PPI Comments on Permeation of Water Pipes and on the AWWA-RF Report on Hydrocarbons

March 16, 2009

Water utilities want to maintain a high standard of water quality and to protect the water from any internal and external contaminates. The AWWA Research Foundation (AWWA-RF), now known as the Water Research Foundation, recently published a report entitled "Impact of Hydrocarbons on PE/PVC Pipes and Pipe Gaskets" which reviewed the susceptibility of different piping systems to permeation of organic compounds.

The polyethylene pipe industry did not have an opportunity to comment on the report prior to its publication. Because information in the report relevant to the susceptibility of polyethylene pipe to hydrocarbon penetration needs additional clarification, the Plastics Pipe Institute, Inc., has issued this statement clarifying some points to ensure that the AWWA-RF report is not misinterpreted by engineers and specifying officials. For more information regarding PE pipe, contact Camille Rubeiz, PE, Director of Engineering, crubeiz@plasticpipe.org.

It is clear from the report that all piping systems appear to have some potential for contamination from external agents through permeation of gaskets, jointed connections or permeation through the pipe wall. The report concluded, however that the overall impact of hydrocarbon permeation is relatively small and stated that the incidents of permeation of water distribution systems is rare, citing less than one reported incident per 14,000 miles of water mains and less than one incident per million service line connections.

The AWWA has addressed concerns regarding hydrocarbon permeation by including a permeation statement in all of its pipe standards including standards for polyethylene (PE) (C901-02 p. 5, C906-07 p. 6), polyvinyl chloride (PVC) (C900-07 p. 6, C905-97 p. 3), steel (C200-05, p. 7), ductile Iron (C110-03, p. 3), and others.

Although, literature suggests that permeation of organic chemicals and hydrocarbons through polyethylene (PE) pipe is possible, actual cases of soil contaminated hydrocarbon permeation are extremely rare as noted in the AWWA-RF report and summarized here.

The mechanism of hydrocarbon and solvent permeation through a pipe is complex due to the many variables that may exist in a situation where permeation is possible. Some of the variables are: soil type and texture; interaction and concentration of contaminates with temperature; rate and extent of diffusion of contaminate into the pipe wall and joint; effect of pipe diameter, wall thickness and flow rates.

When gross hydrocarbon contamination of soil surrounding pipe is a concern, there are several ways to address this issue, including:

- Surround the pipe with good clean soil of Class I or Class II materials to allow the hydrocarbons that may have contacted the pipe's wall to dissipate into the atmosphere and in the envelope of the surrounding soil. The US EPA guidelines prohibit the reuse of excavated hydrocarbon contaminated soil in the envelope of bedding or backfill material.
- Sleeve the pipe in areas where active hydrocarbon contamination is known to exist.
- Hydrocarbon contamination plumes are relatively compact and usually less than fifty feet in length.
  Reroute the pipe around the contaminated plume.

Hydrocarbons do not degrade polyethylene but can diffuse through the wall of PE pipe in areas of gross contamination. The exterior contact may affect sidewall fusions and or butt fusions; thus, after PE pipes have been exposed to grossly contaminated soils, mechanical connections may be preferred.

Again, the incidence of hydrocarbon permeation of PE potable water pipe is rare. Although measures need to be taken to limit the impact of hydrocarbon permeation in grossly contaminated soils, the vast majority of PE water pipe installations will never be impacted by hydrocarbon permeation.

1. **<u>The AWWA-RF report indicates that gasketed pipes including PVC and DI have demonstrated instances of permeation</u>.**

   Page XXIC, Table E.1: "After 8 hours of stagnation in direct contact with gasoline, benzene MCL exceeded in pipes < 24" using SBR and pipes < 10" using NBR gaskets."

   Page XXV, Par. 6: "PVC pipes that become permeated with hydrocarbons should be replaced (if they have not burst due to loss of physical strength) because remediation of the pipe is not feasible."

   Page XXVI, Par. 6: "In a service line where periods of stagnation occur, the 5 ppm MCL for benzene was predicted to be exceeded during an 8 hour stagnation period for SBR gaskets in contact with free product gasoline."

   Page XXVI, Par. 8: "Permeation of gasoline through PVC pipes with SBR and NBR Rieber gaskets was rapid with breakthrough of benzene in 21 days. The MCL for benzene (5 ppm) was exceeded at breakthrough."

