Gas & Odour Suppression: A Comparison of Polyethylene Film Alternative Cover (AC) and Daily Cover Soil

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The use of polyethylene covers in landfills has improved landfill gas collection to utilize the energy value of methane gas and to control air pollution problems resulting from odors and greenhouse gas effects. Compared to earthen final covers of compacted clay for landfill closures, polyethylene final covers are known by landfill operators to be a more efficient barrier to landfill gas. This has to do with the significantly lower effective permeability of polyethylene compared with soil, as well as the tendency for soil barriers to weather, shift and crack over unconsolidated sub-surfaces such as landfill waste.

Polyethylene is a technically “impermeable” material, with no interconnected pores through which fluids can flow. Fluid molecules move very slowly through polyethylene film as a vapor phase via molecular solubility and diffusion, in a phenomenon known as permeation. Polyethylene liner permeation calculated from water vapor transmission (WVT), making assumptions about temperature, humidity and pressure, is compared with permeability for soils measured by Darcy’s Law test apparatus (Koerner, 1994). The effective moisture permeability of polyethylene sheet is then calculated, as exemplified in Figure 1, to be roughly 3×10^{-15} m/sec. This compares with 1×10^{-8} m/sec for typical well-compacted clay. Because of polyethylene’s very low impermeability, methane gas trapped under the film can be very effectively controlled and directed for processing in landfill closures. Permeability is an intrinsic material property, independent of thickness.

Landfill gas contains methane, volatile organic carbons (VOC’s), odorous mercaptans and water vapor. Odorous landfill gases are less polyethylene-permeating than methane (which is odorless) so that the polyethylene film permeation numbers presented below, using the data in Figure 2, are “worst case” when extended to odorous VOC’s and mercaptans. The odorous components of landfill gas permeate even less than the values here presented, displaying an even greater difference compared to compacted soils.

A continuous non-reusable polyethylene film AC will greatly exceed the performance of cover soil in suppressing and controlling the evolution of landfill gas with its odors and air pollution, provided film panels are properly overlapped and punctures are kept to a minimum.

Another important consideration is that compacting clay layers, used for daily cover, can undesirably form interior barriers to the movement of leachate and gas. Such layers are not formed when a non-reusable polyethylene film is used, since the film barrier is designed to lose its integrity within the landfill. Such interior barriers formed by clay can disrupt the desired movement and direction of leachate and gas within a landfill, causing the fluids to migrate sideways resulting in side-slope outbreaks and other seeps at unintended points. Side-slope seeps create significant leachate control problems and can cost un-budgeted dollars in corrective action.

Non-reusable polyethylene film is an excellent continuous fluid barrier at the surface of the waste where it is needed, which, as designed, ceases its barrier action with the landfill, allowing proper fluid flow.

Methane Gas Loss Through Daily Cover Soil

Flow Equation (Darcy's Law): $Q = k_g A (H + t)/t$

where: Q = flow through daily cover, m^3/day

k_g = permeability to methane gas = $k_w \mu_w / \mu_g$

k_w = permeability to water, m/sec

μ_g = viscosity of methane gas at 26°C, 1 ATM (0.011 centipoise)

μ_w = viscosity of water at 26°C (0.9 centipoise)

Assuming: H = effective head of methane = 0.2 m,
t = thickness of cover = 0.3 m,
A = area of working face = 1,000 m^2

Therefore, $Q = k_w(.9/.011)1000(.5/.3)(86{,}400 sec/day)$

$= k_w(136{,}363\ m^2)(86{,}400 sec/day)$

Soil Conditions	**Flow Through (1,000 m² area) Soil Cover,Q**
$k_w=10^{-8}$ m/sec, compacted clay over firm subgrade	117 m^3/day
$k_w=10^{-6}$ m/sec, typical clayey soil compacted over poor subgrade (such as landfill waste)	11,700 m^3/day
$k_w=10^{-5}$ m/sec, typical sandy/clayey soil over poor subgrade	117,000 m^3/day

Methane Gas Loss Through Polyethylene Film (1,000 m² area)

From Matrecon Laboratories, Oakland, Calif., 1991 (Figure 2):

2mil, permeation = 92 cm^3/100 in^2/day	= 1.4 m^3/day
3mil, permeation = 73 cm^3/100 in^2/day	= 1.1 m^3/day
5mil, permeation = 49 cm^3/100 in^2/day	= 0.76 m^3/day

Figure 1

PERMEABILITY OF MEDIUM DENSITY POLYETHYLENE

P_s = pressure of saturated vapor at a given temperature (given in physics textbooks)
H = relative humidity - 60%
T = 23 °C

At T = 23 °C, P_s, = 21.068 mm Hg

$P_s = 21.068 \times 133.3 = 2808$ Pa

The vapor pressure is $p = H \times P_s$.

