Comparison of Dye Testing and Electrical Leak Location Testing of a Solid Waste Liner System

G.T. Darilek
Principal Engineer, Leak Location Services, Inc., San Antonio, Texas, U.S.A.

L.V. Miller
Central Division Manager, Delaware Solid Waste Authority, Sandtown, Delaware, U.S.A.

ABSTRACT: Dye tracing and electrical leak location testing were independently conducted to detect and locate leaks in the primary geomembrane liner of two cells in a municipal landfill. Despite extensive quality control and quality assurance programs, water in the leak detection zone after construction indicated that the primary liner had a leak. Fluorescein dye tests were conducted by placing a fluorescent yellow/green dye in water impounded on the liner and then sampling the water drained from the leak detection zone for periods of at least 40 days. The samples of water were visually inspected and tested with a spectrophotometer. No dye was ever detected. An electrical leak location survey of the same areas located two leaks. One leak was a 90 x 76 mm (7.5 x 3 in.) hole that was near a leak detection drainage pipe. The other leak was a 25-mm (1-in.) diameter hole. The tests showed that dye testing was ineffective for detecting the presence of significant leaks in a liner system with sand above and below the leak. The electrical leak location method quickly and accurately located the leaks.
KEY WORDS: Leak detection, geomembranes, construction quality assurance, landfills, performance evaluation

1 INTRODUCTION

The lining system of a municipal solid waste landfill is the only barrier between the leachate generated and the local groundwater. The installation of the liner system is normally monitored with extensive quality control and quality assurance programs designed to insure that the specifications for materials and procedures for construction are met. Unfortunately, the completed lining system can be damaged during the installation of the leachate collection systems and the drainage/protection layers. Holes in the lining system can go undetected until long after landfilling in the area has started, making the location and repair of the holes almost impossible. Therefore, testing for leaks before waste is introduced can detect problems before they get worse.

The Delaware Solid Waste Authority (DSWA) initiated a post installation testing program that included dye tests and electrical leak location surveys for two cells of a disposal area with eight cells. The disposal area is comprised of two phases, each of which are divided into four drainage areas or cells. The tests on the two cells gave a good comparison of the two leak detection and location methods.

Figure 1 shows a cross section diagram of the typical cell construction. The diagram is not to scale. Each cell has dimensions of approximately 54 x 218 m (178 x 715 ft). The disposal area utilizes a double HDPE geomembrane liner system. The primary liner has a 600 mm (24 in.) protective drainage sand layer above the liner. The leak detection zone has a 300 mm (12 in.) layer of drainage sand between the liners. Leachate and leak detection pipe trenches formed in the primary liner and secondary liner respectively contain 150 mm (6 in.) perforated drainage pipes surrounded with ballast rock enveloped in a woven geotextile. The drainage pipes above the secondary and primary liners connect to common headers which drain to separate internal sumps. All eight cells of the disposal area were dye tested. Only the last two cells were leak tested using the electrical leak location method.

2 DYE TESTS

The dye test included uniformly introducing a known concentration of fluorescent yellow/green fluorescein dye into the water impounded in each cell and then monitoring the water flowing into the leak detection sump for dye. Only one cell was tested at a time. The cells were filled with dyed water to a level just below the lowest berm. Because of the elevation of the lowest berm, only about half of each cell could be flooded. Therefore, the dye testing area in each cell was limited to approximately 50 x 125 m (160 x 410 ft). Samples of water were then collected from the secondary leak detection system and visually inspected under an ultraviolet lamp and analyzed using a spectrophotometer.

Cole-Parmer fluorescent yellow/green dye tracer was used to dye the primary water. The concentration of the dye in the water impounded on the primary liner was compared with the concentration of dye in the water collected in the secondary leak detection system using a Hach model DR/2000 spectrophotometer. The photometer was calibrated for absorbance of light at the 494 nanometer wavelength of the dye, and could detect the dye in concentrations of approximately 0.2 ppm. The minimum visible detectable concentration of the tracer using an ultraviolet lamp is one ppm. A higher initial dye concentration of 4 ppm was used to compensate for any moisture from construction in the leak detection system that would dilute the primary water and to compensate for biodegradation of the dye with time.

