CHLORINE DIOXIDE AND PLASTIC HOT- AND COLD- WATER PLUMBING DISTRIBUTION PIPES

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105 Decker Court • Suite 825 • Irving, Texas 75062 • 469.499.1044 • www.plasticpipe.org

Foreword

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and by developing design aids and reports to help engineers, code officials, specifying groups, contractors, and users.

The purpose of this technical note is to provide information regarding chlorine dioxide (ClO_2) and plastic hot- and cold-water plumbing distribution pipes.

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The Plastics Pipe Institute, Inc.

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TABLE OF CONTENTS

CHLORINE DIOXIDE AND PLASTIC HOT- AND COLD-WATER PLUMBING DISTRIBUTION PIPES

1.0 INTRODUCTION

This PPI Technical Note focuses on the application of chlorine dioxide within buildings and its potential effects on the following plastic hot- and cold-water plumbing distribution pipe materials:

- CPVC: *chlorinated polyvinyl chloride*
- PEX: *crosslinked polyethylene*
- PE-RT: *polyethylene of raised temperature resistance*
- PP-R: *polypropylene random copolymer*
- PP-RCT: *polypropylene random copolymer with modified crystallinity & temperature resistance*

Currently, limited North American industry data is publicly available to predict the impact that chlorine dioxide may have on specific plumbing distribution pipe materials. This Technical Note addresses this topic based on data that has been collected through an extensive analysis of published research combined with the experience and expertise of PPI members.

2.0 POTABLE WATER DISINFECTION METHODS

The majority of public water systems in North America use one or more chemical disinfectants to treat raw surface or groundwater for potable use. In the United States and Canada, the two disinfectants most commonly used in public potable water systems are free chlorine and chloramines and they have proven to be safe and effective methods for keeping our water safe.

Chlorine is typically supplied in a liquid form as sodium hypochlorite, the same chemical found in bleach. It is also available in gas form. Chloramine is formed when ammonia is added to water that has been first treated with chlorine.

Approximately 99% of disinfected potable water systems in the US use free chlorine or chloramine as the disinfectant. Industry research, as published in PPI documents[1] and various research papers[2], indicates that, when used in hot- and cold-water plumbing distribution applications, water services, building supply lines, and other related applications, the plastic piping materials listed in Section 1.0 have proven resistance to exposure to these disinfectants even under hot-water operating conditions.

[1] TN-53 - Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications (plasticpipe.org)

[2] *ASTM F2023 White Paper - Jana Laboratories Oct. 30, 2009*

A less commonly used disinfectant is chlorine dioxide (ClO_2). According to publicly available data from various sources, while chlorine dioxide is commonly used as a primary water disinfectant in water treatment plants, this disinfectant is used as a secondary (i.e., residual) disinfectant in fewer than 1% of the public potable water systems in the United States. For information about the frequency of use of chlorine dioxide in public water systems, see **Appendix A**.

The US EPA has set the maximum level of chlorine dioxide for potable water at 0.8 parts per million (ppm). In public water systems treated with chlorine dioxide, the actual residual level of chlorine dioxide that reaches buildings is typically diminished to an extent, depending on water age, water temperature, distance from the treatment plant, piping material, organic matter in the water, and other factors.

Note 1: For more information about the use of HDPE pipe in municipal water systems, please see PPI document "Use of Chlorine Dioxide & HDPE Pipe for Potable Water Systems"

3.0 USAGE OF CHLORINE DIOXIDE IN POTABLE WATER SYSTEMS WITHIN BUILDINGS

Legionella has been a topic of much research in recent years, with experts in the public health and plumbing fields focusing on piping designs that eliminate dead-legs and stagnant water[3]**.** Research indicates that bacterium *Legionella pneumophila* can grow in water between 68°F and 120°F (20°C to 48°C), with an ideal growth range of 85°F to 110°F (29°C to 43°C)[4].

While chlorine dioxide is used rarely as a secondary (i.e., residual) water disinfectant in public potable water systems[5, 6], in certain types of large facilities such as hospitals, nursing homes, hotels, apartment buildings, and large office buildings, chlorine dioxide is sometimes added to plumbing distribution systems to treat or control outbreaks of bacteria such as *Legionella* which can occur in these systems.

In such facilities, following outbreaks of *Legionella* or other pathogens, specialized chlorine dioxide generation devices can be added to the plumbing distribution systems to inject chlorine dioxide in measured doses directly into the system before hot water is delivered throughout the building.

[3] *Designing to Combat Legionella: Proper design of domestic water systems and use of standards are key to mitigating Legionella bacteria in facilities*
https://www.phcppros.com/articles/15885-designing-to-combat-legionella
[4] *Controlling legionella in potable Water Systems – CDC*
https://www.cdc.gov/legionella/wmp/control-toolkit/potable-water-systems.html
[5] *Examination of the Relative Oxidative Aggressiveness of the Common Potable Water Disinfectants of Chlorine, Chloramines and Chlorine Dioxide on PEX Pipe Materials – Jana Laboratories*
[6] *Understanding Community Water System Disinfection Practices in the United States*
https://awwa.onlinelibrary.wiley.com/doi/epdf/10.1002/awwa.1746

Chlorine dioxide can also be purchased in drums and injected into the system as needed.

