

**Attachment L –  
Literature Review - Potential Risks Associated  
with Leaching of Organic Contaminants  
from Plastic Piping Materials**



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# Draft

## Literature Review

### Potential Risks Associated with Leaching of Organic Contaminants from Plastic Piping Materials

#### Background

During the September 2005 meeting of the Drinking Water Quality Oversight Committee of the Seattle Public Schools, committee members expressed concern regarding the use of plastic materials as a substitute for metal pipe and components that release lead into drinking water. Specifically, concerns were expressed by the Committee with regard to the leaching of organic contaminants, such as endocrine disrupting compounds, which supports the Committee's expectation that the precautionary principle be considered in all deliberations. HDR was therefore directed by the Committee to perform a literature review regarding potential risks associated with leaching of organic contaminants from plastic piping materials as end-use plumbing in Seattle schools.

#### Scope of Review

Leaching can be defined as “the dissolution of metals, solids, and chemicals into drinking water” (Symons et al., 2000). Leaching can result in elevated levels of organic contaminants, metals, or asbestos in water consumed at the tap. Health effects and mitigation techniques related to leaching of lead and copper from lead service lines or household plumbing materials are addressed in the Lead and Copper Rule (USEPA, 1991a). Health effects associated with leaching of asbestos fibers from asbestos-cement piping is currently addressed under Phase II National Drinking Water Regulations (USEPA, 1991b). This literature review focuses on current information with regard to leaching of organic contaminants from plastic materials used in premise plumbing and storage containers for potable water supplies. Specifically, this literature review focuses on plastic materials currently being used as piping and fitting components in place of metals at end-use plumbing for drinking water fountains in Seattle schools.

#### Types of Plastic Materials

The plastic material used for manufacturing plumbing pipe and fittings are known as thermoplastics (Ripka, 1994). Thermoplastics are resins that can be heated and reformed. Plastic pipe is made by the process of extrusion and plastic fittings are made by the process of injection molding. The advantages of using plastic as a piping material are its light weight, low cost, corrosion resistance, smooth surface, and pieces are easily joined. The disadvantages of plastic as a piping material are its low resistance to heat, flexibility requiring extra support, and lower crush and burst resistance compared to metal pipes.

There are five types of plastics commonly used for plumbing pipes and fittings (Ripka, 1994; Mruk, 1992):

- *Acrylonitrile-butadiene-styrene or ABS* – ABS plastic pipe and fittings are black and commonly used to construct sanitary drainage and vent piping systems as well as stormwater drainage systems both above and below ground.
- *Polyvinyl chloride or PVC* – PVC plastic pipe and fittings are light colored and typically used for the same applications as ABS; however, the two pipe materials are not interchangeable and each material has its own special solvent cement. Both ABS and PVC pipe and fittings are available in 1 ¼-inch to 6-inch sizes and pipe is available in 10- and 20-foot lengths. Selection of ABS or PVC is usually based on cost or local plumbing code restrictions.
- *Chlorinated polyvinyl chloride or CPVC* – CPVC plastic pipe and fittings are light or cream colored plastic that has been specially formulated to withstand higher temperatures than other plastics. It is normally rated for 180°F at 100 psi of pressure with substantial safety margin. CPVC is used for piping hot and cold water distribution systems in homes and is available in ½- and ¾-inch sizes and joined by solvent welding.
- *Polyethylene or PE plastic tubing* – PE plastic tubing is flexible and used for water supply piping. It is usually sold in 100-foot coils and joined to nylon or plastic insert fittings with hose clamps or flared and used with cast bronze fittings and soft copper tubing. PE tubing is available in ¾-, 1-, 1½-, and 2-inch sizes.
- *Polybutylene or PB plastic tubing* – PB plastic tubing is a gray flexible tubing used for residential water supply piping. PB plastic tubing is available in 1/8-, ¼, 3/8-, ½-, ¾-, and 1-inch sizes. It is manufactured in 20-foot straight lengths and in 25-, 50-, 100-, 500-, and 1000-foot coils. Mechanical joint fittings (insert and compression) are used to join segments instead of solvent cementing.

