

Experience in locating leaks in geomembrane-lined ponds

Priscila Zidan^{1*}, Matthew Kemnitz² and Elisabeth Ritter¹

¹Rio de Janeiro State University (UERJ), Av. São Francisco Xavier 524– 5° andar, sala 5029 (bloco F), Rio de Janeiro, Rio de Janeiro, Brazil

²Leak Location Service (LLSI) – 16142 University Oak, San Antonio, Texas, United States

Abstract. This study presents the results of five years of applying the dipole method in geomembrane-lined ponds to locate leaks arising from either the construction or operational stage. Inspections were conducted on 136 projects designed with single (n=57) or double (n=79) liner and located in the United States (n=108), Mexico (n=5), or Canada (n=23). The ponds were tested either full or at a depth between 0.3m and 0.8m, both sets of results were compared to the available literature. Approximately 210 ha of primary geomembrane-lined ponds were surveyed, uncovering 825 leaks during the study period. An average number of leaks/ha was 13.2 ranging from 0 to 272. The highest results were 272, 242, and 131 leaks/ha in double-lined, and 80 and 77 leaks/ha in single-lined ponds. The inspected data revealed that 43% of projects had 0-2 leaks/ha, 20% had >2-5 leaks/ha, 14% had >5-10 leaks/ha, and 16% of the ponds had >20 leaks/ha. The results of this study are crucial for designers, Landfill Operators, and Environmental Agencies in establishing inspection practiced for lined ponds, particularly after a period of operation.

1 Introduction

Geomembrane-lined ponds are essential facilities for storing and treating leachate in landfills. However, as mentioned by Rowe [1], constructing a liner without any holes is not likely. According to Peggs [2], damage to the geomembrane is considered unavoidable. Given this understanding, Thiel and Giroud [3] suggested that the most fundamental consideration in designing an exposed geomembrane-lined pond is to assume that the geomembrane leaks.

Over the years, the design of ponds used to contain leachate has evolved. The compacted clay liner, often used in conjunction with the geomembrane as a composite liner, has been replaced by the double liner with a leak detection system, which helps to identify and remove any liquid that may have leaked through the liner. Despite this advancement, many ponds still operate with a single-liner geomembrane system.

Giroud [4] and Rowe [5] have emphasized the importance of adopting quality control procedures during geomembrane installations to reduce the occurrence of holes. According

* Corresponding author: priscilazidan@gmail.com

to Rowe [5], holes may arise from manufacturing defects, handling of the geomembrane rolls, seaming, on-site placement, traffic over the liner, placing the cover soil, waste placement in landfills and subsequent stress cracking. More recently, studies has been published presenting problems of leakage through geomembranes in tailing storage facilities [6-7]]. As noted by Giroud [8], holes caused by geomembrane installation procedures can be detected by employing leak location methods as part of construction quality assurance. These holes can be repaired before the service stage begins, thus preventing environmental contamination [9].

Lined ponds pose an additional risk of damage due to inadequate procedures during the service stage. Moreover, ponds may be more susceptible to damage compared to landfills because the liquid pressure is higher and more evenly distributed, and the pressure does not decrease when the liner settles [10]. In the case of double-lined ponds with a leak monitoring system, it is possible to detect leakage and thus make repairs promptly. However, single-lined pond lacks this level of insight and may take some time to be noticed by the operator.

The primary consequence of failing to identify leaks in single-lined projects is the potential leakage of leachate from the pond through the liner. Several studies [11-14],[4],[5] have been conducted to quantify this leakage rate. Despite this awareness of this risk, no available statistical data has been published regarding leaks in geomembrane-lined ponds after construction and a period of use. This study aims to present the results of five years of applying the dipole method, an electrical leak location method to locate leaks in the primary geomembrane in both single and double-lined ponds immediately after construction or after a period of service and compare this with existing data.

