

The use of geomembranes in Chilean mining industry

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ABSTRACT: This article presents the main results pertaining to CQA programs on geomembranes lining more than 4 800 000 m² on 83 impervious works related to the Chilean mining industry. The mining industry operates many types of lined containment works using geosynthetics. Heap leaching is a technology using lined pads where crushed ore is leached with chemical solutions. Containment works used for heap leaching are leaching pads, ponds for pregnant leach solution (PLS) and ponds for water storage. Solar evaporation ponds, used extensively to concentrate brine and harvest crystalline salts from saturated solutions, are parts of a process for lithium, nitrate, potassium and iodine production. Very large solar ponds using PVC and PE geomembranes are exploited in Northern Chile including in the Atacama Desert. Containment ponds are also used for mine waste disposal and water (being a rare commodity in any desert). Leakage of process solutions is causing major economical and environmental impacts such that the mining industry adopts improved construction quality control programs to minimize the leakage rates. In this article the types of geomembrane materials used, the electrical leak location survey technique performed on exposed liners, the leak density observed, as well as an analysis of the type of leaks encountered are presented.

1. INTRODUCTION

Electrical Leak Location Survey (ELLS) technology has been performed over the past 20 years in environmental applications such as in landfills and containment ponds. GRI White Paper #8, January 2006 on "Construction Quality Assurance-Inspectors Certification Program (CQA-ICP)" inserted a section (#2.0) on ELLS to support that there is a direct relationship between leak occurrence and the presence or absence of a credible CQA program (Forget *et al.*, 2005). Recently, ELLS have been introduced steadily in the mining industry to insure the integrity of their containment ponds and leaching pads. Based on over 3 000 000 m² of surveyed liner, it was concluded that increasing the liner thickness represents an easy solution to improved performance of geomembranes by six fold in some cases (Marcotte *et al.*, 2009). Results gathered from surveys performed over the last four years in 83 operating and under construction ponds in Chile have been used to demonstrate benefits of performing ELLS's in the mining industry (Jacquelin *et al.*, 2008). In this paper, a ELLS technique is presented and statistics regarding detected leaks in geomembranes are presented to support that the leak density decreases as the surveyed area increases. The results support that solvent bonded patches represent between 60 to 80 % of all detected leaks in thin PVC liners.

2. CONTAINMENT WORKS

The mining industry operates many types of lined containment ponds using PE and PVC geomembranes. Heap leaching is a processing technology using lined pads covered with crushed ore to be leached with chemical solutions. Geomembranes are installed at the bottom of the heap leaching pads, as liners in pregnant leach solution (PLS) ponds to contain the solutions and in water storage ponds. These ponds are lined to minimize environmental impact by contaminating the ground with chemicals.

Being the world's largest natural supply of lithium and sodium nitrate, solar evaporation ponds are used extensively to concentrate brine and harvest crystalline salts from saturated solutions in the production of iodine, nitrate, potassium and lithium. Very huge lined containment ponds are exploited in the Atacama Desert such as shown in Figures 1 and 2 (Berube *et al.*, 2007). Damage to liners has a direct impact on the loss of brine, which is accountable by the Environmental Chilean Agency, affecting the global process of salts precipitation.

Containment ponds are also used for mine waste disposal. The Atacama Desert is the driest place on Earth, and is virtually sterile because it is blocked from moisture on both sides by the Andes Mountains and by coastal mountains. The average rainfall in this Chilean region is just 1 mm per year, and at one time no rain fell in the entire desert for

400 years. The water collected in the Andes must then be conveyed to the mining sites by pipelines and stored in containment ponds, water being a rare commodity in any desert.



Figure 1. Picture of evaporation ponds



Figure 2. Picture of evaporation ponds

3. ELLS ON EXPOSED GEOMEMBRANE

ELLS performed on geomembranes have been described in many publications, such as Forget *et al.* (2005 a to c), Laine *et al.* (1991,1993), Jacquelin *et al.* (2008), Marcotte *et al.* (2009) and Rollin *et al.* (1999, 2002, 2004) and are recognized in ASTM D6747, ASTM D7002 and ASTM D7007 standard practices.

The water puddle method consists in the creation of a potential difference between a soil under an exposed geomembrane and a puddle of water projected from a diffuser onto the surface. Most geomembranes being highly electrical insulators, as soon as water percolates through a perforation and reaches the supporting soil, a 'bridge' is created between these two potentials which generate an electrical current. A detector signals the presence of

an infiltration to the operator (via acoustical and visual signals). This technique permits the detection of leaks with dimensions of 1 mm² or greater (ASTM D7002) with a prospecting rate of 5 000 m²/day/operator using a water supply (provided from a tanker or a direct connection) of approximately 4 m³/day by operator depending on site conditions. Figures 3 and 4 provides a general schematic and picture of the water puddle method.