## **Plastic Materials at Fountains in Seattle Public Schools**

The types of plastic plumbing materials that are currently being used as end-use plumbing at drinking water fountains in Seattle schools include schedule 80 PVC pipe and fittings for rigid pipe installations, polyethylene flexible tubing, and polypropylene fittings. The PVC pipe, PVC fittings, and polypropylene tubing are all certified by the NSF 61 Drinking Water System Components program. The polypropylene fittings are certified by the NSF 51 Food Equipment program. Specific plastic materials are summarized in Table 1.

**Table 1. Plastic materials used at drinking water fountains in Seattle schools.**

<b>Plastic Pipe or Component</b>	<b>Manufacturer</b>	<b>Model/Description</b>	<b>Certification</b>
Schedule 80 PVC Connective Piping	Charlotte Pipe and Foundry Co. Monroe, NC	<ul style="list-style-type: none"> <li>▪ Charlotte Pipe FL Flowguard Gold CPVC (<math>\geq 1/4''</math>); CPVC 4120 (<math>\geq 1/8''</math>)</li> <li>▪ Charlotte Pipe FL TrueFit<sup>®</sup> System PVC (<math>\geq 1/2''</math>); PVC 1120 (<math>\geq 1/8''</math>)</li> </ul>	NSF 61 – Products listed as certified for drinking water system components on NSF website on 10/13/05 (1)
Schedule 80 PVC Fittings	Charlotte Pipe and Foundry Co. Monroe, NC	<ul style="list-style-type: none"> <li>▪ Charlotte Pipe Flowguard Gold CPVC (<math>\geq 3/8''</math>)</li> <li>▪ Charlotte Pipe PVC 1-G1 (<math>\geq 1/2''</math>)</li> <li>▪ Charlotte Socketed (<math>\geq 1/2''</math>)</li> <li>▪ Charlotte Threaded (<math>\geq 1/2''</math>)</li> </ul>	NSF 61 – Products listed as certified for drinking water components on NSF website on 10/13/05 (1)
Polyethylene (PE) flexible tubing	Parker Hannifin Corp. – Parflex Division, Ravenna, OH	Type 1, grade E5, 125 psi, 150°F max, OD 3/8", 0.062 wall	NSF 61 – Products listed as certified for drinking water components as E Series (natural, black, red, blue, purple, white, gray, and brown), 1/4" – 5/8", PE on 10/13/05 (2)
Polypropylene (PP) fittings	Parker Hannifin Corp. – Parflex Division, Ravenna, OH	Polypropylene fittings for food zone, Fast & Tite <sup>®</sup> , black and white, any size, 212°F	NSF 51 – Products listed as certified for food equipment materials on NSF website on 10/13/05 (3)

(1) <http://nsf.org/Certified/PwsComponents/Listings.asp?Company=09000&Standard=061>

(2) <http://nsf.org/Certified/PwsComponents/Listings.asp?Company=79020&Standard=061>

(3) <http://nsf.org/Certified/Food/Listings.asp?TradeName=&CompanyName=Parflex&PlantState=&PlantCountry=&PlantRegion=&Standard=&search=SEARCH>

## Codes, Standards, Regulations and Future Trends

[To be written]

- Discuss Plumbing Code, AWWA and ASTM standards for different types of piping materials.
- [www.epa.gov/safewater/tcr/tcr.html](http://www.epa.gov/safewater/tcr/tcr.html)

- National Academy of Sciences, Water Science and Technology Board - Public Water Supply Distribution Systems: Assessing and Reducing Risks (<http://www4.nas.edu/webcr.nsf/ProjectScopeDisplay/WSTB-U-04-06-A?OpenDocument>)
  - “A committee, formed by the Water Science and Technology Board, will conduct a study of water quality issues associated with public water supply distribution systems and their potential risks to consumers. The study will consider, but not be limited to, aspects of distribution systems such as cross connections and backflow, pressure transients, nitrification, permeation and leaching, repair and replacement of water mains, aging infrastructure, and microbial growth.”

