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Drinking Water Problems: Corrosion

Mark L. McFarland, Tony L. Provin, and Diane E. Boellstorff*

Corrosion is one of the most common problems affecting domestic water supplies. Chemical processes slowly dissolve metal, causing plumbing pipes, fixtures and water-using equipment to deteriorate and fail. Corrosion can cause three types of damage:

- The entire metal surface gradually thins and red stains appear in iron or steel plumbing systems or blue-green stains in copper and brass plumbing systems (Fig. 1).

Figure 1. Corrosion at a connection on a water heater indicated by the blue-green color.

Figure 2. Pinhole leaks in copper tubing caused by internal corrosion.

- Deep pits appear that can penetrate pipe or tank walls. This type of corrosion may not add significant amounts of iron or copper to the water, but can eventually perforate a pipe or tank, and cause potentially major water damage to a home or business (Fig. 2).
- Copper or other metals oxidize in a process similar to the rusting of steel. It often reduces water flow through supply lines and destroys water valves and other water control surfaces, creating leaks inside and outside of valves and faucets. This type of corrosion is not necessarily caused by water chemistry, but by exposure to soil or other corrosive environments.

Professor and Extension Water Quality Coordinator, Professor and Extension Water Testing Laboratory Director, Assistant Professor and Extension Water Resources Specialist, Texas AgriLife Extension Service, The Texas A&M System

What health problems can corrosion cause?

Copper and lead can be toxic and can leach into tap water in older or in new homes. This leaching is caused by corrosion.

Copper contamination can cause gastrointestinal problems in the short term and damage the liver and kidneys over time.

Lead contamination can cause physical and mental development problems in children. In adults, it can lead to high blood pressure and kidney problems.

What levels are harmful?

The Environmental Protection Agency has established primary drinking water standards for copper and lead (*http://water.epa.gov/drink/contaminants/index.cfm*). The maximum allowable for copper is 1.3 milligrams/liter; the maximum allowable for lead is 0.015 milligrams/liter. Contaminants may be reported in milligrams/liter (mg/L) or parts per million (ppm); these units are equivalent.

Iron and zinc also are usually present and can cause water to have a metallic taste, but are not health concerns.

How do I know if there is a corrosion problem?

The most common symptoms of corrosive water are:

- Cold water tastes bitter at first use in the morning, and the taste improves after running the water for a few seconds.
- Blue-green stains in sinks and/or at the joints of copper piping.
- Water leaks in floor, wall or ceiling areas from pin-size or larger holes in metal pipes.

If you suspect that your water is corrosive, have it tested by a laboratory. Water-testing laboratories, including the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory, test irrigation and/or livestock water. Elevated copper, iron, or zinc in the water can indicate ongoing corrosion in a water system. However, these tests only indicate a potential problem; further testing is needed to determine the causes and severity of the corrosion potential.

Two common tests can determine if water is likely to be corrosive: the Langelier Saturation Index (LSI) and the Ryzner Stability Index (RSI).

In order to use the LSI, a laboratory must measure pH, electrical conductivity, total dissolved solids, alkalinity, and total hardness. The LSI is typically negative or positive and only rarely zero. Negative values predict that the water is more likely to be corrosive. Potentially corrosive water typically has an LSI value –1 (mild) to –5 (severe).

When the RSI is used, a value over 6.5 indicates that the water is probably corrosive; higher values are increasingly corrosive.

Not all laboratories offer the saturation or stability index. Contact the laboratory to discuss their services, pricing, and procedures for collecting, handling, and submitting samples. The Texas Commission on Environmental Quality maintains a list of laboratories certified to test drinking water: *http://www.tceq.texas.gov/assets/public/compliance/compliance_support/qa/txnelap_lab_list.pdf*

What causes corrosion?

Corrosion is a natural process that occurs when metals react with oxygen and form metal oxides.

All water contains some dissolved oxygen and is therefore somewhat corrosive. The rate of corrosion depends on many factors including the water's pH, electrical conductivity, oxygen concentration, and temperature.

In addition to corrosion, metals dissolve when the water is extremely low in dissolved salts and in the presence of certain water-borne ions. This process causes the plumbing material to gradually dissolve. Though corrosion and dissolution are fundamentally different, the result is similar and they are generally discussed as corrosion.

