EPP Rapid Research
1402 Third Avenue, Suite 1420
Seattle, Washington 98101
Tel 206-352-2050
Fax 206-352-2049
www.pprc.org

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HDPE Pipe for Potable Water Applications
Requested by Jennifer Frey, Sellen Construction

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Request

Metal pipe and plumbing materials have historically had issues with corrosion, sediment build-up, pressure resistance, thermal conductivity, and chemical resistance. Cross-linked polyethylene (PEX) piping is one alternative, but the available sizes are too small for major commercial installations. Is high-density polyethylene (HDPE) pipe a good environmental choice for potable water applications?

Key Findings

- PPRC found no widespread health issues associated with the use of HDPE for food, beverage or potable water pipe applications.
- HDPE is widely approved by both standards organizations and code agencies for potable *cold* water applications. High-temperature HDPE formulations have been widely used in Europe for some time, but there are only a few materials ANSI/NSF[1]-certified for domestic *hot* water in the United States.
- Independent research studies have identified that chemical contaminants do migrate from HDPE pipe materials to water. These contaminants likely occur at low, "safe" levels, but are sufficient to generate odor and taste concerns in some cases.
- Those anticipating the use of HDPE, especially in hot water applications should ask vendors for data and certifications regarding chemical migration, taste and odor, and high-temperature performance.
- Those most concerned about chemical contamination may prefer to forgo the use of plastics entirely, but plastic piping offers some significant installation, use, cost and environmental advantages over copper.

Background

Plastics pipes and tubes are widely used to convey gases and liquids of all types. Plastics are often preferred over metal due to a number of inherent advantages: plastic piping is lightweight and no open flame is required for joining, the flexibility of plastic can simplify installation and reduces breaks due to freezing. Plastics are typically lower in cost, and resist the corrosion and scaling that plague metals in some applications.

In potable water applications, plastics have created some controversy. Polybutylene plumbing materials, introduced in the 1970s, led to unacceptable leakage problems culminating in a large class-action lawsuit. Today, polyvinyl chloride (PVC) and chlorinated-PVC (CPVC) pipe are common, however, some environmental groups have suggested that the risks associated with PVC production and pipe disposal outweigh the advantages of these materials (1).[2] Plastics in all applications are under heightened scrutiny due to concerns of chemical contaminant migration from plastics to foods and beverages, such as bisphenol-a migration from polycarbonate baby bottles, or from direct exposure to contaminants, as with vinyl toys for children (phthalates).

[1] Standards organizations: ANSI – American National Standards Institute, NSF – National Sanitary Foundation
[2] The vinyl chloride monomer used to produce PVC is a carcinogen. Production of vinyl chloride and incineration of waste containing PVC lead to the release of dioxin and other toxins.

High-Density Polyethylene (HDPE) Pipe

HDPE pipe has been used for decades in non-potable water applications. In particular, HDPE pipes are often preferred for their welded joints[3]. While special equipment is required to form the weld, welding eliminates the need for separate fittings, a common source of leaks and contaminant infiltration. HDPE is very flexible and can endure harsher site handling than more brittle polymers like PVC. Flexibility also allows turns in the piping system without the need for additional joints.

For potable water, HDPE was initially limited to cold water service applications, as early formulations were not strong enough for the high temperatures of hot water systems. Suppliers then developed cross-linked polyethylene (PEX) with superior strength and high temperature performance. PEX is common in radiant floor heating applications and, increasingly, in domestic hot/cold water. PEX or PEX-lined pipe has wide code acceptance across the country, but PEX requires special fittings and is not recyclable. The chemical cross-linking required to produce PEX adds expense, and increases the potential for contaminant migration from plastic to water. Both HDPE and PEX are polyethylene (PE), so care should be taken not to confuse these two very different materials.

HDPE can be used for hot water as a liner in multilayer pipe, where the strength is provided by another pipe layer, such as aluminum, but multilayer pipes don't offer all of the performance advantages of plastic alone. Over the past decade or so, new HDPE formulations, for example Dow's PE-RT (polyethylene of raised temperature resistance), have been available for high temperature use, including domestic hot water.

