Evaluation of geomembrane UV exposure using geographic and climate data

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- Polyethylene sensitivity to UV light
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Introduction

- **The exposure of geomembranes to sunlight is a great concern for so-called exposed conditions.**
- **UV laboratory weathering is required by GRI GM13 and GM17 for polyethylene geomembranes, per ASTM D7238**
- **Laboratory testing is artificial weathering, not real life, correspondence to service conditions is often desired for specific project evaluations.**
- **Site conditions include temperature, humidity (rain), irradiance, UV index, latitude, longitude, and altitude. Rarely, all data is available.**

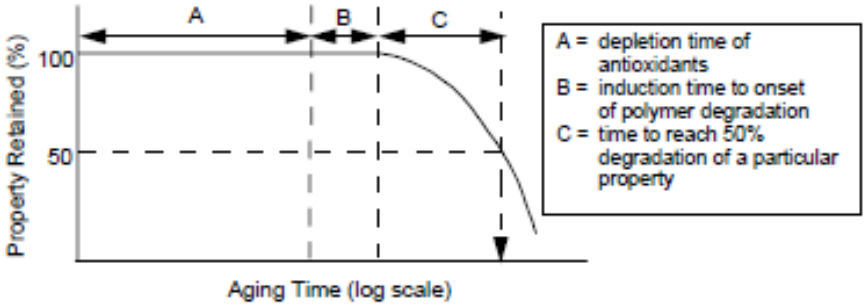
Courtesy of FC LIners

UV exposure of geomembranes

- **Polyethylene geomembranes are mostly controlled with UV-fluorescent weatherometers.**
- **GRI specifications use ASTM D7238 UV light exposure described as follows:**
  - **20 hours UV light, irradiance = 0.78 W/m^2.nm at 340 nm, BPT = 75°C**
  - **4 hours condensation, without light, 60°C**
  - **Total UV light exposure = 1600 hours**
- **EN specifications use EN 12224:**
  - **5 hours UV light, irradiance = 39.2 W/m^2 over 290-400 nm range, BPT = 50°C**
  - **1 hour light and water spray, same irradiance, BPT=25°C**
  - **Total UV light exposure = 50 MJ/m^2**

UV exposure of geomembranes

- **Monitored properties include material properties and mechanical properties**



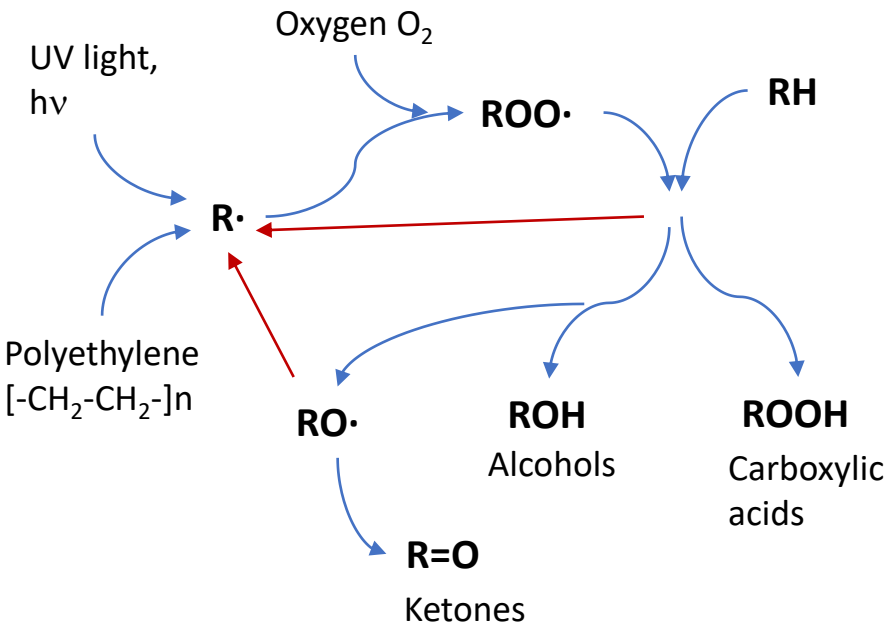
Adapted from Koerner et al. (2002)

- **Antioxidant depletion is preferred for the monitoring of material properties, using:**
  - **Standard OIT, 200°C, 1 atm – specific to degradation by oxidation**
  - **High-Pressure OIT, 150°C, 34 atm – specific to photo-oxidation**

