Gas Impermeable Film and Sheet for Control of Methane and Odors in Agricultural Applications

G. Kolbasuk
Raven Industries, Engineered Films Division, Sioux Falls, South Dakota, USA

Species: Swine, Dairy, Beef, and Poultry
Use Area: Manure Storage, Manure Treatment
Technology Category: Cover
Air Mitigated Pollutants: Methane, ammonia, odor, volatile organic carbon compounds, fumigants.

Description:

For many years, food packaging has incorporated barrier layers to contain odors, flavors, oils and moisture along with the food contents while excluding contamination and oxygen. Until recently, agricultural films and geomembranes were monolithic structures employing only a single polymer or blend. Recent advances in extrusion and lamination equipment allow the incorporation of barrier layers in large scale agricultural structures and operations such as floating covers over animal waste storage, containment geomembranes for biogas generation, silage storage and fumigation films.

Coextruding a thin layer of ethylene vinyl alcohol (EVOH) in a linear low density polyethylene (LLDPE) geomembrane dramatically reduces the permeability to a wide range of gases and volatile organic carbon molecules including: methane, ammonia, carbon dioxide, oxygen, aromatic hydrocarbons, aliphatic hydrocarbons, methyl bromide and most odorous compounds. Methane permeabilites for four geomembranes are given below.

Table 1. Methane Permeability (cc/(m^2•day))

PVC 0.76 mm (30 mils)	LLDPE 1.0 mm (40 mils)	HDPE 1.0 mm (40 mils)	Barrier LLDPE 0.5 mm (20 mils)
900	690	300	<1

Mitigation Mechanism:

Geomembranes used as covers act primarily as a barrier against bulk air and gas movement. This serves to contain most gases generated under the cover and to reduce the amount of odor carrier away from the site. Figure 1 is an example of such a cover being used over a manure storage facility to collect gas. More sophisticated geomembrane structures combining multiple polymers with different barrier properties can enhance the performance of the geomembrane by reducing the permeability to many gases and odors.

Figure 1, Floating cover with gas collection

The structure discussed in this paper is a simple five layer coextrusion used by itself or laminated into a thicker geomembrane with scrim reinforcement. It consists of LLDPE or other types of polyolefin on the two outside surfaces with a core layer of EVOH or nylon. LLDPE and EVOH do not bond to each other and requires a “tie layer” between the two.

Polyethylene is used on the outside layers as the primary polymer because of the ease of extrusion, the toughness it adds to the product, the ease in which it can be welded and because of its relatively low cost. Since polyethylene is a non-polar molecule, it is a good barrier to polar molecules such as water, alcohol and dissolved salts. Unfortunately, the amorphous part of its structure readily accepts non-polar molecules such as methane, oxygen, radon, benzene and a large number of other hydrocarbons. The permeability of polyethylene is too high to be used as an oxygen barrier for food, an oil barrier for packing or a gasoline barrier for fuel tanks.

EVOH and nylon are polar and more crystalline, making them a better barrier to non-polar solvents and gases than polyethylene. Figure 2 illustrates this with the oxygen permeability of several packaging polymers. The y-axis is a log scale and shows LDPE to be more than 1000 times more permeable to oxygen than EVOH. While this table hints that EVOH can be a much better barrier to other chemicals, the oxygen permeability can not be used to calculate the permeability of other non-polar gases and solvents since there are other reactions related to molecule size and chemical interactions that affect the permeability.

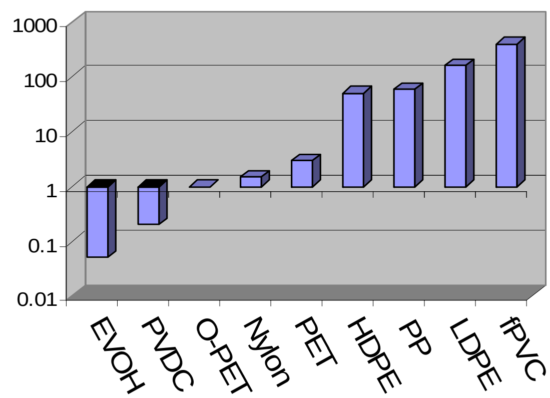

Figure 2, Oxygen Permeability
(cm^3*mm/m^2*day*atm)

Applicability:

This mitigation technology has several agricultural applications. The oxygen data shown in figure 2 indicate the effectiveness of a silage film or bag with an EVOH layer in keeping silage from spoiling.

Chemical pollution from fumigants is another agricultural application. Broadcast flat fumigation is a process by which large fields are treated to kill insects, nematodes, weeds and undesirable microorganisms. Strawberry fields in the southwest United States are commonly treated prior to planting. The process shown in figure 3 involves injecting the fumigant into the ground and immediately covering the applied area with a plastic film to help retain the fumigant. One edge of the film in embedded into the ground and the other is glued to the previously treated and covered area.

The preferred fumigant has historically been methyl bromide because of its effectiveness. Methyl bromide has come under fire because of its toxicity and because it is known to contribute to the depletion of the ozone layer. It has been banned internationally but it still being used by exception, where there is a critical application and for which no suitable equivalent fumigant is available.

HDPE film is typically used to cover the treated area. Figure 4 compares the retention of the methyl bromide in the soil when covered by an HDPE film to that when covered by a Totally Impermeable Film (TIF). The TIF, not actually totally impermeable, is a polyethylene film with a 0.1 mil thick core layer of EVOH. The lower permeability of the TIF film allows the methyl bromide to be used at much lower concentrations and still be effective. The data presented here is from unpublished research in progress, Steve Fennimore, University of California, Davis.