NRCNA (2005). Public Water Supply Distribution Systems: Assessing and Reducing Risks -- First Report (2005), Water Science and Technology Board ([WSTB](http://www.nap.edu/books/0309096286/html/R1.html)) (<http://www.nap.edu/books/0309096286/html/R1.html>)

- “Excessive leaching of organic substances from pipe materials, linings, joining and sealing materials, coatings, and cement mortar pipe have occasionally been noted in the literature. Leaching is a relatively low priority relative to other distribution system problems and can be controlled by regulating the materials that are used in distribution and premise plumbing systems, by specifying the water chemistry that must be used if certain materials are to be employed, and by appropriate monitoring requirements.” (page 32)
- “Lead leaching to water from old lead pipe is managed in this way via the LCR. For new materials, the NSF establishes levels of allowable contaminant leaching through ANSI/NSF Standard 61.” “... it is currently believed that leaching is a relatively low priority relative to other distribution system problems.” (page 28)

## Plastic Materials and Environmental Exposure

New developments in analytical instrumentation, advances in human health and medical sciences, and increased use and disposal of plastic materials have contributed to the growing awareness and concern regarding the occurrence, fate, and ecological and human health effects of trace levels (ppb and lower) of organic contaminants in the environment (Alvarez-Cohen and Sedlak, 2003). For example, changes have been made in the production of PVC since the 1970s to comply with regulations regarding workplace exposure and environmental emissions of vinyl chloride monomer after recognizing that vinyl chloride is a human carcinogen (Borrelli et al., 2005). Consequently, NSF International currently requires testing of residual vinyl chloride monomer as a leachate as a part of certification of drinking water system components (NSF/ANSI 61 – 2003e, Section 4 Pipes and related products). This literature review focuses on understanding current information regarding the occurrence and effects of leaching and exposure to trace levels of organic contaminants and their degradation products in drinking water that comes in contact with plastic materials.

## *Endocrine Disruptors and Other Emerging Environmental Concerns*

One group of emerging contaminants, with potential widespread occurrence in the environment at trace levels, is known as endocrine disruptors (Damstra et al., 2002; Anderson, 2005). An endocrine disrupting compound (EDC) can be described as a compound that affects the normal functioning of the endocrine system (McLachlan, 2001; Daston et al., 2003). The U.S. Environmental Protection Agency defines EDCs as “exogenous agents that interfere with the production, release, transport metabolism, binding, action or elimination of the natural hormones in the body responsible for the maintenance of homeostasis and the regulation of developmental processes” (USEPA, 2003). EDCs can be found within many classes of chemicals including naturally occurring and synthetic steroid hormones (e.g.,  $17\beta$ -estradiol, estrone, testosterone), organohalides (e.g., alachlor, DDT, dioxins, PCBs), metals (lead, mercury, tributyl tin, cadmium), alkylphenols (e.g., nonylphenol, bisphenol A), polynuclear aromatic hydrocarbons or crude oil (e.g., benzo(a)pyrene, benz(a)anthracene), and plasticizers (e.g., di-*n*-butyl phthalate, butylbenzene phthalate, di-2-ethylhexyl phthalate) (Damstra et al., 2002). EDCs and their metabolites are continually introduced into aquatic environs and are prevalent at detectable concentrations, which can affect water quality and ecosystem health and potentially impact drinking water supplies (Daughton and Ternes, 1999; Roefer et al., 2000; Snyder et al., 2003). The occurrence of EDC contaminants in natural and engineered waters is a growing global environmental concern (Damstra et al., 2002) and the long-term effects of continuous, low-level exposure to EDCs and their metabolites are not understood well (Daughton and Ternes, 1999).

Suspected endocrine disruptors currently regulated in the U.S. with maximum contaminant levels by the Safe Drinking Water Act are the following (AWWA, 2005):

- Inorganic chemicals (Cd, Pb, Hg),
- Pesticides (atrazine, chlordane, DDT, endrin, lindane, methoxychlor, simazine, and toxaphene), and
- Nonpesticide organics (benzo(a) pyrene, di-(2-ethylhexyl)-phthalate (DEHP), dioxin, and polychlorinated biphenyls).

DEHP is a compound of particular interest for this literature review because it is commonly used as a plasticizer in the manufacturing of plastic materials such as PVC. Numerous other compounds have been identified for further study as potential EDCs. For example, the European Commission (ECDGE, 2000) developed a priority list of compounds based on the following three criteria: high persistence or high production volume; at least one study showing endocrine disruption in an intact organism; and high concern in terms of human and wildlife exposure. A total of 564 compounds were considered and 60 substances were ranked by the European Commission as high priority concerns.

This literature review considers the potential for leaching of harmful chemicals from plastic materials used in plumbing for drinking water fountains at Seattle schools. This literature review focuses on current research information and safeguards that are currently in-place for protecting human health.