- **Mechanical properties change once the protection against oxidation or photo-oxidation is depleted:**
  - **Tensile elongation at break is reduced, usually the primary property observing changes**
  - **Cold temperature brittleness is reduced with plasticized polymers**

Polyethylene sensitivity to UV light

- **Photo-oxidation is initiated from UV light, resulting in chain reactions.**
- **Dissociation is related to molecular bond energy and related to radiation and thermal energy**
- **Polyethylene sensitivity relates to the spectral sensitivity of PE from UV exposure with cut-on filters**
- **The sensitivity change was measured with exposure time.**
- **The reference is related to the sensitivity of exposed PE.**



Polyethylene sensitivity to UV light

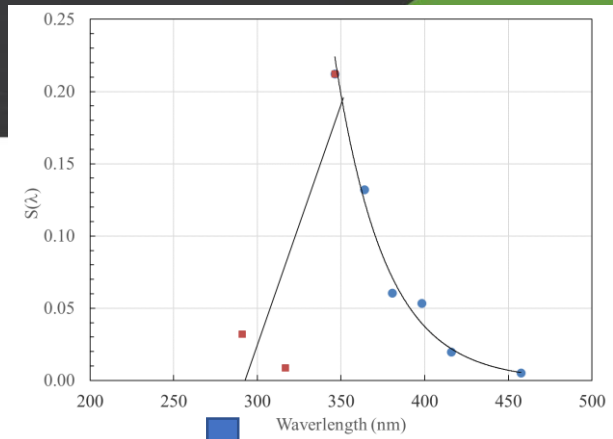
- **Effective irradiance , E_{eff}**

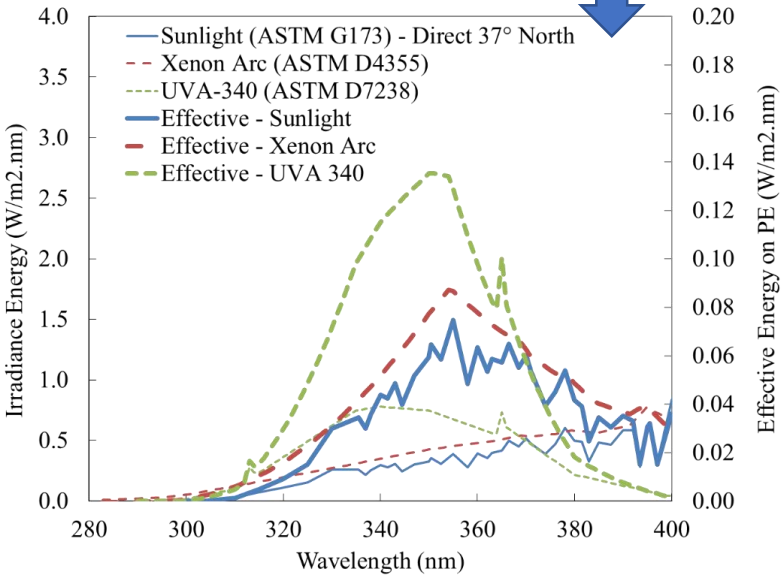
$$E_{eff} = \int E_{\lambda} \cdot S(\lambda) \cdot d\lambda$$

- **Sensitivity, S(λ), when combined with the activation spectrum, results in the effective energy to photo-oxidation**

- **Reaction rate, k, using Arrhenius**

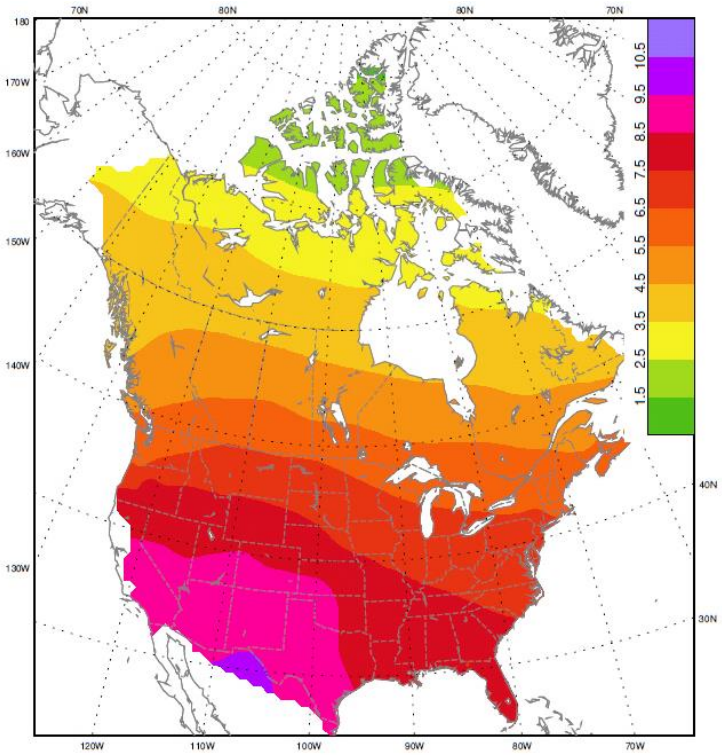
$$k = A \cdot E_{eff} \cdot e^{-\frac{E_a}{RT}}$$





