



---

## A Literature Review of Chemicals Found in Potable Water Plumbed with PEX and CPVC

---

June 1<sup>st</sup>, 2018

Roger Hess  
Redwood Energy  
1887 Q Street  
Arcata, CA 95521  
(707) 826-1450  
[sean@redwoodenergy.net](mailto:sean@redwoodenergy.net)

As green buildings have been gaining popularity so has plastic plumbing being used as the material of choice for plumbing in these buildings. Chlorinated polyvinyl chloride (CPVC) and Cross-linked polyethylene (PEX) are the two most commonly used types of plastic piping that are being used for potable water. Potable water is defined as water that is safe to drink or to prepare food with. Purdue University lists two benefits that have led to an increase in the use of CPVC and PEX for potable water. Those benefits are:

“Plastic piping is generally less expensive, lighter and easier to install than metal pipes.

In comparison plastic piping is on average about \$2.00 cheaper than copper plumbing, costing 43 cents per foot compared to copper piping, at \$2.55 per foot. Along with potentially saving thousands of dollars during construction by installing plastic instead of metal plumbing systems, proponents assert plastic pipes require less energy to manufacture - generating less carbon dioxide compared to metal pipes. (Venere, 2014)<sup>1</sup>

Although the benefits listed above from using PEX and CPVC may be enticing, it is crucial to note that there are more important factors than money and greenhouse gas emissions when choosing the appropriate materials for a drinking water system. The most important factor to choosing the right plumbing system for potable water is choosing the piping material with the least amount of adverse health effects.

### **Chemicals Found in Plastic Drinking Water Systems:**

There has been extensive research that has looked into the health effects of PEX and CPVC piping being used for potable water. One of research articles looking into the health

---

<sup>1</sup> Venere, Emil. “Drinking Water Odors, Chemicals above Health Standards Caused by 'Green Building' Plumbing.” *Purdue University*, National Science Foundation, 20 Oct. 2014, [www.purdue.edu/newsroom/releases/2014/Q4/drinking-water-odors,-chemicals-above-health-standards-caused-by-green-building-plumbing.html](http://www.purdue.edu/newsroom/releases/2014/Q4/drinking-water-odors,-chemicals-above-health-standards-caused-by-green-building-plumbing.html)

effects of PEX piping is authored by Kelly, Keven M, et al and is titled, “Release of drinking water contaminants and odor impacts caused by green building cross-linked polyethylene (PEX) plumbing systems”. In the research conducted,

“they found sixteen different organic chemicals present when testing six different brands of PEX pipes sold in the USA and a PEX-a green building plumbing system impacted chemical and drinking water odor quality. Of those organic chemicals toluene was the only one found to be regulated by the Environmental Protection Agency (EPA). Pyridine, methylene-trichloroacetate, Pentadecane, 1,1,1,2-Tetrachloroethane, Hexadecane and Heptadecane are a couple of the organic chemicals that were found in the water and that are not currently being regulated by any health agencies (Kelley et al., 2014)”<sup>2</sup>.

As for contaminants that are affecting drinking water in CPVC piping an article written by Heim, Timothy H, and Andrea M Dietrich called, “Sensory aspects and water quality impacts of chlorinated and chlorinated drinking water in contact with HDPE and CPVC pipe”, takes an in depth look into the health effects CPVC has on the leaching of total organic carbon (TOC), VOC’s, trihalomethane (THM) formation, and disinfectant residual.

“The main compounds identified in the research conducted included antioxidants (4-methyl-2,6-di-t-butylphenol, alkyl-thiophene), several aldehydes and plasticizers (phthalates and tributyl-phosphate). Along with these compounds being found in the water there was also a burnt plastic odor found that was due to butylated-hydroxytoluene (Heim et al., 2006)”<sup>3</sup>.

---

<sup>2</sup> Kelly, Keven M, et al. “Release of Drinking Water Contaminants and Odor Impacts Caused by Green Building Cross-Linked Polyethylene (PEX) Plumbing Systems.” *Egyptian Journal of Medical Human Genetics*, Elsevier, 10 Sept. 2014, [www.sciencedirect.com/science/article/pii/S0043135414006289](http://www.sciencedirect.com/science/article/pii/S0043135414006289).

