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Effect of Synthetic MSW Leachate on Chemical Compatibility of PVC Geomembrane

PVC 지오멤브레인의 화학적 적합성에 합성 MSW 침출수가 미치는 영향분석

Choi, Hangseok[1]* 최 항 석

ABSTRACT

The resistance of flexible PVC geomembranes to leachate chemicals is an important factor when PVC geomembranes are being considered as a barrier layer in a composite liner system. This paper describes laboratory test results that evaluate the chemical compatibility of a 0.76 mm (30 mil) thick flexible PVC geomembrane exposed to a synthetic municipal solid waste (MSW) leachate. Changes in dimensional, physical, and mechanical properties were measured after exposure to the synthetic MSW leachate at 23℃ and 50℃ for 30, 60, 90, and 120 days. Although some variability of the test results is observed due to experimental factors and product variability, the synthetic MSW leachate did not significantly degrade the physical or mechanical properties of the flexible PVC geomembrane. As a result, this paper will conclude the PVC geomembranes are not adversely affected by the synthetic MSW leachate.

요 지

복합 라이너 시스템에서 차수막으로서 PVC 지오멤브레인을 사용하기 위해서는 PVC 지오멤브레인의 침출수내의 화학성분에 대한 화학적 적합성이 중요한 요소이다. 본 논문에서는 0.76mm 두께의 PVC 지오멤브레인이 갖는 합성 일반도시 폐기물 침출수와의 적합성을 실내실험을 통해 살펴보았다. 23℃와 50℃ 두 가지 경우에 대해 각각 30일, 60일, 90일, 120일 동안 합성 침출수에 PVC 지오멤브레인을 노출시켜 외적형태와 물리적, 역학적 성질의 변화를 측정하였다. 비록 약간의 실험오차와 멤브레인 자체의 불균일성이 존재하지만, 합성된 침출수는 실험에 사용된 PVC 지오멤브레인의 물리적, 역학적 성질을 크게 변화시키지 않았다.

Keywords : PVC geomembrane, Synthetic MSW leachate, Chemical compatibility

1. INTRODUCTION

Long-term chemical effect of MSW leachate on PVC geomembranes is important to determine the effective service life of the PVC geomembrane used as a barrier layer in landfill liners. Because the quantitative evaluation of chemical compatibility of PVC geomembranes to MSW leachate is not applicable in the field, laboratory tests for assessing the chemical compatibility are recommended.

Haxo *et al*. (1985) conducted a laboratory study to determine the chemical compatibility of various lining materials to leachate from MSW landfills. The tested lining materials were Butly rubber, CPE, CSPE, EPDM, LDPE, and PVC. The lining materials were placed in landfill simulators in which MSW leachate was generated for up to 56 months. Haxo *et al*. (1985) conclude that PVC geomembranes slightly swell but retain their original properties. However, the PVC geomembranes show signs of plasticizer loss and stiffening.

Fayoux *et al*. (1993) investigated a 1 mm thick PVC

1* 정회원, 고려대학교 공과대학 사회환경시스템공학과 조교수 (Member, Assistant Professor, Department of Civil and Environmental Engineering, Korea University, E-mail: hchoi2@korea.ac.kr)

geomembrane excavated from a pond liner subjected to domestic landfill leachate in France after 10 years in service. The initial plasticizer content was 33.6% and the plasticizer retention was assessed for different field conditions. Fayoux *et al*. (1993) show that plasticizer loss from a sample immersed in leachate for ten years is much less than the samples exposed to air for ten years. Thus, exposure to air causes more volatile loss and UV degradation than the samples immersed in leachate for the same period. The exposure to leachate did not result in a high loss of plasticizer. The plasticizer loss ratio of 37% while exposed to air was much greater than the plasticizer loss ratio of 16% while exposed to the leachate.

This paper describes laboratory test results performed by TRI/Environmental (2003) to determine the chemical compatibility of a PVC geomembrane product with one synthesized MSW leachate. The objective of this study is to determine the resistance of the PVC geomembrane to changes caused by exposure to MSW leachate. Changes in dimensional, physical, and mechanical properties were measured after exposure to the MSW leachate at 23℃ and 50℃ for 30, 60, 90 and 120 days following the exposure regimen specified in ASTM D 5322-98.

2. MATERIALS AND TEST METHODS

The product used in this chemical compatibility study is a 30 mil PVC geomembrane which is provided by Canadian General Tower Ltd. The waste leachate is a synthetic MSW leachate constituting various organic and inorganic substance which are commonly found in leachate of MSW landfills (TRI/Environmental, 2003).