Climatic data

- **The World Ozone and Ultraviolet Data Centre (WOUDC) has developed a wide range of data on UV radiations.**
- **Pyrometers measure irradiances with wavelengths from 295 to 325 nm. UV index is calculated from monitoring.**
- **Standard sunlight spectra are also documented in ASTM G173, and used for the wavelength distribution of sunlight.**
- **Data also include latitude, altitude, temperature, year time, and day time.**



Source : WOUDC

Results & Discussion

Materials. Benchmark was conducted on several geomembranes, exposed to ASTM D7238, with:

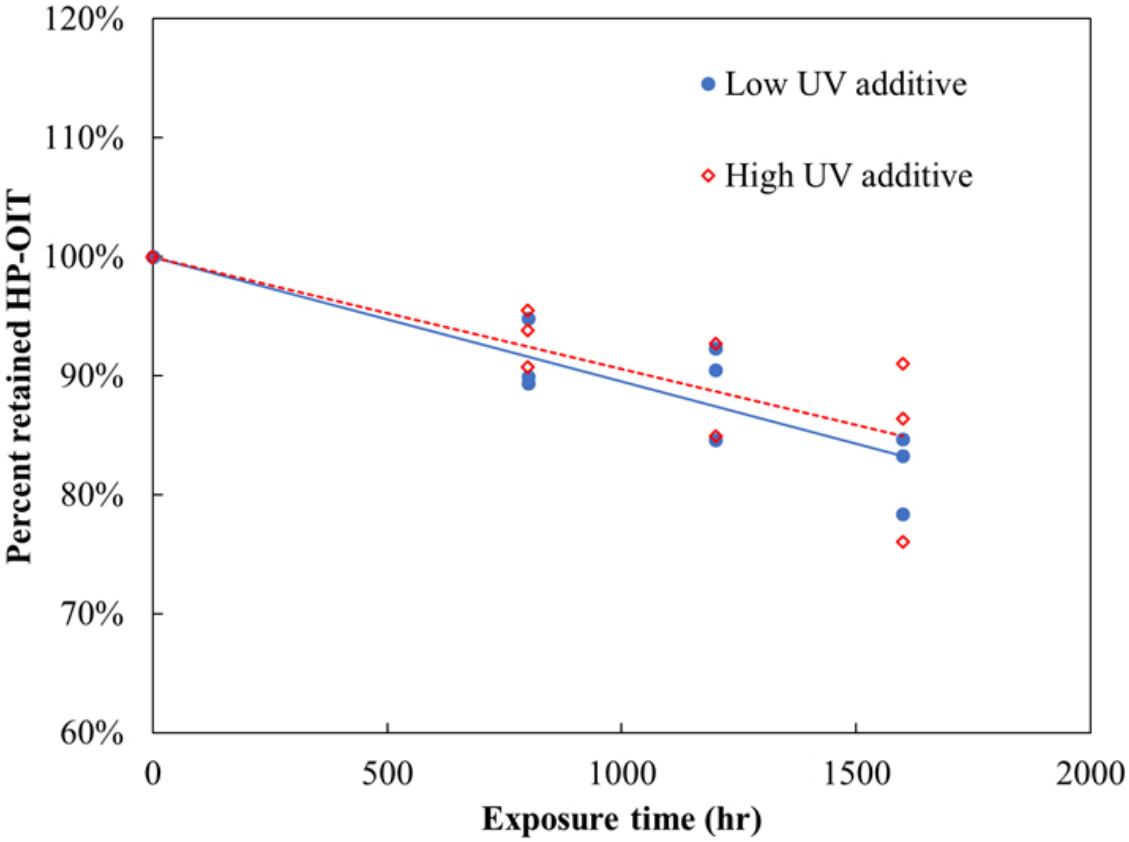
- **Different UV additive loading**
- **Blown film or flat die**
- **Smooth or textured**
- **1.5 or 2.0 mm thick**
- **Black or white surface**