<sup>3</sup> Heim, Timothy H, and Andrea M Dietrich. “Sensory Aspects and Water Quality Impacts of Chlorinated and Chloraminated Drinking Water in Contact with HDPE and CPVC Pipe.” *Egyptian Journal of Medical Human Genetics*, Elsevier, 16 Jan. 2007, [www.sciencedirect.com/science/article/pii/S0043135406006713](http://www.sciencedirect.com/science/article/pii/S0043135406006713).

As previously stated, plasticizers leaking out of plastic piping is one of the gravest concerns with it being used as plumbing for potable water. Since, research stated above proves that this a common occurrence when water being plumbed through plastic piping is chlorinated it is highly advised that CPVC piping isn't used for potable water. When Plasticizers leach out of plastic piping this is a part of the process, which is called crazing.

More evidence pointing towards CPVC leaching VOC's is a research paper done by a masters student at Virginia Polytechnic Institute and State University (Virginia Tech) on CPVC and PEX piping called, "Impact of Pipe Materials on the Odor, Disinfectant Residual and TOC-Levels of Drinking Waters". In the article they quote a research article called, "Identification of Organic Compounds Migrating from Polyethylene Pipelines into Drinking Water." The author talks about one of the major drawbacks associated with PEX and CPVC is the leaching of Volatile Organic Compounds (VOCs) directly from the plastic or from antioxidants and other solvents used to protect the plastic pipe from oxidation (Brocca et al., 2002).<sup>4</sup> Not all VOCs have the same health effects most will irritate your skin, cause difficulty breathing and damage your nervous system. Along with these health effects some VOCs are carcinogenic. VOCs have tendencies to leak out into the air while being transported or stored and will react with other pollutants that are already in the air to create ozone.

According to an article titled, "Potential Water Quality Deterioration of Drinking Water Caused by Leakage of Organic Compounds from Materials in Contact with the Water", Additional mechanisms that can add organic compounds to the water include permeation and oxidation of the internal surface of the plastic pipe during the extrusion process (Hem et al.,

---

<sup>4</sup> Brocca, D, et al. "Identification of Organic Compounds Migrating from Polyethylene Pipelines into Drinking Water." *Water Research* 36 3675–3680, Elsevier, 15 Feb. 2002, pdfs.semanticscholar.org/136c/537aaaf3ac179ab125365e2686f11c876d7a.pdf.

2002).<sup>5</sup> As articulated above the extrusion process is another mechanism in which, hazardous compounds can leach into potable water. This is an important finding given that, the extrusion process is a process that molds plastics into a form with a constant cross section and if done improperly can lead to pipe oxidation (Durand et al., 2005).<sup>6</sup> Given, that all plastic piping uses the extrusion process to form the desired molds it is important to understand that if the molds are made improperly or cheaply it adds yet another health hazard associated with plastic piping being used for potable water.

Another mechanism for leaching of hazardous chemicals in CPVC rigs is the cement and primer that holds each section or fitting together. The containers that the adhesives come in have adamant warnings about the potential for the cement and primer to cause cancer if the proper safety precautions aren't taken. After finished using the primer and cement the user is instructed to wash their hands as soon as possible. Even after washing their hands the first time the individual who has been handling the primer and cement is highly advised to wash their hands again before they come into contact with food or water. These strict guidelines detailing how to safely handle the primer and cement aren't reassuring for the water quality of plastic piping that use cement and primers to hold segments and joints of plastic piping together. Some of the more common binding products for CPVC piping is made by The Hercules Chemical Company. The Hercules Chemical Company sells a primer called Oatey Purple Primer, which can be used for PVC and CPVC piping. Along with their primer they also sell a cement, called Oatey Heavy

---

<sup>5</sup> Hem, Lars J., and Ingun Skjevraak. "Potential Water Quality Deterioration of Drinking Water Caused by Leakage of Organic Compounds from Materials in Contact with the Water ." *Proceedings, 20 Th NoDig Conference, Copenhagen May 28-31 2002.*, Regional Food Control Authority, May 2002, [www.forskningsradet.no/csstorage/vedlegg/nodig\\_02.pdf](http://www.forskningsradet.no/csstorage/vedlegg/nodig_02.pdf).

