Permeation & Leaching: Background Information on Distribution System Areas of Concern

Findings from White Paper

Distribution system infrastructure and appurtenances can react with both water within the pipe and external water, potentially allowing contaminants into the drinking water. Leaching is the dissolution of metals, chemicals, and other materials of the piping and appurtenances into water. Permeation is the movement of chemicals from outside the pipe, through the pipe or appurtenance materials themselves (as opposed to through orifices or leaks, as in intrusion), and into water.

Characterization of contaminants due to permeation

Over 100 incidents of drinking water contamination resulting from permeation of subsurface mains and fittings have been reported in the United States. Permeation contaminants include: benzene, toluene, ethylbenzene, xylenes (BTEX), and other gasoline-range organics. The most common pipe materials in permeation incidents are polybutylene (PB), polyethylene (PE), and polyvinyl chloride (PVC).

A state reported concluded that gasoline-contaminated soil led to benzene permeation of a 30-inch PE service line, resulting in 527 µg/L of benzene. The benzene MCL is 5 µg/L, the taste threshold is 500–4,500 µg/L, and the odor threshold is 2,000 µg/L. Therefore, in some cases benzene may not have been detected.

PVC and PE pipes have increased contamination potential once organic chemicals have permeated. The organics cause the pipes to swell allowing a higher rate of diffusion. If a gasoline spill occurs and BTEX compounds permeate through PE pipe and the pipe is flushed and not replaced, future exposures to organics result in substantially increased permeation rates. This can cause elevated drinking water contamination levels for a second spill.

Characterization of contaminants due to leaching

Contaminants that have been reported to leach, and their sources, include: vinyl chloride (PVC pipe manufactured prior to 1977); aluminum (cement-mortar lining); alkyl benzenes (reservoir coating/lining); polycyclic aromatic hydrocarbons (PAHs) (reservoir coating/lining, coal-tar lining), epoxy resin oligomers (epoxy coating); lead, copper, and asbestos (pipes). Leaching is more common in the following materials:

Plastic mains–pre-1977 PVC pipe contains elevated levels of vinyl chloride monomer known to leach into drinking water. Vinyl chloride is a regulated drinking water contaminant (MCL of 2 µg/L) and a known carcinogen. Samples collected from 4 sites at a rural water system in Kansas, over a 6-year period, with pre-1977 PVC pipe, had vinyl chloride levels over the MCL in 55 percent of the samples.

Cement mains and linings–cement materials may degrade in acidic waters or waters aggressive to calcium carbonate; many inorganic chemicals in cement leach. Several illnesses and a 32 percent mortality at a receiving dialysis center were attributed to aluminum leaching from cement-mortar lined pipe (over 100 µg/L). A laboratory study showed leaching of arsenic, barium, cadmium, and chromium from cement-mortar lined pipe. The leachate had concentrations of 10–20 percent of the MCL; the acid-soluble contents of the contaminants were only 3–13 percent of the cement industry maximum.

Bituminous coatings and linings–contain a complex mixture of chemicals, some derived from coal or petroleum; solvents added to coatings can diffuse through the coatings into the water. Elevated levels of

alkyl benzenes and PAHs have been reported in reservoirs with new bituminous coatings and linings.

Epoxy coating and linings–consist of epoxy resins, curing agents, fillers, and pigments. A laboratory study of five NSF- and AWWA-approved epoxy resins showed substantial leaching (above the concentrations specified in the MCL for three of the five coatings) of BTEX compounds.

What contributes to the public health risk?

Dilution is a primary factor influencing permeation and leaching risks. Small diameter service lines, with low or no flow, are more susceptible to elevated levels of contamination.

What indicates permeation or leaching has occurred?

Current compliance sampling for VOCs, SOCs, and metals (except lead and copper) takes place at entry to the distribution system; thus, permeation and leaching occurring in the distribution system will not be detected.

- O&M practices such as installation inspection, site use review, and release to service monitoring.
- Taste and odor problems; however, many chemicals are not detectable before reaching their MCLs.

Taste and Odor Thresholds for Pure Compounds Compared to MCLs

Contaminant	MCL	Taste Threshold	Odor Threshold	Detect Before Risk?
Benzene	5 g/L	500-4,500 g/L	2,000 g/L	No
Ethylbenzene	700 g/L	29 g/L	29 g/L	Yes
Xylenes	10 mg/L	No Data	2.2 mg/L	Yes
1,2-Dichloroethane	5 g/L	29,000 g/L	No Data	No
Tetrachloroethylene (PCE)	5 g/L	300 g/L	No Data	No
Vinyl Chloride	2 g/L	None	None	No
Styrene	100 g/L	730 g/L	No Data	No

What are the existing prevention and mitigation methods?

Standards: ANSI/AWWA standards include acceptable pipe materials (some regarding conditions outside the pipe), appurtenances, coatings, and linings. Ten State Standards requires nonpermeable materials be used in areas of distribution systems where the groundwater is contaminated by organic compounds. NSF Standard 61 and AWWA Standards address pipe materials in contact with drinking water.

Operational and maintenance techniques: minimize water residence time; extend the curing time for coatings; replace pipe that has had permeation; and pre-soak newly lined pipes prior to release to service.

What other areas of research related to permeation and leaching exist?

Determine the amount of metals and organics that can be removed by flushing.