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Calculating the Longevity of High Density Polyethylene

According to Robert Koerner and Grace Hsuan[1] with the Geosynthetics Research Institute (GRI) at Drexel University, "High Density polyethylene (HDPE) geomembranes have been used extensively as primary and secondary containment materials in critical applications. The required service lifetime of these materials varies depending upon the application they are used for." Calculations below can be used to develop estimated service lifetimes of geomembranes. The "Service Lifetime" is to be defined as the length of time before the material begins to degrade.

Geo Products' Envirogrid HDPE Geocell is produced by welding strips of HDPE geomembrane liner together to form panels.

Let me start with a bit of background on the aging process of HDPE. The degradation of an HDPE geomembrane occurs by both physical aging and chemical aging.

Physical aging of HDPE involves changing the crystallinity of the material. Because there are no primary bonds broken in this definition, the material does not degrade. Chemical aging, however implies breaking of bonds through a chemical process, which eventually leads to a reduction in engineering properties. From a practical point of view, chemical aging is the most important degradation mechanism.

HDPE ages chemically in three stages. The first stage (Stage A) involves the gradual depletion of antioxidants which protect the geomembrane from degradation. Antioxidants are often added into a resin to reduce the rate of degradation. Once these are all depleted, the material goes through a period called Oxidation Induction Time (OIT)(B). This is defined as the time from full depletion of antioxidants until the material begins degrading. Stages (A) and (B) are considered the “Service Lifetime” of the material. The Third stage (c), in which the polymer actually starts to degrade, ends at what we call the half-life of the material, or the time to reach 50% degradation of material properties (See chart below)

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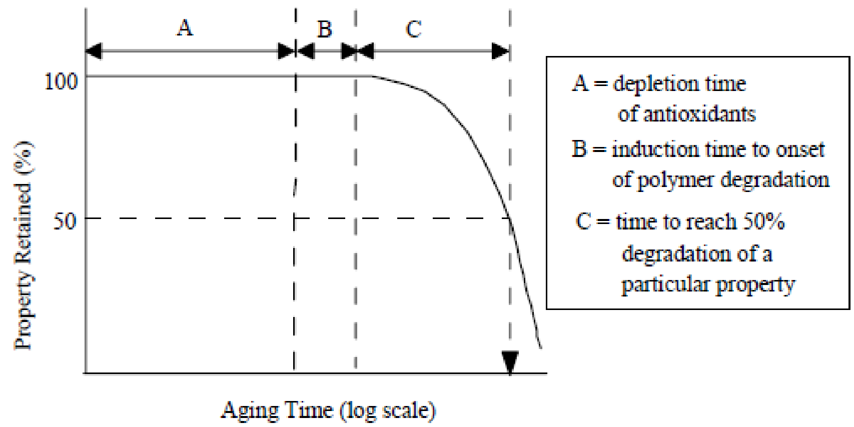

Below is a table compiled from research by Dr. Koerner and Dr. Hsuan, along with literature values from Martin & Gardner, and Viebke.

Table 4 – Lifetime Prediction of HDPE at Elevated Field Temperatures

Field Temperature		Stage "A" (yrs.)		Stage "B" (years)	Stage "C" (yrs.)		Total Ave. Years
C (deg)	F (deg)	Std OIT	HP-OIT		Ref. 1	Ref. 2	
20	68	200	215	30	208	740	712
25	77	135	144	25	100	441	435
30	86	95	98	20	49	259	270
35	95	65	67	15	25	154	170
40	104	45	47	10	13	93	109

Notes: Stage "A" measured values from G. Hsuan research
Stage "B" estimated values from field samples
Stage "C" literature values from Martin & Gardner[17] and Viebke, et al.[18]

With the results above, a standard HDPE geomembrane has a typical service life of 160 years at a temperature of 25°C before any degradation occurs. For the material to degrade to 50% of its original properties, you are looking at an average of 435 years.

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Now that you have a better understanding of the degradation process of HDPE, you will better understand the equation that Koerner developed for service lifetime estimation of HDPE geomembrane products based on a temperature of 25°C. The results from this equation, as you saw in table 4 above, are very conservative as well.

$$\frac{[\ln(OIT) - \ln(P)]}{S} = t\ (in\ months)$$

Where OIT =OIT for Pure HDPE Resin without added antioxidants and equals 0.5 minutes.
P = The original Std-OIT value of the geomembrane.
S = The Std-OIT Antioxidant Depletion Rate of a sample fully immersed in water on both sides and equals -0.0096. This value reflects the harshest conditions tested by Koerner in his study.

[1]*Equation for Antioxidant Lifetime at 25 °C Service Temperature, Koerner and Hsuan, 2005.*