FIGURE 1 100-foot diameter shop fabricated PTFE secondary containment liner ready for final QC and packaging.

Contamination from a leaking geomembrane—A necessary and imminent evil?

Using an inert geomembrane solution with 100% PTFE material is one possibility.

By John Tippett, P.E., and Michael Goard, P.Eng.

One major purpose of a geomembrane in many lining applications around the world is to prevent the contamination of groundwater (water below the ground that can affect rivers, lakes, oceans and drinking water sources) by the chemicals contained above the geomembrane. Geomembranes have other purposes, but maintaining clean and healthy drinking water is likely the most important one.

For many geomembrane materials, a 10- or 20-year warranty is typical. With the concept of long-term sustainability being ever-present in every facet of life and industry, can owners and operators realistically afford to think in terms of geomembrane barriers that will degrade and leak due to corrosion? Should a geomembrane be considered "successful" if contamination of groundwater occurs after the warranty period?

Recent evolution within the last decade of material science allows us to consider inert geomembrane materials. An inert geomembrane material is a barrier that is unaffected by any chemical, regardless of time. By using an inert geomembrane material, "lifetime" containment and indefinite protection of groundwater can be considered a realistic target. Certainly, if the bar is set higher and the overall target to prevent contamination is "lifetime" containment rather than "warranty-life" containment, the higher expectation will ultimately result in a cleaner world.

The corrosion variable

In any containment application using a polymeric geomembrane liner, numerous variables present design challenges. The recent paper "Protecting the Environment from Contamination with Barrier Systems: Advances and Challenges" (Rowe, Jefferis, et al. 2022) highlights the complexities involved in the design of containment systems and the selection of a liner material. Tensile/tear/puncture/burst strength, temperature

PROJECT HIGHLIGHTS

400 DEGREES "HOT TANK" ABOVE GROUND STORAGE TANK SECONDARY CONTAINMENT

OWNER
Refinery in Canada

LOCATION
Alberta, Canada

CONTRACTOR
Terrafix Geosynthetics Inc.

CONSTRUCTION COMPANY
Cyntech Construction

ENGINEERS
Cyntech Construction

GEO PRODUCT
Everliner 2130

GEO MANUFACTURER
Textiles Coated International (TCI)

John Tippett, P.E. holds a degree in chemical engineering from Dartmouth College and is CEO of Textiles Coated International (TCI), a manufacturer of fluoropolymer films and related products based in Manchester, N.H.

Michael Goard, P.Eng. holds a degree in civil engineering from McGill University and is a product manager who has worked in the manufacturing of industrial products and materials for over 25 years. He is based near Montreal, Quebec, Canada.

All figures courtesy of Textiles Coated International.

resistance, thermal stability characteristics, chemical resistance, UV resistance, seam strength, permeability, coefficient of friction and many other properties may need to be taken into consideration. This article explores how this task can be simplified by removing one of the most important and potentially less predictable variables: corrosion.

John Scheirs' 2020 webinar and document on the "Periodic Table of Geomembranes" illustrates the wide range of available materials to select from. Each has its advantages and disadvantages, but each also has some susceptibility to corrosion—except one category.

Many geomembrane materials contain additives that help provide or enhance needed properties like UV protection and crack resistance. While the base material may be suitable for the foreseen conditions, these antioxidants/plasticizers/stabilizers can be subject to chemical attack or degradation.

Inert liners eliminate the corrosion variable

Different geomembrane materials can be selected to guard against corrosion, depending on the expected chemical exposure. During the early design phase, it is critical to know what chemicals the liner will be expected to be exposed to and therefore to resist. A material selection can then be made, and clear instructions/directives for its use can be established and provided to the user. During the entire life of the liner, it is then critical to ensure that only the chemicals the liner was designed to contain are what the liner ends up being exposed to. While every attempt can be made to predict what will be put into a landfill or containment area, there is always a risk that something unforeseen may be introduced.

There are situations when exposure to certain amounts of a particular chemical is expected. One such challenging industrial process, the Bayer Process for manufacturing alumina (and ultimately aluminum metal), results in bauxite residue with an average pH of 11 (pH range of 9–13). With such severe alkaline exposure, an inert liner is a necessity to avoid long-term contamination. Clearly, this is an industrial case where a typical high-density polyethylene (HDPE) liner will not be a long-term barrier to leakage due to corrosion.

