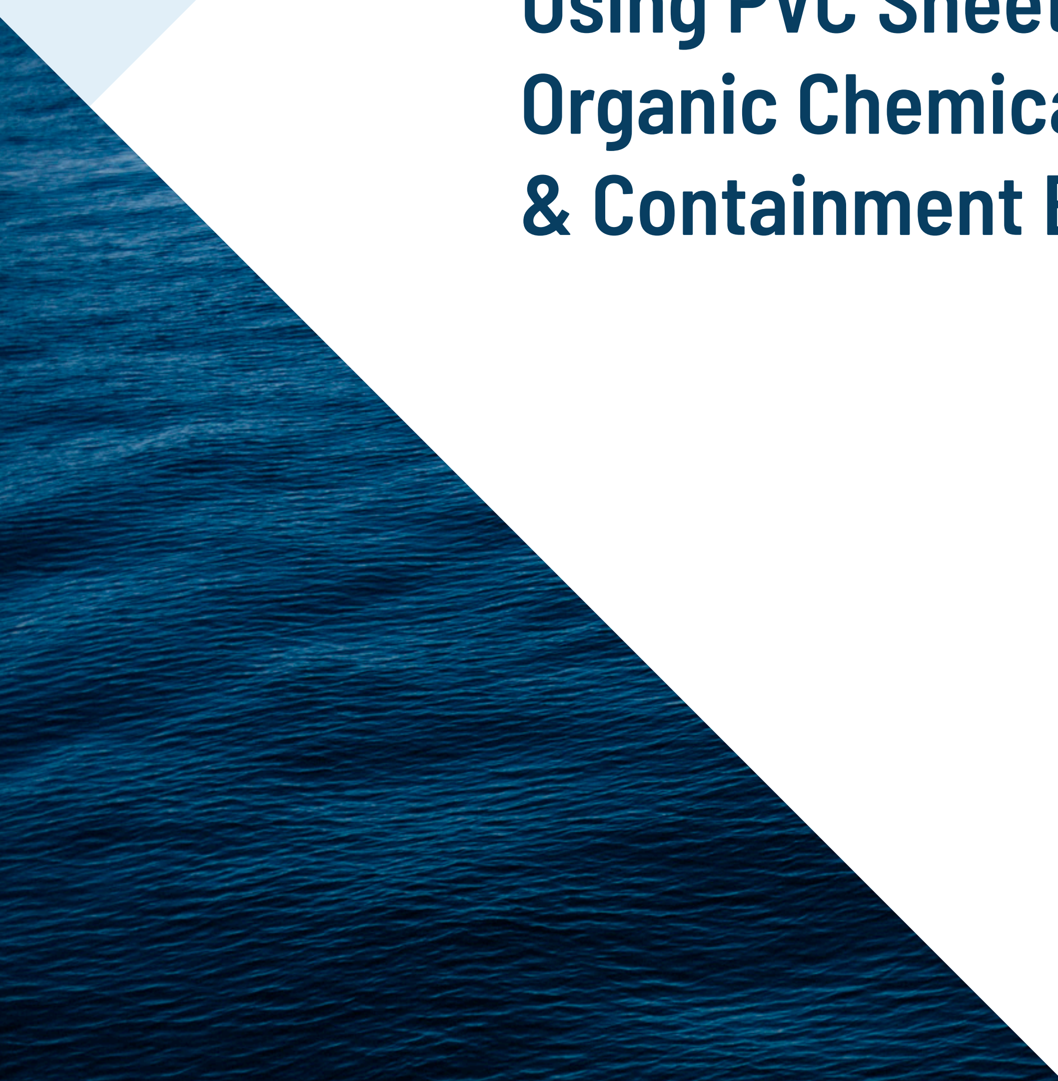

Using PVC Sheet Piling for Organic Chemical Cut-off & Containment Barriers

A Whitepaper by:
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Polyvinyl chloride (PVC) sheet piling compatibility with hydrocarbons, solvents and common fuel additives like benzene, toluene, ethylbenzene, xylene and naphthalene [BTEX(N)][1] along with creosotes and other similar chemicals are of particular interest to engineers and their clients.

For these pollutants, PVC sheet piling can offer increased chemical cut-off and containment performance and design life, as well as reduced costs over conventional solutions. Because standard chemical resistance tables typically show these chemicals as "incompatible" or "not recommended" with PVC, there has been some hesitancy in the adoption of PVC sheet piling for chemical cut-off and containment applications. It is the goal of this paper to review real world contamination levels for commonly contained chemicals and the resulting predicted permeation of the PVC sheet pilings used for their containment.