<sup>6</sup> Durand, Monique. *Disinfectants and Plumbing Materials: Effects on Sensory and Chemical Characteristics of Drinking Water* . Virginia Polytechnic Institute and State University, 16 Nov. 2005, [vtechworks.lib.vt.edu/bitstream/handle/10919/35861/ThesisMoniqueDurand2.pdf?sequence=1#page=64](http://vtechworks.lib.vt.edu/bitstream/handle/10919/35861/ThesisMoniqueDurand2.pdf?sequence=1#page=64).

Duty CPVC Orange Cement, which is meant to be used in tandem with the cement when building a rig. According to the U.S Department of Health and Human Services Household Products Database,

“The ingredients listed in each of these products is almost identical expect for a few chemicals. Both of the adhesives listed above have Acetone, Cyclohexanone and tetrahydrofuran as main ingredients. The difference between the primer and cement is that the primer contains Methyl ethyl ketone (MEK) and the cement has CPVC resin and fumed silica, which is more commonly known as silicon dioxide.”<sup>7</sup>

The adhesives used in plastic piping is often overlooked when thinking about the possible sources of leaching chemicals into potable water from plastic plumbing and might be just as harmful as the leaching from the plastics themselves. The best way to determine the potential health effects of the cement, primer and agents that have been proven to leach out of the plastic piping is by analyzing the chemicals and their effects on humans health.

#### **Health Effects Associated with Contaminants:**

Within the water quality research written by Kelly, Keven M, et al, a handful of organic molecules were consistently detected in water that had come into contact with the PEX piping. As previously mentioned toluene was the only EPA regulated organic compound found in water that was detected when testing PEX piping. According, to the Agency for Toxic Substances and Disease Registry,

“Toluene is a clear colorless liquid that has a very similar odor to paint thinner and is commonly used as a solvent. It occurs naturally in crude oil and is often added to

---

<sup>7</sup> Household Products Database - Health and Safety Information on Household Products.” *U.S. National Library of Medicine*, National Institutes of Health, June 2018, [hpd.nlm.nih.gov/cgi-bin/household/brands?tbl=brands&id=15001057&query=cpvc&searchas=TblBrands](http://hpd.nlm.nih.gov/cgi-bin/household/brands?tbl=brands&id=15001057&query=cpvc&searchas=TblBrands).

gasoline to help the formation of benzene. Its range of health effects associated with it vary based off of exposure. These effects can be temporary, such as headaches, dizziness, or unconsciousness. However, effects such as incoordination, cognitive impairment, vision and hearing loss may become permanent with long-term repeated exposure.”<sup>8</sup>

Although, temporary symptoms such as headaches and dizziness can seem insignificant they often can lead to the more serious and possibly permanent health effects associated with repeated exposure. If the PEX piping system that is leaching toluene is in a home it is guaranteed there will be repeated exposure to the unknowing victim of the contaminated water. This risk can easily translate to repeated high exposure, which is concerning because of its potential to effect pregnant women, whose baby could develop retardation of mental abilities and growth. Not only is that mom risking her own wellbeing, but she risking the life and health of an unborn human just by drinking water in her own home. Even with the known effects of repeated long-term exposure by toluene, the U.S. EPA has determined that there is not enough evidence to determine whether it is carcinogen, but have found that its effects are serious enough for it be regulated by the EPA.

According to the EPA, for a chemical to be regulated by the government there a couple of steps the chemical has to go through before it is categorized as such.

