PERFORMANCE OF 30 mil PVC GEOMEMBRANE EXPOSED TO SYNTHETIC MSW LEACHATE

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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 landfill 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 using ASTM D 5322. Changes in dimensional, physical, and mechanical properties were measured after exposure to the synthetic MSW leachate at 23°C and 50°C for 30, 60, 90, and 120 days. Although there is some variability in the test results 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, it is concluded that this PVC geomembrane is not adversely affected by the synthetic MSW leachate.

RÉSUMÉ
La résistence des géomembranes flexibles de CPV aux chimiques “leachate” est très importante en ce qui concerne les géomembranes de CPV qui sont considérés comme une couche barrière dans les systèmes d’enfouissement de déchets. Ce document explique les résultats des épreuves de laboratoire pour l’évaluation de la compatibilité des produits chimiques en contacte avec la géomembrane flexible de CPV ayant une épaisseur de 0.76 mm (30mil) et exposé aux déchets solides des minicipalités, utilisant la methode ASTM D 5322. Les changements aux propriétés de dimension, physique, et mécanique sont mesurés apres qu’ils sont exposés aux “leachate” synthétiques (MSW) a 23° C et 50° C pour 30, 60, 90, et 120 jours. Même avec la variabilité des résultats d’épreuves causée par certains facteurs d’experimentation et la variabilité des produits, les “leachates” MSW synthétiques non pas dégradés les propriétés physiques et mécaniques des géomembranes de CPV. Par conséquence, nous affirmons que les géomembranes de CPV ne sont pas affectés par les “leachates” MSW synthétiques.

1. INTRODUCTION

The long-term chemical effect of MSW leachate on PVC geomembranes is important to determine the effective service life of a PVC geomembrane used as a barrier layer in landfill liner systems. Because it is difficult to exhume PVC geomembranes that have been subjected to MSW leachate, laboratory submersion tests are recommended to assess the chemical compatibility of a PVC geomembrane.

Haxo *et al*. (1985) used laboratory tests to determine the chemical compatibility of various lining materials to leachate from MSW landfills. The tested lining materials are 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 swell slightly but retain their original properties. However, the PVC geomembranes showed signs of plasticizer loss and stiffening.

Fayoux *et al*. (1993) investigated a 1 mm thick PVC 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 cause a large decrease in plasticizer retention. The plasticizer loss ratio of 37% while exposed to air is much greater than the plasticizer loss ratio of 16% for exposure to the leachate.

This paper describes laboratory test results performed by TRI/Environmental (2003) to determine the chemical compatibility of a PVC geomembrane with a synthetic 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°C and 50°C for 30, 60, 90 and 120 days following the exposure regimen specified in ASTM D 5322-98.

2. MATERIALS AND TEST METHODS

The geomembrane used in this chemical compatibility study is a 30 mil PVC geomembrane from Canadian

General Tower Ltd. The waste leachate is a synthetic MSW leachate constituting various organic and inorganic substances that are commonly found in leachate of MSW landfills (TRI/Environmental, 2003).

PVC geomembrane specimens are exposed to the synthetic MSW leachate using the specifications of EPA Method 9090A as they relate to exposure to waste fluids. The tanks used for these exposures are maintained at 23 ± 2°C and 50 ± 2°C throughout the 120-day exposure period. Tanks consist of chemically resistant stainless steel or glass, fitted with stirrers and heated with a circulating hot water heat exchanger system. The 50°C 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, 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 doubled for baseline determinations on unexposed material.

Table 1. Tests performed on PVC geomembrane

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

A typical tensile testing procedure is illustrated in the photographs of Figure 1.

