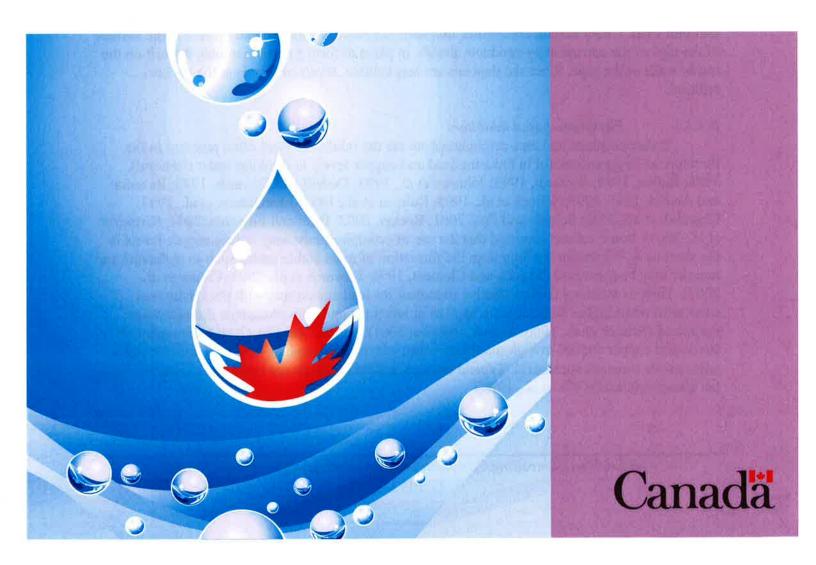# Guidance on Controlling Corrosion in Drinking Water Distribution Systems

Canada

B.4.3   Corrosion inhibitors

Two predominant types of corrosion inhibitors are available for potable water treatment: phosphate- and silicate-based compounds. The most commonly used inhibitors include orthophosphate, polyphosphate (typically, blended polyphosphates) and sodium silicate, each with or without zinc.

The successful use of corrosion inhibitors is very much based on trial and error and depends on both the water quality and the conditions prevailing in the distribution system. The effectiveness of corrosion inhibitors is largely dependent on maintaining a residual of inhibitors throughout the distribution system and on the pH and alkalinity of the water.

Measuring the concentration of inhibitors within the distribution system is part of any good corrosion control practice. Generally, direct correlations between the residual concentration of inhibitors in the distribution system and the levels of lead, copper or iron at the tap are not possible.

Health Canada recommends that, where possible, water utilities and consumers choose drinking water additives, such as corrosion inhibitors, that have been certified as conforming to the applicable NSF/ANSI health-based performance standard or equivalent. Phosphate- and silicate-based corrosion inhibitors are included in NSF/ANSI Standard 60, Drinking Water Treatment Chemicals—Health Effects (NSF International, 2005). These standards have been designed to safeguard drinking water by ensuring that additives meet minimum health effects requirements and thus are safe for use in drinking water.

Recently, the use of tin chloride as a corrosion inhibitor for drinking water distribution systems has been added to NSF/ANSI Standard 60. However, very few experimental data on this inhibitor exist. Under certain conditions, this inhibitor reacts with the metal present at the surface of the pipe or the corrosion by-products already in place to form a more insoluble deposit on the inside walls of the pipe. Since the deposits are less soluble, levels of metals at the tap are reduced.