## *Chemical Additives in Plastics and Environmental Exposure*

The performance of plastic materials used in plumbing applications, such as PVC and PE, is typically enhanced by adding chemical additives during the manufacturing process. For example, plasticizers are commonly used as additives in plastic products to improve their flexibility, workability, softness, and elongation properties (Wypych, 2004; Mruk, 1992). Plasticizers are derived from a variety of specialty chemical types such as phthalates, adipates, epoxides, sulfonates, and other organic compounds. Other chemical additives commonly used by the plastics industry to tailor products and/or improve plastic performance include impact modifiers, heat stabilizers, lubricants, biocides, antioxidants, antiblocking agents, slip agents, light stabilizers, clarifying agents, flame retardants, organic peroxides, blowing agents, antistatic agents, coupling agents, and other additive types (Tullo, 2000). For the purpose of this literature review, three common types of chemical additives (phthalates, phenolics, and organotins) and other trace-level organic contaminants and their environmental significance are discussed below.

### *Phthalates*

Plasticizers used in flexible PVC, such as DEHP and diisononyl phthalate (DINP), have been associated with adverse effects on the human reproductive system (Tullo, 2000; McGuire, 2004b). DEHP is commonly used for a variety of applications including medicinal devices, toys, building products, clothing, car products, and non-polymer materials such as paints, adhesives, fillers and printing inks. According to Latini et al (2004), DEHP is not chemically bound to PVC and it leaches out from PVC items with time and use. Consequently, DEHP (and possibly other phthalate esters used as plasticizers) is an ubiquitous environmental contaminant and may be damaging to human fertility and reproduction based on available toxicity and human exposure data (Latini et al., 2004; Nakamiya et al., 2005). Plasticizers have been detected in the environment in air, sediment and soils, surface water, ground water, and drinking water samples (Roy, 2004). According to Tullo (2000), phthalate plasticizers in medical products represent approximately 10% of the phthalate plasticizers market. On July 5, 2005, the European Parliament voted to prohibit the use of 3 phthalate plasticizers in toys and child care items and to restrict three other plasticizers throughout the European Union (Hileman, 2005).

According to Roy (2004), plasticizers have been reported in samples of drinking water at concentrations ranging from 0.03 to 470 µg/L of phthalates. Information regarding exposure is based on the Hazardous Substances Data Bank (HSDB). For the purpose of this literature review, selected phthalate compounds listed by Roy (2004) were looked up in the HSDB to better understand drinking water exposure. The references cited in the HSDB (2005) regarding probable routes of human exposure for these phthalate compounds were based on peer-reviewed publications from the 1980s. NSF International currently requires testing of phthalates leaching from drinking water system components when phthalate ester plasticizers are used in the formulation of the plastic material (NSF/ANSI 61 – 2003e, Section 4 Pipes and related products). Based on this information, newer plastic materials that have been manufactured in accordance with current NSF requirements likely pose a lower risk of exposure by leaching into drinking water compared to older plastic plumbing materials.

Current research on phthalates includes efforts aimed at developing new techniques for quantifying the occurrence, understanding the health effects, and reducing and remediating phthalate contaminants in the environment. For example, Feng et al. (2005) developed new analytical methods for determining phthalate esters in raw cow's milk. Latini et al. (2004) studied the extent of DEHP exposure in infants and Nakamiya et al. (2005) proposed a method for microbial treatment of DEHP in polyvinyl chloride. According to Greiner (2005), NSF International continuously updates their acceptance criteria and testing protocols for certification of materials based on new scientific developments.

### *Phenolics*

Bisphenol A, 4,4'-(1-methylethylidene) bisphenol, or 2,2-(4,4-dihydroxydiphenyl) propane is widely used in the manufacture of polycarbonate products (e.g., baby bottles), and as a stabilizing material or antioxidant for many types of plastics such as polyvinyl chloride (Chang et al., 2005). Bisphenol A elicits estrogenic hormonal activity at trace levels (Gould et al., 1998). Yamamoto and Yasuhara (1999) investigated the quantity of bisphenol A leaching into water from a variety of plastic wastes and concluded that polyvinyl chloride yielded the highest concentration. The leaching rate of bisphenol A from polycarbonate into water was shown to be affected by pH and the presence of amino acids (Sajiki and Yonekubo, 2004). Similar to phthalates and other trace level concentrations of organic compounds, Chang et al. (2005) has developed analytical methods for detecting bisphenol A at concentrations as low as the ng/L level. Chang et al. (2005) determined that bisphenol A leached from three representative plastic containers (a baby feeding bottle, a PVC bottle, and a food platter) in the presence of hot water in the range of 0.7 to 78.5 µg/L. In another study, Hu et al. (2003) used a quantitative structure-activity relationship to examine the estrogen receptor binding affinities of 25 compounds. The study included 17 industrial phenolic compounds, which are possibly released from epoxy and polyester-styrene resins used in lacquer coatings of concrete tanks and lining of steel pipe in water supply systems.

