Determining and Applying Diffusion Coefficients for High-Performance Gas Vapor Barriers

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1. Introduction

Brownfields are areas the United States Environmental Protection Agency defines as “abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination”. In many states brownfield redevelopment is possible through risk-based corrective action. However, new construction on many of these remediated sites still has the potential for vapor intrusion, primarily with volatile organic compounds (VOCs). A common vapor intrusion mitigation method is to use a combination of sub-slab ventilation and a sub-slab liner. Over the last few decades, the use of specially formulated asphalt emulsion and polychloroprene latex spray applied barriers has proven to be effective in controlling hazardous gases or vapors. The asphalt emulsion component of the membrane is durable and capable of being applied at ambient temperature. Polychloroprene latex and other proprietary additives provide superior chemical resistance, resistance to heat sagging and cold flexibility. In combination, this cold spray-applied membrane offers a seamless, monolithic and non-toxic gas vapor barrier for redevelopment applications.

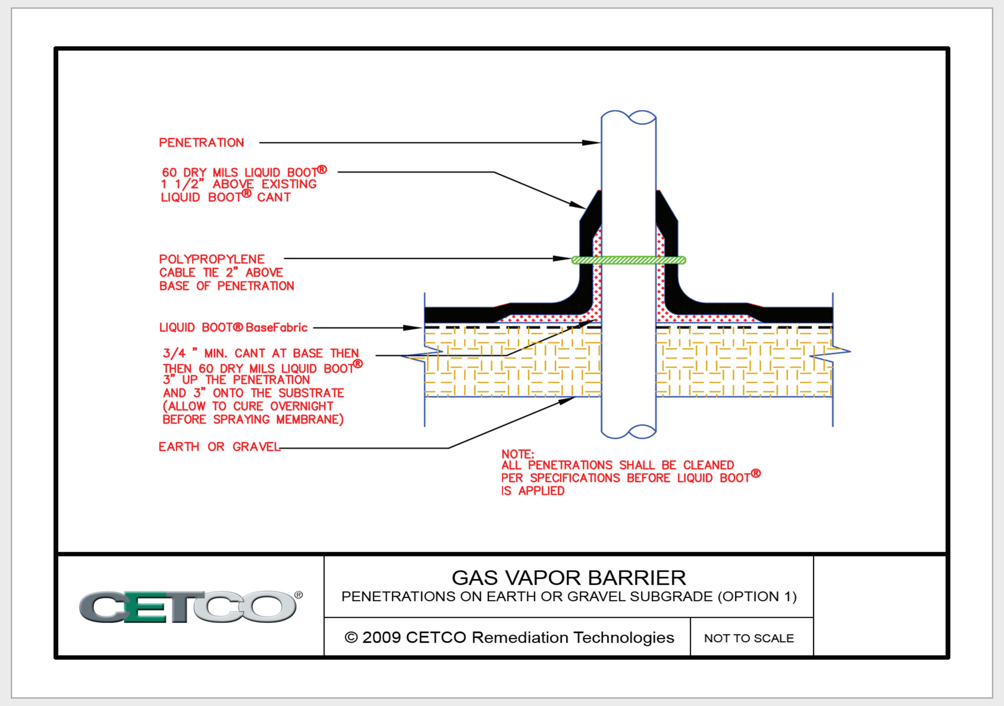
2. Project Examples with VOC Contamination

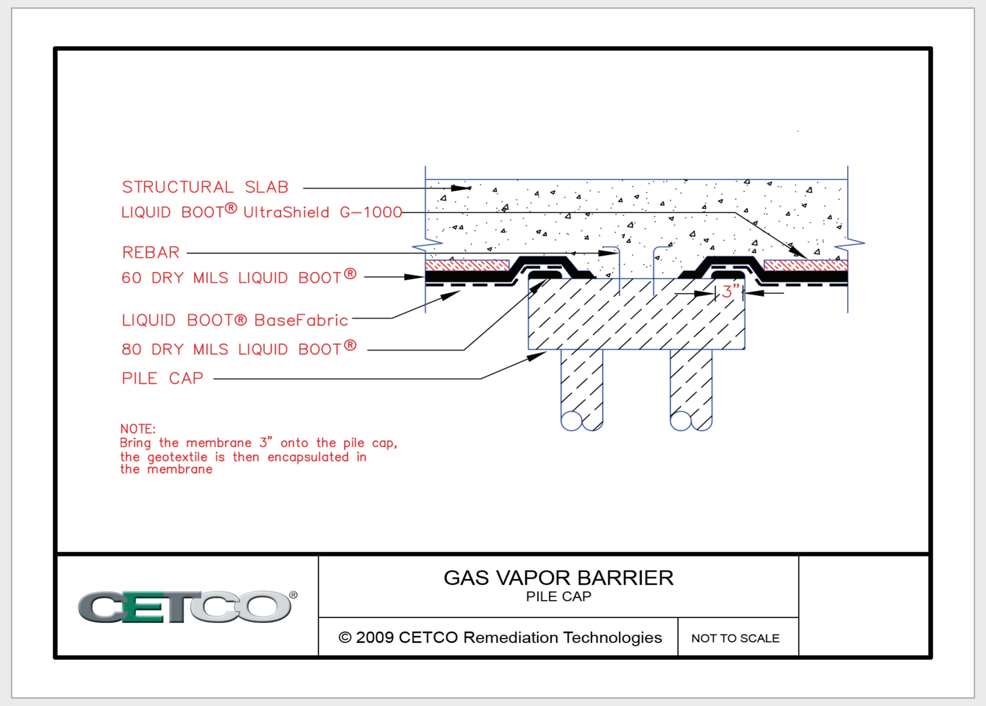
Large Retail Box Store
140,000 square feet; box store built over a VOC plume