Is HDPE Pipe Safe for Use with Potable Water?

All plastics contain some residual of the chemicals required for their manufacture. These may include one or more catalysts that assist the polymerization reaction, as well as traces of unreacted raw material. A number of additives are typically compounded along with polymer resin prior to forming the final product. These may including stabilizers, UV-blockers, plasticizers, antioxidants, colorants, etc., to enhance both processing and performance characteristics (2). These additives may not be disclosed, so the risk of chemical migration must be evaluated for any material that comes into contact with potable water, food, or beverages. Chemical contamination, when it occurs, is usually due to migration of these non-polymer additives.

The Role of Regulation and Third-Party Certification

Under the Safe Drinking Water Act, the United States Environmental Protection Agency (USEPA) establishes regulations for contaminant levels in drinking water distribution systems (3). These standards mainly address water quality *where it enters the distribution system a*nd do not address changes in quality from contamination downstream, such as in building plumbing. Drinking water standards include a long list of contaminants and their maximum allowable level (maximum contaminant level, or MCL) for drinking water.

Building water system components are predominantly governed by local codes. Many code agencies rely on third-party certification, especially ANSI/NSF Standard 61, as a minimum requirement for safety of materials that come into contact with drinking water. NSF 14 is another certification particular to plastic pipes. These standards are widely recognized and at least thirty-six states have adopted them as requirements for residential plumbing, and the Uniform Plumbing Code requires that plastic materials for potable water meet both ANSI/NSF 14 and 61 (4).

Certification provides a basic level of "protection" from chemical migration. For NSF 61 approval, plumbing materials are placed in contact with various test water samples (typically a three-week exposure), including waters with typical post-disinfection chemical characteristics and a range of acidity levels to simulate different "in-use" conditions (5). The contact water is then tested for the presence of over 300 chemicals and compared

[3] Welding is usually done by electric heating, aka electrofusion, though some codes may require fittings or other methods.

with "safe" levels.[4] Unfortunately, the list of contaminants monitored is not widely available, so purchasers have only a yes/no certification result, with little additional information to allay their concerns.

NSF certification is not accepted by all as sufficient protection. In California, a prolonged battle occurred over whether the state should approve PEX tubing in the state building code. Opponents suggested that there were chemical migration concerns not fully addressed by the NSF 61 certification process (6).

European governments and safety agencies have a patchwork of regulations governing water quality. Most of these address issues of chemical migration and require some type of certification testing. According to manufacturers' promotional material, some standard and high-temperature HDPE formulations have been approved for potable water applications across Europe (7).

Independent Research on Chemical Migration from HDPE

At least initially, research in contaminant migration seemed to focus on taste and odor issues, rather than chemical hazards from plastic pipe. In addressing these sensory characteristics a recent study by Skjevrak, published in 2003, identified a wide variety of leachates from HDPE pipe.[5] Odors associated with these leachates were above acceptable levels set by USEPA's non-mandatory quality standards (8).

Skjevrak found that the dominant source of contamination was likely due to breakdown-products of common polymer antioxidants. While these contaminants are not of remarkable toxicity, a host of other minor contaminants were identified, including benzene and xylene. Similar aromatic hydrocarbon contaminants occurred in all samples, but at sub-part-per-billion levels, well below the maximum contaminant levels set by the USEPA for safe drinking water (9).

A number of studies on chemical migration from HDPE to water are reviewed in 2005-6 research by Monique Durand (10; 11). Durand states that chemicals identified as contributing to taste and odor *"originated from 1) alteration or degradation products, produced from original additives during the extrusion step (200-250 C) in the pipe manufacturing process and 2) compounds were by-products or impurities resulting from synthesis of pure phenolic additives."* The phenolic additives mentioned are, again, common polymer antioxidants. Chlorinated water and high temperature seem to accelerate leaching and, over time, chlorine can break down polymer antioxidants leaving the pipe more vulnerable to chemical attack. To reduce migration, manufacturers have investigated methods of binding antioxidants to the polymer matrix and reducing impurities in the antioxidant additives.