2 Methodology

All the presented data was provided by LLSI (Leak Location Service, Inc) and are the results of the application of the dipole method in lined ponds covered by liquid to locate leaks in the primary geomembrane. Ponds were tested when full, in a deep-water survey, or when the liquid level was at a depth between 0.3m and 0.8 m, in a shallow-water survey. The inspections were conducted after construction or in the operational phases.

The dipole method has already been established according to international regulatory standards [15], enabling the location of leaks in the geomembrane covered by liquid. This method's principle is based on applying electrical voltage to the liquid covering the geomembrane. After systematic measurements in the liquid, leaks in the geomembrane are detected and located when an anomaly in the electrical field is found. The inspection identifies leaks but not holes without leakage through them. If moisture passes through a defect in the liner, it can be detected. One leak area can have more than one hole.

Field data collection utilized a one-meter grid system. Measurements with a probe were conducted along parallel lines on the grid. The data was collected using a portable detector, scanning probe and a power supply. One electrode was installed in the soil beneath the geomembrane while another electrode was positioned inside the pond, as specified by ASTM D7007. In double-lined configurations, instead of installing the electrode in the soil, it was placed in the drainage layer between the primary and secondary geomembranes. This setup allows the inspection of the primary geomembrane. On each inspection day, a test was performed using an artificial leak to ensure that the criteria necessary for conducting the test were met.

In the deep-water survey, two operators positioned outside the pond move the probe along a defined grid using a nylon rope. In the shallow water survey, one operator walks inside the pond, moving another probe along a marked grid. In this setup, the probe could detect leaks smaller than 1.0 mm in diameter.

Signs of potential leaks above the geomembrane covered with liquid were detected due to a beep emitted by the portable detector. A mark is placed on the border of the

geomembrane (deep water survey), or a sandbag with a float is positioned on the leak signal to indicate the possible hole. As the inspection was conducted in a pond with liquid, the quantities presented refer to leaks.

The total inspected area was 210 ha from 2017 to 2021, of which 198 ha are from deep water and 12 ha are from shallow water surveys. Each new pond inspection was considered a project for this study. Data were analysed in Microsoft Excel, and the results are presented in Figures 1 to 5.

3 Results and Discussion

The application of the deep-water survey in 116 projects, most of them in the United States, from 2017 to 2021, resulted in 634 leaks found in almost 198 ha of inspected geomembrane-lined ponds, as shown in Table 1. This data presents an average of 7.5 leaks/ha in a range of 0-131 leaks/ha.

Table 1. Summary of deep-water survey data from 2017 to 2021.

Year	Inspected projects	Inspected area (ha)	Leaks	Project location			Typical liner	
				Mexico	Canada	USA	Single	Double
2017	30	54.39	152	4	7	19	14	16
2018	32	57.62	309	1	6	25	13	19
2019	20	39.49	66	0	3	17	8	12
2020	16	15.85	51	0	1	15	4	12
2021	18	30.57	56	0	4	14	5	13
Total	116	197.91	634	5	21	90	44	72

The shallow-water survey was applied to 20 projects, mostly in the United States, from 2017 to 2021, resulting in 191 leaks found in almost 12 ha of inspected geomembrane-lined ponds. This data shows an average of 46 leaks/ha in a range of 0-272 leaks/ha.

Table 2. Summary of shallow-water survey data from 2017 to 2021.

Year	Inspected projects	Inspected area (ha)	Leaks	Project location			Typical liner	
				Mexico	Canada	USA	Single	Double
2017	2	0.72	56	0	2	0	2	0
2018	8	4.36	45	0	0	8	4	4
2019	4	3.65	52	0	0	4	2	2
2020	4	3.10	34	0	0	4	3	1
2021	2	0.16	4	0	0	2	2	0
Total	20	11.99	191	0	2	18	13	7

The highest average of leaks/ha in shallow-water compared to deep-water is associated with the greater accuracy of the shallow probe compared to deep-water. The deep-water method employs a highly sensitive probe that will not distinguish between two or three leaks that are close together.