   Page XXVII, Par. 1: "After 8 hours of stagnation in contact with free product gasoline, the concentration of benzene in pipes of diameters up to 24 inches using SBR gaskets was predicted to exceed the MCL. Under the same conditions, the MCL would be exceeded in pipes of diameters up to 10 inches using NBR gaskets. In pipes of diameter > 12 inches with NBR Rieber gaskets, the concentration of benzene was not predicted to exceed the MCL."

Page XXVIII, Par. 4: "For conditions of 8-hour stagnation in contact with free product gasoline, the MCL was predicted to be exceeded for pipes using SBR Rieber gaskets up to 24 inches in diameter and for NBR Rieber gaskets up to 10 inches in diameter."

Page 2, Par. 6: "In a national survey done for AwwaRF (Thompson and Jenkins 1987), 43% of reported permeation incidents in the US involved PB pipe, 39% involved PE pipe, and 15% involved PVC."…

Page 3, Par. 1: "BTEX and chlorinated solvents also soften PVC pipe …, thereby causing it to be susceptible to permeation in a manner similar to PB and PE."

Page 3, Par. 2: "Olson et al. (1987) studied the permeation of toluene, hexane and 1,1,1 trichloroethane (pure solvents) through gasketed pipes of PVC, asbestos cement and ductile iron pipes and found that all three gasketed pipe systems became penetrated. Seo and Kim (1998) conducted permeation experiments using cast iron pipes with SBR gaskets in the presence of gasoline and toluene (pure solvents) and found that the breakthrough times were approximately 100 days. Glaza and Park (1992) conducted permeation experiments with ductile iron pipes using SBR, NBR, and a special NBR gasket in the presence of gasoline. They found that NBR was more resistant to gasoline permeation than SBR and the order of breakthrough for different compounds was benzene, toluene, ethylbenzene, m-xylene and o+p-xylene. The results of the previous studies indicate that gaskets are likely to be susceptible to permeation by various organic compounds."

Page 6, Par. 2: "Vonk indicated that for hydrocarbons that soften PVC readily such as chlorinated hydrocarbons, ketones, nitrobenzenes and some anilines, activities of < 0.1 (0.1 times the maximal concentration in water) result in pure Fickian diffusion and no softening of PVC occurs. For compounds which soften PVC somewhat less readily, such as BTEX compounds, the activities indicated for Fickian diffusion by Behrens (1985) are < 0.25."

Page 7, Par. 2: "Based on current literature, gasketed water mains (using SBR and EPDM), regardless of the pipe material used, are susceptible to permeation through the gaskets."

Page 18, Par. 6: "Of the 6 reported incidents, 3 involved gasoline, 1 involved chlorinated solvents, and 2 involved unknowns. The pipe materials involved in the permeation incidents were PVC (4), asbestos cement (AC) (1), and cast iron (CI) (1).

Page 18, Par. 6: "Reports of permeation of water mains were rare, approximately 1 report per 14,000 miles of mains. Of the 6 reported permeation incidents, 3 involved gasoline, 1 involved chlorinated solvents, and 2 involved unknowns. The pipe materials involved in permeation incidents were PVC (4), asbestos cement (AC) (1), and cast iron (CI) (1) .."

Page 21, Par. 3: "Of the 44 reported permeation incidents, 36 involved permeation of PB by gasoline."

Page 21, Par. 3: "There were 2 reports of permeation of DI/SBR SCs by chlorinated solvents. There was one report of permeation of an EPDM gasket on a copper SC by asphalt solvents which had entered the curb box."

Page 21, Par. 3: "Reports of permeation of PVC or PE SC (Service Connections) were about 0.9 reports per million SCs... Reports of permeation of all types of SCs were about 8 reports per million SCs. Of the 44 reported permeation incidents, 36 involved permeation of PB by gasoline. The permeation incidents involving PE (3) and PVC (2) were with gasoline. There were 2 reports of permeation of DI/SBRSCs by chlorinated solvents."

Page 23, Figure 2.14: The figure shows the permeation incidents and successful uses for the reported service connections. 'The successful uses were occurrences of known contamination that did not result in incidents." The successful uses are shown in the chart as: PE, 1; PVC, 0, DI, 13, PB, 1 and Cu, 562

Page 175, Par. 2: "While PVC pipe is vulnerable to permeation by concentrations of benzene and toluene considerably higher than those found in gasoline or aqueous solutions of gasoline, the gaskets used in water mains are far more permeable and are the limiting factor for engineering decisions in such cases. The permeability of gaskets similarly limits the use of DI pipe in such cases."