“The first step is being listed by the Toxic Substances Control Act (TSCA) inventory, which is a list a 70,000 different existing chemicals in commerce. In order for a chemical to be added to the list it has to go through a review process prior to being added, were it will then be tested for potential adverse effects on human health and potential catalysts for environmental hazards. Once a chemical has been tested and the EPA has determined

---

<sup>8</sup> “Toxic Substances Portal - Toluene.” *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 21 Jan. 2015, [www.atsdr.cdc.gov/phs/phs.asp?id=159&tid=29](http://www.atsdr.cdc.gov/phs/phs.asp?id=159&tid=29).

that there is sufficient evidence showing that it will be beneficial to restrict the chemical it will then be regulated.”<sup>9</sup>

Understanding how the process of chemicals being regulated by the EPA works helps one understand the serious precautions that should be taken when making decisions involving U.S. EPA regulated chemicals. It is important to remember that if a chemical is not found to be carcinogenic by the EPA it still has the potential to have negative life altering effects on humans. Although, regulating dangerous compounds is helpful in educating people about the dangers of compounds it is also important to not underestimate the negative health impacts of chemicals that aren't regulated by the EPA.

For specific chemicals that are not regulated by the U.S. EPA, methyl-trichloroacetate (MTA), pyridine, heptadecane, hexadecane and diethylhexyl-adipate are some of the more dangerous organic molecules that were found in the research done by Kelly, Keven M, et al. According to said research,

“Methyl-trichloroacetate was consistently found the most in the water quality testing. The researchers had six different brands of PEX rigs and found that twice MTA was found in all of the pipes after 3, 15 and 30 days when there was 2 mg/L of free chlorine present.”<sup>10</sup>

Even though MTA is not regulated by the EPA that doesn't eliminate the health concerns of it being found in potable water. According to the website (Pubchem, 2018)

“MTA is toxic if it is inhaled, ingested or if skin and eyes comes in contact with vapors and can also cause severe injury, burns or death. Reaction with water or moist air will

---

<sup>9</sup> “Learn About the Toxic Substances Control Act (TSCA).” *EPA*, Environmental Protection Agency, 1 Sept. 2016, [www.epa.gov/assessing-and-managing-chemicals-under-tsca/learn-about-toxic-substances-control-act-tsca](http://www.epa.gov/assessing-and-managing-chemicals-under-tsca/learn-about-toxic-substances-control-act-tsca).

<sup>10</sup> Kelly, Keven M, et al. “Release of Drinking Water Contaminants and Odor Impacts Caused by Green Building Cross-Linked Polyethylene (PEX) Plumbing Systems.” *Egyptian Journal of Medical Human Genetics*, Elsevier, 10 Sept. 2014, [www.sciencedirect.com/science/article/pii/S0043135414006289](http://www.sciencedirect.com/science/article/pii/S0043135414006289).



release toxic, corrosive or flammable gases and can generate a significant amount of heat that will increase the concentration of fumes in the air (Pubchem, 2016).”<sup>11</sup>

Specifically, the most alarming aspects of methyl-trichloroacetate being traced to PEX piping being used for potable water and its health effects on potable water is chemically how it reacts with water. As discussed in the previous quote when it reacts with water it can lead to corrosive gases being formed. Corrosive gases are particularly alarming for their ability to breakdown plastic piping, which inevitably will lead to more leaching of other organic chemicals.

In research conducted pyridine was found in only one of the brands of PEX piping, but was found in the water on the first interval of testing (Kelley et al., 2014).<sup>12</sup> According to Pubchem,

“Pyridine is a clear liquid with an odor that is sour, putrid, and fish-like. Historically it has been obtained from crude coal tar or is synthesized from acetaldehyde, formaldehyde and ammonia. It is often used as a denaturant for antifreeze mixtures, for ethyl-alcohol and for fungicides. Pyridine is a harmful substance if inhaled, ingested or absorbed through the skin and is a known carcinogen. Common symptoms of acute exposure to pyridine are headaches, coughing, asthmatic breathing, laryngitis, nausea and vomiting (Pubchem, 2018).”<sup>13</sup>

---

<sup>11</sup> “Methyl Trichloroacetate.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, [pubchem.ncbi.nlm.nih.gov/compound/methyl\\_trichloroacetate#section=Health-Hazard](http://pubchem.ncbi.nlm.nih.gov/compound/methyl_trichloroacetate#section=Health-Hazard).