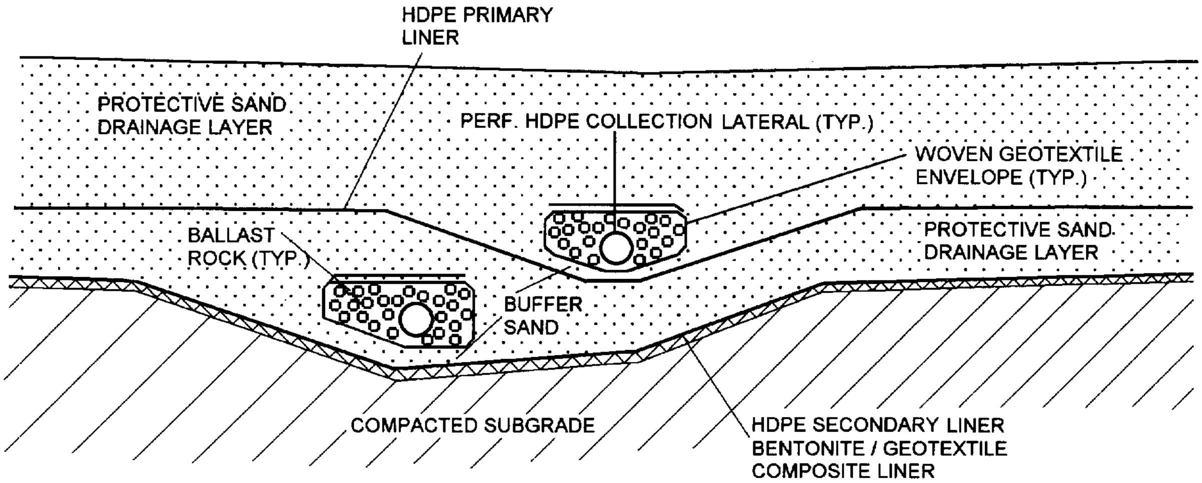

Figure 1. Typical Cross-Section View of Leachate and Leak Detection System

The maximum migration distance for the dye through the sand to a leak detection drainage pipe was approximately 14 m (46 ft). The minimum distance was approximately 1 m (3 ft). The estimated worst-case time necessary for the dye to migrate through the sand to the nearest part of the leak detection pipe was calculated using the equation from Giroud et al (1997):

$$t_{travel} = n\, x / (k \sin \beta \cos \beta); \qquad (1)$$

where t_{travel} = leakage travel time;
n = porosity of the sand;
x = length of the leakage path;
k = hydraulic conductivity; and
β_L = slope of the leak detection layer.

The worst-case leakage travel time through the sand was calculated to be 38 days. The leakage travel time through the leak detection pipe was estimated to be a maximum of one day. Therefore, the dye tests were monitored for a minimum of 40 days. During the dye testing, two of the cells were tested in the summer where the increased temperature accelerated the biodegradation of the dye. Therefore, additional dye was added when the concentration of the dye decreased. Samples of the water in the leak detection sump were collected, analyzed, and stored twice a week.

3 RESULTS OF THE DYE TESTS

No dye was detected in any of the eight cells in the water collected from the leak detection zone using visual ultraviolet inspection and the spectrophotometer measurements. The absorbance of the water collected in the leak detection zone remained at a very low and constant level. The concentration of dye in the primary water decreased to the visible limit of 1 ppm in 16 to 28 days except for two cells that maintained a visible concentration throughout the 40 days of monitoring. From previous tests, the dye in water that was not exposed to sunlight or high surface temperatures was much slower, requiring more than two months to degrade below the visible level.