Commercial Office Building
25,000 square feet; built over a plume of TCE and PCE

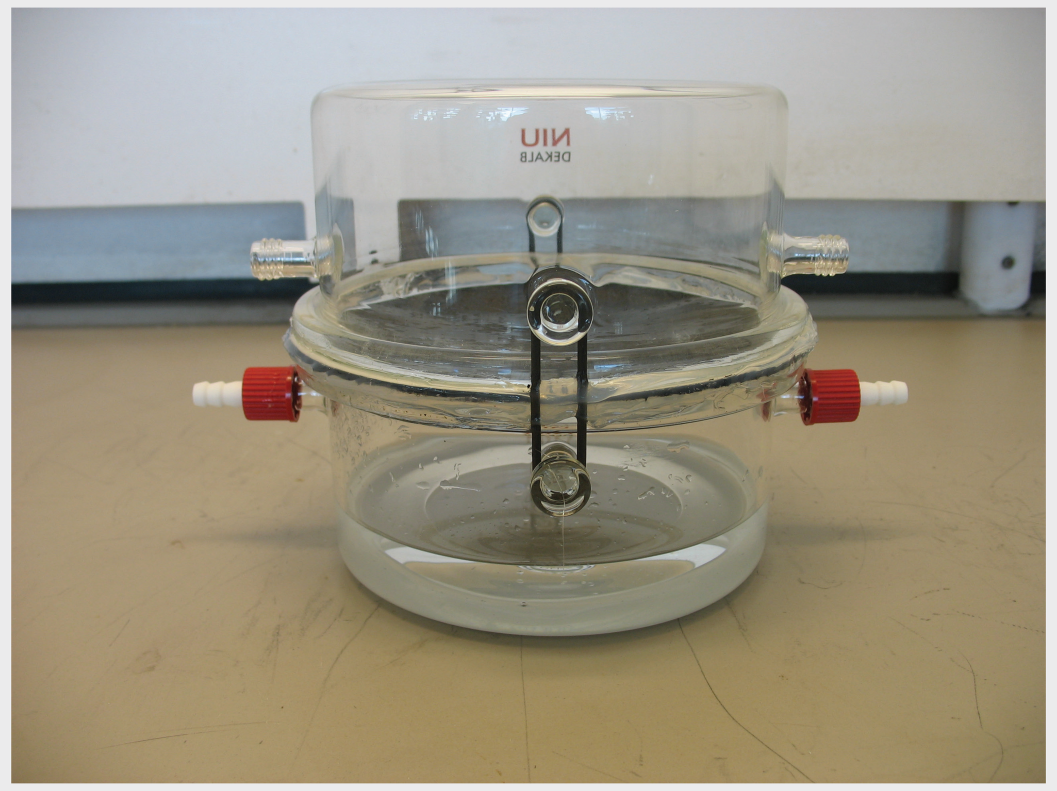
3. Detailing Around Penetrations and Pile Caps

Typical membrane installation covers the entire footprint of the structure to mitigate vapor intrusion on even the most complicated structures built on Brownfields, landfills or other contaminated sites, such as former manufacturing facilities, dry cleaners and gas station sites.