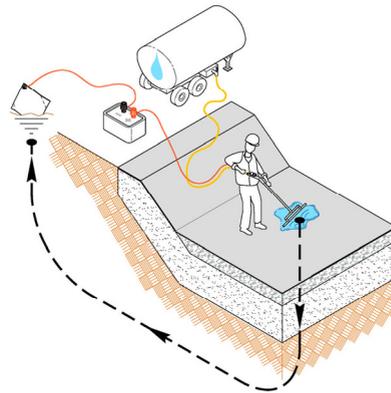


Figure 3. Water puddle technique on exposed géomembranes

4. RESULTS FROM ELLS

Leaks in a geomembrane are a result of many factors: as the installer experience, the Quality Control procedures implemented, the geomembrane thickness, the subgrade quality and the pond design. The results obtained during ELLS's performed on 83 ponds located in 9 different copper and lithium mining sites totaling more than 4.8 millions m² of covered area are presented in Table 1. These surveys have been performed during the 2002-2008 period.

The ELLS's results have been presented by grouped projects with similar liner material. For example, the first line in Table 1 shows the survey results obtained in four ponds lined with 0.5 mm thick PVC liner. The given area represents the total area surveyed for the four ponds, as well as the total number of leaks detected.

It can be noted on the last line of the Table 1 that 3 506 leaks have been located with a mean leak density of 7.25 leaks per hectare (10 000 m²) for the 4.8 millions square meters prospected.



Figure 4. Leak location survey using the water puddle technique

Data collected in ponds lined with PVC geomembrane can be used to support that the expected number of leaks is inversely proportional to the liner thickness as shown in Table 2. Data issued from ELLS's on evaporation ponds lined with a 0.5 mm thick PVC geomembrane are compared with those obtained in ponds lined with a 0.75 mm thick PVC geomembrane. This comparison stands

since all ponds were constructed with similar conditions: same soil conditions, same PVC formulation and supplier, same installer following proved Quality Control procedures, and huge covered areas. As expected, the leak density found in ponds lined with the 0.5 mm thick geomembrane (16.3 leaks/hectare) is four time greater than the one obtained in the ponds lined with the 0.75 mm thick geomembrane (4.5 leaks/hectare).

Data collected in ponds lined with a HDPE geomembrane cannot be used to support that the expected number of leaks is inversely proportional to the liner thickness as shown in Table 1 but can be used to support that there is a direct relationship between leak occurrence and the presence of a credible CQA program (Forget *et al.*, 2005).

For PVC geomembrane of 0.50 mm thickness the majority of identified leaks have been located at patches where solvent bonding is used (see Table 3). For thicker PVC liner, such as for 0.75 mm thick, the leaks at patches and at seam represent respectively 1 % and 33 % of all detected leaks.

Table 1. Results from ELLS in mining applications in Chile

Type of geomembrane	Thickness (mm)	Number of projects	Total area (m ²)	Number of leaks	Leak density (leaks/ha)	Leaks per project	Occurrence (area/leaks)
PVC	0.5	4	1 145 000	2 127	18.58	531.8	538
PVC	0.5	1	444 886	472	10.61	472.0	941
PVC	0.75	2	600 000	267	4.45	133.5	2 239
LLDPE	1.0	5	9 951	25	25.12	5.0	383
HDPE	1.0	50	2 525 092	522	2.07	10.4	4 828
HDPE	1.5	12	92 362	79	8.55	6.6	1 155
HDPE	2	9	20 380	14	6.87	1.6	1 359
Total		83	4 837 671	3 506			
Average value					7.25	42.2	1 380

Table 2. Results from ELLS's on exposed PVC Geomembranes

Containment Application	Type of geomembrane	Geomembrane thickness (mm)	Total areas surveyed (m ²)	Number of leaks detected	Leak density (leaks per hectare)
Solar Evaporation Ponds	PVC	0.50 mm	1 589 886	2 599	16.3
Solar Evaporation Ponds	PVC	0.75 mm	600 000	267	4.5

Table 3. Results from ELLS's on exposed liners

Material	Thickness	% leak located at patches	% leak located at field seams	% leak located in liner
PVC	0.50 mm	60 to 80 %	7 to 27 %	13 %
PVC	0.75 mm	1.4 %	34.1 %	64.5 %

The leak density for the 83 projects with surveyed areas varying from 600 to 2 000 000 m² is presented in Figure 5. Those results, as well as statistics

published in other papers (Colluci *et al.*, 1995), support that the leak density decreases with pond area. ELLS data in Table 1 for thick HDPE geomembrane

(1.5 and 2.0 mm) obtained on ponds having many years of operation support that the selection of a thick geomembrane does not guarantee low leak densities in all the cases. The relation between leak density and the application, or not, of a rigorous CQA program during installation and covering has been found to be crucial (Forget *et al.*, 2005a). The CQA allows a preventive control of leaks, and considerably reduces their number.