4 ELECTRICAL LEAK LOCATION SURVEY

The electrical leak location method (Laine and Darilek, 1993) was used to search for leaks in two of the eight cells. The electrical leak location method is to apply a voltage across the liner and then detect the areas where electrical current flows through leaks in the insulating liner. Figure 2 shows a diagram of the principles of the method. Figure 3 shows an operator collecting the data. One electrode was placed in the sand on the primary liner. A second electrode was placed in the water at the end of a cleanout pipe in the leak detection zone. The electrodes were connected to a 300 VDC power supply. The geomembrane leak location survey was conducted by systematically making potential gradient measurements on the cover soil. Heavy vegetation on the sand layer along the survey lines was removed prior to the survey. Data was taken on survey lines spaced 760 mm (30 in.) apart. A measurement was taken every 760 mm with electrodes spaced 760 mm apart. The data was recorded using portable digital data loggers programmed so the operator could enter the survey parameters including file name, line number, starting position, position increment, and time interval between readings. The data collected with the digital data recorders was then downloaded to a laptop computer in the field and the data was plotted and analyzed for characteristic leak signals. The entire area of the two cells was surveyed using the electrical leak location method. The survey of 22,500 square m (5.5 acres) required eight man-days.

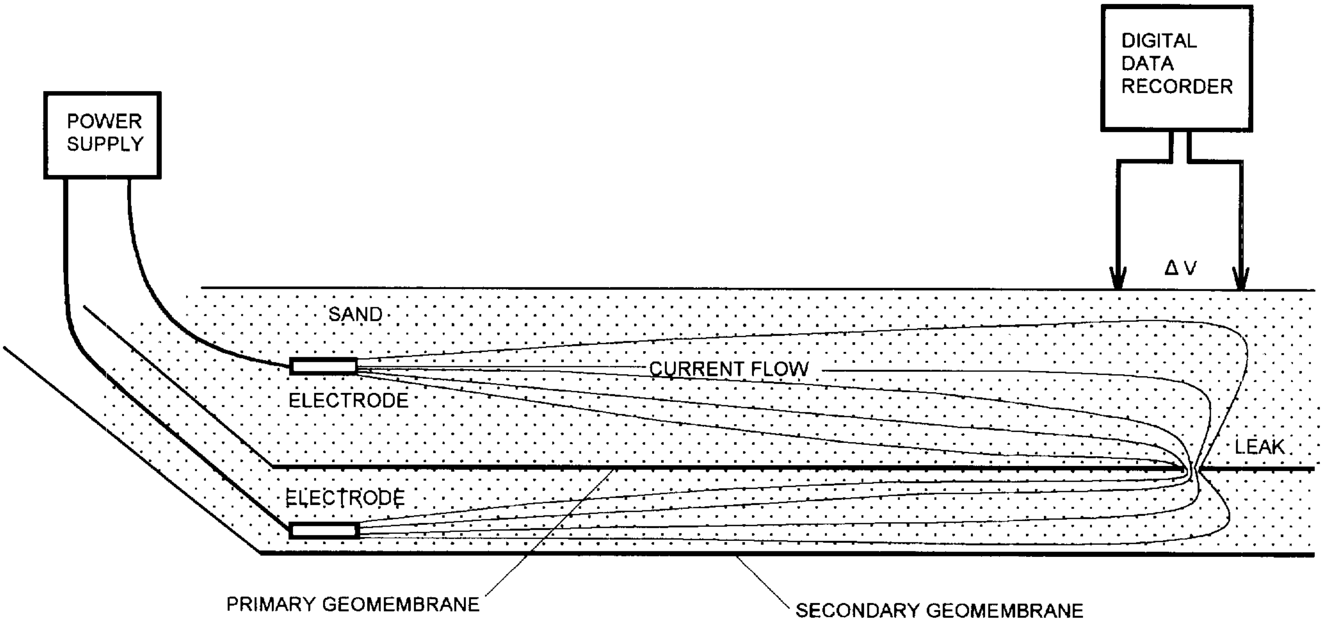

Figure 2. Principle of the Electrical Leak Location Method for Sand-Covered Geomembrane Liners

Figure 3. Geomembrane Electrical Leak Location Data Acquisition

5 RESULTS OF THE ELECTRICAL LEAK LOCATION SURVEY

Two leaks were found using the electrical leak location method. One leak was a 190 x 76 mm (7.5 x 3 in.) hole. It was excavated while the leak location survey crew was on the site. Figure 4 shows this leak in-situ with a 15 mm (6 in.) marker shown for scale. The second leak was a 25 mm (1 in.) diameter hole. Figure 5 shows both leaks after they were cut from the parent material. A 300 mm (12 in.) scale is also shown in the photograph.