There are also unexpected results that can lead to entirely unpredicted concentrations of chemicals. Most, if not all, geomembrane applications are susceptible to combinations of chemistry, temperature and/or moisture. Chemistry can change over time as the contained materials decompose and mix with each other. As the biodegradation takes place, heat may result, thus hastening the degradation of a geomembrane. As moisture gets introduced, new chemicals may result from the new molecules that have formed as the result of biodegradation. Geomembrane materials with an inability to handle the full pH range of 0–14 are ill-equipped to survive a witch's brew scenario in a challenging landfill with many variables.

There are many items considered household hazardous waste (HHW) that are not permitted in landfills. These include paints, solvents, bleach, batteries, household cleaners, glue and adhesives, electronics, oil mixtures, etc. Many of the HHW items are extreme pH products that are incompatible with geomembrane materials. Given the extensive list of HHW products used in the typical household, it is not hard to conceive that even households with the best intentions put extreme pH products into their garbage.

Should the world rely upon perfect behavior of household and business disposal practices or is it safer to assume bad behavior and noncompliance? From a long-term safety perspective, assuming good behavior over bad behavior results in failure. Systems must be designed around bad behavior to provide an indefinite safety sustainability. The same is true for geomembrane systems. The geomembrane material should be compatible to the full pH range of 0–14 in case bad behavior persists, and extreme pH products enter landfills.

Inert liners are made from materials that will not corrode regardless of the chemical exposure. PTFE is an example of an inert material. PTFE will not corrode when exposed to virtually any known chemical, and it is compatible to the full pH range of 0–14. Selecting such an inert material simply removes one of the most critical variables, corrosion, from the equation. The consideration of compatibility to chemicals for PTFE is an easy one, as the table below reflects.

Reduce the number of different materials—additives and reinforcements

Many geomembrane materials contain additives that help provide or enhance needed properties like UV protection and crack resistance. While the base material may be suitable for the foreseen conditions, these antioxidants/plasticizers/stabilizers can be subject to chemical attack or degradation, thereby leading to losses in the desired properties over time. In some cases, these additives may migrate to the surface of the material and become a contaminant.

This is another aspect that introduces a variable into the effective life span of a liner. How long will the additive remain functional? If both the geomembrane base material and the additives sustaining the life of the geomembrane are not fully inert materials, two corrosion variables must be considered instead of one.

One plus one does not equal two when combining an inert material with a chemically susceptible material.

FIGURE 2 Shop fabricated PTFE liner accordion folded and ready for shipment and rapid deployment at site.

CHEMICAL	PVC-EIA	HDPE	PVDF	PTFE
Acetic acid (50%)	Chemically attacked	Chemically resistant	Chemically resistant	Chemically resistant
Acetone	Chemically attacked	Chemically resistant	Chemically attacked	Chemically resistant
Ammonium hydroxide	Chemically attacked	Chemically resistant	Chemically attacked	Chemically resistant
Benzene	Chemically attacked	Chemically attacked	Chemically resistant	Chemically resistant
Diesel	Chemically resistant	Chemically attacked	Chemically resistant	Chemically resistant
Ethyl acetate	Chemically attacked	Chemically resistant	Chemically attacked	Chemically resistant
Furfural	Chemically attacked	Chemically resistant	Chemically resistant	Chemically resistant
Gasoline	Chemically resistant	Chemically attacked	Chemically resistant	Chemically resistant
Methyl ethyl ketone	Chemically attacked	Chemically resistant	Chemically attacked	Chemically resistant
Methyl isoamyl ketone	Chemically attacked	Chemically resistant	Chemically attacked	Chemically resistant
Nitric acid (50%)	Chemically attacked	Chemically attacked	Chemically resistant	Chemically resistant
Perchloroethylene	Chemically attacked	Chemically attacked	Chemically resistant	Chemically resistant
Phenol	Chemically attacked	Chemically resistant	Chemically resistant	Chemically resistant
Sulphuric acid	Chemically attacked	Chemically resistant	Chemically attacked	Chemically resistant
Toluene	Chemically attacked	Chemically attacked	Chemically resistant	Chemically resistant
Xylene	Chemically attacked	Chemically attacked	Chemically resistant	Chemically resistant

TABLE 1

A general way of thinking about it is that if all the strength of a material comes from a component that can be chemically degraded in time, then the geomembrane will have a regression of strength over the years that eventually leads to failure/leakage.