4. Membrane Testing Apparatus



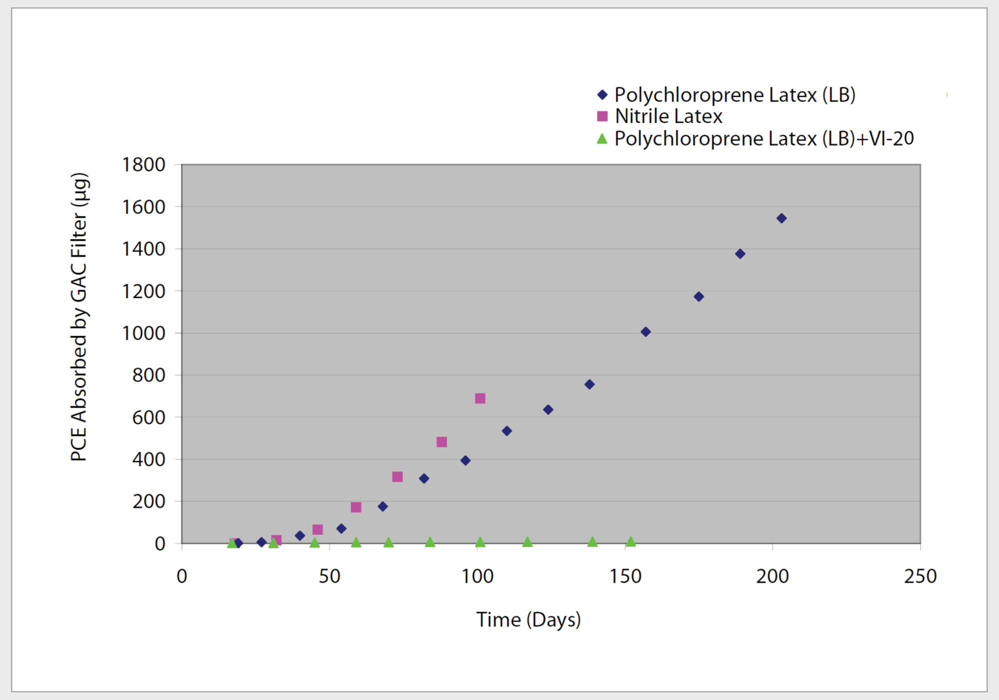
- Each membrane was exposed to the vapor phase ~300 grams of DI water saturated with PCE.
- The concentration of PCE in saturated aqueous solutions is reported to be about 200mg/L.
- There is a constant excessive supply of PCE at the bottom of the lower chamber.
- PCE vapor concentration in the lower chamber was calculated per Henry’s law.
- PCE vapor passing through the membrane was collected by active carbon and measured by GC. Diffusion coefficient was calculated per Fick’s law.

5. Diffusion Coefficient Testing Utilizing Fick’s Law

CETCO’s R&D laboratory performed series of PCE diffusion tests and compared diffusion coefficients of each cold sprayed applied asphalt-latex membrane system under mild to severe exposure conditions. Asphalt-polychloroprene latex (Liquid Boot® membrane) when exposed to ~18,000 ppm (1.20×10^{8} mg/m^3) of PCE vapor concentration has diffusion coefficient of 1.07×10^{-13} m^2/s. The duration of PCE exposure ranges from 60 to 203 days to ensure saturation limits were achieved. Other implementation in this study such as the use of asphalt-polychloroprene latex and VI-20™ geomembrane provided by CETCO. The table below summarized exposure conditions, PCE vapor concentration and their relative diffusion coefficient. The polychloroprene latex and VI-20™ geomembrane composite system reported approximately two order of magnitude lower diffusion coefficient compare to asphalt-chloroprene latex membrane.

$$E = A(C_{source} - C_{g0}) D_{cz}^{eff} / L_{cz}$$

where
- E = Rate of mass transfer, g/s
- A = Cross-sectional area through which vapors pass, cm^2
- C_{source} = Vapor concentration within the capillary zone, g/cm^3-v
- C_{g0} = A known vapor concentration at the top of the capillary zone, g/cm^3-v (C_{g0} is assumed to be zero as diffusion proceeds upward)
- D_{cz}^{eff} = Effective diffusion coefficient across the capillary zone, cm^2/s
- L_{cz} = Thickness of capillary zone, cm



Vapor Barrier Testing Summary

Lab	Samples	PCE Vapor Conc (mg/m³)	Trending Solvent Diffusion Rate (µg/day)	Area (m²)	Membrane Thickness (m)	Calculated Diffusion Coefficient (m²/s)	Test Length (days)	Notes
Geokinetics	Polychloroprene Latex	6.00E+06	0.12	1.45E-02	1.68E-03	2.68E-14	123	
CETCO	Polychloroprene Latex	1.20E+08	12.0	1.82E-02	1.68E-03	1.07E-13	203	ongoing
CETCO	Nitrile Latex	1.20E+08	8.38	1.82E-02	1.68E-03	7.46E-14	101	
CETCO	Polychloroprene Latex + VI-20	1.20E+08	0.06	1.82E-02	1.68E-03	5.61E-16	152	ongoing

6. Conclusion

Asphalt-polychloroprene latex technologies has proven effective in last 20+ years to control vapor intrusions in Brownfield sites. However new application such as asphalt-polychloroprene latex and VI-20™ geomembrane system has proven to have lower diffusion coefficient and is more effective in highly concentrated VOC’s contaminants.