PVC geomembrane specimens are exposed to the synthetic MSW leachate following the specifications of EPA Method 9090A (1992) as they relate to exposure to waste fluids. The tanks used for these exposures are maintained at 23±2℃ and 50±2℃ throughout the 120-day exposure period. Tanks are constructed from chemically resistant stainless steel or glass, fitted with stirrers and heated with a circulating hot water heat exchanger system. The 50℃ tanks are sealed with a lid and a reflux condenser is installed to minimize loss of volatile leachate components.

3. TESTING PROCEDURES

After PVC geomembrane specimens are exposed to the synthetic MSW leachate for 30, 60, 90, and 120 days, respectively, the dimensional, physical, and mechanical properties of the PVC geomembrane specimens are tested in general accordance with ASTM D 5747-95a (2002). Table 1 lists the tests performed on the PVC geomembrane specimens. The number of test replicates is

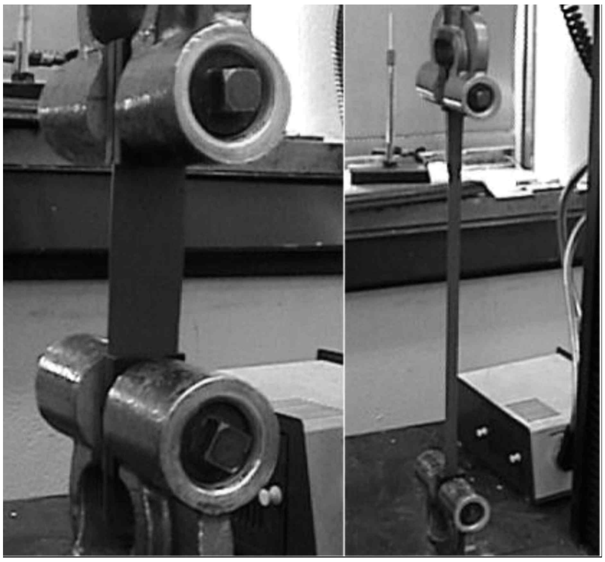

Fig. 1. PVC geomembrane before and during tensile testing

Table 1. Tests performed on PVC geomembrane

Physical property	Test method	Number of replicate specimens
Dimension and weight	ASTM D 5747-95a	3
Hardness	ASTM D 2240-02b D scale	3
Volatiles and Extractables	EPA SW 870 Appendix 3	2
Specific gravity	ASTM D 792-00	3
Tensile properties	ASTM D 882-02 20/min strain rate	3
Hydrostatic resistance	ASTM D 751-00 Procedure A	3
Tear strength	ASTM D 1004-74a	3
Puncture resistance	ASTM D 4833-88	3

doubled for baseline determinations on unexposed material. A typical tensile testing procedure is illustrated in the photographs of Figure 1.

4. TEST RESULTS AND DISCUSSION

4.1 Weight and Dimension

After each period of 30, 60, 90, and 120 days, three pre-weighed pieces of the PVC geomembrane from the MSW leachate are quickly dried with water-absorbent or paper towels and then weighed to the nearest 0.001 g. The percent weight change is calculated to the nearest 0.1%. The thickness is measured at three locations near the center of the pieces of the PVC geomembrane used for weight change measurement before and after immersion in the MSW leachate. The length and width (machine and transverse direction) are measured at two locations on the sheets of the PVC geomembrane used for the physical testing before and after immersion in the MSW leachate. The percent changes of thickness, length, and width are calculated to the nearest 0.1%.

Table 2. Weight and dimension measurement

Test parameter	Temp. (℃)	% Change			
		30 days	60 days	90 days	120 days
Weight (g)	23	0.1	0.1	0.1	−0.8
	50	0.0	0.2	0.2	0.2
Thickness (mils)	23	0.0	0.0	0.0	0.0
	50	0.0	0.0	0.0	0.0
Length (inches)	23	0.0	0.0	−0.2	0.0
	50	−1.2	−0.7	−1.1	0.0
Width (inches)	23	0.0	0.0	−0.1	−0.3
	50	0.0	0.0	0.0	0.0

Table 2 shows the test results of weight and dimension change after 30, 60, 90, and 120 days of immersion in the MSW leachate. There are no significant changes in weight and dimensions at a temperature of 23℃ and 50℃ even after 120 days of immersion.

4.2 Physical property

The indentation hardness is measured according to ASTM D 2240-02b with a durometer. Hardness measurements are based on the penetration of a specific type of indentor (Type D in this research) when forced into the PVC geomembrane specimen under specified conditions. The indentation hardness is dependent on the elastic modulus and viscoelastic behaviour of the PVC geomembrane. Table 3 shows a change in hardness of the PVC geomembrane after immersion in the MSW leachate. The average values of hardness after 30, 60, 90, and 120 days of immersion in the MSW leachate are compared with the baseline measurement. 1 to 2% of hardness reduction is observed even after 120 days of immersion at a temperature of 23 and 50℃. This change can be compared with the test results presented by Haxo *et al.* (1985) in which the hardness reduction of PVC is 7% after 56 months of exposure to leachate in a MSW landfill simulator.