<sup>12</sup> Kelly, Keven M, et al. “Release of Drinking Water Contaminants and Odor Impacts Caused by Green Building Cross-Linked Polyethylene (PEX) Plumbing Systems.” *Egyptian Journal of Medical Human Genetics*, Elsevier, 10 Sept. 2014, [www.sciencedirect.com/science/article/pii/S0043135414006289](http://www.sciencedirect.com/science/article/pii/S0043135414006289).

<sup>13</sup> “Pyridine.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, [pubchem.ncbi.nlm.nih.gov/compound/1049#section=Top](http://pubchem.ncbi.nlm.nih.gov/compound/1049#section=Top).

Pyridine having an industrial use as a denaturant is particularly concerning for water quality given that to denature a substance means to make said substance unconsumable. As mentioned above in the last quote pyridine is often used to denature ethyl-alcohol, which is the drinkable form of alcohol.

Heptadecane and hexadecane were both detected in one of the PEX brands on the 30th day of testing in an assessment of the water quality impact caused by PEX plumbing systems (Kelley et al., 2014). According to Pubchem,

“Heptadecane and hexadecane are both alkanes and as a result have similar health effects in humans that are exposed to them. These effects are that they are both deadly if inhaled, swallowed and have an acute and chronic hazard of combusting when in a gaseous state (Pubchem, 2018) (Fromm, 1998).”<sup>14</sup>

Chemicals detected in water that easily have the ability to combust aren't necessarily concerning for the ability to catch fire, but more so their deadly health effects associated with them when ingested. The primary concern in this paper of heptadecane and hexadecane being ingested is due to the findings of the compounds being found in potable water when plumbed through PEX plumbing systems.

Diethylhexyl-adipate (DEHA) was found in water that had been plumbed through PEX piping in research conducted by Kelly, Keven M, et al. It was consistently found in numerous different brands of piping that were being tested throughout the research. According to Pubchem,

---

<sup>14</sup> “Hexadecane.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, 16 Sept. 2004, [pubchem.ncbi.nlm.nih.gov/compound/11006#section=Related-Compounds](http://pubchem.ncbi.nlm.nih.gov/compound/11006#section=Related-Compounds).

Fromm, James Richard. “Introduction to the Alkanes.” *Explosives and Fertilizers*, May 1998, [www.3rd1000.com/chem301/chem301j.htm](http://www.3rd1000.com/chem301/chem301j.htm).

“Heptadecane.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, 16 Sept. 2004, [pubchem.ncbi.nlm.nih.gov/compound/12398#section=Safety-and-Hazards](http://pubchem.ncbi.nlm.nih.gov/compound/12398#section=Safety-and-Hazards).

“Diethylhexyl-adipate is a colorless to straw-colored liquid that floats on water and has a mild odor. It is a serious eye, skin irritant and is a known carcinogen. Along with being carcinogenic it is very toxic to aquatic life and the environment with long lasting effects. DEHA is combustible when it is exposed to a heat or flame making it that much more hazardous (Pubchem, 2018).”<sup>15</sup>

Since, DEHA has been consistently detected in research conducted on PEX piping’s health effects and isn’t the only carcinogen found in PEX piping being used for potable water it is important to take any health effects found from Diethylhexyl-adipate seriously especially because of how it reacts to heat. When using potable water in a home and a tenant uses the hot water the average temperature is anywhere from 120-140 degrees Fahrenheit. This raises the concern regarding DEHA being found in potable water systems that use PEX piping.

As previously mentioned in this paper trihalomethane’s (THM’s) are a class of contaminants that have been found in water quality research of CPVC piping when chlorine is used to clean drinking water. According to the National Groundwater Association,

“Trihalomethane’s are a group of four main chemicals that are commonly known for being a byproduct of chlorine based disinfectants. The four main chemicals that are found in water quality research associated with THM’s are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. These chemicals are mainly used to control the amount of microbial contaminants in drinking water, but are also commonly used as refrigerants (National Groundwater Association, 2018).”<sup>16</sup>

---

<sup>15</sup> “Diethylhexyl Adipate.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, 26 Mar. 2005, [pubchem.ncbi.nlm.nih.gov/compound/7641#section=Health-Hazard](https://pubchem.ncbi.nlm.nih.gov/compound/7641#section=Health-Hazard).

