





Introduction




Chemical Resistance of Geosynthetic Polymers to Hydrocarbons and Toxic Soil Contaminants

Presented by James Holt



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Outline




- Background
- Environmental Contaminants
- Review Geosynthetic materials
- Review of Chemical Resistance test methods
- Chemical Resistance
- Permeation
- New Barrier Technology
- Applications
- References

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Background



- Established 1989
- Producer of building membranes and chemical protection fabrics
- Expertise in Flame Retardant and Chemical Resistant Technologies
- Product Groups
 - Weather Protection & Containment
 - Building Membranes
 - Gas Barriers
 - Chemical Barriers



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Background

- Weather Protection & Containment
- Building Membranes
 - UV Resistant Facade membranes
 - Roof Underlays
 - Breather Membranes & Vapour Control Layers





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Background

- Chemical Barrier fabrics
 - CBRN shelters
 - Chemical protection clothing

- Barrier technology incorporated into Puraflex




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Environmental Contaminants

- Aliphatic Hydrocarbons
 - Cyclohexane
 - Diesel Fuel
 - Hexane
 - Jet Fuel
 - Petrol / Gasoline
 - White Mineral Oil
- Aromatic Hydrocarbons
 - 1,1-Biphenyl Anthracene (PAH)*
 - Acenaphthene (PAH)*
 - Benzene (BTEX)
 - Benzo(a)anthracene (PAH)*
 - Benzo(a)pyrene (PAH)*
 - Benzo(b)fluoranthene (PAH)*
 - Benzo(ghi)perylene (PAH)*
 - Benzo(k)fluoranthene (PAH)*
 - Chrysene (PAH)*
 - Dibenzo(ah)anthracene (PAH)*
 - Ethylbenzene (BTEX)
 - Fluoranthene (PAH)*
 - Fluorene (PAH)*
 - Idendo(1,2,3-cd)pyrene (PAH)*
 - Isopropyl BenzineNaphthalene (PAH)*
 - Pyrene (PAH)*
 - Styrene
 - Toluene (BTEX)
 - Xylene (BTEX)

- Halogenated Hydrocarbons
 - 1,1,1,2-Tetrachloroethane
 - 1,1,2,2-Tetrachloroethane
 - 1,1,1-Trichloroethane
 - 1,2-Dibromoethane
 - 1,2-Dichloroethane
 - 1,2,4-Trichlorobenzene
 - Carbon Tetrachloride
 - Chlorobenzene (VOC)**
 - Chlorotoluene
 - Chloroform
 - Dioxins and Furans
 - Hexachlorobuta-1,3-diene
 - Pentachlorobenzene
 - Pentachlorophenol
 - Polychlorinated biphenyls
 - Tetrachlorobenzene
 - Tetrachloroethylene
 - Trichloroethene (VOC)**
 - Vinyl Chloride (VOC)**

- Metals
 - Arsenic, Beryllium, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc
- Organics
 - Methyl-tert-butyl-ether
 - Phenol
- Inorganics
 - Carbon Disulphide
 - Cyanides
- Pesticides
 - Dieldrin
 - DDT
 - HCH
- Gases
 - Carbon dioxide
 - Methane
 - Radon



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* Polycyclic Aromatic Hydrocarbons

** Volatile Organic Compound

Geosynthetic Materials

- PVC polyvinyl chloride
- Butyl Rubber polyisobutylene / PIB
- EDPM ethylene propylene diene monomer
- CSPE chlorosulphonated polyethylene [*Hypalon™*]
- CR polychloroprene [*Neoprene™*]
- PP polypropylene
- LDPE low density polyethylene
- HDPE high density polyethylene
- EIA ethylene interpolymer alloy
[*Coolgard™, XR-5™, UltraTech™, Elvaloy™*]
- Aluminium Laminates



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Geosynthetic Materials

▪ Limited Chemical Resistance Information

- Industry practice to compile resistance charts
- Information often sparse and qualitative
- Do not provide any performance data



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Test Methods



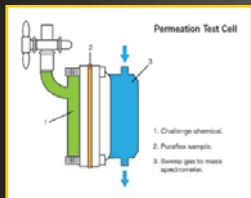
- EN 14414 and EN 14415 Test Procedure
 - Immersion test
 - 50 °C for 56 days
 - Visual inspection
 - Measurements of Tensile Strength & Elongation variances
 - Pass criterion is merely residual strength >75%

