveys

Electrical leak location (ELL) surveys can be performed on exposed or covered geomembranes, provided that the geomembrane used is electrically isolative. Double-lined systems (used in some types of leach pads) can be surveyed if a conductive layer is installed in between the two geomembranes such as a geosynthetic clay liner (GCL) or a conductive geotextile. In some cases, the leak detection layer can be flooded to enable the leak detection survey.

The water lance method (ASTM D 7002) is used to locate holes in exposed, dry geomembranes. This technique is able to locate the holes created during the liner installation, including pinholes which are invisible to the naked eye. To perform the survey, water charged with a low voltage is sprayed on the liner surface and the underlying subgrade is grounded to the power source. In the case of a hole, the water creates a passage for the current to flow to the grounded subgrade. An ammeter detects the presence of an increase in current flow, thereby indicating a hole in the liner.

The dipole method (ASTM D 7007) is used to locate holes in the liner after it has been covered by water or earth material. In the case of soil or rock cover, the thickness of the cover layer can affect the sensitivity of the equipment. Holes as small as 5 mm in diameter can be located under 0.6 meters of cover, and successful surveys have been conducted on 1.5 meters of material, although detection sensitivity is subject to many site-specific variables. To perform the survey, a positive electrode is placed in the overlying cover material and a high voltage is introduced. The underlying subgrade is grounded to the power source. The dipole instrument takes measurements of voltage potential in a grid pattern over the survey area. In the case of a hole, current flows through the hole and creates a voltage potential spike followed by a distinct drop before resuming the “background noise” values. This method is especially useful for leach pads, since the most significant damage to the liner occurs during placement of the overlying drainage rock (Thiel, Darilek, and Laine, 2000). In addition, solution ponds can be surveyed using the dipole method after filling.

Input Parameters And Assumptions

Many of the parameters used to calculate the value of leak detection services for gold and copper mine sites are highly variable. For this reason, a statistical approach was taken to find the probability that the benefit-to-cost ratio would be greater than unity. Employing the statistical method developed by Duncan (Duncan, 2000), most likely average values

(MLV) of all the variables were assumed, as well as the highest conceivable (HCV) and lowest conceivable values (LCV). The chosen values represent a best estimate of averages for conventional leach pads throughout the world, gleaned from the authors' mining and landfill engineering experience as well as published data. On-off pads (aka dynamic heaps) vary considerably in terms of percent active life where the liner is wet, as well as probable defect frequency. Valley fill heaps have considerably higher hydraulic heads (up to 40 m in one case). Due to the fact that heap leach mining sites do not have the same regulatory construction quality assurance (CQA) requirements as an average landfill, the average values chosen are higher than what is represented by the historic waste industry figures (Rollin et al., 1993). Table 1 shows the range and most likely values of the variables used.

Table 1. Variable Input Parameters

Variable	Units	HCV	MLV	LCV
Hole Frequency	No. of Holes/ha	30	17	5
Hole Diameter	mm	50	11	1.6
Head	m	3	1	0.3
Hydraulic Conductivity	cm/sec	5.0E-05	1.0E-05	5.0E-07
Contact Factor		1.15	0.60	0.30
Gold Concentration in Pregnant Solution	ppm	2.0	1.5	1.0
Copper Concentration in Pregnant Solution	ppm	7,000	5,500	4,000
Survey Cost	$ /ha	$5,380	$3,230	$2,150

In addition to the variable input parameters, several assumptions were made. A ten-year pad life was assumed, with any part of the pad wet only 25% of its life. Two feet of underlying subgrade with the given hydraulic permeability was assumed. The liner defects were considered to be circular in shape (though the shape of the defect has a second order affect on leakage). Metal values of $12.88 per gram of gold ($365/oz.) and $2.76 per kilogram of copper ($1.25/lb) were used. To calculate the benefit-to-cost ratio, an interest rate of 20% was assumed, common in mining. The concentration of the cyanide in the leachate solution for gold was assumed to be 75 mg/L and the cost $1.21/kg ($0.55/lb). The concentration of sulfuric acid in the leachate solution for copper was taken to be 1.5% and the cost $0.16/L ($80/ton).

Additional costs not taken into account for this study include potential liability costs for environmental degradation due to chemical leakage. The cost of hole repairs once they are located are not accounted for. Given the size of mining projects, it would be typical for most of the leak survey to be completed while a welding crew was still on site. This may not always be the case, however, and could affect the net present value of the analysis by a few thousand dollars.

Benefit-To-Cost Ratios

The benefit-to-cost ratios were calculated by finding the average leakage rate and the corresponding value of the PLS lost during the life of the site and comparing it to the cost of performing a leak detection survey. The leakage rate was calculated using the leakage rate equation for a circular hole in a composite liner (Giroud et. al, 1997). This was multiplied by the grade of the metal and the average leaching time. The future worth of the annual loss of PLS was divided by the future worth of a leak detection survey performed at the beginning of the site's life. The benefit-to-cost ratios for both gold and copper were calculated for the most likely values and plus or minus one standard deviation. The difference in the benefit-to-cost ratios obtained were used to calculate the overall standard deviation and coefficient of variation for the benefit-to-cost ratios. Assuming a normal distribution, the probability that the benefit-to-cost ratio would be greater than 1 was calculated. Tables 2 and 3 show the benefit-to-cost ratios for gold and copper, respectively.