Chlorine dioxide is used in different concentrations than free chlorine or chloramines and has a different mechanism of attack on the various materials and substances to which it is exposed. Chlorine dioxide is a dissolved gas and is highly volatile and efficient as an oxidizing agent for disinfection [7].

The injection of chlorine dioxide into the plumbing distribution system within buildings may be occasional (i.e., as needed), such as to treat an outbreak, or the process of injecting chlorine dioxide may be maintained for recurring or permanent treatment of the system, especially in large facilities with complex potable water distribution layouts where persistent biofilms are established within metallic piping components and *Legionella* outbreaks are recurring. Therefore, the exposure (e.g., concentration, time, and temperature) of piping materials to chlorine dioxide can vary significantly.

4.0 EFFECTS OF CHLORINE DIOXIDE ON PLUMBING DISTRIBUTION PIPING MATERIALS

Chlorine dioxide water treatment can be aggressive to most plumbing distribution materials, including metallic piping materials such as copper, which can impact the long-term performance. Chlorine dioxide may also have an effect on elastomeric materials[8] such as seals and gaskets which may be used in pumps and appurtenances (e.g., valves).

PPI's investigation into this topic has found that multiple research teams around the world have performed various types of laboratory testing to evaluate the effects of chlorine dioxide on piping materials of copper[9], steel[9], PEX[10], PE-RT[9], and PP-R[9, 11].

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[7] *Project 09-1190 Technical Report: Usage and Effects of Chlorine Dioxide on PEX Plumbing and Water Distribution Systems in North America* https://plasticpipe.org/common/Uploaded%20files/1-PPI/Divisions/Building%20and%20Construction/Division%20Publications/BCD%20Technical%20Literature/Jana/Jana%20Report%2009-1190%20-%20Usage%20and%20Effects%20of%20Chlorine%20Dioxide%20on%20PEX%20Plumbing.pdf

[8] *Degradation of Polymer & Elastomer Exposed to Chlorinated Water—A Review* https://www.scirp.org/journal/paperinformation.aspx?paperid=109745

[9] *Chlorine Dioxide Degradation Issues on Metal and Plastic Water Pipes Tested in Parallel in a Semi-Closed System, Vertova, Miani, Lesma, Rondinini, Minguzzi , Falciola and Ortenzi (2019)* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6888174/

[10] *An examination of the relative impact of common potable water disinfectants (chlorine, chloramines, and chlorine dioxide) on plastic piping system components – Jana Laboratories*

[11] *Investigation and Comparison of Accelerated Pipe Testing Data with True Pipe Installations in Contact with Chlorine Dioxide As Disinfectant* https://www.pe100plus.com/PPCA/Investigation-and-comparison-of-accelerated-pipe-testing-data-with-true-pipe-installations-in-contact-with-chlorine-dioxide-as-disinfectant-p615.html

While such testing was experimental in nature and did not accurately simulate the exposure of hot treated flowing water through pressurized piping systems, the published results indicate that chlorine dioxide has the potential to reduce the service life of most plumbing distribution materials to below normal expected lifetimes.

According to PPI's investigation, published research regarding chlorine dioxide was not available for PP-RCT and CPVC pressure piping materials at the time of publication of this Technical Note. Evaluation by PPI member firms indicates that polypropylene (PP)-based materials cannot adequately withstand ClO_2 long-term exposure at levels used for hot- and cold-water plumbing systems. Evaluation by PPI member firms indicates that chlorine dioxide is not known to be aggressive to CPVC at elevated temperatures of 200°F (93°C) and below.

For many plumbing distribution piping materials, the actual effects of chlorine dioxide are dependent upon the combination of factors such as the concentration of chlorine dioxide and any other water treatment chemicals, water temperature, system pressure, water velocity, and other potential variables which are unique to each plumbing piping system. Data does indicate that chlorine dioxide has the potential to be substantially more aggressive than free chlorine or chloramine, even at comparatively lower concentrations[9].

5.0 PLUMBING DESIGN RECOMMENDATIONS

PPI recognizes that plumbing distribution system design is a dynamic challenge with several interactive variables such as fixture demands and water flow rates, pipe diameters and lengths, water temperatures, recirculation velocities, conservation demands, and other factors.

Designers of plumbing systems are recommended to follow local regulations (e.g., plumbing codes) and the following industry publications:

- ASHRAE Guideline 12 *Managing the Risk of Legionellosis Associated with Building Water Systems*
- ASHRAE 188 *Legionellosis: Risk Management for Building Water Systems*
- ASHRAE 514 *Risk Management for Building Water Systems: Physical, Chemical and Microbial Hazards*
- IAPMO Uniform Plumbing Code (UPC) Appendix N *Impact of Water Temperature on the Potential for Scalding and Legionella Growth*
- ASPE *Engineering Methodologies to Reduce the Risk of Legionella in Premise Plumbing Systems*

6.0 CONCLUSION

Based on the available published information, the usage of chlorine dioxide as a secondary (i.e., residual) water disinfectant through public (treated) water in the United States is rare. Therefore, the likelihood of potable water treated with chlorine dioxide and passing through water service lines and building supply lines and into plumbing distribution systems is very low.