NSF International currently requires testing of phenolic compounds leached into water in contact with plastic drinking water system components (NSF/ANSI 61 – 2003e, Section 4 Pipes and related products). The lowest acceptance criteria for bisphenol A is 0.02 mg/L, according to current NSF/ANSI standards. As part of a recent study of drinking water treatment plants in Louisiana and Ontario, Boyd et al. (2003) collected water samples at various stages of treatment and reported non-quantifiable but detectable concentrations of bisphenol A (<0.1 ng/L) and identified a need for more data and information regarding contributions by containers and/or chemical conveyor systems to low-level bisphenol A contamination in drinking water treatment and distribution systems. Trace levels of bisphenol A reported by Boyd et al (2003) are several orders of magnitude less than the NSF acceptance criterion. Currently, it is unknown if trace levels of bisphenol A occur in drinking water distribution systems and, if so, what are their sources? Furthermore, the level of exposure through leaching of these chemicals into drinking water is an important component of risk assessment and such exposure has been considered very low (Falwell and Chipman, 2001). More research may be needed in this area, but current standards (i.e., NSF) appear to provide protection based on generally accepted knowledge in this area.

### *Organotins*

According to Tullo (2000), heat stabilizers are used in rigid and flexible PVC. The main kinds of heat stabilizers are organotins; lead; mixed metals such as barium/cadmium, barium/zinc, and cadmium/zinc; and other organic materials. In North America, lead is only found in wire and cable applications. Organotins generally are used instead of lead in rigid PVC applications such as pipe. According to Jones-Lepp et al. (2001), organotin compounds (e.g., dibutyltin and dimethyltin) have a large market as heat and UV-oxidation resistance stabilizers for the rigid PVC industry. Organotins also are widely used in antifouling paints for ships and they have been measured extensively as environmental contaminants in coastal waters and sediments (Landmeyer et al., 2004).

Organotin compounds recently have been found to leach out of PVC pipe (McGuire, 2004a). For example, recent studies (Sadiki et al., 1996; Forsyth and Jay, 1997; Sadiki and Williams, 1999) demonstrated the occurrence of trace levels of organotin compounds leaching in Canadian drinking water supplies that had flowed through recently installed PVC and CPVC pipes (typically less than 6 months). Contaminant levels were reported as high as 291 ng Sn/L.

The dialkyl form of organotins is considered much more neurotoxic than the trialkyl or monoalkyl forms, with an effect in brain cells as low as 30 ppb (Richardson, 2003). Concerns for drinking water have emerged from the discovery that dibutyltin (DBT) leaches from PVC at 1 µg/L levels, and that cutting and gluing PVC pipe and components can increase the initial levels of DBT leaching out of the pipe. The increase in DBT was attributed to an increase in exposure of the interior surface of the pipe; solvation of the glue and primer on the pipe thereby releasing DBT; or DBT leaching from the primer and glue itself (Jones-Lepp et al., 2001). NSF International currently requires testing of tin when tin-based stabilizers are used in the formulation of the product (NSF/ANSI 61 – 2003e, Section 4).

### *Other Emerging Contaminants in Drinking Water*

There are numerous other emerging low-level contaminants in drinking water, several of them known or suspected human carcinogens or endocrine disruptors. These other contaminants may or may not be directly associated with plastic materials used in pipe and plumbing components. For example, nitrosodimethylamine (NDMA) is a contaminant originating from rocket fuel, plasticizers, polymers, batteries and other industrial sources and has been discovered in waters treated with chloramines or chlorine (Richardson, 2003). Wilczak et al. (2003) identified cationic polymers, which are widely used for coagulation at drinking water treatment plants, as a source of trace levels of NDMA when the treated water is chloraminated. Another group of emerging organic contaminants being detected at trace levels is known as pharmaceuticals and personal care products (PPCPs) (Daughton and Ternes, 1999). PPCPs potentially could affect drinking water supplies because they are not effectively removed by wastewater treatment. PPCPs can enter potable water sources, survive drinking water treatment processes, and possibly transformed to new disinfectant byproducts (Richardson, 2003; Boyd et al., 2003; 2005; Westerhoff et al., 2005).