Until recently, the only way to realistically employ a fluoropolymer like PTFE, with its extreme corrosion resistance and high temperature capability, was by using it in combination with other materials that compensate for certain properties, like strength.

Supported geomembrane materials may have improved tensile strength, owing to a reinforcement (scrim) that is incorporated into the material. In applications where high strength is paramount, this reinforcement can give the material the necessary property. A weakness of scrim-reinforced material can occur if the scrim becomes subject to degradation due to corrosion. While the scrim is intact, it gives the material the strength it is intended to provide. However, the scrim can be chemically attacked at discontinuities such as seams. At every seam, there is a likely interruption in the protection of the scrim by the base material. Exposure to corrosive chemicals at the exposed edges will lead to corrosion of the reinforcement and loss of the property it is there to provide—strength.

A general way of thinking about it is that if all the strength of a material comes from a component that can be chemically degraded in time, then the geomembrane will have a regression of strength over the years that eventually leads to failure/leakage. The strength of the liner must come from inert material that will not weaken over time due to chemical exposure. Using a material that never weakens from chemical exposure eliminates the corrosion variable and prevents the strength of the geomembrane from regressing toward zero, which may result in leakage.

By combining an inert material with a chemically susceptible material, chemical attack can still occur. The corrosion variable must still be considered. But by simply using an inert material, chemical attack cannot happen. The corrosion variable no longer needs to be considered. Further, by joining or seaming one inert material with another, the concern for edge exposure at a seam is eliminated. This is also true for repairs or patches that may be required on-site if damage occurs.

100% PTFE—Nothing else

One possibility for an inert geomembrane solution is a 100% PTFE material. PTFE is one of the family of fluoropolymers, well known in many industrial applications for their amazing chemical resistance and high temperature properties. Because the geomembrane is inert across the pH scale of 0–14, the corrosion variable is eliminated with PTFE. Even with long-term severe chemical exposure, the properties of PTFEs will not change.

In addition, the temperature range of PTFE of -400°F to 600°F (-240°C to 316°C) eliminates concern for geomembrane failure due to significant excursion temperature situations. Even the biodegradation temperature of 149°F (65°C), which can often be found in a landfill, does not get anywhere near the maximum temperature capability of an all-PTFE material.

Ultraviolet exposure is also a major cause of destruction of geomembranes. An inert liner will be one that is unaffected by severe and continuous exposure to sunlight.

Equal or better in terms of other properties

Testing done by ExcelPlas Polymer Testing demonstrates that multilayer, laminated PTFE has:

- Better/comparable tear strength to that of HDPE
- Significantly better puncture resistance than HDPE

- Significantly better flex fatigue resistance than HDPE and linear low-density polyethylene (LLDPE)

For any application where the tear, puncture and flex fatigue characteristics of HDPE meet the requirements, one can be confident that PTFE will meet them as well. See **Table 2**.

Conclusion

Contamination of rivers, lakes, oceans and drinking water sources should not occur in the future due to corrosion of geomembranes. The job of installing a geomembrane system without leaks is a challenging one with many design considerations.

Furthermore, the absence of the corrosion variable sets the bar much higher for the geomembrane industry. Instead of discussing a potential life for a geomembrane in terms of years or decades, the industry can start focusing on design consideration to achieve "forever" containment using inert materials. In the past, "forever" could not be a realistic target when using materials susceptible to corrosion. But the use of inert materials eliminates corrosion and makes "forever" a realistic target; certainly, rivers, lakes, oceans, drinking water sources and future generations deserve this inspirational target.

References

Rowe, R. K., Jefferis, S., et al. (2022). "Protecting the environment from contamination with barrier systems: Advances and challenges." Proc., 20th International Conf. on Soil Mechanics and Geotechnical Engineering, Australian Geomechanics Society, Sydney, Australia.

Scheirs, J. (2020). "Periodic table of geomembranes." Webinar, May 26, ExcelPlas Materials Testing.