The graph presented in Figure 1 presents the number of leaks detected in a year and the corresponding inspected area by applying the dipole method (n=136) in one of the two options: deep (n=116) or shallow (n=20) water to locate leaks for the period of this study (2017 to 2021). According to this figure, in 2020, there was a significant reduction in the

total inspected area due to restrictions of the COVID-19 pandemic, but in 2021, the areas increased again.

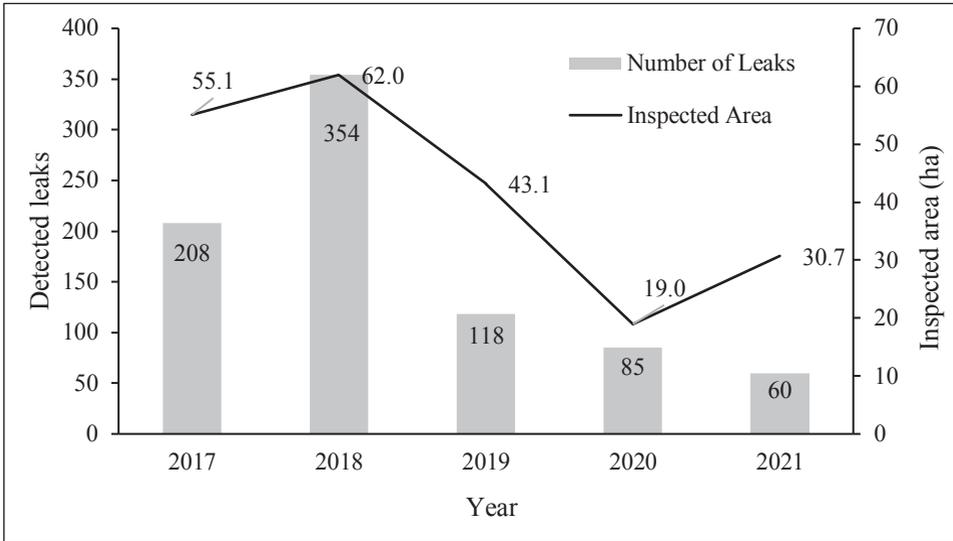


Fig. 1. Progression of deep (n=116) and shallow (n=20) water inspections in geomembrane-lined ponds from 2017 to 2021.

Figure 2 displays the number of inspected projects (n=136) distributed in five ranges of leaks/ha.