Page 175, Par. 5: "… any PVC pipe that does become permeated without bursting should be replaced because remediation of the pipe is not feasible."

Page 176, Par. 3: "Free product benzene, toluene, or TCE will rapidly swell (rubberize) PVC pipe, with breakthrough (complete rubberization) in ungasketed 1-inch PVC pipe in 20, 16, and 6.5 days, respectively."

Page 180, Par. 5: "The gasoline piping to the pumps at a convenience store was leaking, and a PVC water service line passed directly below the area of leakage. There were taste and odor complaints … The service line was replaced …"

Page 183, Case study H: Permeation of PVC Main by Chlorinated Solvents "Customers served by a 2-inch PBC main (schedule 120) complained of bad taste and odor. The main was found to be in soil that had been saturated by a spill of chlorinated solvents. … The main was replaced…"

Page 185-186 Case History L: Three failures of PVC/SBR Mains. "While they are recorded as permeation incidents …, they may actually have been infiltrations since leaks were involved. These are the only incidents for which PVC pipe was reported to be blistered, leaking, and brittle.

Page 188, Case History P: Permeation of a PVC Distribution System by Gasoline

Page 189-190, Case Study S: Diesel Fuel in a Meter Box. "Other researchers have shown that SBR gaskets are considerably more permeable than PE…."

2. **<u>The report provides 4 statements indicating that pipe permeation issues are very rare.</u>**

Page XXII, Par. 3: "The overall impact of permeation on the water industry is relatively small. Reports of permeation incidents involving potable water distribution are rare, with reports of one incident per 14,000 miles of mains and 0.9 incidents per million service connections in this survey."

Page 18, Par. 4: "Respondents considered only 0.54% of mains to be at risk of permeation."

Page 21, Par. 2: "Respondents considered only 0.31% of SCs to be at risk of permeation."

Page 21, Par. 3: "Of the 44 reported permeation incidents, 36 involved permeation of PB by gasoline. The permeation incidents involving PE (3) and PVC (2) SCs were with gasoline."

<u>3. There is a larger question of the applicability of this study to the actual field conditions experience by PE pipe</u>. No attempt is made by the researchers to deal with the high vapor pressure and tendency of these aliphatic components to evaporate. Additionally, the aliphatic components would be expected to be diminished in ground water due to biological activity. In fact, this study takes steps to eliminate biological activity.

Also notable, is that the researchers derive data at 73°F and then apply it to the field condition without accounting for the effect on rate of permeation caused by the lower soil temperatures expected under normal conditions.

Page 34, Par. 2: "Sodium azide (1.5 g) was added and thoroughly mixed with the sand by rotating the bottle in order to inhibit potential biodegradation of BTEX.

Page 52, Par. 1 – "The permeation process is temperature dependant. It has been established (Naylor, 1989) that for small temperature changes between 5 to 25°C, the Arrhenius relationship can be used to describe the dependence of the diffusion coefficients on temperature. Based on the above, the diffusion coefficients are expected to be lower at lower temperatures. The experiments were conducted at room temperature 23°C while the average soil temperature in the field may be in the range of 14 – 15°C. Therefore it is likely that the measurements at room temperature will overestimate the permeation risk in the field."

<u>4. Permeation of a contaminant is a function of not only the material type, but also, and more significantly, the concentration of the contaminant in the soil and the rate of flow through the pipe</u>.

Page XXII, Par. 5 – "For a given contaminant in soil water, smaller pipes are more vulnerable than larger pipes and the risk of exceeding EPA MCLs is much higher during periods of stagnation than during continuous flow. Laboratory experiments showed that, due to sorption, the organic content of soils can lower the concentration of hydrocarbon contaminants in the soil pore water. But once the organic adsorption capacity of the soil is exceeded, the organic content of the soil makes no difference in the permeation since the steady state permeation rates in PE pipes are dependant on the external bulk concentration regardless of the soil types."

Page 6, Par. 3 – "Accordingly, for a given contaminant concentration, plastic pipes in high organic soils are less susceptible to permeation by hydrocarbons than those in low organic soils."

Page 7, Par. 4: "Many of the laboratory studies conducted used pure solvents or gasoline which typically represents extreme or gross contamination conditions. Although there is a need to understand the risk of permeation at different concentration levels, there are very few studies available to assist in this assessment."

