



## Fluoridation of Drinking Water and Corrosion of Pipes in Distribution Systems

The concern that using fluorosilicate additives to fluoridate drinking water causes water system pipes to corrode is not supported by science. At the level recommended by the U.S. Public Health Service for fluoridation of public water supplies (0.7 to 1.2 mg/L, or parts per million), the fluoride ion has little influence on either corrosion or on the amounts of corroded metals released into the water. Fluorosilicates contribute to better water stability with less potential for corrosion, because silica stabilizes the pipe surface.

### Causes of corrosion in water system pipes

Pipes used to distribute drinking water are made of plastic, concrete, or metal (e.g., steel, galvanized steel, ductile iron, copper, or aluminum). Plastic and concrete pipes tend to be resistant to corrosion. Metal pipe corrosion is a continuous and variable process of ion release from the pipe into the water. Under certain environmental conditions, metal pipes can become corroded based on the properties of the pipe, the soil surrounding the pipe, the water properties, and stray electric currents. When metal pipe corrosion occurs, it is a result of the electrochemical electron exchange resulting from the differential galvanic properties between metals, the ionic influences of solutions, aquatic buffering, or the solution pH.

For corrosion of metal water pipes to occur, an electrochemical cell must be present. An electrochemical cell can be thought of as a battery, with an electric current between a positive potential (anode) and a negative potential (cathode). The corrosive electrical potential is typically created by differences in the types of chemicals in soil or the surface of the metal pipe.

### Galvanic properties between dissimilar metals

All metals have slightly different properties, and galvanic differences are the tendency of one metal to release electrons to another metal. The galvanic series of metals is the hierarchy of which metals will release their electrons to other metals. Metals lower in the galvanic series more negatively charged will sacrifice their electrons to metals higher in the series. An example that many people are familiar with is zinc galvanizing of steel, where the zinc surface coating protects the steel from rusting. The galvanic interaction of different metals has a significant role in pipe corrosion, because many commercial metals are alloys of various metals. Therefore, the interior or exterior surfaces of the pipe can provide locations for an electrochemical cell which can start the process of pipe corrosion.

### Influence of ionic impurities on corrosion

Chemical additives are added to water during the water treatment process. More than 40 chemical additives can be used to treat drinking water.

Many of these commonly used additives are acidic, such as ferric chloride and aluminum sulfate, which are added to remove turbidity and other particulate matter. Various chlorine disinfectants, also act as acids and have the potential to reduce pH, alkalinity, and buffer intensity. These acidic water treatment additives can interfere with corrosion protection. The amounts of each of these other additives used in water treatment typically are 5 to 10 times the amount of the fluoride additive for fluoridation of drinking water; therefore, their potential effect on the factors affecting water corrosivity is proportionately greater.

The fluoride ion interacts weakly with common metals in plumbing materials and the American Water Works Association Research Foundation has reported that fluoride ions contribute to corrosion to the same extent as at the same concentration chloride and sulfate ions. Most of the fluoride interaction will be to form a precipitate that will be incorporated into pipe scale (the deposits on the inside of pipes that are mostly calcium) or removed by routine system flushing. Therefore, the corrosive influence of fluoride in drinking water is not significant compared with other ionic influences. (*Internal Corrosion of Water Distribution Systems*, 2nd Edition, American Water Works Association Research Foundation; 1996).

### **Lead and copper in drinking water**

Lead and copper are rarely detected in most drinking water supplies. However, these metals are a concern to consumers. Because some household plumbing fixtures may contain lead or copper, corrosive waters may leach (pick up) lead and copper from household plumbing pipes after entering a home. This is a greater issue for older houses (i.e., houses built before 1981, if the plumbing system has not been replaced) than for newer houses. The most common reason for water utilities to add corrosion inhibitors is to avoid lead and copper corrosion with older homes, and the second most common reason is to minimize corrosion of pipes in the distribution system.

When waters are naturally corrosive, many substances have a tendency to dissolve in water. Because of this tendency, the U.S. Environmental Protection Agency (EPA) has issued a Lead and Copper Rule that requires all water systems to periodically monitor a set number of samples for lead and copper levels at different locations. This is based on population size and previous tests of lead and copper content. If a certain percentage of the samples exceeds the “action level,” the utility system must take corrective actions to control the potential for corrosion in the water system. This often involves the addition of corrosion inhibitors.