>> For more, search **geomembranes** at GeosyntheticsMagazine.com.

Fatigue Resistance per AS 4878.9–2001 Results Summary	
SAMPLE ID	**CYCLES UNTIL FAILURE**
Cross-laminated PTFE 1.5mm	5,390,648 (No Failure Observed)
HDPE 1.5mm	105,366

Excelplas Polymer Analysis

TABLE 2

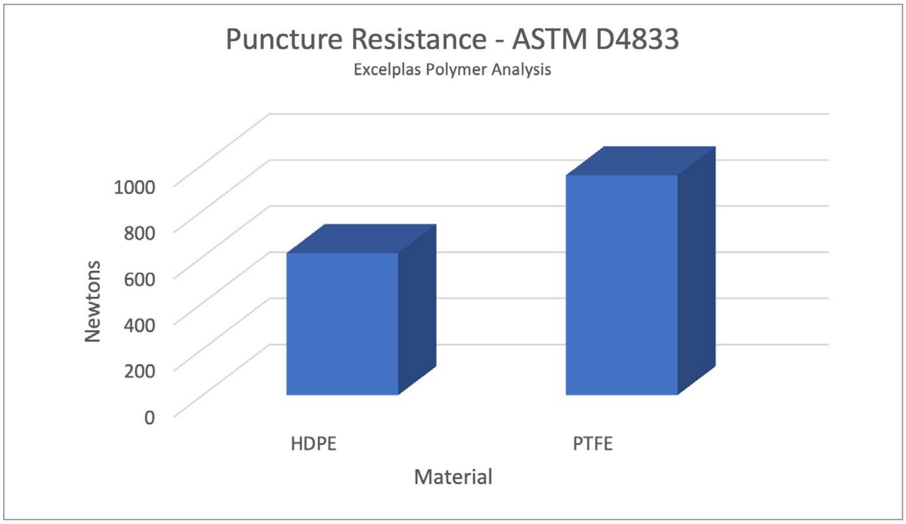

FIGURE 3

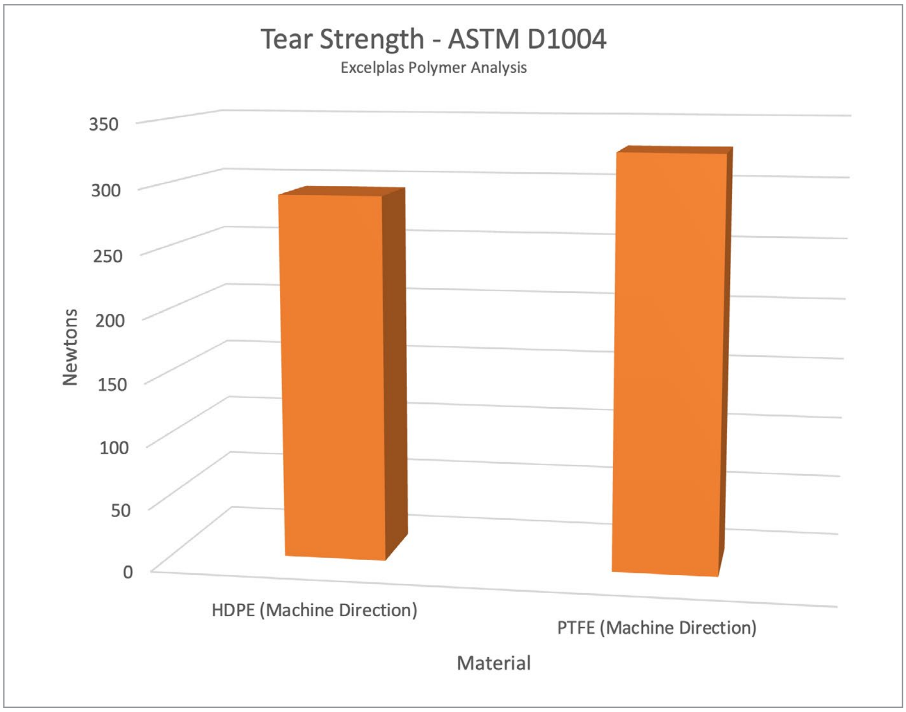

FIGURE 4