** Test Procedures equivalent to ASTM D5322 within EPA method 9090 and ASTM D5747.*

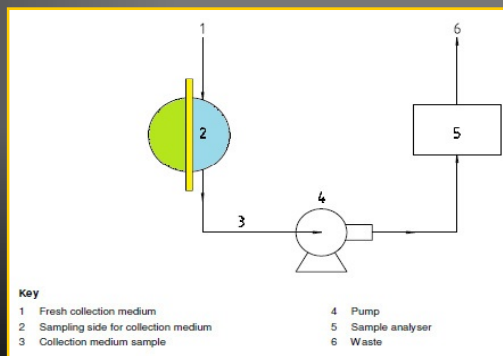


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Permeation



- Permeation Test Method
 - Each challenge chemical exposed to the sample in a permeation cell
 - Sweep gas to MS or GC

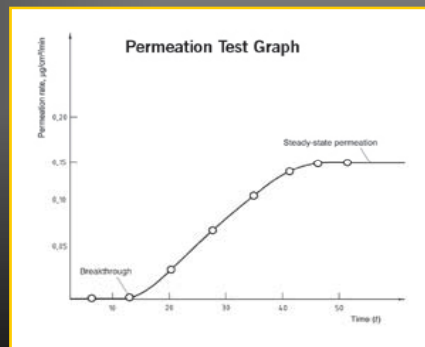


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Permeation



- Permeation Testing
 - Breakthrough time
 - Steady State Permeation Rate $\mu\text{g}/\text{cm}^2/\text{min}$



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Key Points – Materials & Tests



- Common Geosynthetic Materials
 - Limited chemical resistance spectrum of homogenous mono-polymer membrane materials
- Current Test Methods
 - Limited scope of challenge chemicals
 - Lack of Quantitative chemical resistance data

Immersion testing measures Resilience, i.e. the effect of the challenge chemical on the membrane's physical characteristics. Performance is measured by Permeation



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'Hydrocarbon Resistant'

- Common HDPE membranes:
 - Active-guard HB hydrocarbon barrier [Timloc]
 - CarbonBlock – [Geosynthetics]
 - Corden™ EPS Hydrocarbon Membrane Barrier
 - Hazgard™/Arctic Liner NT™ (America)
 - Landflex™ HCR – [Landline]
 - Monarflex® Besoguard [Icopal]
 - Visqueen® GX geomembrane [BPI plc]

- How effective is HDPE ?

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Landflex HCR [Landline]

- Landflex HCR [Landline] published data
- 1.0mm HDPE
- ISO 6170 method B
 - Toluene 6.4 gm/m²/hr (= 56,064 gm/m²/yr)
 - Xylene 3.5 gm/m²/hr (= 30,660 gm/m²/yr)

- Are these permeation rates really fit for purpose?

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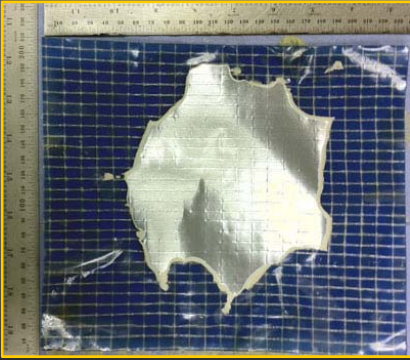
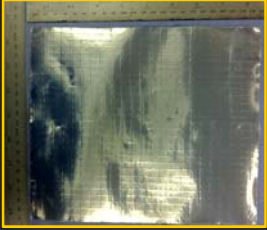
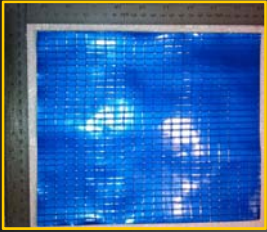


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Aluminium Laminate


Control Sample

- EN 14414 Method A
- Immersion 20% Sulphuric Acid
- Failure (oxidation)



0 days

2 weeks

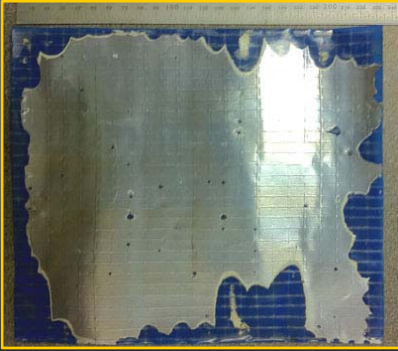
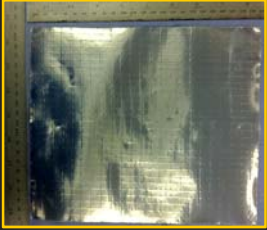
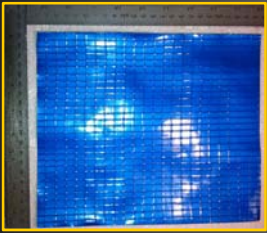