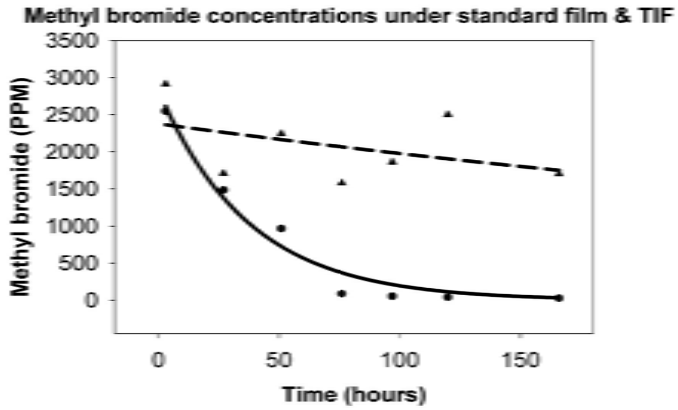

Figure 4, Methyl Bromide under standard HDPE film (solid line) and LL / EVOH film (dashed line)

Animal waste storage has become a major issue as the size of animal feed lots and commercial farms grow in size. One solution to control odor is to move the manure into holding ponds covered by floating covers. Polyethylene covers help control the odor but odor readily permeates and penetrates the cover. As in food packaging applications where barrier films contain odors, so can an Absolute Barrier Geomembrane be an effective odor barrier in covers. The following study of the permeability of several geomembranes illustrates the improvement seen when a thin layer of EVOH is included in a polyolefin geomembrane.

	LLDPE	LL/PA	LL/EVOH
Benzene	4.5	25	40,000
Toluene	6.5	37	55,000
Ethylbenzene	9.0	45	100,000
m/p-Xylenes	7.5	40	105,000
o-Xylenes	6.0	30	70,000

Figure 5, Relative Diffusion Properties Compared to PVC (higher value represents lower permeability)

Rebecca McWatters, under the direction of Dr. Kerry Rowe, has been conducting diffusion tests on several geomembranes. They included a 0.76 mm (30 mil) PVC, a 0.5 mm (20 mil) linear low density polyethylene, a 0.36 mm (14 mil) LLDPE containing a core barrier layer of polyamide (LL / PA) and a 0.5 mm (20 mil) LLDPE containing a core layer of EVOH (LL / EVOH). Each of the materials was challenged with an aqueous solution containing BTEX, a mixture of benzene, toluene, ethylbenzene and xylenes in concentrations representative of what would be found in a landfill. Details of the procedure are given in the referenced 2007 paper. The current work is not yet complete and will be published in the future. The permeability testing of the LL / EVOH is ongoing and the values given in the table are estimates based on the data collected at the time of this writing.

Figure 5 contains the diffusion coefficient of the PVC geomembrane divided by the diffusion coefficient of the tested geomembrane, normalized for thickness. The higher the value in the table, the lower the permeability. In order of permeability, from highest to lowest, PVC > LL > LL / PA > LL / EVOH. The inclusion of EVOH dramatically reduces the permeability of BTEX through the LL.

Limitations:

EVOH owes some of its impermeability to its high level of crystallinity. This makes EVOH more rigid than many of the softer polymers used in geomembranes. While EVOH has ultimate tensile elongation in excess of 200% and is flexible when in relatively thin layers, it is not elastic and should not be used as part of an elastomeric geomembrane.

Cost:

EVOH is more expensive than polyethylene, the equipment needed to processes it is more expensive and any scrap that is generated has little or no value. As such, the cost of a membrane containing EVOH is 30% to 50% more expensive than one without the EVOH. However, cost savings in fumigation applications resulting from using less fumigants more than offset the cost of the EVOH. In the case of covers, since the cost of the geomembrane is a small part of the finished installation, the additional cost of the barrier geomembrane is small when expressed as a percentage of the project.

Engineered floating covers with ballasted weight systems, gas extraction systems and a rainwater removal systems costs vary greatly. For a waste lagoon of about 1/2 acre in size, the cover system can cost from $150,000 to $200,000. Addition of the barrier layer to the geomembrane adds less than $5,000.

Implementation:

Implementing the use of barrier films and geomembranes in agricultural applications is no different than using films or membranes without the barrier layer.

Technology Summary:

The incorporation of layered technology that includes high barrier materials such as used in food packaging greatly reduces the permeability of films and membranes to a variety of gases, pollutants and odor. Applications include containment liner is bioreactors, floating covers over waste lagoons, silage storage and fumigation films. Polyolefin products incorporating barrier layers can be used the same as those without. The barrier products result in enhanced odor and pollution control and can be more economical in applications such as fumigation.

References:

Fennimore, Steve (2007), *Methods to Facilitate the Adoption of Alternatives to Methyl Bromide by California Strawberry Growers*,

Koerner, Robert, (2006). *Designing with Geosynthetics, fifth edition*. Prentice Hall.

McWatters, R., Rowe, K. (2007) *Diffusive Migration of Volatile Organic Compounds through PVC Geomembranes*, Geosynthetics 2007, IFAI, 106-120.

Stark, T., Choi, H. (2005), *Methane gas migration through geomembranes*, Geosynthetics International, 120-125.

Point of Contact:

Gary Kolbasuk
Raven Industries, EFD
1813 E Ave
Sioux Falls, SD 57104
USA
800-635-3456
Gary.Kolbasuk@Ravenind.com
Ravenind.com

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