The volatiles and extractables are measured according to the EPA SW-870 (1980). These test methods evaluate how much and fast external plasticizers migrate out of

Table 3. Physical property measurement

		Base-line	30 days	60 days	90 days	120 days
Hardness	Ave.	49	48/48[1]	48/48	48/48	48/48
	% change		−2/−2	−2/−2	−2/−2	−1/−2
Volatiles (%)	Ave.	0.15	0.11/0.12	0.11/0.18	0.12/0.14	0.12/0.15
	% change		−	−	−	−
Extractables (%)	Ave.	26.3	24.7/25.0	24.5/24.9	24.6/24.8	24.6/25.1
	% change		−	−	−	−
Specific Gravity	Ave.	1.268	1.269/1.268	1.269/1.273	1.271/1.273	1.276/1.270
	% change		0.11/0.03	0.08/0.37	0.21/0.39	0.61/0.16

[1] values at a temperature of 23/50℃, respectively.

PVC geomembranes into air and liquid, respectively. The external plasticizers increase flexibility, softness, workability, and distensibility, and decreases the glass transition temperature (T_g). Because there is no chemical bonding between polymer resin and external plasticizer molecules, volatile loss and extraction of the plasticizer molecules can occur (Stark *et al*. 2004). Table 3 shows no significant changes in volatiles and extractables of the PVC geomembrane after immersion in the MSW leachate. As can be expected, the test results at the higher temperature of 50℃ show more volatiles and extractables than at the lower temperature of 23℃.

The specific gravity of the immersed specimens is measured according to ASTM D 792-00, which determines a relative density of PVC geomembrane specimens with water or liquids other than water. The specific gravity is calculated based on the mass of a specimen of the PVC geomembrane in air and its apparent mass when immersed in a liquid. Change in the specific gravity may be due to changes in crystallinity, plasticizer migration, absorption of solvent, etc. Portions of a sample may differ in the specific gravity because of inherent product variability such as types or proportions of resin, plasticizer, pigment, or filler in the PVC geomembrane. Although some inherent product variability exists, Table 3 shows a slight increase in the specific density, which may be caused by a small amount of plasticizer migration.

4.3 Mechanical property

Tensile properties of the immersed specimens are measured according to ASTM D 882-02. The tensile properties considered herein to characterize the PVC geomembrane for control and specification purpose are tensile stress at break, tensile stress at 200% elongation, and elongation at break. Specimens are tested in both machine and transverse direction.

The tensile stress at break is calculated by dividing the maximum load at break by the original minimum cross-sectional area of the specimen. The tensile stress at 200% elongation is calculated by dividing the measured load at 200% elongation by the original minimum cross-sectional area of the specimen. The result shall be expressed in force per unit area, e.g., psi. Table 4 shows a change in the tensile stress at break and at 200% elongation for both machine and transverse direction after immersion in the MSW leachate. Although the test results are not consistent with duration of immersion due to experimental factors and product variability such as method of specimen preparation, type of grips used, and/or specimen thickness, there are no significant changes in the tensile stress at break and at 200% elongation of the PVC geomembrane after immersion in the MSW leachate. This change can be compared with the test results presented by Haxo *et al*. (1985) in which an increase in tensile stress at break is 6.2% after 56 months of exposure to leachate in a MSW landfill simulator. In addition, all of the test results of tensile stress at break after 30, 60, 90, and 120 days of immersion in the MSW leachate satisfy PGI-1103 specification of 2433 psi for a 30 mil PVC geomembrane.

The tensile elongation at break is calculated by dividing the extension at the moment of rupture of the specimen by the initial gage length of the specimen and multiplying by 100. The result shall be expressed in percent. Table 4 shows a change in the tensile elongation at break for both machine and transverse direction after immersion in the MSW leachate. No significant changes are observed in the tensile elongation at break of the PVC geomembrane after immersion in the MSW leachate. This change can be compared with the test results presented by Haxo *et al*. (1985) in which an increase in tensile elongation at break is 21% after 56 months of exposure to leachate in a MSW landfill simulator. Additionally, all of the test results of tensile elongation at break after 30, 60, 90, and 120 days of immersion in the MSW leachate satisfy PGI-1103 specification of 380% for a 30 mil PVC geomembrane. Thus, the test data show a sufficient percent elongation at break, which indicates that the material retains flexibility even after immersion in the MSW leachate.