Another group of emerging contaminants, polybrominated diphenyl ethers (PBDEs), are flame retardant additives widely used in thermoplastics, polyurethane foam and textiles (Hale et al. 2003). PBDE compounds have been found in samples of wildlife from many areas of the globe, including recent studies of marine and freshwater birds in British Columbia, Canada (Elliott et al., 2005) and in sediments of the Great Lakes (Song et al., 2005). Like other trace-level contaminants, new analytical methods currently are being developed to quantify PBDEs in water and complex environmental matrices.

## NSF International

The NSF/ANSI standards and certification program for all direct and indirect drinking water additives is based on a consortium led by NSF International. Other members of the Consortium include the American Water Works Association Research Foundation, the Association of State Drinking Water Administrators, the Conference of State Health and Environmental Managers and the American Water Works Association. NSF/ANSI Standard 61 establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted into drinking water from products, components, and materials used in drinking water systems (NSF, 2003). NSF/ANSI Standard 61 is the only such drinking water standard that is based on risk assessment criteria (Greiner, 2005).

### *NSF/ANSI Standard for Drinking Water Additives – 61 Drinking Water System Components – Health Effects.*

For testing of pipes and pipe-related products, NSF/ANSI Standard 61 requires that the manufacturer provide NSF with the following information regarding the product:

- intended use
- surface area in contact with water
- expected service life
- maximum, minimum, and average volume of water in contact with the product for 24 h
- complete formulation information (chemical composition)
- maximum intended temperature
- method of manufacturing
- handling and packaging
- when available, list of known or suspected impurities and percentages
- when available, solubility, hydrolysis products, and extraction rates of chemicals within the product or material
- when available, a list of published and unpublished toxicological studies relevant to the chemicals and impurities present in the product.

Information regarding product formulation is used to establish a minimum test battery in accordance with material-specific analyses. Table 2 shows the material-specific analyses required for pipes and pipe-related products that could be used to connect drinking water fountains in Seattle schools.

Section 4 of NSF/ANSI 61 – 2003e provides testing requirements that apply to pipes and pipe-related products. There is no definition in this section that specifically applies to drinking water fountains in schools, but two definitions may have some application:

- **4.2.1 Cold water application:** A product application that is intended to result in continuous exposure to water of ambient temperature. Products are tested for an end-use temperature of  $23 \pm 2$  °C ( $73 \pm 4$  °F).

- 4.2.3 Domestic hot water applications:** A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is considered to be any hot water contact that is not continuous. Products are tested for an end-use temperature of  $60 \pm 2$  °C ( $140 \pm 3$  °F).

**Table 2 - Material-specific Analyses\***

Material Type	Required Analyses
Polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC)	Phenolics <sup>1</sup> , regulated metals <sup>2</sup> , VOCs, tin <sup>4</sup> , antimony <sup>5</sup> , residual vinyl chloride monomer (RVCM) <sup>6</sup>
Polyvinyl chloride (flexible)	Phenolics <sup>1</sup> , regulated metals <sup>2</sup> , VOCs, tin <sup>4</sup> , RVCM <sup>6</sup> , phthalates <sup>7</sup> , zinc <sup>8</sup>
Polybutylene (PB)	VOCs, regulated metals <sup>2</sup> , phenolics <sup>1</sup>
Polyethylene (PE)	VOCs, regulated metals <sup>2</sup> , phenolics <sup>1</sup>
Polypropylene (PP)	VOCs, regulated metals <sup>2</sup> , phenolics <sup>1</sup>
1 Analysis in accordance with EPA Method 420.2 or other as indicated in NSF/ANSI 61 – 2003e, section B.7.4. 2 Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, selenium, thallium 4 Required when tin-based stabilizers are used. 5 Required when antimony-based stabilizers are used. 6 Analysis of residual vinyl chloride monomer in PVC and CPVC products using GC-FID by analyzing 0.5 g of plastic material to method sensitivity of 0.5 ppm (mg/kg). 7 Required when phthalate ester plasticizers are used. Analysis shall be for the specific phthalate ester(s) used in the formulation. 8 Required when zinc-based stabilizers are used.	