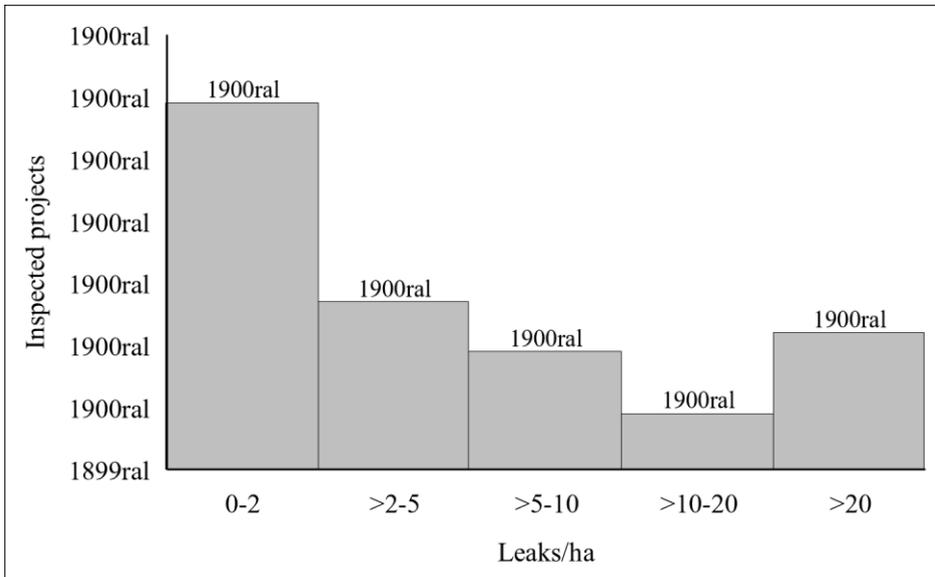


Fig. 2. Histogram chart illustrating the distribution of the number of inspected projects (n=136) across five ranges of the leaks/ha: 0-2; >2-5; >5-10; >10-20; and > 20. Data from electrical leak location inspections performed in geomembrane-lined ponds in deep (n=116) or shallow (n=20) water surveys from 2017 to 2021.

According to Figure 2, 77% of the inspected ponds fall within the ranges of 0-2 leaks/ha (n=59), >2-5 leaks/ha (n=27), and >5-10 leaks/ha (n=19). Additionally, it is important to note that results were observed at 272, 239, and 131 leaks/ha (in double-lined projects) and 80 and 77 leaks/ha (in single-lined ponds). Due to the absence of a drainage layer in single-lined ponds, leaks are not easily noticed and infiltration into the ground cannot be avoided, resulting in the contamination of the soil and/or other damages [3]. Despite the double-lined projects potentially including a drainage layer, the leakage rate should not exceed the capacity of the removal system [3]. It is recommended that ponds should be taken out of service if the leakage rate exceeds its removal capacity until the leaks are located and repaired [3].

This higher value of leaks/ha found differs from the available data in the literature for constructed geomembrane-lined ponds. In 2016, Giroud [4] reviewed 150 cases of electrical leak location surveys conducted across 250 ha of HDPE-installed geomembrane in the United States, with typical construction quality assurance, and found an average of 5.4 holes/ha. The same article [4] concluded that 5 to 6 holes/ha could be considered typical at the end of geomembrane installation when quality control procedures were implemented. However, in situations where this is not the case, a higher number of leaks/ha can be expected, as suggested by Giroud and Bonaparte [11], who stated that "a frequency of 25 holes/ha or more is possible when quality assurance is limited to an engineer spot-checking the work done by geomembrane installers". Due to the lack of data indicating when each pond started to operate, it is impossible to classify this data as relating to newly constructed or already operational ponds. The surveyed projects that exhibited numerous leaks/ha likely required the implementation of quality control procedures during geomembrane installation or may have adopted inadequate pond operating procedures. Further data analysis is essential to draw conclusions about trends of high values of leaks/ha in the operational stage.

At least one leak was found in 104 of the inspected ponds in this study, which means approximately 77% of the surveyed pond, with 45 ponds from this group being single-lined and 59 being double-lined projects. Based on this information, it is crucial to establish an inspection frequency post-construction during the operational stage for this type of pond to minimize leakage. Figure 3 illustrates the detected leaks/ha based on deep (n=116) or shallow (n=20) water survey by size of the inspected area in geomembrane-lined ponds from 2017 to 2021.

According to Figure 3, most shallow water data showed higher leaks/ha than deep water data. The highest results for leaks/ha, such as 272 and 242, were found in shallow water inspections. Furthermore, most results from this type of inspection were higher than those from deep water inspections. This difference is attributed to the greater accuracy of the probe used in the shallow method compared to deep water method. In other words, during the deep water inspections, several small leaks can appear as a single leak. In shallow water inspections, this occurrence is less likely.

The graph presented in Figure 4 illustrates detected leaks/ha per size of inspected area during 2017 and 2021 from shallow water surveys (n=20). This figure also displays the results of Laine and Miklas [17] using the same method. Despite the difference in survey period between the two studies, the high number of leaks/ha found by Laine and Miklas [17] can be observed in some projects inspected in this study. However, most projects from this study exhibit leaks/ha lower than results reported by Laine and Miklas.

