Geosynthetic Barriers for PFAS containment: current options, historical precedents, and new materials

Gus Martins
Business Manager, HUESKER Australia Pty Ltd

Abstract:
Every modern landfill, containment facility and construction and infrastructure site utilize geosynthetic materials across a broad range of applications. The relatively recently identified need to contain sites and materials containing and contaminated with Per- and polyfluoroalkyl substances (PFASs) has caused increasing interest, research, and materials development in the geosynthetics field.

How well will the existing materials contain PFASs? Are the technical specifications and material compositions that have worked for similar applications in the past suitable for PFASs or are new materials necessary? This presents an overview of what is in the "solution toolbox" today and the best available options. The economics and realistic performance levels are also presented as a contribution to the ongoing discussion of appropriate regulatory requirements.

This presentation includes references for the testing of both geomembrane (thick plastic sheet, and GCL (Geosynthetic Clay Liners) and "GCL-similar" materials specific to PFAS containment. The permeation rates, adsorption rates, effectiveness at retaining absorbed PFAS materials are compared, both as a comparison to similar past performance and as estimates of what can be expected in the future for newly developed materials. These materials have a broad and impressive track record as civil engineering barriers, however, even with the best practices and materials, some of the proposed regulatory requirements may not be attainable, and certainly not without significant expense.

Keywords: Geosynthetic, PFAS, Barrier, Geocomposite, Containment

Introduction:

The traditional methodology for barrier/containment materials in civil engineering (containment of waste, industrial liquids or water) has three "levels" of efficacy. For basic containment, where some leakage is allowed and should be expected, a single layer of geosynthetic barrier is used. This is commonly either a geomembrane or a Geosynthetic Clay Liner (GCL). For additional containment performance, these two material types are used in combination – called a composite liner. The composite liners have been proven to be significantly more effective barriers than single liners and are used in landfills and other applications where the consequences of leakage are more severe. For the containment of extremely hazardous waste (radionuclide contamination, infectious waste etc.) a double composite liner is used. This is four layers of geosynthetic – two composite liners, usually with a leak detection layer sandwiched in between the two composite liners.

The question of how these systems contain PFASs has been under study for several years. Permeation testing, Adsorption testing and other testing both standardized and laboratory scale has been undertaken with some, but not all results available for use and reference. In short summary, the existing materials function as barriers, but newly created materials, designed for PFAS, appear to offer improved performance.

However, even with these improvements, some of the proposed regulatory requirements do not seem to be attainable, and certainly not without significant expense. While the ideal situation would be complete containment of PFASs, with a low-cost system, in the real world today, the most expensive and complex systems would not contain PFASs as desired, especially when the parts per trillion requirements and standards that are being propagated are used as performance measures. However, effective solutions do exist to dramatically reduce the spread of PFAS-type contamination and can provide containment that can be expected to be effective and durable.

Regulatory and containment requirements:

While it is not the purpose of this paper to suggest regulatory requirements for PFAS, an overview of the regulatory situation is needed to properly understand the containment options. The multiple varieties of per and poly fluoro substances are clearly a human health concern, in no small part due to their tendency to strongly resist biodegradation and to bio-accumulate in humans and animals. Regulations have been proposed in Australia and multiple other countries that set limits on the concentrations of PFASs that are very different than other types of contaminate regulations. In contrast to the requirements for aromatics, oils and other chemical compounds, the regulations both proposed and propagated for PFAS are requiring PFAS at much lower levels. US EPA has suggested a maximum of 70 ppt (part per trillion) for PFASs in groundwater. The Australian proposed regulations contained in the PFAS National Environmental Management Plan Version 2.0 suggest a limit of 230 ppt for freshwater marine environments among other recommendations.

To place these values in context, 230 ppt is the equivalent of less than 4 minutes in a time period of 31,710 years. These concentrations are extremely low. To achieve barrier performance at these values of concentrations, over a long period of time (years and decades), is practically impossible. PFASs can be contained, absorbed and prevented from further propagation and spread, but there are performance limits to all systems.

Design variations:

In an oversimplification, there are two choices for containment of PFASs. One choice is a plastic sheeting, called a geomembrane. This comes in multiple varieties, thicknesses and PFAS permeation rates. The critical factor in this option is the barrier to all liquids. A geomembrane can be considered to be an umbrella (if placed over the top of the materials to be contained) or a Ziplock bag / baggie (if placed top and bottom). These function by preventing water intrusion into the PFAS containing materials and thus halting the spread of PFAS that could be transported by rain or surface water. The limitation of this system is that there is no adsorption or remediation of the PFAS and it remains in the contaminate as placed under/within the barrier. An additional concern is that the liquid on the outside of the barrier may be found to carry PFASs, particularly at very low concentrations.