For drinking water fountains in schools, the product application for plumbing can be described as “intermittent” and “cold water”. This specific application is not identified as a test category in the NSF/ANSI standard. Therefore, the testing protocols for both 4.2.1 and 4.2.3 will be considered further in the discussion below.

In all cases, the test sample must be prepared so that the laboratory surface area-to-volume ratio is equal to or greater than the surface area-to-volume ratio at which the product is intended to be used in the field (4.5.2.1). Test samples are rinsed in cold water until any extraneous debris or contamination that occurred during shipping and handling is removed, and then rinsed in reagent water (e.g., distilled, RO, deionized, or other method per B.9.2.1) (4.5.2.2). Exposed surfaces are oriented during testing in accordance with 4.5.2.3 and 4.5.2.4.

Extraction water is prepared at pH 8 with 0 mg/L available chlorine and 100 mg/L hardness in accordance with B.2.5 (4.5.3.1) for analyses of organics (solvents and VOCs). The chemical

\* Based on Table 3.1 – Material-specific analyses, NSF/ANSI 61-2003e, page 7.

characteristics of the extraction water are prepared by mixing 25 ml of 0.04 M NaHCO<sub>3</sub> and 25 mL of 0.04 CaCl<sub>2</sub> and diluting to 1 liter with reagent water (B.9.6).

NSF/ANSI 61 allows for *single time-point conditioning* for cold or hot applications (4.5.5). For cold applications (4.5.5.1), the product is allowed conditioning in the exposure water at a temperature of 23 ± 2 °C (73 ± 4 °F) for 14 d. During the 14-d period, the exposure water is changed at least 10 times with a minimum period of 24 ± 1 h between water changes. The free available chlorine concentration during the conditioning period is 2 mg/L. After the 14-d conditioning period, the exposure water in the product is decanted and discarded. An example conditioning schedule is shown in Table 3.

**Table 3 - Example single time point conditioning schedule \***

Conditioning Time	Elapsed Time	Comments
24 ± 1 h	1 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	2 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	3 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	4 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	7 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	8 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	9 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	10 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
24 ± 1 h	11 d	Exposure water is decanted and discarded; the product is refilled with exposure water and conditioning is continued.
72 ± 1 h	14 d	Exposure water is decanted and discarded; conditioning is terminated.

Immediately following conditioning, *single time point exposure* of the product sample (4.5.6) is performed in accordance with the schedule in Table 4. The exposure water is the same pH and temperature as the water used for conditioning. A separate sample is exposed for each type of exposure water.

\* Derived from Table 4.1 with the same title, NSF/ANSI 61-2003e, Table 4.1, page 17.

**Table 4 - Single time point exposure schedule \***

<b>Exposure Time</b>	<b>Elapsed Time<sup>1</sup></b>	<b>Comment</b>
24 ± 1 h (optional)	15 d (optional)	Extraction water is decanted and discarded; the exposure product is refilled with exposure water and exposure is continued.
24 ± 1 h (optional)	16 d (optional)	Extraction water is decanted and discarded; the exposure product is refilled with exposure water and exposure is continued.
16 h	17 d (15 d if the two optional exposure periods are not elected)	Extraction water is collected for analysis.
1 Elapsed time includes the 14 d of conditioning preceding the exposure.		

For hot applications, additional steps are included in the protocol for intermittent and continuous hot water conditioning (4.5.5.2) and single time point exposures (4.5.6.2). Additional conditioning and exposure are performed at temperatures of  $60 \pm 2$  °C ( $140 \pm 3$  °F) or  $82 \pm 2$  °C ( $180 \pm 3$  °F) for designated periods. These elevated temperatures are not likely to occur at drinking water fountains in Seattle schools; therefore, the hot water testing protocol is not discussed further for this review.

For *intermittent* hot water conditioning (4.5.5.2.1), the same procedure as the cold application conditioning procedure is followed, and then the product is further conditioned in the exposure water at elevated temperatures for two consecutive 60-min periods. No specific protocol is described in this Standard for *intermittent cold water applications*.

Sample collection (4.5.8) and analyses (4.6) are performed in accordance with accepted and most recent EPA Methods and *Standard Methods for the Examination of Water and Wastewater*.