Chemistry & Permeation

Chemical compatibility tables are usually built from exposing the PVC to the "neat" or a highly concentrated form of the chemical approaching 100% purity. Indeed, at extremely higher concentrations, 40% or greater toluene for example, there can be deleterious effects ranging from degradation to swelling or softening, but at lower concentrations the degradation does not occur.[2] Significant research has been dedicated to this subject.

In Berens' investigation of the "Prediction of Organic Chemical Permeation Through PVC Pipe", he concluded that "Softening and significant permeation of PVC pipe seems possible only in the presence of nearly undiluted solvents or swelling agents for PVC. At lower activities [concentrations], which still correspond to unusually high levels of environmental pollution, solvent transport follows ideal Fickian diffusion kinetics... The calculated permeation rates are virtually zero for many centuries, indicating that rigid PVC pipe is an effective barrier against permeation of environmental pollutants."[2]

Maug, Gaunt, Cheng, and Ong validated and built on Berens' research and developed a predictive model based on the behavior of toluene (the more aggressive PVC solvent component of BTEX) in National Institute of Standards and Technology (NIST) fuel. The following equation from "Microscopic Visualization Technique to Predict the Permeation of Organic Solvents through PVC Pipes in Water Distribution Systems"[3] relates the swollen layer to the chemical's concentration and time.

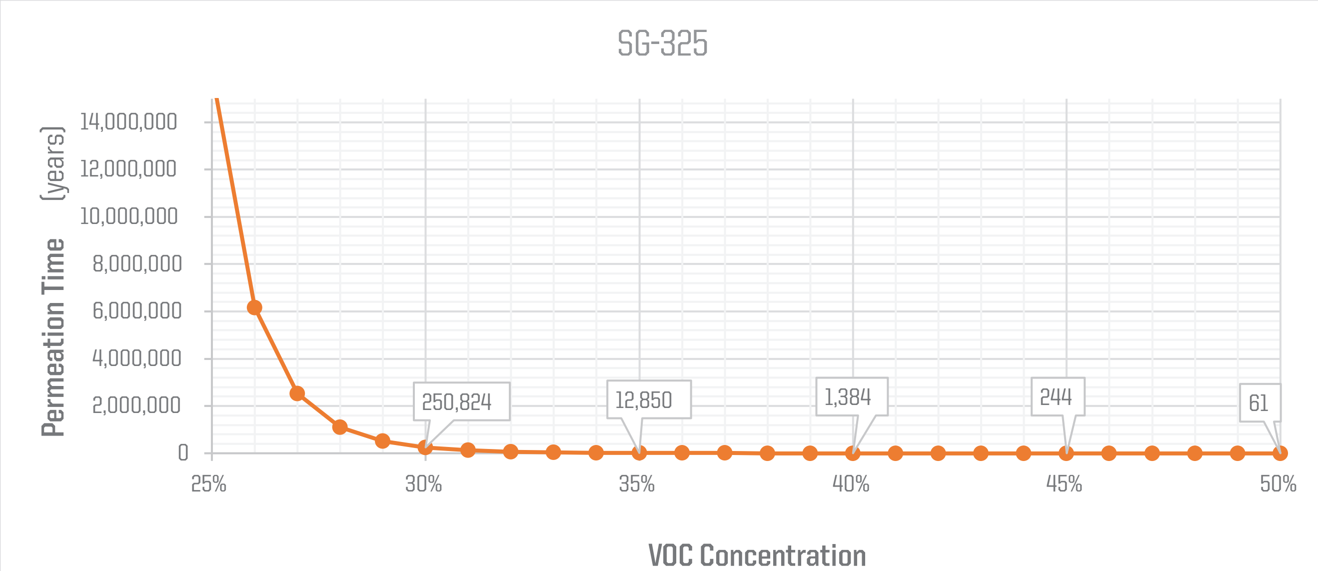
$$L_{s,t} = [21.8\, e^{-(3.12/vf)}]\, t^{1/2}$$