Based on the data that has been analyzed by The Plastics Pipe Institute regarding the effects of chlorine dioxide on piping materials in hot- and cold-water plumbing systems, PPI recommends caution when considering the use of chlorine dioxide as a chemical disinfectant to treat water for the control of *Legionella* or other pathogens.

PPI recommends contacting each piping system supplier for guidance related to the use of their pipe and fitting material(s) in circumstances where chlorine dioxide has been selected as the disinfection chemical.

This recommendation is based on the lack of industry research and data related to the effects of chlorine dioxide on metallic and most plastic piping materials in North American plumbing systems.

APPENDIX A: USAGE OF CHLORINE DIOXIDE IN NORTH AMERICAN POTABLE WATER SYSTEMS

Several studies have reported that chlorine dioxide (ClO_2) is used in fewer than 1% of the potable water distribution piping systems in the U.S. as a secondary water disinfectant in the delivered water leaving the treatment plant.

According to the July 2010 Jana Laboratories report 09-1190 *Usage and effects of Chlorine Dioxide on PEX Plumbing and Water Distribution System in North America*, "Jana examined the usage pattern of Chlorine Dioxide in North America to determine the potential impact of Chlorine Dioxide residuals within the distribution network on… piping distribution and plumbing systems."

Findings of this report included:

- "Chlorine dioxide is used in a limited number of potable water systems in North America. In the United States, it is estimated that it is used for oxidation and/or primary disinfection in less than 1% of community water systems (or 600 systems) overall. As a secondary disinfectant, it is estimated that less than 200 systems use chlorine dioxide for the maintenance of residual in the distribution system, primarily in conjunction with chlorine and/or chloramines."

- "Typical chlorine dioxide levels in distribution systems in the United States appear to be less than 0.40 mg/L, with two-thirds of systems carrying a chlorine dioxide residual of less than 0.15 mg/L. The actual values are expected to be lower for the bulk of the distribution system due to decay of the residual along the distribution network. The residual level is projected to be even lower in household plumbing systems due to further potential dissipation and decay of the residual in the household hot-water tank."

"There does not currently appear to be a significant trend toward increased chlorine dioxide usage. However, the increased focus on the control and monitoring of disinfection by products produced by traditional chlorination practices may continue to promote the use of alternative disinfectants such as chlorine dioxide in the future. It is recommended that the industry continue monitoring trends to identify any significant shifts in usage patterns in the future."

The 2021 *AWWA Journal* article "**Understanding Community Water System [CWS] Disinfection Practices in the United States**" contains recent information about the use of chlorine dioxide as a water disinfectant. https://awwa.onlinelibrary.wiley.com/doi/epdf/10.1002/awwa.1746

Findings of this report included:

- “According to USEPA’s Safe Drinking Water Information System (SDWIS) Federal Reporting Services, as of July 2020 there were more than 145,000 active public water systems in the United States…”
- “Merging the data allowed us to examine both primary and secondary disinfection practices by state, system size, primary source, and other water system features.”
- The following analysis includes a total of 3,823 small, medium, large, and very large CWSs, representing 7.7% of the total current number of all five size categories of CWSs (including very small systems) in the United States according to SDWIS.”
- These sample sizes are large enough to indicate a 90% confidence that the population proportions—i.e., the proportions of the CWS population using the various primary and secondary disinfection strategies—are statistically significant (margin of error of ±2.5%) for the four largest USEPA CWS size categories.”
- “Free chlorine” (undefined by USEPA in the UCMR4 documentation, but includes elemental chlorine gas as well as offsite and onsite generated sodium hypochlorite) is by far the most utility-reported residual disinfectant for very large, large, medium, and small CWSs.”
- “Chloramines are the second most reported secondary disinfectant in large and very large CWSs…We estimate that around 18% of CWSs, excluding very small systems, use chloramines for secondary disinfection.”
- “Many CWSs reported using multiple disinfectants and oxidants over the course of a given year for centralized treatment of drinking water, including … Chlorine dioxide for taste and odor control.”
- "Large systems are far more likely to use free chlorine as a secondary disinfectant than any other size class…”
- “Alternative disinfectants like chlorine dioxide, ozone, and UV radiation appear to be gaining greater use in some cases—especially in combination with chlorine and chloramine technologies—for secondary disinfection.”

The graphs in Figure 4 of this study contain the specific estimates for chlorine dioxide usage as a secondary disinfectant, as shown in **Table A1**.

Table A1: Secondary Disinfectant Data from 2021 *AWWA Journal* article "Understanding Community Water System Disinfection Practices in the United States", Figure 4

System Size	Total No. of Reporting Systems	No. of Reporting Systems Using ClO_2	Ratio of Systems Using ClO_2
Very large systems	373	4	1.1%
Large systems	2,983	18	0.6%
Medium systems	296	4	1.4%
Small systems	171	6	3.5%
Totals	**3,823**	**32**	**0.83%**