

Tech Brief

A NATIONAL DRINKING WATER CLEARINGHOUSE FACT SHEET

Corrosion Control

Summary

Corrosion occurs because metals tend to oxidize when they come in contact with water, resulting in the formation of stable solids. Corrosion in water distribution systems can impact consumers' health, water treatment costs, and the aesthetics of finished water.

Various methods can be used to diagnose, evaluate, and control corrosion problems. Techniques for controlling it include distribution and plumbing system design considerations, water quality modifications, corrosion inhibitors, cathodic protection, and coatings and linings.

Corrosion Can Cause System Problems

What problems does corrosion cause?

Corrosion can cause higher costs for a water system due to problems with:

- decreased pumping capacity, caused by narrowed pipe diameters resulting from corrosion deposits;
- decreased water production, caused by corrosion holes in the system, which reduce water pressure and increase the amount of finished water required to deliver a gallon of water to the point of consumption;
- water damage to the system, caused by corrosion-related leaks;
- high replacement frequency of water heaters, radiators, valves, pipes, and meters because of corrosion damage; and
- customer complaints of water color, staining, and taste problems.

How is corrosion diagnosed and evaluated?

The following events and measurements can indicate potential corrosion problems in a water system:

Consumer complaints: Many times a consumer complaint about the taste or odor of water is the first indication of a corrosion problem. Investigators need to examine the construction materials used in the water distribution system and in the plumbing of the complainants' areas. (See table on page 4.)

Corrosion indices: Corrosion caused by a lack of calcium carbonate deposition in the system can be estimated using indices derived from common

water quality measures. The Langelier Saturation Index (LSI) is the most commonly used measure and is equal to the water pH minus the saturation pH (LSI = pH water – pH saturation). The saturation pH refers to the pH at the water's calcium carbonate saturation point (i.e., the point where calcium carbonate is neither deposited nor dissolved). The saturation pH is dependent upon several factors, such as the water's calcium ion concentration, alkalinity, temperature, pH, and presence of other dissolved solids, such as chlorides and sulfates. A negative LSI value indicates potential corrosion problems.

Sampling and chemical analysis: The potential for corrosion can also be assessed by conducting a chemical sampling program. Water with a low pH (less than 6.0) tends to be more corrosive. Higher water temperature and total dissolved solids also can indicate corrosivity.

Pipe examination: The presence of protective pipe scale (coating) and the condition of pipes' inner surfaces can be assessed by simple observation. Chemical examinations can determine the composition of pipe scale, such as the proportion of calcium carbonate, which shields pipes from dissolved oxygen and thus reduces corrosion.

Can system design affect the potential for corrosion?

In many cases, corrosion can be reduced by properly selecting distribution and plumbing system materials and by having a good

engineering design. For example, water distribution systems designed to operate with lower flow rates will have reduced turbulence and, therefore, decreased erosion of protective layers. In addition, some piping materials are more resistant to corrosion in a specific environment than others. Finally, compatible piping materials should be used throughout the system to avoid electrolytic corrosion.

Other measures that help minimize system corrosion include:

- using only lead-free pipes, fittings, and components;
- selecting an appropriate system shape and geometry to avoid dead ends and stagnant areas;
- avoiding sharp turns and elbows in the distribution and plumbing systems;
- providing adequate drainage (flushing) of the system;
- selecting the appropriate metal thickness of piping, based on system flow and design parameters;
- avoiding the use of site welding without replacing the pipe lining;
- reducing mechanical stresses, such as flexing of pipes and “water hammer” (hydraulic pressure surges);
- avoiding uneven heat distribution in the system by providing adequate coating and insulation of pipes;
- providing easy access for inspection, maintenance, and replacement of system parts; and
- eliminating the grounding of electrical circuits to the system, which increases the potential for corrosion.

How can system corrosion be reduced?

Corrosion in a system can be reduced by changing the water’s characteristics, such as adjusting pH and alkalinity; softening the water with lime; and changing the level of dissolved oxygen (although this is not a common method of control). Any corrosion adjustment program should include monitoring. This allows for dosage modification, as water characteristics change over time.

pH adjustment: Operators can promote the formation of a protective calcium carbonate coating (scale) on the metal surface of plumbing by adjusting pH, alkalinity, and calcium levels. Calcium carbonate scaling occurs when water is oversaturated with calcium carbonate. (Below

the saturation point, calcium carbonate will redissolve; at the saturation point, calcium carbonate is neither precipitated nor dissolved. See the section on “corrosion indices,” page 1.) The saturation point of any particular water source depends on the concentration of calcium ions, alkalinity, temperature, and pH, and the presence of other dissolved materials, such as phosphates, sulfates, and some trace metals.

It is important to note that pH levels well suited for corrosion control may not be optimal for other water treatment processes, such as coagulation and disinfection. To avoid this conflict, the pH level should be adjusted for corrosion control immediately prior to water distribution, and after the other water treatment requirements have been satisfied.

Lime softening: Lime softening (which, when soda ash is required in addition to lime, is sometimes known as lime-soda softening) affects lead’s solubility by changing the water’s pH and carbonate levels. Hydroxide ions are then present, and they decrease metal solubility by promoting the formation of solid basic carbonates that “passivate,” or protect, the surface of the pipe.

Using lime softening to adjust pH and alkalinity is an effective method for controlling lead corrosion. However, optimum water quality for corrosion control may not coincide with optimum reduction of water hardness. Therefore, to achieve sound, comprehensive water treatment, an operator must balance water hardness, carbonate levels, pH and alkalinity, as well as the potential for corrosion.