B.4.3.1   Phosphate-based inhibitors

Orthophosphate and zinc orthophosphate are the inhibitors most often reported in the literature as being successful in reducing lead and copper levels in drinking water (Bancroft, 1988; Reiber, 1989; Boffardi, 1993; Johnson et al., 1993; Dodrill and Edwards, 1995; Rezania and Anderl, 1995, 1997; Schock et al., 1995; Boireau et al., 1997; MacQuarrie et al., 1997; Churchill et al., 2000; Schock and Fox, 2001; Becker, 2002; Dudi and Edwards, 2004; Kirmeyer et al., 2004). Some authors reported that the use of orthophosphate may reduce copper levels in the short term, but that in the long term the formation of more stable scales such as malachite and tenorite may be prevented (Schock and Clement, 1998; Edwards et al., 2001; Cantor et al., 2003). There is evidence that ineffective treatment for lead and copper with phosphate was successful when higher dosages were applied or when pH and orthophosphate dosages were optimized (Schock et al., 1996; Schock and Fox, 2001). Schock and Fox (2001) demonstrated successful copper control in high-alkalinity water with orthophosphate when pH and alkalinity adjustments were not successful. Typical orthophosphate residuals are between 0.5 and 3.0 mg/L (as phosphoric acid) (Vik et al., 1996).

polyphosphate generally reduced soluble copper concentrations, copper concentrations significantly increased at pH 7.2 and alkalinity of 300 mg/L as calcium carbonate, since polyphosphates hinder the formation of the more stable malachite scales.

B.4.3.2 Silicate-based inhibitors

Only limited data are available on the impact of sodium silicate on lead and copper solubility. As sodium silicate is a basic compound, it is always associated with an increase in pH, making it difficult to attribute reductions in lead or copper concentrations to sodium silicate alone when an increase in pH may also result in a decrease in lead and copper concentrations.

A study conducted by Schock et al. (2005a) in a medium-sized utility was able to solve problems from iron in source water as well as lead and copper leaching in the plumbing system. The problems were solved simultaneously through the addition of sodium silicate with chlorination. Sodium silicate was added to the three wells that contained elevated levels of iron and manganese and that serviced homes containing lead service lines. A fourth well required only chlorination and pH adjustment with sodium hydroxide. At the three wells, an initial silicate dose of 25–30 mg/L increased the pH from 6.3 to 7.5 and immediately resulted in 55% and 87% reductions in lead and copper levels, respectively. An increase in the silicate dose to 45–55 mg/L increased the pH to 7.5 and resulted in an even greater reduction in the lead and copper levels (0.002 mg/L and 0.27 mg/L, respectively). It is also interesting to note that the quality of the water after treatment, as it relates to colour and iron levels, was equal or superior to that prior to treatment. However, the use of sodium silicate alone was not shown conclusively in the literature to reduce lead or copper concentrations.

Between 1920 and 1960, several authors reported reductions in red water occurrences when using sodium silicate (Tresh, 1922; Texter, 1923; Stericker, 1938, 1945; Loschiavo, 1948; Lehrman and Shuldener, 1951; Shuldener and Sussman, 1960). However, a field study conducted in the distribution network of the City of Laval, Quebec, in the summer of 1997 revealed no beneficial effects of using low levels of sodium silicate (4–8 mg/L; pH range of 7.5–8.8) to control iron concentrations in old cast iron and ductile iron pipes. A camera inserted inside a cast iron pipe (1) prior to the injection of sodium silicate, (2) prior to the injection of sodium silicate and immediately following the mechanical removal of the tubercles and (3) after 5 months of sodium silicate use revealed that no reductions in the degree of tuberculation or the prevention of the formation of tubercles were found using sodium silicates at these low concentrations (Benard, 1998). Although very few studies have proven the efficiency of sodium silicates as corrosion inhibitors or their true mechanism of action, manufacturers recommend that a large dose of sodium silicate be initially injected to form a passivating film on the surface of the pipe. Manufacturers recommend concentrations ranging from 20 to 30 mg/L; once the film is formed, concentrations from 4 to 10 mg/L are recommended to maintain this film on the surface of the pipes (Katsanis et al., 1986).

Experiments that studied effects of high levels of silica at different pH found that at pH 8, silica may play a role in the stabilization of cement pipe matrix by interfering with the formation of protective ferric iron films that slow calcium leaching (Holtschulte and Schock, 1985).