Considerable energy would be required to form leaks this large, so damage from machinery is suspected. The larger leak had scrape marks leading to the leak and the other edge of the leak had the torn piece of liner attached as a flap. The larger leak was found on the edge of a leachate collection trench, which was approximately 3 m (10 ft) from a leak detection drainage pipe under the primary liner. Visual observation of the excavated leak after a moderate rainfall showed approximately 75 mm (3 in.) of storm water flowing over the hole.

6 ANALYSIS

For the larger leak, the dye had to travel a distance of only 3 m (10 ft) through the sand on the primary liner, through the leak, through the sand in the leak detection zone, to the leak detection drainage pipe. The time required for this transit, again using equation (1), is approximately 8 days plus an additional day for the dye to flow down the leak detection drainage pipe. The absorbance of the primary water at the 8-day interval had decreased to 36 percent of the initial concentration, but was clearly visible. The absorbance of the water samples taken from the leak detection sump six, eight, and eleven days after the start of the test for that cell show no evidence of dye.

Since the completion of the construction of the disposal area, flow measurements were made of the water collected from each of the two phases. Each phase has four cells. The flow rate from Phase 2 has always been higher than Phase 1. This was originally believed to be due to the higher

Figure 4. 90 x 76 mm (7.5 x 3 in.) Leak Found Using the Electrical Leak Location Method

Figure 5. Samples of Geomembrane Liner Containing the Leaks Found Using the Electrical Leak Location Method

precipitation during the construction of Phase 2. Since landfilling has started in both phases the secondary flow rates have continued to decrease.

Prior to the repair of the holes, the flow rate was approximately 112 liters/10,000 sq m/day (lhd) (12 gallons/acre/day (gad)) for Phase 2 and 56 lhd (6 gad) for Phase 1. Since the repairs, the flow rate from Phase 2 has decreased to approximately 70 lhd (7.5 gad). The flow rate from Phase 1 has also continued to decrease to about 14 lhdd (1.5 gad).

The secondary flow in Phase 2 dropped dramatically to approximately 70 lhd (7.5 gad) after patching the two holes. Because the flow before the leaks were repaired was approximately 112 lhd (12 gal/acre/day), the estimated leakage from the holes contributed 42 lhd (4.5 gad).

7 CONCLUSIONS

The tests showed that dye testing was ineffective for detecting the presence of significant leaks in a liner system with sand above and below the leak. Biodegradation of the dye significantly decreases the concentration of the dye during the long time required for water to flow to the leak detection sump. Considering that sand is a good filter for water, the failure of the dye test for the leak that was close to a leak detection drainage pipe may be because the sand adsorbed the dye from the water. Even if the dye tests would have indicated the presence of the leaks, the specific locations of the leaks would have been unknown.

The electrical leak location method not only detected the leaks, but also accurately located the leaks. The leaks were easily excavated for repair before waste was put in the disposal cell.

An electrical leak location survey for geomembrane liners is an effective method for detecting leaks present during the installation of the geomembrane liner or for detecting leaks caused by machinery while putting sand on the liner.

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REFERENCES

1 Giroud, J.P., Gross, B.A., Bonaparte, R., and McKelvey, J.A., (1997) "Leachate Flow in Leakage Collection Layers Due to Defects in Geomembrane Liners", Geosynthetics International, Vol 4, Nos. 3-4.

2 Laine, D.L., and Darilek, G.T., (1993) "Locating Leaks in Geomembrane Liners Covered With a Protective Soil," *Geosynthetics '93* , IFAI, Vancouver, British Columbia, Canada, Vol. 3, pp. 1403-1412.