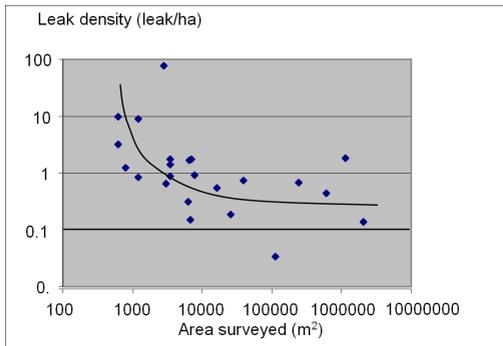


Figure 5. Leak density as a function of surveyed areas

5. CONCLUSION

ELLS has been introduced steadily in the Chilean mining industry to insure the integrity of their containment ponds and leaching pads securing environmental concerns and economical impact. Data resulting from these surveys performed over more than 83 ponds indicate the necessity of performing ELLS during geomembrane installation. For ponds lined with PVC geomembranes the expected number of leaks is inversely proportional to the liner thickness and that the majority of identified leaks have been located at patches where solvent bonding have been performed for PVC geomembrane of 0.50 mm thickness. On a short term basis, leak detection allows to qualify the geomembrane and to ensure its integrity at the time it is put into operation. QA and electrical leak detection, when used jointly, are today the best guarantee of short and long term integrity of containment ponds using geomembranes.

REFERENCES

- ASTM D6747. Standard Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes.
- ASTM D7002. Standard Practice for Leak Location on Exposed Geomembrane Using the Water Puddle System.
- ASTM D7007. Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials.
- Bérubé, D., Diebel, P., Rollin, A.L. & Stark, T. 2007. Massive Mining Evaporation Ponds Constructed in Chilean Desert. *Geosynthetics*, Feb. pp. 26-33.
- Colucci, P. & Lavagnolo, M.C. 1995. Three Years Field Experience in Electrical Control of Synthetic Landfill Liners. *Proc. Sardinia '95*, CISA, Cagliari, pp. 437-451.
- Forget, B. 2005a. A Case Study Comparing the Impact of the Thickness of Exposed P.V.C. Geomembranes on the Integrity of Containment Systems. *Proc. Forum on Geosynthetics 2005*, Environmental Works and Roadways Design with Geosynthetics, Edmonton, Canada, May 4th, 2005.
- Forget, B., Rollin, A.L., Jacquelin, T. 2005b. Lessons Learned from 10 Years of Leak Detection Surveys on Geomembranes. *Proceed, Sardinia 2005*.
- Forget, B., Rollin, A.L., Jacquelin, T. 2005c. Impacts and limitations of quality assurance on geomembrane integrity: Statistical Study Based on a Decade of Leak Location Surveys. *Proceedings NAGS 2005/GRI-19, Dec. Las Vegas*.
- Jacquelin, T., Bone, S.C., Marcotte, M. & Rollin, A.L. 2008. Recent Results in Geoelectrical Leak Location in the Chilean Mining. *Proceed, The First Pan American Geosynthetics Conference*, 2-5 March, Cancun, Mexico, pp. 1556-1562.
- Laine, D.L. 1991. Analysis of Pinhole Seam Leaks Located in Geomembrane Liners Using the Electrical Leak Location Method. *Proceed, Geosynthetics '91*, Atlanta, pp. 239-253.
- Laine, D.L. & Darilek, G.T. 1993. Locating Leaks in Geomembrane Liners of Landfills Covered with a Protective Soil. *Proceed, Geosynthetics '93*, Vol. 3, pp. 1403-1412.
- Marcotte, M., Rollin, A.L. & Charpentier, C. 2009. The importance of liner thickness and CQA implementation in landfills. *Proceed, Geosynthetics 2009*, February 25-27, Salt Lake City, Utah, pp. 369-376.
- Rollin, A.L., Marcotte, M., Jacquelin, T. & Chaput, L. 1999. Leak Location in Exposed Geomembrane Liners Using an Electrical Leak Detection Technique. *Proceedings of Geosynthetics '99*, Boston, pp. 615-626.
- Rollin, A.L., Marcotte, M., Chaput, L. & Caquel, F. 2002. Lessons Learned from Geo-electrical Leaks Surveys. *Proceedings Geosynthetics 2002*, Nice, pp. 527-530.
- Rollin, A.L., Jacquelin, T., Forget, B. & Saunier, P. 2004. A Guide to Detect Leaks on Installed Geomembranes. *Proceedings EuroGEO*, Munich, pp. 235-240.