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Aluminium Laminate


Control Sample

- EN 14414 Method A
- Immersion 2.0% Sulphuric Acid
- Failure (oxidation)




0 days

16 weeks




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Chemical Resistance

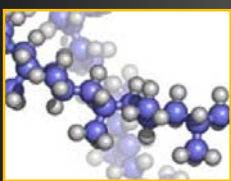


- Factors affecting Chemical Resistance
 - Geosynthetic material polymer
 - Challenge chemical
 - Chemical concentration
 - Toxic Additivity
 - External Factors
 - Area, Duration and Frequency of chemical exposure
 - Temperature
 - pH
 - Aeration, Flow velocity, Exposure to weathering, Mechanical load




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Chemical Resistance







- Molecular structure characteristics
 - Molecular Weight
 - Chain length is directly related to polymer strength
 - Molecular Weight Distribution
 - Relationship between the number of species and the molar mass
 - Crystallinity
 - Ratio of amorphous regions to crystalline regions within the polymer's structure
 - Polarity
 - Distribution of electrons




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Chemical Resistance

Polymer	HDPE	LDPE	PP	PVC
Crystallinity %	55-65	30-45	40-45	0
Tensile Strength	Good	Fair	Good	Poor
Brittle Deformation	Poor	Good	Fair	Excellent
Chemical Resistance	Good	Fair	Good	Poor
Polarity	Non-Polar	Non-Polar	Non-Polar	Polar

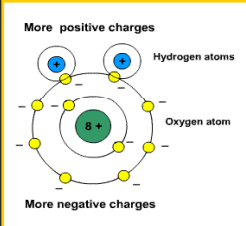


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Polarity

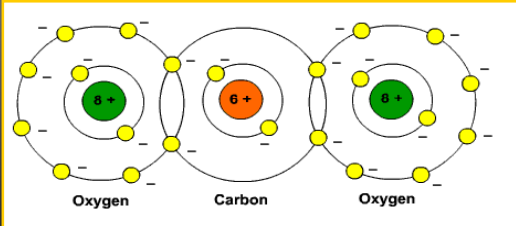
- Polar & Non-polar Chemicals
 - Normally an atom has an even distribution of electrons in the orbits
 - If more end up on one side that the other in a molecule, there is a resulting electrical field in that area

Polar




H₂O

Non-polar



CO₂



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Polarity

- General rule
 - Polar + Polar = Soluble
 - Non-polar + Non-polar = Soluble
 - Polar + Non-polar = Not Soluble
e.g. Water (Polar) + Oil (Non-Polar)
- Why is this significant?


Methanol (Polar)

↓

Hydrocarbons (Non-polar)

↓


HDPE (Non-polar)



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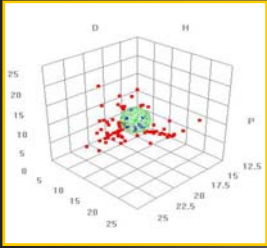
Polarity

▪	PVC	polyvinyl chloride	Polar
▪	Butyl Rubber	polyisobutylene / PIB	Non-Polar
▪	EDPM	ethylene propylene diene monomer	Non-Polar
▪	CSPE	chlorosulphonated polyethylene <i>[Hypalon™]</i>	Polar
▪	CR	polychloroprene <i>[Neoprene™]</i>	Polar
▪	PP	polypropylene	Non-Polar
▪	LDPE	low density polyethylene	Non-Polar
▪	HDPE	high density polyethylene	Non-Polar
▪	EIA	ethylene interpolymer alloy <i>[Coolgard™, XR-5™, UltraTech™, Elvaloy™]</i>	Polar



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Chemical Resistance



δD Dispersion Solubility Parameter
 δH Hydrogen Bonding Solubility Parameter
 δP Polar Solubility Parameter

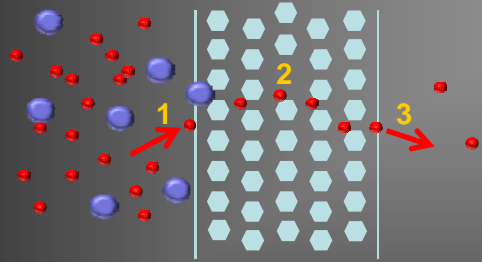
- Solubility Parameters
 - Graphical representation
 - **Green Sphere** = polymer
 - **Red Satellites** = challenge chemicals

- The closer the challenge chemical is to the polymer
 - > Solubility
 - > Permeation rate