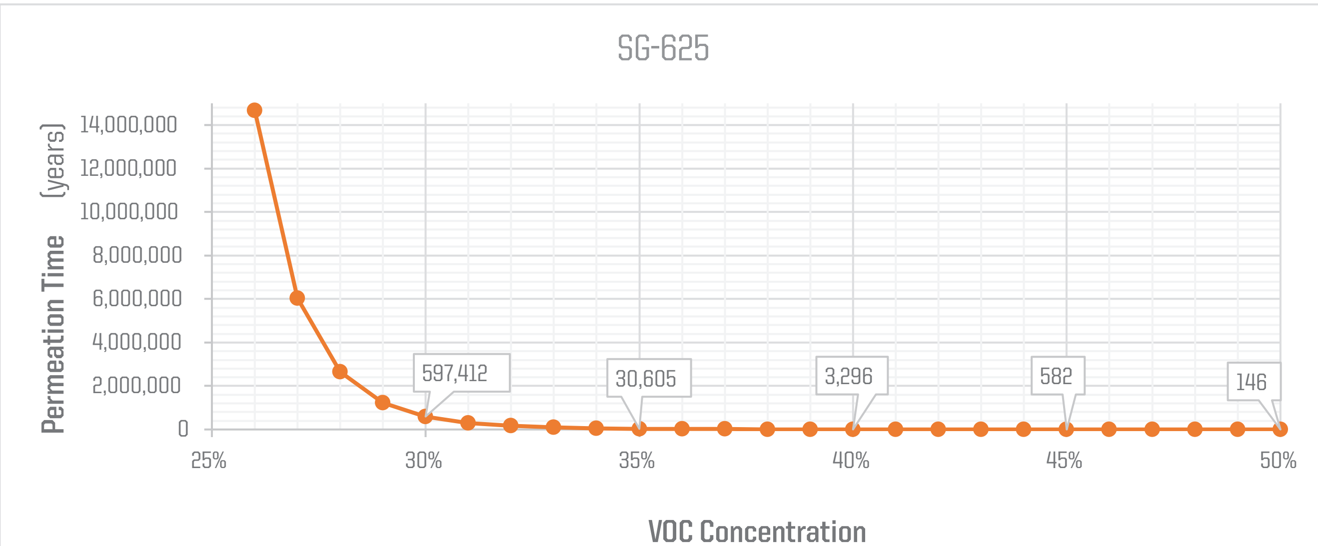
Where:

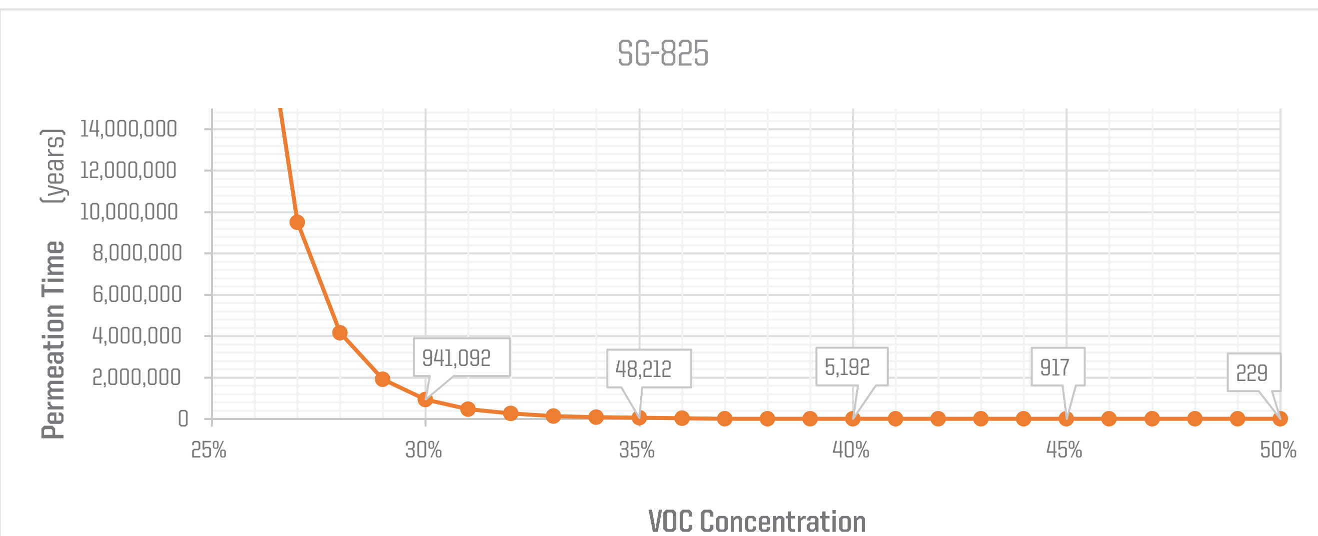
L_s = swollen layer thickness (mm)
vf = volume fraction concentration
t = time (days)

Applying this equation to three common PVC sheet pile products results in the following predictions for permeation to occur. At lower concentrations the time to permeate a given thickness is on the order of centuries.