The hydrostatic resistance of a PVC geomembrane is

Table 4. Tensile property measurement

		Base-line	30 days	60 days	90 days	120 days
Tensile stress at break (psi) (machine direction)	Ave.	2971	2967/2865[1]	3051/2850	2885/2950	2987/3031
	% change		0/−4	3/−4	−3/−1	1/2
Tensile stress at break (psi) (transverse direction)	Ave.	2789	2789/2817	2657/2814	2803/2781	2785/2668
	% change		0/1	−5/1	1/0	0/−4
Tensile stress at 200% elongation (psi) (machine direction)	Ave.	1998	2009/1946	1996/1875	1989/1956	1994/1980
	% change		1/−3	0/−6	0/−2	0/−1
Tensile stress at 200% elongation (psi) (transverse direction)	Ave.	1869	1877/1849	1809/1928	1838/1883	1987/1852
	% change		0/−1	−3/3	−2/1	6/−1
Tensile elongation at break (%) (machine direction)	Ave.	435	462/470	497/580	446/486	484/498
	% change		2/4	10/28	−1/7	7/10
Tensile elongation at break (%) (transverse direction)	Ave.	488	495/508	478/478	518/486	465/462
	% change		1/4	−2/2	6/0	−5/−5

[1] values at a temperature of 23/50℃, respectively.

Table 5. Other mechanical property measurement

		Base-line	30 days	60 days	90 days	120 days
Hydrostatic resistance (psi)	Ave.	113	118/1181	118/118	115/118	118/118
	% change		4/4	4/4	1/4	4/4
Tear resistance (lbs) (machine direction)	Ave.	11.7	11.3/11.3	11.7/11.3	11.3/11.7	11.7/11.3
	% change		−3/−3	0/−3	−3/0	0/−3
Tear resistance (lbs) (transverse direction)	Ave.	10.7	10.7/10.7	11.3/10.7	11.0/11.3	11.0/10.7
	% change		0/0	6/0	3/6	3/0
Puncture resistance (psi)	Ave.	44.8	39.3/40.3	39.3/36.7	40.7/38.3	41.7/44.3
	% change		−12/−10	−12/−18	−9/−14	−7/−1

[1] values at a temperature of 23/50℃, respectively.

determined by Procedure A which uses a Mullen-type hydrostatic tester or by Procedure B which uses the hydrostatic pressure of a rising column of water according to ASTM D 751-00. Procedure A is used to measure the hydrostatic resistance after immersion in the MSW leachate herein. Table 5 shows a change in the hydrostatic resistance after immersion in the MSW leachate. No significant changes are observed, and all of the test results of hydrostatic resistance after 30, 60, 90, and 120 days of immersion in the MSW leachate satisfy PGI-1103 specification of 100 psi for a 30 mil PVC geomembrane.

The tear strength of the immersed specimens is measured according to ASTM D 1004-74a. This test method is designed to measure the force to initiate tearing a flexible plastic film or geomembrane. The specimen geometry of this test method produces a stress concentration in a small area of the specimen. The maximum stress is recorded as the tear resistance in pounds-force. Table 5 shows a change in the tear strength after immersion in the MSW leachate and the test results can be compared with the test results presented by Haxo *et al*. (1985) in which a reduction of the tear strength is 15% after 56 months of exposure to leachate in a MSW landfill simulator. In addition, the test results of the tear strength after 30, 60, 90, and 120 days of immersion in the MSW leachate satisfy PGI-1103 specification of 8 lbs for a 30 mil PVC geomembrane.

The index puncture resistance (ASTM D 4833-88) is an index test for determining the puncture resistance of the PVC geomembrane before and after immersion in the MSW leachate. A test specimen is clamped without tension between circular plates of a ring clamp attachment. The maximum force exerted against the center of the unsupported portion of the test specimen is the value of puncture resistance. Table 5 shows a change in the puncture resistance after immersion in the MSW leachate. The test results show about 10% reduction in the puncture resistance after immersion.

5. CONCLUSION

Some changes in measured dimensional, physical, and mechanical properties of the PVC geomembrane were measured after exposure to the synthetic MSW leachate at a temperature of 23℃ and 50℃ for 30, 60, 90, and 120 days. Although some variability of the test results is observed due to experimental factors and product variability, the synthetic MSW leachate in this study did not significantly degrade the physical or mechanical properties of the flexible PVC geomembrane. With geomembranes, a range of physical and mechanical index test values covering 10% or more of the average value is common, which means geomembranes possess inherent product variability.

As a result, this paper concludes that the PVC geomembranes are not adversely affected by the synthetic MSW leachate duringthe tested period. This result is in agreement with the previous test results (Haxo *et al*. 1985, Fayoux *et al*. 1993). For evaluating the comprehensive long-term chemical effect of MSW leachate on PVC geomembranes, it is recommended to extend the period exposure to the MSW leachate beyond 120 days and to consider different temperature.

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