### **Water properties influencing corrosion**

Many water quality factors affect corrosion of pipes used in water distribution, including the chemistry and characteristics of the water (e.g., pH, alkalinity, biology), salts and chemicals that are dissolved in the water, and the physical properties of the water (e.g., temperature, gases, solid particles). The tendency of water to be corrosive is controlled principally by monitoring or adjusting the pH, buffer intensity, alkalinity, and concentrations of calcium, magnesium, phosphates, and silicates in the water. Actions by a water system to address these factors can lead to reduced corrosion by reducing the potential for the metal surface to be under the influence of an electrochemical potential.

Waters differ in their resistance to changes in their chemistry. All waters contain divalent metals such as calcium and magnesium that cause water to have properties characterized as hardness and softness. If a water is “hard,” it is less likely to “leach” metals from plumbing pipes but often leaves a deposit on the inside of the pipe, while if a water is “soft” it has less of a tendency to leave deposits on the inside of plumbing pipes. If a water is soft, then it has low hardness. Some people in communities with hard water will use water softeners. Water systems adjust the hardness

and softness of water because of these tendencies and also for taste considerations.

Alkalinity is a characteristic of water related to hardness. Waters with low hardness, or alkalinity (less than 50 mg/L as calcium carbonate), are more susceptible to the factors affecting corrosion; such systems will typically use additives that can prevent corrosion (corrosion inhibitors) to comply with federal and state regulations.

### **Corrosion inhibitors**

Chemical additives used for corrosion control include phosphates, silicates, and those affecting the carbonate system equilibrium (amount of carbonate in the system), such as calcium hydroxide, sodium hydroxide, sodium bicarbonate, and sodium carbonate. Corrosion inhibitors are commonly used to address the corrosion influence of acidic water treatment additives. The most common forms of fluoride for approximately 92% of the drinking water that is fluoridated are fluorosilicates, as either fluorosilicic acid or sodium fluorosilicate. Using fluorosilicates to fluoridate drinking water adds silica, a corrosion inhibitor, to the water and increases the silicates available for stabilizing the pipe surface, which contributes to reduced corrosion.

### **Many substances with fluoride have low solubility in water**

The water fluoridation additives that are used to increase the fluoride content of water are carefully chosen for their favorable solubility in water. Many divalent metals or heavy metal substances that have an ionic association with fluoride have poor solubility. These include calcium and magnesium cations, as well as many of the heavy metal ions such as nickel and lead. As the pH of the water increases to basic levels, these compounds will precipitate out of the water and be incorporated into a calcium-carbonate scale that will form on the pipe surface.

### **Soft waters with low buffering**

A special case exists when the water source is a high-purity groundwater with little natural buffering. Buffering is the ability of a water to resist pH changes when acids or bases are added to it. Low natural buffering is not typical for community water systems. In such cases, adding acidic chemical additives, such as fluorosilicic acid or sodium fluorosilicate, could potentially result in a slight increase in corrosion because of the influence of the acid additive. However, the acidity added by such fluoride additives would be less than the acidity introduced from chlorine disinfectants. Any change in water properties is typically addressed by adding a corrosion inhibitor or adjusting the pH. This would be a standard water system practice, since water systems regularly monitor for compliance with the U.S. E.P.A. Lead and Copper Rule and take corrective action, particularly if the regulatory action levels for lead and copper are being approached.

### **Additional resources**

Urbansky ET, Schock MR. Can fluoridation affect lead (II) in potable water? hexafluorosilicate and fluoride equilibria in aqueous solution. *International Journal Environmental Studies* 2000;57:597–637.

The following publications provide more information on corrosion of water pipes and may be purchased from the **American Water Works Association** (<http://www.awwa.org>).\*

- *Internal Corrosion of Water Distribution Systems*, 2nd Edition No. 90508.
- *Peabody's Control of Pipeline Corrosion*, 2nd Edition, No. 20487.
- *External Corrosion-Introduction to Chemistry and Control (M27)*, 1st Edition No. 30027.

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