Figure 5 plots detected leaks/ha per size of inspected area during 2017 and 2021 from deep water survey (n=116). This Figure also depicts the results of Laine and Miklas [17] using the same method. The majority of the projects from this study exhibited leaks/ha lower than those reported by Laine and Miklas. These results suggest that improvements in the practice of QA/QC over the last 30 years, including the adoption of electrical leak location which began to be commercialized in about 1985 [18], may have influenced the reduction in leaks, as proposed by Giroud [8].

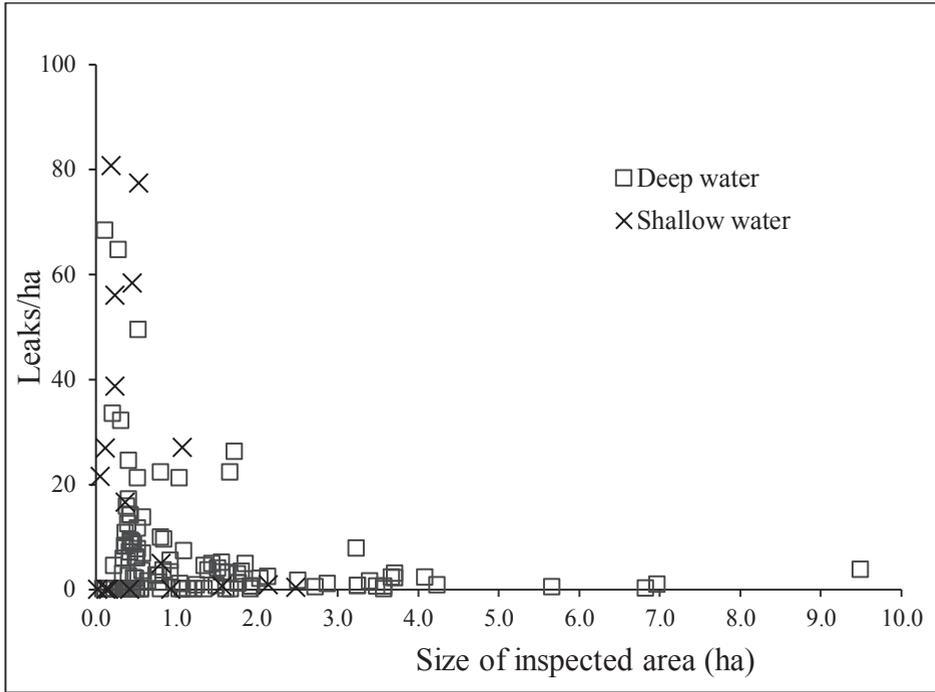


Fig. 3. Distribution of leaks/ha per size of inspected area (ha) from this study. Data from electrical leak location inspections performed in deep (n=116) or shallow (n=20) water survey in geomembrane-lined ponds from 2017 to 2021.