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Permeation




1 Sorption
 Partitioning of the chemical to the liner governed by Henry's Law :

$$C_g = Sg f \cdot C$$

2 Diffusion
 Migration on a molecular scale through the barrier expressed by Fick's first Law :

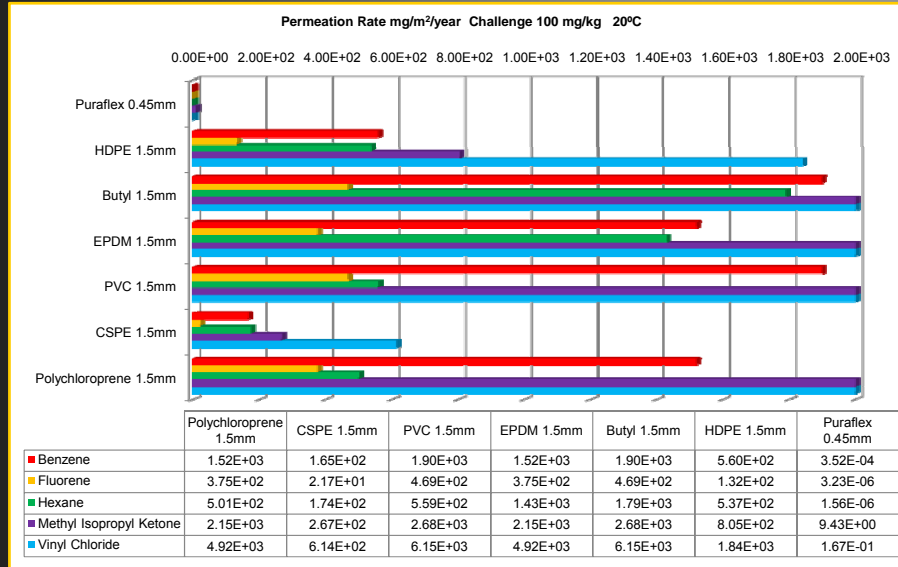
$$f = -D_g \cdot (dc_g / dz)$$

3 Desorption
 Partitioning between the chemical and the outer surface of the barrier



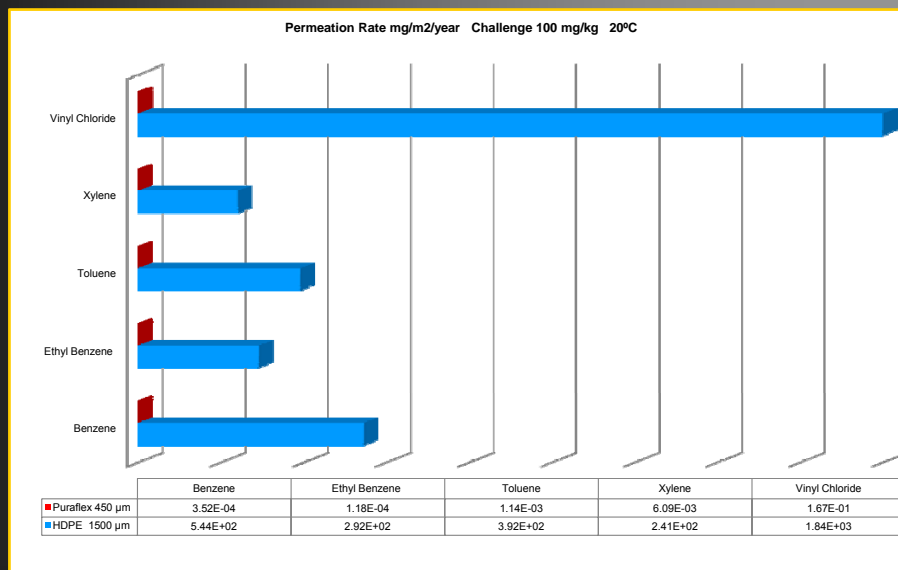
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Permeation – polymer comparisons





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Permeation – BTEX Comparisons




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New Technology


- Composite construction
- Polar and Non-polar polymers
- Resistant to Non-Polar and Polar challenge chemicals
- Barrier Technology
 - Extruded multi-layer composite
 - Incorporates Polar and Non-polar layers
 - Chemical Resistant core
 - Thermally weldable

Polar (Methanol)	Non-Polar (Hydrocarbons)
↓	↓
Non-polar	
Polar	
Non-polar	




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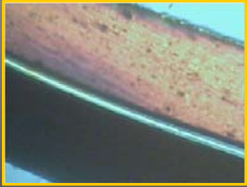
Microscopy