Dissolved oxygen levels: The presence of excessive dissolved oxygen increases water’s corrosive activity. The optimal level of dissolved oxygen for corrosion control is 0.5 to 2.0 parts per million. However, removing oxygen from water is not practical because of the expense. Therefore, the most reasonable strategy to minimize the presence of oxygen is to:

- exclude the aeration process in the treatment of groundwater,
- increase lime softening,
- extend the detention periods for treated water in reservoirs, and
- use the correct size water pumps in the treatment plant to minimize the introduction of air during pumping.

What about the use of corrosion inhibitors?

Corrosion inhibitors cause protective coatings to form on pipes. Although they reduce corrosion, they may not totally arrest it. Therefore, the success of any corrosion inhibitor hinges upon the water operator's ability to:

- apply double and triple the design doses of inhibitor during initial applications to build a protective base coat that will prevent pitting; (Note that initial coatings typically take several weeks to form.)
- maintain continuous and sufficiently high inhibitor doses to prevent redissolving of the protective layer; and
- attain a steady water flow over the system's metal surfaces to allow a continuous application of the inhibitor.

There are several commercially available corrosion inhibitors that can be applied with normal chemical feed systems. Among the most commonly used for potable water supplies are inorganic phosphates, sodium silicates, and mixtures of phosphates and silicates.

Inorganic phosphates: Inorganic phosphate corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates, and bimetallic phosphates. Zinc, added in conjunction with polyphosphates, orthophosphates, or glassy phosphates, may help to inhibit corrosion in some cases.

Silicates: The effectiveness of sodium silicates depends on both pH and carbonate concentrations. Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity, and pH of less than 8.4. Typical coating maintenance doses of sodium silicate range from 2 to 12 milligrams per liter. They offer advantages in hot-water systems because of their chemical stability, unlike many phosphates.

Before installing any technology for delivering corrosion inhibitors, several methods or agents first should be tested in a laboratory environment to determine the best inhibitor and concentration for each water system.

Is cathodic protection an option?

Cathodic protection is an electrical method for preventing corrosion of metallic structures. However, this expensive corrosion control method is not practical or effective for protecting entire water systems. It is used primarily to

protect water storage tanks. A limitation of cathodic protection is that it is almost impossible for cathodic protection to reach down into holes, crevices, or internal corners.

Metallic corrosion occurs when contact between a metal and an electrically conductive solution produces a flow of electrons (or current) from the metal to the solution. The electrons given up by the metal cause the metal to corrode rather than remain in its pure metallic form. Cathodic protection stops this current by overpowering it with a stronger, external power source. The electrons provided by the external power source prevent the metal from losing electrons, forcing it to be a "cathode," which will then resist corrosion, as opposed to an "anode," which will not.

There are two basic methods of applying cathodic protection. One method uses inert electrodes, such as high-silicon cast iron or graphite, which are powered by an external source of direct current. The current impressed on the inert electrodes forces them to act as anodes, thus minimizing the possibility that the metal surface being protected will likewise become an anode and corrode. The second method uses a sacrificial anode. Magnesium or zinc anodes produce a galvanic action with iron, so that the anodes are sacrificed (or suffer corrosion), while the iron structure they are connected to is protected.

Are commercial pipe coatings and linings effective?

The nearly universal method of reducing pipe corrosion involves lining the pipe walls with a protective coating. These linings are usually mechanically applied, either when the pipe is manufactured or in the field before it is installed. Some linings can be applied even after the pipe is in service, but this method is much more expensive.

Mechanically applied coatings and linings differ for pipes and water storage tanks. The most common types of pipe linings include coal-tar enamels, epoxy paints, cement mortar, and polyethylene.

Water storage tanks are most commonly lined to protect the inner tank walls from corrosion. The most common types of water storage tank coatings and linings include coal-tar paints and enamels, vinyls, and epoxy.



Typical Water Quality Complaints That Might Be Due to Corrosion

Customer Complaint	Possible Cause
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of natural iron in raw water
Bluish stains on fixtures	Corrosion of copper lines
Black water	Sulfide corrosion of copper or iron lines or precipitations of natural manganese
Foul taste and/or odors	Byproducts from microbial activity
Loss of pressure	Excessive scaling, tubercle (buildup from pitting corrosion), leak in system from pitting or other type of corrosion
Lack of hot water	Buildup of mineral deposits in hot water system (can be reduced by setting thermostats to under 60 degrees C [140 degrees F])
Short service life of household plumbing	Rapid deterioration of pipes from pitting or other types of corrosion

Source: U.S. Environmental Protection Agency

Where can I find more information?

Information for this fact sheet was obtained from three primary sources: *Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities*, EPA/625/4-89/023; *Corrosion Manual for Internal Corrosion of Water Distribution Systems*, EPA/570/9-84/001; and *Corrosion in Potable Water Supplies*, EPA/570/9-83/013. All of these documents are free and may be ordered from the U.S. Environmental Protection Agency (EPA) Office of Research and Development by calling (513) 569-7562.

If these publications are no longer available from the EPA, call the National Drinking Water Clearinghouse (NDWC) at (800) 624-8301. A photocopied version of the 209-page document *Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities*, item #DWBKDM04, costs \$30.05. There is no charge for the other two documents listed above; however, postage charges apply to all orders.

Also, the NDWC's Registry of Equipment Suppliers of Treatment Technologies for Small Systems (RESULTS), version 2.0, is a public reference database that contains information about technologies—including those related to corrosion—in use at small water systems around the country. For further information about accessing or ordering RESULTS, call the NDWC at (800) 624-8301 or (304) 293-4191. You may also obtain more information from the NDWC's World Wide Web site at <http://www.ndwc.wvu.edu>.

For additional copies of "Tech Brief: Corrosion Control," item #DWBRPE52, or for a copy of the previously published "Tech Brief: Filtration," item #DWBRPE50, or "Tech Brief: Disinfection," item #DWBRPE47, call the NDWC at the number printed above.