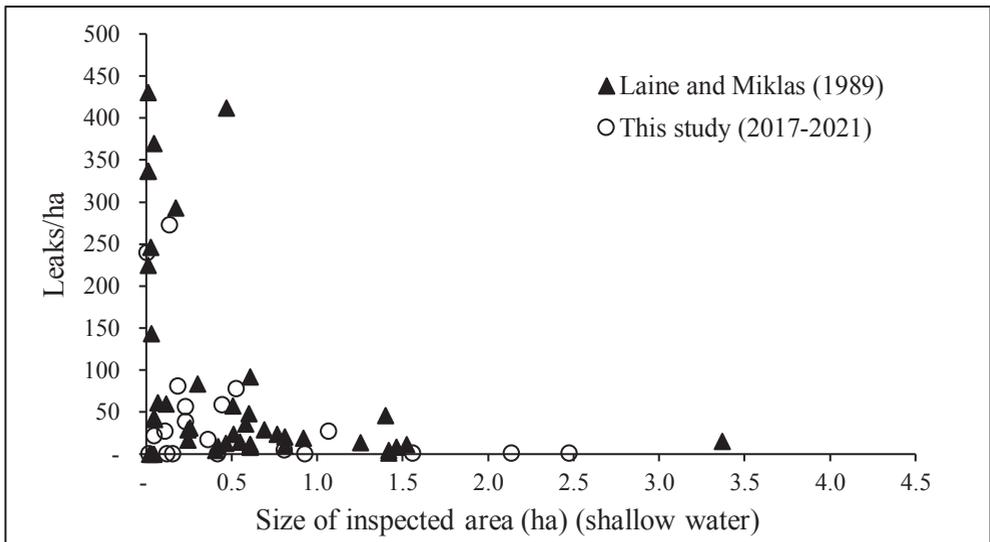


Fig. 4. Distribution of leaks/ha per size of inspected area (ha) from this study (n=20) and Laine and Miklas (n=47). Data from electrical leak location inspection performed in shallow water survey in geomembrane-lined ponds.

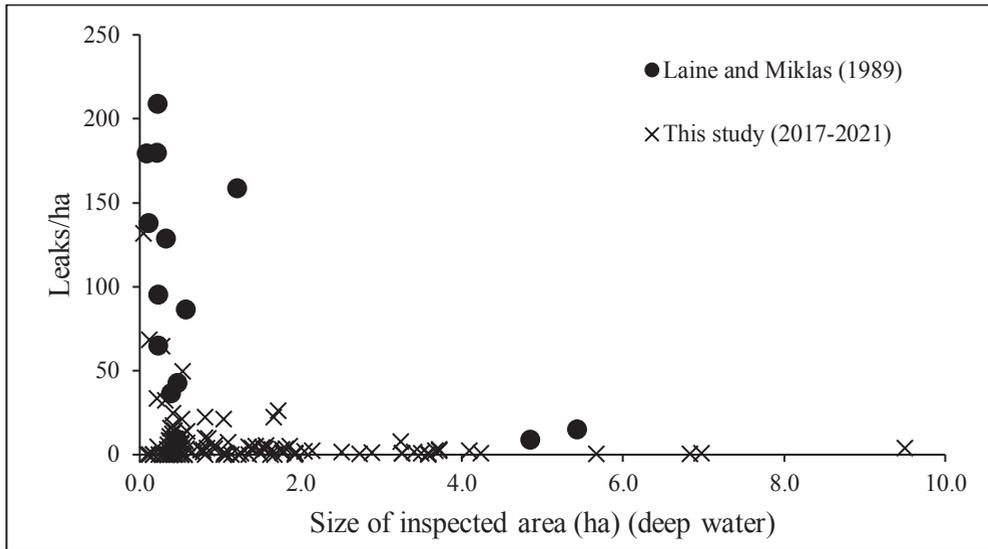


Fig. 5. Distribution of leaks/ha per size of inspected area (ha) from this study (n=116) and Laine and Miklas (n=14). Data from electrical leak location inspections performed in deep water surveys” in geomembrane-lined ponds.

In Figure 3, 4 and 5, the data from this study and Laine and Miklas indicated that the number of leaks is smaller for large areas of geomembranes (greater than 2 ha). This behaviour was described by Giroud and Touze-Foltz [16] and Giroud [4]. This similar pattern suggests that larger ponds likely receive greater attention to quality control and assurance procedures during the installation of the geomembrane, consequently reducing leaks.

4 Conclusion

The results presented in this study suggest that the number of leaks tends to be lower in areas of geomembrane greater than 2 ha. This behaviour was also observed in the results of Laine and Miklas. The variation in the average leaks/ha between deep and shallow water results is attributed to the differing accuracy of their probes, and this information is crucial to consider when selecting which method to apply.