Page 44, Par. 3: "Figure 3.6 indicates that only very low water flow velocities (< 0.3 m/s (<1 ft/s)) will pose a risk of exceeding the MCL for benzene under the conditions of full pipe flow. Given a water flow velocity of 0.3 m/s or above, a long contaminated pipe (>100 m) and a high bulk concentration (> 40 mg/L), which is not usually encountered in the real permeation incidents, would be needed to exceed the MCL. When the bulk concentration is below 10 mg/L and the length of contaminated pipe was less that 150 m, it is expected that the concentration of benzene in pipe-water would be below its MCL for any typical water flow velocity. Due to the effect of dilution, the hydrocarbon concentrations in PE pipes with water flow would be less than those for conditions of stagnation."

Page 45, Par. 2: "Generally, it is believed that D is independent of polymer thickness since D is only determined by the chemical characteristics of the polymer, the concentration (activity) of the contaminant compound, and the interactions between the contaminant and the polymer. However, Park et al. (1996) investigated the effects of thickness on diffusion coefficients for HDPE geomembrane exposed to four organic compounds and found the diffusion coefficients decreased to 28 to 36 % when the thickness increased from 0.76 mm to 2.54 mm at an initial concentration of 100 mg/L. Here D is assumed to be a constant for various pipe sizes since this assumption would be conservative, but safe, to predict the permeation risk for large pipe dimensions."

Page 46, Par. 1: "The higher susceptibility of small size pipes to permeation is supported by the findings of real permeation incidents, as reported in the study by Holsen et al. (1991a), where all permeation incidents for service lines were associated with 1 inch or less diameter pipes. For the same bulk concentration, the concentration of contaminant in pipe-water decreased with an increase in pipe size, mainly due to the increase of wall thickness and consequently the decrease of permeation rate."

Page 46, Par. 2: "In comparisons with PE service lines, PE water mains have much lower susceptibility to permeation, particularly under a heavy contamination conditions. As shown in Figure 3.7, a bulk concentration of 10 mg/L would result in exceeding the benzene MCL in SIDR 7 and SIDR 9 series of PE service lines for a stagnation period of 8 hours, while that would not be expected to occur in DIPS DR 17 100 PSI series of PE water mains. For water mains with a size of 14 inch or larger, the concentration of benzene in pipe-water would not exceed its MCL for a stagnation period of 8 hours even at an extremely high bulk concentration of 100 mg/L.

5. The recommendation that is shown on Page 42 to replace PE pipes when contamination occurs is not correct. It is obvious from this work that stagnation must be avoided to keep the concentrations of benzene in the drinking water acceptably low. However, water stagnation does not occur in mains and the recommendation to replace PE mains is not correct. In service connections where this is a high level of contamination, the user can follow the 3 bullet points on page 2 of this report. As noted earlier, it is speculated that the avoidance of stagnation is part of the reason that gasketed PVC has been so successful.

Page 42, Par 1: "Stagnation, representing the worst-case scenario is typically found during the night in service lines to residences or office buildings."

Page 42, Par 2: "Prevention of potential risk of benzene in drinking water should be a priority if PE pipes are exposed to gasoline-contaminated groundwater. Conservatively, if the bulk concentration of benzene is 1 mg/L or above, PE pipes must be rapidly replaced by other pipe materials (such as copper pipe) since the MCL in pipe-water will be exceeded within several hours. It should also be emphasized that Figure 3.5 was based on an 8-hour stagnation period."

6. The conclusions drawn by the AWW-RF report are inconclusive and perhaps misleading.

Page XXIX, last Par.: "There is a need for a more definitive predictive test method to assess the permeability of gasket materials. The gravimetric sorption test method serves as a rapid method but does not provide sufficient data to provide relative magnitudes of the permeation rates."

Page 161, Par. 6: "Data obtained from the survey described in this report were not sufficient to draw conclusions regarding the thresholds of hydrocarbon contamination that would result in hydrocarbons permeation and require a utility to choose more resistant pipe or gasket materials."

Page 173, Par. 2: "Nothing in this chapter should be construed to recommend not following the guidance in the AWWA permeation statement for contaminant material combinations not studied in this report."

Appendix: The report refers to multiple incidences of permeation to PVC. In addition, the Plastic Water Line survey by the Iowa Department of Natural Resources refers to 7 states that had permeation incidents involving PVC; the states were identified as Georgia, Iowa, Louisiana, Missouri, Nebraska, Oklahoma and Vermont. These facts seem to have been either ignored or de-emphasized by this report.