Fig. 1 – Permeation Time as function of Sheet Piling Thickness & Chemical Concentration







Additionally, from the Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring, Ranney and Parker concluded from their research with known PVC solvents (see below)[4] — many of which are on the Environmental Protection Agency's (EPA) VOC and semi-volatile organic compound (SVOC) target list — that at concentrations of 10% or less, there was no measureable degradation of PVC sample well casings:

Hydrocarbons (aliphatic & aromatic)
- Benzene
- Gasoline (93 octane, unleaded)
- Hexane (85% N-hexane)
- Kerosene (K-1)
- Toluene
- o-Xylene

Chlorinated solvents (aliphatic & aromatic)
- Bromochloromethane
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- 1,2-Dichlorobenzene
- 1,2-Dichloroethane
- trans-1,2-Dichloroethylene
- Methylene chloride
- Tetrachloroethylene
- Trichloroethylene

Oxygen-containing compounds
(either a ketone, alcohol, aldehyde or ether)
- Acetone
- Benzaldehyde
- Benzyl alcohol
- Cyclohexanone
- Methyl alcohol
- Methyl ethyl ketone
- Tetrahydrofuran

Nitrogen-containing compounds
- N-Butylamine
- Diethylamine
- Dimethylformamide
- Nitrobenzene

Acids & bases
- Acetic acid (glacial)
- Hydrochloric acid (25% w/v)
- Sodium hydroxide (25% w/v)

Real World Contamination Levels

Over the years, many PVC sheet pile products have been installed in numerous cut-off and containment barriers. These products have been exposed to chemicals ranging from acid mine run-off consisting of very acidic sulfur and iron compounds to polychlorinated biphenyls (PCB) to salt water. However, the most commonly remediated contaminates are in the hydrocarbon family. These pollutants may consist of volatile organic compounds (VOC), solvents, and fuels including gasoline, which can contain up to 28% BTEX.3 Coal tar creosote also contains similar amounts of these compounds.5

The vast majority of remediation projects experience contamination levels in the parts per million (ppm) or parts per billion (ppb), which are magnitudes lower than the ≤10% level cited by the Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring. A survey of remediation projects of contaminated sites in the United States containing BTEX, or the individual components that make up BTEX, showed pre-treatment contamination levels averaging 0.49% with a maximum level of about 9% (see Fig. 2).6