In 77% of inspected ponds, at least one leak was found, highlighting the importance of electrical leak location as a practice to be adopted in conjunction with quality control procedures to minimize leakage. Many projects exhibited more than 20 leaks/ha, with ponds having 272, 239, and 131 leaks/ha in double-lined and 80 and 77 leaks/ha in single-lined systems. These higher results could be attributed to inadequate operational procedures, defects that occurred after the ponds were filled, or the poor quality control procedures during the geomembrane installation.

These findings indicate the importance of considering the risk of leaks in the geomembrane when designing new ponds. Additionally, it is crucial to incorporate electrical leak location post-construction, in conjunction with QC procedures and in the operational phase when leakage rates approach the removal rate of the drainage layer.

The Authors are grateful to LLSI for providing all the field data to this study.

References

1. R. K. Rowe, Systems engineering: the design and operation of municipal solid waste landfills to minimize contamination of groundwater. *Geosynth. Int.* **18** (6), 391–404 (2011)
2. I. Peggs, Geomembrane liner action leakage rates: What is practical and what is not? *Land and Water Magazine*, pp. 47-50 July/August (2009)
3. R. Thiel, J. Giroud, Important Considerations for Geomembrane-Lined Ponds. In: *Proceedings of 13th International Waste Management and Landfill Symposium*, p.12 (2011)
4. J. Giroud, Leakage control using geomembrane Liner. *Soils and Rocks* **39** (3), 213-235 (2016)
5. R. K. Rowe, Short-and long-term leakage through composite liners. The 7th Arthur Casagrande Lecture. *Can. Geotech. J.*, **49**, (2), 141–169 (2012)
6. R. K. Rowe, Protecting the environment with geosynthetic. 53rd Karl Terzaghi Lecture. *J. Geotech. Geoenviron Eng.* **146** (9) (2020)
7. J. Fan, R. K. Rowe, Effect of subgrade on leakage through a defective geomembrane seam below saturated tailing. *Geotext. Geomembranes*, **51**(2), 360-369 (2023)
8. J. Giroud, Lessons Learned from Case Histories of reservoirs lined with geomembranes. *ver. Fr. Geotech.*, **159**(2), 1-13 (2019)
9. L. Pandey, S. Shukla, Detection of Leakage of MSW - landfill leachate through liner defect: experimental and analytical Methods, *J. Geotech. Geoenviron Eng.* **146** (8) (2020)
10. D. Elton, I. Peggs, Geomembrane research needs – technical paper. *Geosynth. Int.* **9** (3), 283-300 (2002)
11. J. Giroud, R. Bonaparte, Leakage through liners constructed with geomembranes, Part I: geomembrane liners. *Geotext. Geomembranes*, **8**(1), 27-67 (1989a)
12. J. Giroud, R. Bonaparte, Leakage through liners constructed with geomembranes, Part 2: Composite Liners. *Geotext. Geomembranes*, **8**, 71-111 (1989b)
13. J. Giroud, K. Badu-Tweneboah, R. Bonaparte, Rate of leakage through a composite liner due to geomembrane defects. *Geotext. Geomembranes*, **11**, 1-28 (1992)
14. J. Giroud, Equations for calculating the rate of liquid migration through composite liners due to geomembrane defects. *Geosynth. Int.* **4** (3-4), 335-348 (1997)
15. ASTM D7007. Standard Practice for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials.
16. J. Giroud, N. Touze-Foltz, Geomembrane for Landfills. *Geosynth. Int.* **10** (4), 124–133 (2003)
17. D. Laine, M. Miklas, Detection and location of leaks in geomembrane liners using an electrical method: case histories, *Superfund'89 Proceedings of the 10th national Conference*, p. 35-40 (1989)
18. R. M. Koerner, J. M. Koerner, G. R. Koerner, Status of the electrical leak location survey (ELLS) method among state environmental protection agencies in the USA – white paper #34, *Geosynth. Inst.*, 1 (2016)