Table 2. Benefit-to-cost ratios for Gold.

GOLD $B/C_{MLV} = 6.18$			
Variable	**Condition**	**B/C**	**Delta B/C**
Hole Frequency	MLV+σ =	7.70	3.03
	MLV-σ =	4.67	
Hole Size	MLV+σ =	7.58	3.40
	MLV-σ =	4.18	
Head	MLV+σ =	9.14	5.75
	MLV-σ =	3.39	
Hydraulic Conductivity	MLV+σ =	9.65	7.94
	MLV-σ =	1.70	
Contact Factor	MLV+σ =	7.64	2.92
	MLV-σ =	4.72	
Pregnant Solution Grade	MLV+σ =	6.86	1.37
	MLV-σ =	5.50	
Survey Cost	MLV+σ =	5.30	-2.12
	MLV-σ =	7.42	

Table 3. Benefit-to-cost ratios for Copper.

COPPER B/C$_{MLV}$ = 5.60			
Variable	**Condition**	**B/C**	**Delta B/C**
Hole Frequency	MLV+σ =	6.98	2.75
	MLV-σ =	4.23	
Hole Size	MLV+σ =	6.87	3.08
	MLV-σ =	3.79	
Head	MLV+σ =	8.28	5.21
	MLV-σ =	3.08	
Hydraulic Conductivity	MLV+σ =	8.74	7.20
	MLV-σ =	1.54	
Contact Factor	MLV+σ =	6.93	2.65
	MLV-σ =	4.28	
Pregnant Solution Grade	MLV+σ =	6.04	0.88
	MLV-σ =	5.16	
Survey Cost	MLV+σ =	4.80	-1.92
	MLV-σ =	6.72	

Results/Sensitivity

This study shows that on average, it would most likely be economically beneficial for a heap leach mine site to perform a leak detection survey, with a 97% probability for a gold site and a 96% probability for copper. However, there are several operational parameters specific to each mine site that can possibly lower the benefit-to-cost ratio below unity. Three variables used in this analysis that are site-dependent are the hydraulic head on the liner, the concentration of the metal in the PLS, and the hydraulic conductivity of the subgrade. If a site operates at an average head of 0.3 meters and stays in the range of 0.1 to 0.4 meters, without changing any of the other variables, the benefit-to-cost ratios become 1.9 for gold and 1.7 for copper, with respective probabilities of exceeding unity of 70% and 66%. Some low-grade tailings heap leach sites have PLS concentrations as low as 0.3 ppm of gold. Leaving all other variables as they appear in Table 1, by changing the range of gold concentration to 0.3(LCV) to 0.7(HCV) and the MLV to 0.4, the benefit-to-cost ratio for gold mining becomes 1.7, with a probability of exceeding unity of 60%. Due to the nature of the hydraulic conductivity of soils, which can differ several orders of magnitude, this site specific parameter can drastically change the benefit-to-cost ratio. According to Nevada Best Practice, subgrade hydraulic conductivity should be 1 x 10^{-6} cm/s. Changing the hydraulic conductivity HCV to 2 x 10^{-6}, the LCV to 8 x 10^{-7} and the MLV to 9 x 10^{-7}cm/sec , leaving all other variables unchanged from Table 1, the benefit-to-cost ratios become 1.0 and 0.9 for gold and copper, respectively and the probabilities of exceeded unity 40% and 34%.

On the other hand, the HCV figures also do not represent the known range of operating conditions. Hydraulic heads on conventional pads in excess of 10 meters are known, and valley fill pads can impound 40 meters. Dynamic heaps (on/off pads) expose the liner to solution about 75% of the time, versus 25% assumed in this study; and the high, cyclic service loads probably result in higher defect frequencies and sizes. Increasing these parameters would significantly increase the benefit-to-cost ratios and associated probabilities presented here.

Summary

Though metal concentrations and market prices vary considerably between gold and copper operations, the value per liter of PLS is almost the same. For most heap leach gold and copper sites, the cost benefit from performing a geoelectric leak detection survey initially could, in general, lead to savings of $15,000 net present value per hectare of liner area or more throughout the life of the site. For a large leach pad of 100 ha, this would equate to a savings of $1,500,000 present value during the life of the site. Sites operating with low head, low ore quality or with low permeability subgrade should be analyzed using site-specific values to ensure that a survey would pay for itself by the end of the pad life. In addition to the economic value that a leak detection survey adds to heap leach sites, unquantifiable environmental degradation can be avoided.

References

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