Acidity or low pH

The pH scale ranges from 0 to 14; a pH of 7.0 represents the point where acid and alkaline materials are in balance. Water with a pH value below 7.0 is considered acidic, while water above 7.0 is alkaline.

Alkalinity and pH often are confused. Total alkalinity refers to the total bases in water that can neutralize acid. These include bicarbonates, carbonates, hydroxides, and some phosphates and silicates. Alkalinity is reported in milligrams per liter of calcium carbonate.

Groundwater can be acidic or alkaline in pH, depending on several factors. Rainfall is typically acidic because it picks up carbon dioxide as it falls to the earth, forming carbonic acid. As water percolates through the soil, it also can come in contact with acidic materials such as decaying organic matter.

Limestone (calcium carbonate) and dolomite (calcium magnesium carbonate) in the soil neutralize the acid and the water is usually alkaline—pH between 7 and 8—and "hard" due to the carbonates. If there is no limestone or dolomite, the groundwater will remain acidic with pH values between 6 and 7.

Water that contains calcium or magnesium salts (hard water) is less corrosive, because the minerals that cause hard water tend to coat and protect the inside of pipes. Soft water that contains sodium salts does not coat the pipes and consequently is more corrosive.

Water that is moderately alkaline (40 to 70 mg/L) with a pH between 7.0 and 8.2 is usually not corrosive. Water with a pH below 6.5 will be corrosive, especially if alkalinity also is low. However, water with pH values above 7.5 also can be corrosive when alkalinity is low.

High dissolved solids and electrical conductivity

Minerals dissolved in water separate into charged particles (ions) that conduct electricity. Conductivity is a problem only when water has a high mineral content; pure water does not conduct electricity.

Plumbing systems use several types of metals. When different metals are in contact with each other and a solution that conducts electricity, the result is a galvanic cell. The cell generates electricity, which corrodes one of the metals. Galvanic corrosion occurs at or very near the joint between the two metals.

Plumbing systems that use galvanized pipe often have brass values. Likewise, copper plumbing often has solder joints and valves made of a different alloy. Every joint where different metals connect is a potential site for galvanic corrosion if the water has high amounts of dissolved minerals.

Dissolved oxygen and other gases

Oxygen dissolved in water is a primary corrosive agent. Water exposed to the air absorbs oxygen. Oxygen in rain and surface water is usually removed when water seeps into the ground; deep wells are usually oxygen free. In contrast, shallow wells and surface water often contain more oxygen. Water also may absorb oxygen when a pneumatic pressure tank is used. Hydrogen sulfide in groundwater also can corrode metals significantly. You can see high levels of dissolved gases by dispensing water into a clear glass. In extreme cases, the water may look milky due to very small air bubbles.

Water temperature

Corrosion is more likely and more rapid at higher water temperatures. The rate of corrosion triples or quadruples as water temperature rises from 60°F to 140°F. Above 140°F, the rate of corrosion doubles for every 20°F increase.

Design flaws

In some cases, leaks in copper plumbing systems are caused by excessive water velocity, especially when it passes through 90-degree fittings. Water flows faster when the demand for water from the plumbing system is too great for the diameter of the supply line. Over time, the water erodes the copper, causing leaks—almost always in angle fittings. This type of leak is caused not by corrosion but by poor system design. The prevention methods listed above will not solve this problem.

In rare cases, manufacturing defects can make copper piping more susceptible to corrosion. While uncommon, this problem can result in pinhole leaks that occur relatively soon after the system is put into service.

How can I reduce corrosion?

Treating your water can reduce corrosion to acceptable levels, but generally will not eliminate it. Treatment method depends on what is causing the corrosion.

Treating for acidity

If acidity is the problem, installing a neutralizing filter usually works best. These filters contain chips of calcium carbonate (limestone), marble, magnesia (magnesium carbonate), or other alkaline materials that dissolve as the water neutralizes.

Acid-neutralizing filters are usually installed after the pressure tank. As water flows through the filter, pH increases which decreases corrosivity. This process makes the water harder. It also may decrease water pressure.

The neutralizing material must be replenished as it is dissolved. The chips can last from weeks to months, depending on the type of material, how corrosive the water is, and how much water you use. The filters usually must be backwashed to remove trapped particles and oxidized metals.

Another way to neutralize acidic water is to add a solution of sodium hydroxide or sodium carbonate (soda ash). This is usually done by installing a chemical feed pump before the pressure tank. If you are on a low-sodium diet, consider using potassium hydroxide instead of the sodium salts.