The concentration of analytes detected in the extraction water is multiplied by a calculated *normalization factor* to account for the difference between laboratory and field surface area-to-volume ratios (4.7). The general formula for the derivatization of the normalization factor is described in the following equations:

$$NF = N1 \times N2$$

$$N1 = \frac{SA_F}{SA_L} \times \frac{V_L}{V_{F(static)}}$$

$$N2 = \frac{V_{F(static)}}{V_{F(flowing)}}$$

\* Derived from Table 4.2 with the same title, NSF/ANSI 61-2003e, page 17.

where

- $SA_F$  = surface area exposed in the field
- $SA_L$  = surface area exposed in the laboratory
- $V_L$  = volume of extraction water used in the laboratory
- $V_{F(static)}$  = volume of water to which the product is exposed under static conditions
- $V_{F(flowing)}$  = volume of water to which the product is exposed under flowing conditions during a period of time equivalent to the laboratory test.

The normalization factor,  $NF$ , is thus multiplied by laboratory-measured concentration,  $LC$ , to determine the normalized concentration,  $NC$ .

$$NC = NF \times LC$$

The selection of normalization conditions depends on the laboratory test conditions as expressed by  $N2$  (4.7.5) and the criterion for acceptance by NSF is based on the respective maximum contaminant level (MCL), total allowable concentration (TAC), or single product allowable concentration (SPAC) (4.8.1). The TAC and SPAC are risk assessment based criteria as described in Annex A of NSF/ANSI 61. Representative compounds that have been assigned TAC and SPAC criteria (NSF/ANSI Standard 61-2003e) are summarized in Table 5.

**Table 5 - NSF International drinking water criteria (not externally peer reviewed)\***

Substance	CAS#	Total Allowable Concentration (TAC), mg/L	Single Product Allowable Concentration (SPAC), mg/L
Bisphenol A	80-05-7	0.2	0.02
Butyltin compounds (mono- and di- only)	N/A	0.02 (total)	0.004 (total)
Diisononyl phthalate	28553-12-0	0.05	0.05
Isophthalic acid	121-91-5	0.01	0.01
Terephthalic acid	100-21-0	0.01	0.01

The NSF protocol for normalization of contaminant concentration of lead leaching from inline brass plumbing products has been critically reviewed by Dudi et al. (2005). The investigators demonstrated that small devices made of pure lead can easily pass the leaching protocol for lead, and therefore could pose a public health hazard. As a result of their study, the investigators called for reforms of NSF/ANSI Standard 61 - Section 8 (mechanical devices) to prevent such outcomes in the future. Given that similar protocols are used in NSF/ANSI Standard 61 - Section 4 (pipes and related products) to determine acceptable levels of organics leached into drinking water, more study may also be needed to determine if reforms should be recommended for this protocol.

\* Derived from Table E1, NSF/ANSI Standard 61-2003e, page E3.

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## Conclusions

- Seattle Public Schools currently uses plastic materials as end-use plumbing that meet current NSF standards with regard to leaching of organic substances.
  - PVC piping, PVC fittings and PE tubing are all certified by the NSF 61 Drinking Water System Components program.
  - Polypropylene fittings are certified by the NSF 51 Food Equipment program.
- A recent report by the National Research Council of the National Academies identified leaching of organic substances from pipe and sealing materials as a relatively low priority relative to other distribution system problems.
- Recent concerns have been raised in the peer-reviewed literature regarding the leaching of low-level contaminants into drinking water from plastic materials used as pipe and plumbing components.
- NSF has established risk-assessment based criteria for acceptance of plastic components and parts in contact with drinking water. Further, NSF continuously updates its testing protocols and certification criteria based on new developments in science.
- NSF currently tests for low-level contaminants that can leach from plastic products and are toxic and/or known or suspected endocrine disruptors. The testing of specific compounds is based on information provided by the manufacturer regarding the formulation of the plastic product.
- NSF testing protocol appears to provide an opportunity for “ageing” or “conditioning” of the plastic products before determining whether or not to certify the product for drinking water applications. Testing protocol for plastic pipes and related products (Section 4) provides a period of “conditioning” of the product, which is similar to the protocol for testing mechanical devices (Section 8).
- Based on studies reported in the literature, leaching of some contaminants from plastics may be elevated during initial contact with water and then decrease in concentration with time. More study would be needed to determine if this phenomenon occurs with plastic pipe and components as end-use plumbing in Seattle schools.

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