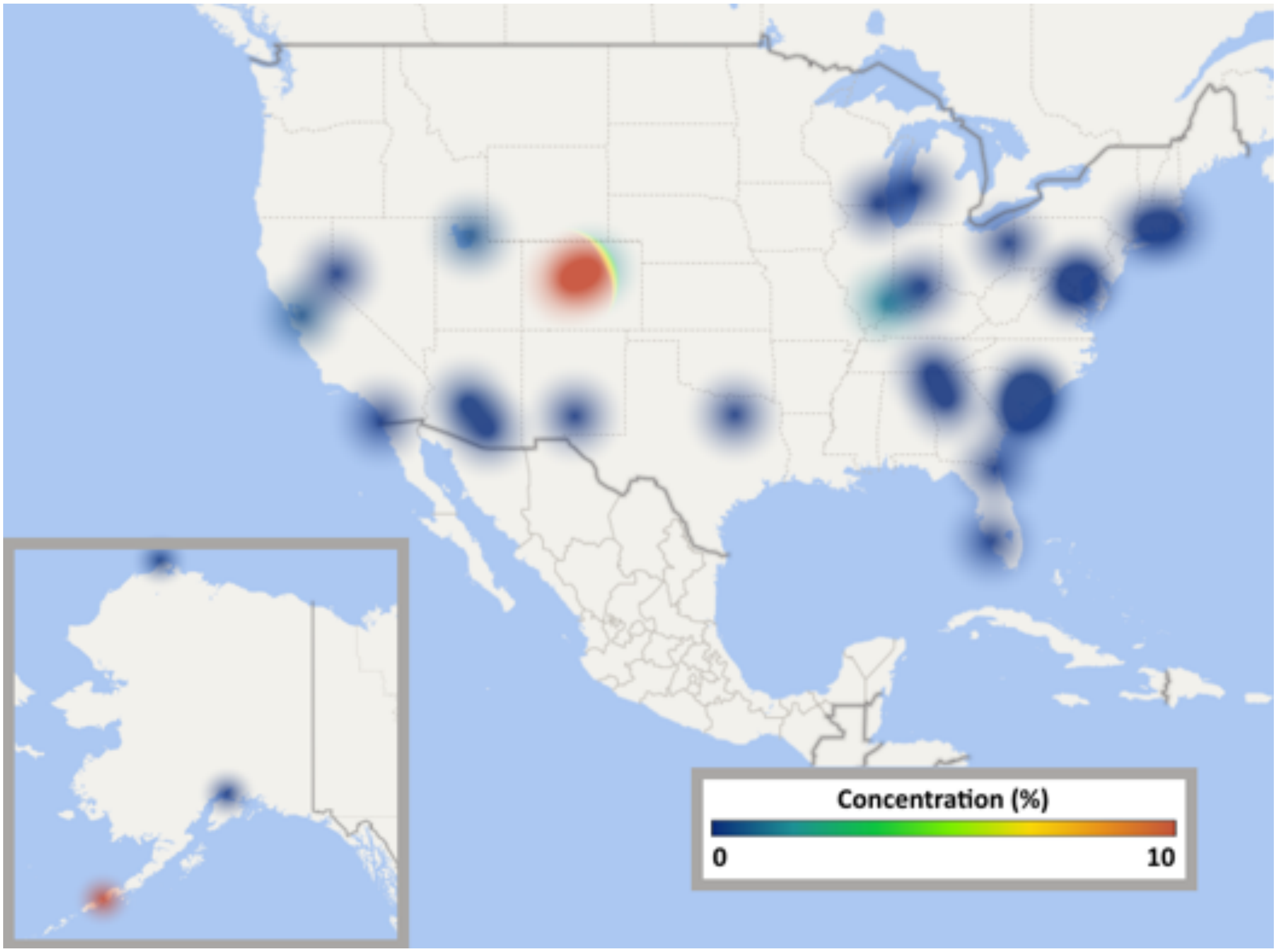


Fig. 2 - Contaminated sites with relative contamination levels. Data compiled by the author from levels reported in Abstracts of Remediation Case Studies, Volumes 1-10[6]

Conclusion & Summary

At contamination levels less than about 40%, PVC sheet piling will perform well in chemical cut-off and containment applications with hydrocarbons, solvents and common fuel additives (see Fig. 3). Real world contamination levels are most frequently in the ppm or ppb levels.

Contamination Level (%)	PVC Performance
< 10%	**Experts conclude there is no degradation**
10-25%	Nearly infinite design life may be expected
25-40%	Evaluate the site specifics, but PVC will likely perform well
> 40%	Evaluate the site specifics, but PVC may be a valid, finite life design

Fig. 3 – Contamination Level & PVC Performance

Reference Notes

[1] Ohio Department of Health, Bureau of Environmental Health, Health Assessment Section, BTEX: Benzene, Toluene, Ethylbenzene, and Xylenes, Columbus, OH. Revised Jan. 12, 2014.

[2] Berens, Alan R., "Prediction of Organic Chemical Permeation Through PVC Pipe," American Water Works Association Journal, Nov. 1985, pp. 57-65.

[3] Mao, Feng; Gaunt, James A.; Cheng, James A.; and Ong, James A., "Microscopic Visualization Technique to Predict the Permeation of Organic Solvents through PVC Pipes in Water Distribution Systems," Journal of Environmental Engineering, Feb. 2011, pp. 137-145.

[4] David M. Nielsen, ed., Practical Handbook of Environmental Site Characterization and Ground Water Monitoring, Second Edition, Boca Raton, FL: CRC Press, Taylor & Francis Group, 2005.

[5] World Health Organization, "Identity, Physical/Chemical Properties, and Analytical Methods," in

Concise International Chemical Assessment Document 62, Coal Tar Creosote, Geneva, 2004, section 2.

[6] Member Agencies of the Federal Remediation Technologies Roundtable, Abstracts of Remediation Case Studies, Volumes 1-10, (Abstracts: EPA-542-R-95-001, EPA-542-R-97-010, EPA-542-R-98-010, EPA-542-R-00-006, EPA-542-R-01-008, EPA-542-R-02-006, EPA 542-R-03-011, EPA 542-R-04-012, EPA-542-R-05-021, EPA-542-R-06-002), Cincinnati, OH: National Service Center for Environmental Publications, 1995-2006.