Tests. Characterization was conducted before and after UV exposure:

- **Thickness and density**
- **HP-OIT, per ASTM D5885**
- **Std-OIT, per ASTM D8117**

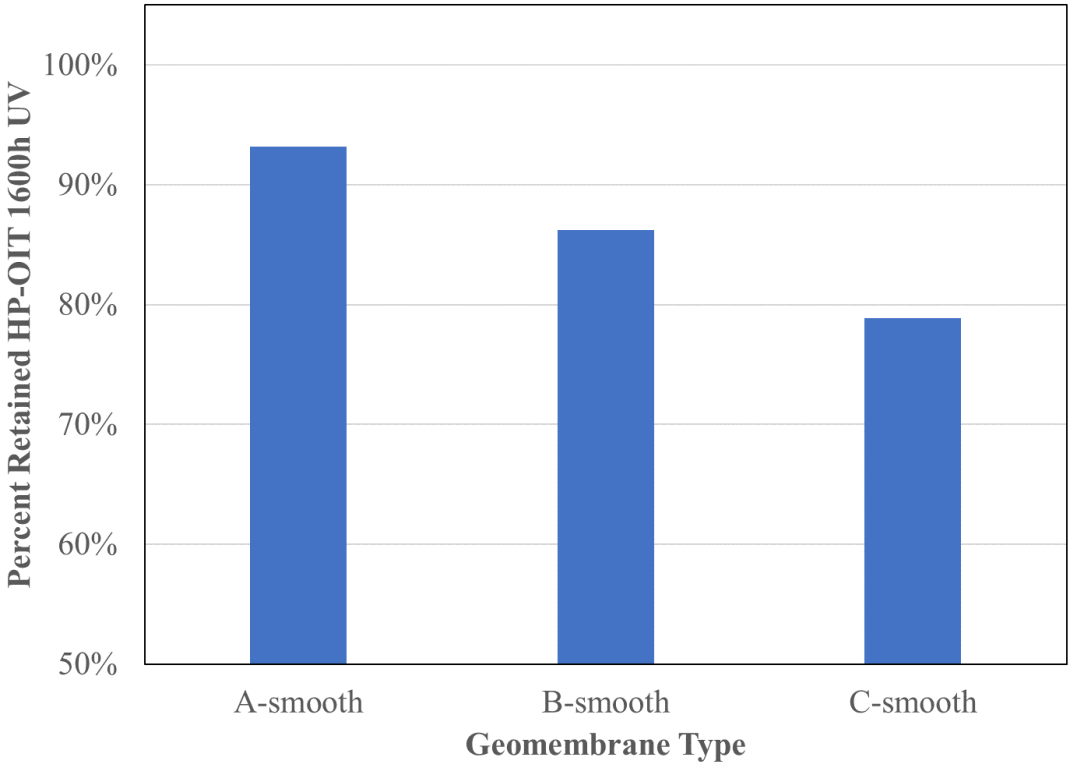
Results & Discussion

- **Based on % retained HP-OIT, the additive loading has not shown a significant difference**
- **Range of additive concentration : 0 – 1.5 wt-%**
- **Conclusion: The % HP-OIT retention is not related with high loadings.**