$p = 0.6 \times 2808 = 1685$ Pa

Water Vapor Transmission WVT = 0.04 g/m^2.24h for 40 mil HDPE

WVT = p x w (w is the permeance)

$$w = \frac{WVT}{p} = \frac{0.04 \times 10^{-3}}{8.64 \times 10^{4} \times 1685} = 2.75 \times 10^{-13} \text{ kg/m}^2\text{. Pa. s}$$

Permittivity $K_t = w \times g$ ($g = 9.81$ m/s^2)

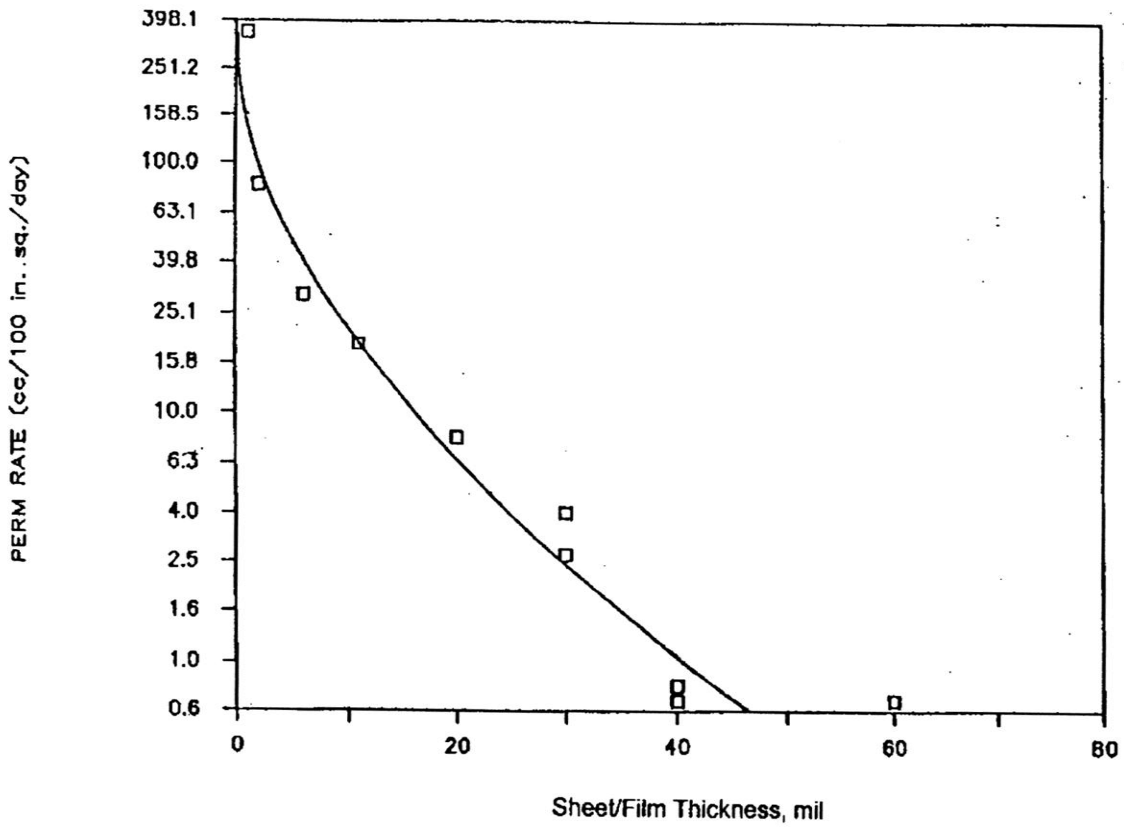
$K_t = 2.75 \times 10^{-13} \times 9.81 = 2.70 \times 10^{-12}$/s

Permeability $k = K_t \times t$ (t = thickness), t = 40 mils = 1 mm = 10^{-3} m

$k = 2.70 \times 10^{-12} \times 10^{-3}$

$k = 2.70 \times 10^{-15}$ m/s

Figure 2 METHANE PERMEATION OF MEDIUM DENSITY POLYETHYLENE SHEET/FILM (Matrecon Laboratories, 1991)



References

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2. Matrecon Laboratories, Oakland, California, for Poly-America Corp, Grand Prairie, TX, 1991.