A second choice is the use of a geocomposite material – also in the geosynthetic family, these materials will contain an adsorbent that will bind to the PFAS and absorb the PFASs molecules (within limits) and thus prevent the spread of PFAS contamination. Water and other liquids may pass through the geocomposites, but the PFAS will remain behind – adsorbed by the geocomposite. Again, there are multiple varieties available. The limitation here is that the adsorbent must be present in sufficient quantity to adsorb the PFASs present and the geocomposite, when containing PFAS after use, will need to be properly disposed of. These products are also used a remediation aid – concentrating the PFASs in a physical system.

As with landfill applications, for critical situations, the two products are used in combination, achieving much better results than when used individually.

Application One – Short term storage of contaminated soils (laydown pads)

This application is when materials are to be stored on a long-term, but non-permeant basis. An example is PFAS contaminated soils being temporarily removed from a site during works. These soils would be stored on a pad, to prevent groundwater contamination and eventually returned to the site or moved to a permeant disposal location. For this situation, a geocomposite material is likely the best option – this protects against the spread of PFASs and does not involve the complications of a geomembrane in this situation – specifically management of surface water during the storage period.

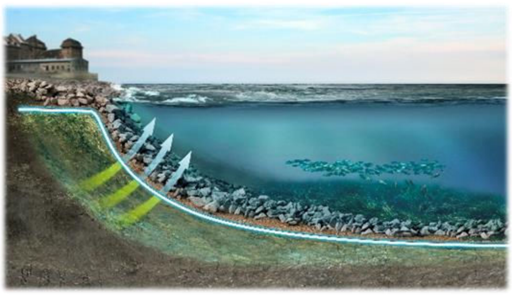
Application Two – Permanent closure (capping) of a contaminated site

In this situation, the contaminated area is not moved, rather a cap or umbrella is placed over the area to provide a barrier to water intrusion and the resulting spread of PFASs into groundwater. In this case, the goal is to reduce or eliminate water moving into the contaminated soils. This is not a remediation, more of an isolation. Geomembrane is the common material of choice and is primarily selected for the ability to keep water out, rather than PFASs "in". These caps can be covered with soil, or in some cases exposed. The exposed option offers improved access for inspection and repair, however usually a shorter lifespan due to exposure to sunlight. The exposed materials are sometimes in green coloured materials, or even artificial turf to improve aesthetics. As a second layer of protection, a geocomposite can be used as a bottom layer to avoid any the spread of the contamination in case of an eventual leak from the capping layer.

Application Three - Permanent storage (base liner and capping) of contaminated materials

In this situation, materials are being moved to a location and installation designed to hold the contaminated soils for a long period of time. This movement is planned, in advance and a geotechnical barrier is installed to provide this containment for decades, or even centuries. This is the "Ziplock bag / baggie" option with barrier above and below the contaminated soils. It is usually used for highly contaminated materials due to the expense of construction and movement of the contaminated materials. Commonly in the landfill and PFAS arena, this is lined with composite materials – a geomembrane to act as a barrier and a geocomposite material to attenuate leakage in the geomembranes, which should not be expected to perform perfectly. For PFAS containment, a geocomposite that selectively absorbs PFASs will improve the performance of these designs. As with capping alone, decisions are required for lifespan. Further, for base liners, other considerations exist: gas generation underneath the liner must have a path to vent, avoiding gas uplift. Also, leak detection systems are a possibility in PFAS containment and regularly used in landfills.

Application Four – Minimization of PFAS spread, sediment lining and short-term barriers



This application is the most complex and subject to site specific variations. In this case there is contaminated water or semi-liquid sediment that needs to be isolated, reducing PFAS spread. Geocomposites are nearly always the material of choice here. Geomembranes are problematic in that they commonly float/are buoyant in water, and those materials that do have negative buoyancy require anchoring to resist the forces of moving water. Geocomposites are used as they can be manufactured with negative buoyancy, anchor more easily (can be penetrated by anchors) and will absorb PFAS, reducing the quantity of the PFASs that are mobile. In these cases, absolute containment is understood to be impossible, and the goal is to mitigate the PFAS spread and reduce the area and concentrations. There is a great deal of experience in this application, but each site tends to have unique priorities and requirements.