Durand suggests that of the common plastics, HDPE generated more intense odors than PEX or CPVC plastic material. CPVC and copper were the least odor-causing materials. Durand also reports that organic leachates were low in CPVC and HDPE and somewhat higher in some PEX materials. No claims were made about health risks associated with these leachates (12).

A recent review by Stern and Lagos points out the complexity of risk assessment of plastic water pipes (13). Which chemicals migrate from any given pipe depend not only on chemical formulation, but also on pipe material characteristics. Formulations can vary from supplier to supplier and over time. Migration may change with water quality and usage environment. Little is known about some contaminants, while others are known to be harmful, especially to vulnerable populations. With this dynamic background, assuring safety is a challenge.

Chemical migration from PEX pipes to water was reviewed during the California state code approval process. The final environmental impact report suggests that while chemical migration is an issue, contaminant levels rapidly decline over time to safe levels. Opponents argued for more thorough testing of polymer formulations and chemical leachates (14).

In addition to contamination from leaching processes, chemicals can enter drinking water by permeation of contaminants through the pipe wall from contaminated soil around the piping (5). In most cases, permeation problems have involved plastic materials and diesel or petroleum-product

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[4] For example, with the USEPA listed organic contaminants, the ANSI/NSF 61 standard requires that contaminant levels be no more than one-tenth of the maximum level allowed in water by the USEPA or other regulating authorities.

[5] The specific formulations used in these Norwegian tests are not known. Presumably European formulations are standardized to some degree, as in the United States.

contaminated soils in industrial areas, for example, near a gasoline station. Plastics should be avoided where soil contamination by organic liquids is likely.

Conclusions

By and large, HDPE is reported to be one of the "good" plastics, safe for use with food and water. A common plastics memory aid can be found in various sources:

One, four, five and two,
all of these are good for you.

referring to the recycle code numbers found on plastic containers, where 1 is PET, 2 is high-density polyethylene (HDPE), 4 is low-density polyethylene (LDPE) and 5 is polypropylene (PP). PPRC found no evidence of any widespread health problems related to the use of HDPE in food and beverage or potable water applications.

Independent studies have shown that organic contaminants leach from HDPE pipe into water. While contaminant levels are likely "safe" by USEPA drinking water standards, there are some who will doubt the safety of any level of contamination. The chemical exposure risks cannot be fully elucidated, given the complexity of material types, changing formulations, and varying application circumstances.

While commodity costs have driven contractors toward increased plastic use, states and municipalities have been slow to add new material types to their building codes. CPVC was added to California code only in 2007 and PEX in 2009. HDPE pipes are widely approved for use in potable cold water applications in Europe and the United States. Additional approvals for some high-temperature formulations have satisfied the standard chemical migration requirements of ANSI/NSF 61 and some European standards organizations. Unfortunately, a search of NSF listings suggest that only two hot-water HDPE formulations have been approved to date, and code acceptance of high-temperature applications may take some time in the US.

Several green building organizations recommend polyethylene as a good alternative to other piping materials, though this is probably due more to the desire to eliminate PVC (15; 16). Industry groups have highlighted the favorable life-cycle impacts of plastic versus copper and the high potential for recycled material sourcing for some piping applications (17).

There are pros and cons to any choice of piping materials, but it seems likely that the risk of chemical contamination from copper piping is lower and better understood than for plastic pipe. On the other hand, plastic offers reduced cost, lower flow resistance, and reduced breaks and leaks. For anyone anticipating use of HDPE for potable water, it is critical to choose materials that have passed ANSI/NSF 14 and 61 certification requirements. Furthermore, it seems reasonable to question the vendor regarding potential for chemical migration, odor and taste issues, and high-temperature performance. For example, new installations may require special flushing protocols to be sure contaminants are below USEPA MCL thresholds.

Regardless of pipe material choice, a significant risk of contamination still exists from some plumbing fixture types (18). Furthermore, due to on-going and legacy pollution, introduced chemicals, pharmaceuticals, pesticides, fertilizers, industrial chemicals, etc., are returning to us through surface water (19). As a result, drinking water may be contaminated *prior to* building supply and distribution. Plumbing materials may simply add another "dose" to this ongoing contamination.

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