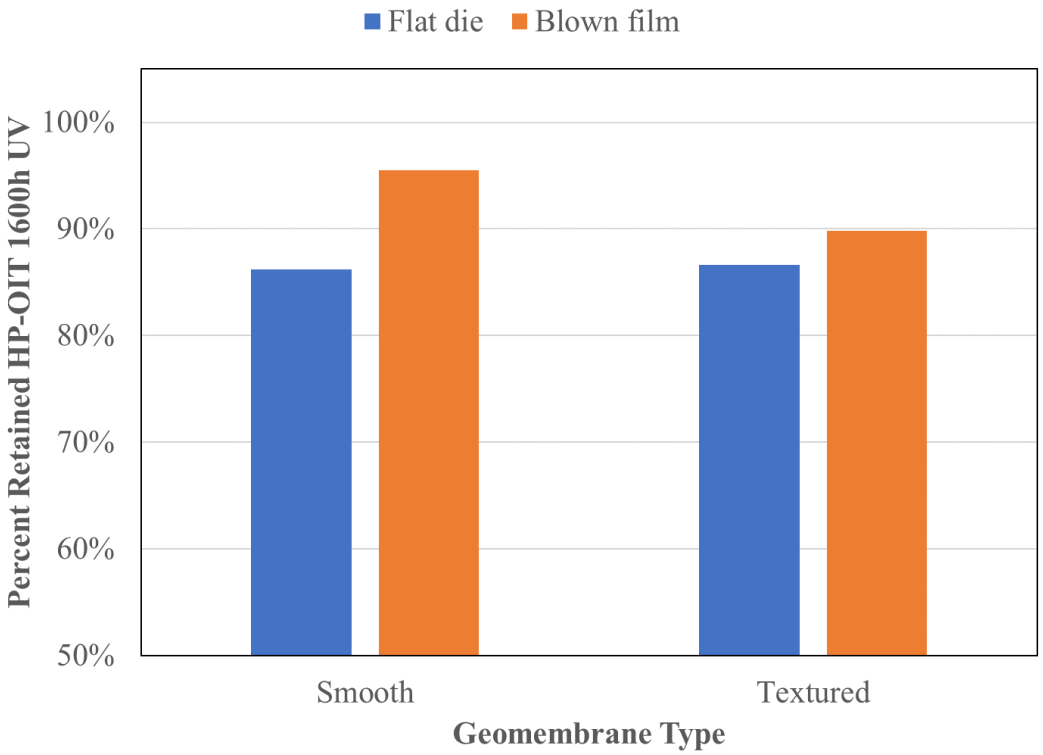
Results & Discussion

- **Formulation (A, B, C) influences percent retention HP-OIT**
- **Conclusion: The selection of additives has a greater effect on the retention of HP-OIT than high loadings.**



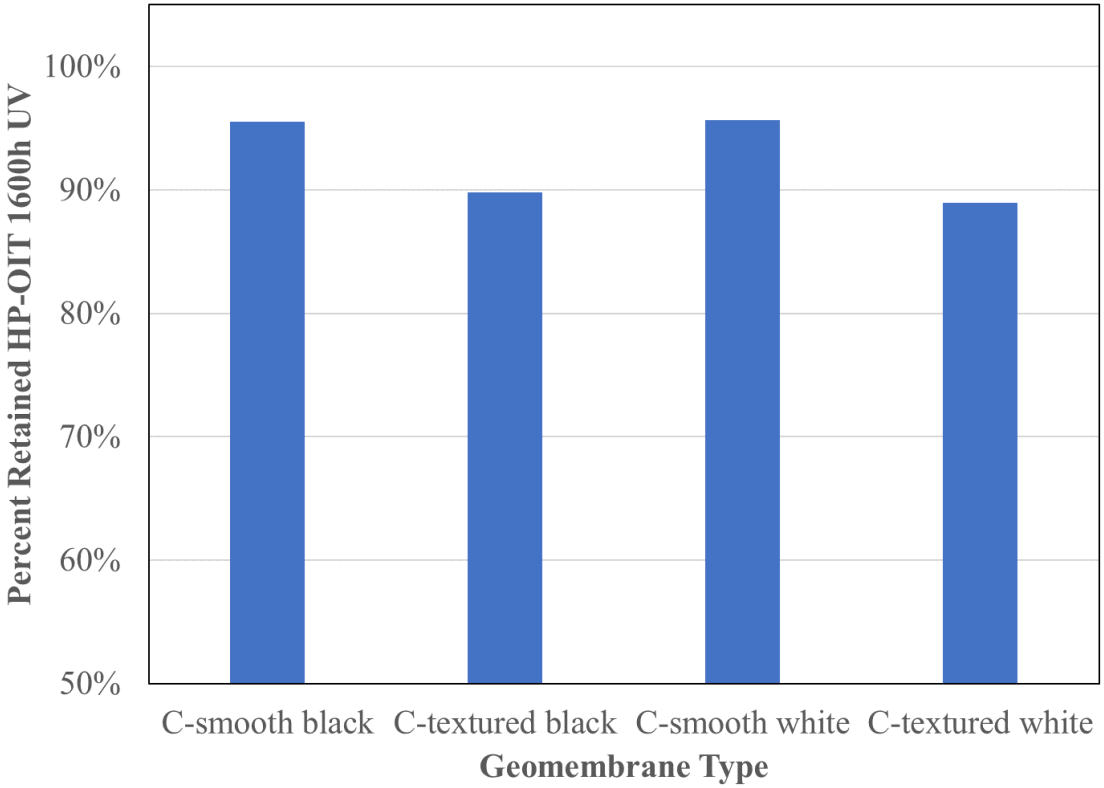
Results & Discussion

- **The manufacturing process influences HP-OIT retention with surface**
- **Conclusion: Flat-die geomembranes have a lower additive depletion difference between smooth and textured HDPE GMs.**