Cross section



Seam weld



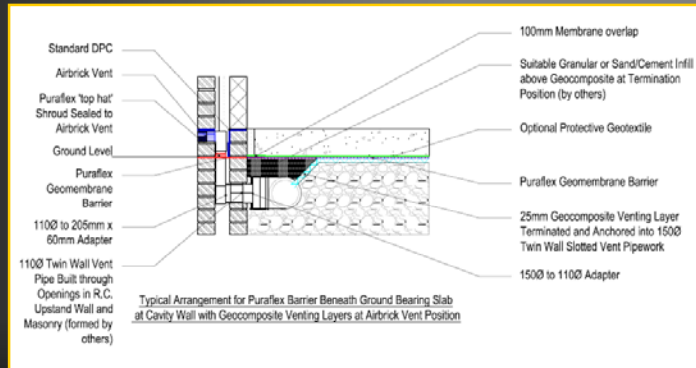
After creasing



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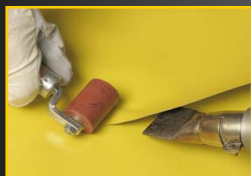
Design & Installation

- Can be thermally welded on site or pre-fabricated under factory conditions.
- Can be installed in various ways for the foundations of buildings. Textured vertical DPC is available
- Puraflex tank incorporates a bituminous adhesive on one side for tanking applications.



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Design & Installation




- Installation
 - Compatible with existing installation methods
 - Conventional geosynthetic membrane welding equipment
 - Typically a Leister Twinny S hot air wedge welder
 - BS EN 13067 Qualified Installers recommended
 - Rapid 4m/min installation



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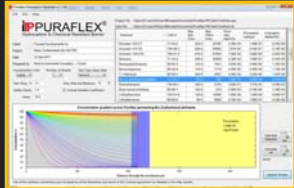
Applications

- **INDUSTRIAL**
 - Chemical waste containment
 - Petrochemical sites
 - Retention ponds
 - Secondary containment liners & basins
 - Sludge desiccation basins
 - Under Tank foundations
 - Pipeline trench liners
- **CIVIL ENGINEERING & CONSTRUCTION**
 - Basement linings
 - Brown-field developments & Land reclamation
 - Building foundations (gas barrier)
 - Tanking
 - Tunnel linings
 - Underground structures
- **PROTECTING WATER RESOURCES**
 - Groundwater protection
 - Canals, dikes & dams
 - Effluent treatment
 - Fluid barrier
 - Reedbeds
 - Reservoir & potable water lining
 - Water storage & treatment
- **WASTE**
 - Landfill capping
- (not liner itself – 2mm HDPE)
 - Transfer stations
 - Waste disposal & storage sites (liquid & solid)
- **AGRICULTURE**
 - Agricultural waste
 - Biogas production tanks
 - Slurry lagoons




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Puraflex Permeation Modeller





- **Permeation Modeller Software**
 - Specifically written for environmental consultants, hydro-geologists & geotechnical engineers
 - Upload soil analysis concentrations
 - Enter variables
 - Output permeation rates
 - Risk Assessment Models (e.g.CLEA)



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Website and Technical Publications

- Puraflex Permeation Modeller (PPM) Software
- Product Information brochure
- Technical Data Sheet
- Design & Installation instructions
- Sample Specification
- Safety data sheet COSHH, MSDS

puraflex.com


▪ Software
▪ Downloads
▪ Technical Updates
▪ Project News
▪ Latest Chemical Test Data



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References

- **ASTM D5322.** Laboratory Immersion Procedures for evaluating the Chemical Resistance of Geosynthetics to liquids.
- **ASTM D5747.** Tests to Evaluate Chemical Resistance of Geomembranes to Liquids.
- **CLAIRE Report.** The soil generic assessment criteria for human health risk assessment.
- **Bromwich.D.W** The design of permeation cells for testing chemical protective clothing (1999). Phd Thesis – Griffith University.
- **EN 14414 Geosynthetics** – Screening test method for determining chemical resistance for landfill applications (2004).
- **EN 14415 Geosynthetics barriers** – Test methods for determining the resistance to leaching (2004).
- **Lampman.S.W.** Characterization and failure analysis of plastics (2003). ASM International.
- **Method 9090A.** Compatibility test for Wastes and Membrane Liners.
- **Sangam.H.P. & Rowe.R.K.** Migration of dilute aqueous organic pollutants through a HDPE geomembrane (2001). Geotextiles and Geomembranes, 19 pp 329 – 357.
- **Scheirs.J.** A guide to polymeric geomembranes: A practical approach (2009). Wiley.



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