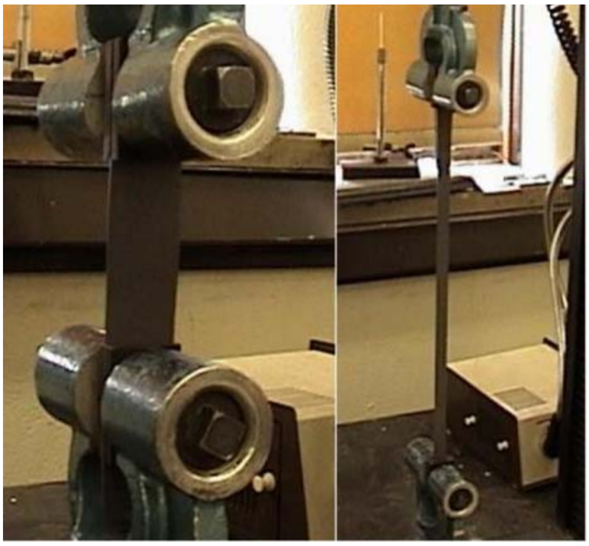

Figure 1. PVC geomembrane before and during tensile testing (from Stark et al., 2002)

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

Table 2. Weight and dimension measurement

Test parameter	Temp. (°C)	% 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

4.2 Physical property

The indentation hardness is measured according to ASTM D 2240 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 slight reduction 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. Table 3 shows only a 1 to 2% hardness reduction even after 120 days of immersion at a temperature of 23 and 50°C. This change is comparable to 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 volatile loss and extractables are measured according to the EPA SW-870 Appendix 3. These test methods evaluate how much and how fast the external plasticizers migrate out of the PVC geomembrane 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 for 120 days. As expected, the test results at the higher temperature of 50°C show more volatiles and extractables than at the lower temperature of 23°C.

The specific gravity of the immersed specimens is measured according to ASTM D 792, which determines the relative density of the PVC geomembrane 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 specific gravity, 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. The tensile properties used herein to characterize the PVC geomembrane for control and specification purposes are tensile stress at break, tensile stress at 200% elongation, and elongation at break. Immersed specimens were tested in both machine and transverse direction.

Table 3. Physical property measurement

		Base-line	30 days	60 days	90 days	120 days
Hard-ness	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		-	-	-	-
Extrac-tables (%)	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°C, respectively.

The tensile stress at break is calculated by dividing the tensile force 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 is 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 is no significant change in the tensile stress at break and at 200% elongation of the PVC geomembrane after immersion in the MSW leachate. This change is comparable to the results presented by Haxo *et al*. (1985) in which the 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 is expressed in percent. Table 4 shows a change in the tensile elongation at break for both machine and transverse directions after immersion in the MSW leachate. No significant change is observed in the tensile elongation at break of the PVC geomembrane after immersion in the MSW leachate. This change is also comparable to the test results presented by Haxo *et al*. (1985) in which the 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 data show a sufficient percent elongation at break, which indicates that the material retains flexibility even after immersion in the MSW leachate.

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% elog-gation (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% elog-gation (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 (%i) (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°C, respectively.

The hydrostatic resistance of a PVC geomembrane is 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 of ASTM D 751. Procedure A is used to measure the hydrostatic resistance after immersion in the MSW leachate herein. Table 5 shows a slight change in the hydrostatic resistance after immersion in the MSW leachate. All of the hydrostatic resistance test results 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. This test method is used to measure the force to initiate tearing of 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 slight change in the tear strength after immersion in the MSW leachate. Again, these test results are comparable to the results presented by Haxo *et al*. (1985) in which the reduction in 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) 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 a 10% reduction in the puncture resistance after immersion.

Table 5. Other mechanical property measurement

		Base-line	30 days	60 days	90 days	120 days
Hydrostatic resistance (psi)	Ave.	113	118/118[1]	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°C, respectively.

5. CONCLUSION

Slight changes in dimensional, physical, and mechanical properties of the PVC geomembrane were measured after exposure to the synthetic MSW leachate at a temperature of 23°C and 50°C 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. As a result, it is concluded that the PVC geomembrane tested is not adversely affected by the synthetic MSW leachate used herein. 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.

6. REFERENCES

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ASTM D 1004-74a, Standard test method for initial tear resistance of plastic film and sheeting.
ASTM D 2240-02b, Standard test method for rubber property-Durometer hardness.
ASTM D 4833-88, Standard test method for index puncture resistance of geotextiles, geomembranes, and related products.
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