Materials efficacy:

The goal of this section is to orient the reader and to provide connections (references) to literature that demonstrates the efficacy of these materials and provide specific test results and values. PFAS compounds are unusual – they are manmade, not naturally occurring and thus the materials commonly used for containment and adsorption have not been historically tested with PFASs. The general chemical principle of similar structures and composition producing similar behaviour can be applied here, but in recent years some specific testing with PFASs (multiple varieties) has been undertaken.

Testing of geomembrane materials has been undertaken by Professor Kerry Rowe and team (Di Battista, V. as referenced) at Queens University, Canada. Multi-layer geomembrane materials appear to offer better performance.

Professor Craig Benson at the University of Virginia (USA) is heading a research team investigating "Fate and Transport of Per- and Polyfluoroalkyl Substances (PFAS) in Environmental Containment Systems" (https://engineering.virginia.edu/geoenvironmental-research-group/projects) This work is in association with the Environmental Research and Education Foundation (https://erefdn.org/) which has hosted several web events on this topic.

Monash University has been active in this area also – see references below (Bouazza, Gates)

The sum of this work indicates that existing materials and systems will contain PFASs, but perhaps not to the extent required by proposed regulations. It should be also noted that the International Geosynthetics Society (IGS), the Australasian and the North American chapters of the IGS have specifically offered webinars and discussions on this topic in recent years where specific values can be found.

Conclusions

Laboratory testing and results of field trials have indicated that PFAS can be contained by existing geosynthetic materials. However, the extremely low regulatory requirements proposed make the degree and efficacy of containment problematic. This factor, coupled with the variety of PFAS types and structures as well as the variation in soil types and other site-specific factors makes absolute values impossible to predict. This paper describes the various options for structuring the containment of PFAS contamination. The general option of an adsorbent, as contrasted with a plastic barrier layer is recommended, in that the PFAS is bound and adsorbed, as well as contained, rather than held within a barrier that should be expected to be imperfect.

References

Buck, R.C., (2001), "Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins", Integrated Environmental Assessment and Management — Volume 7, Number 4—pp. 513–541.

Bouazza, A. 2021, 'Interaction between PFASs and geosynthetic liners: current status and the way forward', Geosynthetics International, vol. 28, no. 2, pp. 214-223. https://doi.org/10.1680/jgein.20.00033

Commonwealth of Australia: "PFAS National Environmental Management Plan Version 2.0", weblink: https://www.awe.gov.au/sites/default/files/documents/pfas-nemp-2.pdf . Accessed February 10, 2022.

Daniel, D. E. and Koerner, R. M. (1993), US EPA Technical Guidance Document: "Quality Assurance and Quality Control for Waste Containment Facilities", EPA/600/R-93/182, Washington, DC, Office of R & D, Cooperative Agreement No. CR-815546-01-0, Project Officer: D. Carson, 305 pgs.

Di Battista, V. et al., (2020), "PFOA and PFOS diffusion through LLDPE and LLDPE coextruded with EVOH at 22 °C, 35 °C, and 50 °C", Waste Management, https://doi.org/10.1016/j.wasman.2020.07.036

Gates, W., et al., (2020). "Interactions of Per-and Polyfluoralkyl Substances (PFAS) with Landfill Liners" Https://DOI:10.21926/aeer.2004007

Koerner, R. M. (2012), Designing With Geosynthetics, 6th ed., Xlibris Publ. Co., Indianapolis, IN.

Nosko, V., and Touze-Foltz, N., (2000) "Geomembrane Liner Failure: Modelling of Its Influence on Contaminate Transfer", Proceedings of the Second European Geosynthetic Conference, Patron Editore, Bologna, Italy, pp-557-560.

Rowe, K.R. and Barakat, F.B. (2021), "Modelling the transport of PFOS from single lined municipal solid waste landfill", Computers and Geotechnics, issue September 2021, link: https://doi.org/10.1016/J.COMPGEO.2021.104280

Sunderland E.M., et al. (2019), "A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects", J Expo Sci Environ Epidemiol. 2019 March; 29(2): 131–147. doi:10.1038/s41370-018-0094-1.

United States Environmental Protection Agency (2019): "Draft Interim Recommendations for Addressing Groundwater Contaminated with PFOA and PFOS:, Document EPA-HQ-OLEM-2019-0229, weblink: https://www.regulations.gov/docket/EPA-HQ-OLEM-2019-0229 , Accessed February 9, 2022