Results & Discussion

- **Comparison of 2mm-thick blown-film HDPE geomembranes**
- **The color has less effect on additive or HP-OIT depletion than the effect of texturizing.**

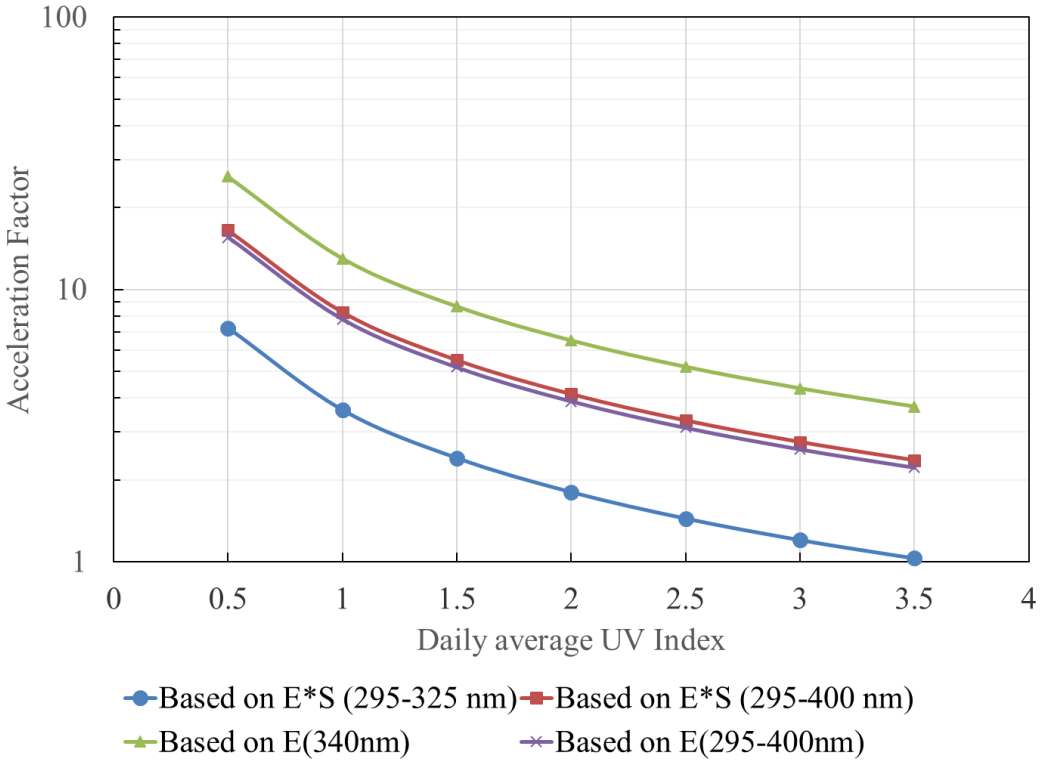


Results & Discussion

- **Relation from artificial weathering to real life is calculated with an acceleration factor (AF)**

$$AF = \frac{T_{UVI}}{T_{D7238}}$$

- **Correlated with UV index, and its erythemal function, based on skin sensitivity**



Results & Discussion

Real-life equivalency of ASTM D7238, 1600 hours UV light, with acceleration factors:

	Toronto, ON	Everglades, FL
UVI (yearly avg.)	0.961	1.596
Service life w/AF (E 340nm), months	30	18
Service life w/AF (E*S 295-400nm), months	19	11.5
Service life w/AF (E 295-400nm), months	18	10.8
Service life w/AF (E*S 295-325nm), months	8.4	5.1

Conclusion

- **Photo-oxidation degradation is driven by several chemical chain reactions. A deep understanding of parameters is required to predict degradation with accuracy.**
- **The first stage of UV degradation is predicted with the additive depletion of HDPE geomembranes, by monitoring HP-OIT UV before and after UV exposure, per ASTM D7238 or EN 12224.**
- **Laboratory testing with ASTM D7238 shows different percent loss rates with formulation and surface aspect, but not with additive loading or color.**
- **Acceleration factors (AF) were related to UV index, commonly used in climate data. When considering polyethylene sensitivity and the complete spectral UV light distribution, are evaluated lower than references based on the irradiance at 340nm.**
- **Long time exposure should consider longer laboratory weathering for adequate prediction. In addition, Further site conditions should be considered, i.e. temperature and humidity (rain).**

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Thank you for your attention!

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