<sup>16</sup> “Trihalomethanes – Wellowner.org.” *Wellowner.org*, National Groundwater Association, 2018, [wellowner.org/water-quality/trihalomethanes/](https://wellowner.org/water-quality/trihalomethanes/).

Researching the affects, quantity and occurrences of THM's in potable water that is plumbed through plastic piping is an important aspect in fully understanding the risks associated with using plastics for potable water. One of the most alarming facts about THM's occurrence in water being plumbed through plastic piping is how the chlorine reacts with the CPVC piping. Chlorine is a common chemical used to disinfect public drinking water, which paired with the increase of plastic piping being used in developing urban areas, causes a human health hazard that is easily avoidable with some planning. Understanding and being able to prevent these adverse health effects is why this paper covers trihalomethanes and their health effects.

According to the Water Research Center,

“The four THM's listed above are all Cancer Group B carcinogens, which means that they have all been proven to give cancer to laboratory animals. These THM's are commonly found in drinking water that has used water chlorination to clean it and can be found in higher concentration if the chlorinated water is plumbed through a CPVC water system. Most THM's found in potable water have been determined to have the potential to damage the fertility of a pregnant mom and harm an unborn child (PubChem, 2018).”<sup>17</sup>

Out of the four previously mentioned THM's, chloroform stands out from the others because of its frequency in being detected in water quality research. Along, with how often it has been detected in testing it also has the highest risk of harming future offspring and their mothers.

Out of the ingredients that are used by the Hercules Chemical Company in their Oatey Heavy Duty CPVC Orange Cement and their Oatey Purple Primer cyclohexanones health effects

---

<sup>17</sup> “Chloroform and Bromoform.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, 2018, [pubchem.ncbi.nlm.nih.gov/compound/chloroform#section=GHS-Classification](https://pubchem.ncbi.nlm.nih.gov/compound/chloroform#section=GHS-Classification).

were the most alarming. This is because it the only chemical listed in those products that has the potential to cause harm to future offspring. According to Pubchem,

“Cyclohexanone is an oily colorless liquid with an odor resembling acetone and peppermint. It has a low boiling point, which qualifies it as a volatile organic compound (VOC). Along with, being a VOC it also has thirteen different GHS Hazard Statements. Most of the hazard statements for cyclohexanone briefly talk about the flammability and the potential toxicity it has if ingested. Two of the more serious hazard statements for the health of future generations is H361 and H341. H361 is defined by having the potential to damage the fertility of a human and the fertility of an unborn child and H341 is defined by a chemical having the ability to cause genetic defects (PubChem, 2018).”<sup>18</sup>

Cyclohexanone having a vast quantity of Global Hazard Statements (GHS) is important to helping determine the scope of its potential health effects. This is in part because of how universally used the GHS labeling and classification system is and how since its beginning it has had prominence in classifying potentially harmful chemicals.

#### **Determination from Findings (Conclusion):**

Due to a majority of the chemicals that have been detected in water quality research for PEX and CPVC piping having adverse health effects it is important to think twice about installing this material for potable water. This is especially true for cases where there is likely to be repeated long-term exposure to unknowing people. A common precursor to getting cancer or having life altering defects from ingesting toxic chemicals and carcinogens is having multiple

---

<sup>18</sup> “Cyclohexanone.” *National Center for Biotechnology Information. PubChem Compound Database*, U.S. National Library of Medicine, [pubchem.ncbi.nlm.nih.gov/compound/cyclohexanone#section=Safety-and-Hazards](https://pubchem.ncbi.nlm.nih.gov/compound/cyclohexanone#section=Safety-and-Hazards).

avenues where these potential health hazards combine together to make what health experts consider a cancer cocktail. Throughout this research paper there have been 10 plus different chemicals found in PEX and 15 plus detected in CPVC during water quality research. These chemicals health effects range from headaches and nausea to cancer and birth defects in children. The previously listed side-effects from the chemicals that have been detected in the water quality research are alarming in and of themselves. An important issue that factors into the recommendation of not using CPVC and PEX piping for potable water is how many chemicals and carcinogenic pollutants humans are exposed on a daily basis and throughout their lifetime.