This treatment system is simple, and inexpensive; it does not increase water hardness or reduce the water pressure. The injection rate should be adjusted to produce water with a pH of 7.5 to 8.0.

Injection units require significant maintenance that includes filling solution tanks and maintaining the feed pump. Soda ash is preferable to sodium hydroxide, which is extremely caustic and requires special safety precautions; it should be handled only by trained individuals.

Reducing salts

Removing high concentrations of dissolved salts from water requires a reverse osmosis system. This method can require that the water be pretreated, and whole-house systems require large storage tanks. Reverse osmosis systems increase overall water use by 30 to 200 percent and generate wastewater with concentrated salts.

Reverse osmosis can remove 80 to 95 percent of salts from the water entering the system. In some cases, treated water may be so low in total dissolved salts that it corrodes plumbing components. Generally, reverse osmosis water should be transferred and dispensed through non-metallic pipe and fixtures.

It is generally not feasible to remove high levels of dissolved salts from whole-house water systems. Instead, food-grade polyphosphate or silicate compounds can be added into the water system to control corrosiveness.

These materials deposit a thin coat inside the pipe which limits contact with the water. The film will slowly dissolve so the material should be maintained and fed at proper levels. Initially, existing corrosion can loosen and flush through the system making the red water problem seem to be worse. A higher feed rate will clean the system and establish a protective film. Then reduce the amount to maintain the protective film.

Reducing dissolved oxygen

Often, there is little you can do to reduce dissolved oxygen in small water systems. Installing a flexible membrane or a floating disc in the pressure tank will minimize the water's contact with air. This type of tank also minimizes waterlogging, which is common with highly aerated water. However, it may be necessary to inject polyphosphate or silicate compounds to protect the water system over the long term.

A large, semi-open storage tank can be used to allow air to escape similar to the way bubbles escape in a drinking glass. This requires a tank twice the size of the daily-use rate and chlorination since the water is no longer pressurized.

Corrosion on the outside of supply lines?

The outside of plumbing also can corrode. This is most common when copper or galvanized supply lines touch highly acidic or basic soil. This can happen when acid soil materials are exposed by trenching or alkali is created from burning construction materials, trees, or old buildings.

Modern water systems often use plastic-jacketed copper tubing. Be careful when installing this type of piping to avoid cutting or tearing the jacket as this will expose the pipe to corrosion.

Aboveground, exterior corrosion often occurs where hazardous materials are stored, mixed, or used, such as swimming pool systems that use hydrochloric acid (muriatic acid). If local plumbing codes allow it, use PVC, CPVC, or PEX pipe in potentially corrosive environments.

What if toxic metals are the only concern?

In many cases, the water is not corrosive enough to cause leaks, but it does increase the amount of copper and/or lead in the water. Since copper and lead normally accumulate when water sits in the plumbing, the simplest and cheapest solution is to run the water for at least 1 minute before drinking it. This draws fresh water from the pressure tank or well that has not had sufficient time in the plumbing system to accumulate metals. Flushing is only necessary when water has been in the plumbing for at least one hour.

If you use this method, collect a water sample after running the water for 1 minute and have it analyzed for copper and lead to ensure that the levels are reduced to safe concentrations.

To conserve water, flush the plumbing system in the morning and fill a container with drinking water for the day.

In recent home construction, lead is restricted to the brass components. By running the water for several seconds, any dissolved lead from brass fixtures will be flushed out.

If lead and copper persist after flushing, or if flushing is not possible, you can install small point-of-use devices to remove the metals at individual taps. Water that will be used only for drinking and cooking can be treated by reverse osmosis, activated alumina filtration, or distillation.

Can corrosion be prevented?

One way to correct or prevent plumbing system corrosion is to install corrosion-resistant components. Most often this involves replacing copper pipe or substandard plastic pipe with approved plastic pipe. PEX plumbing has gained wide acceptance in recent years. Unlike PVC, many PEX manufacturers claim it can tolerate high heat and freeze solid with no damage. Approved plastic pipe is stamped with NSF (National Sanitation Foundation) and Drinking Water on the side. Local plumbing and building codes vary; consult local regulations before replacing or installing plumbing materials.

For more information

These publications may be downloaded from the Texas AgriLife Bookstore at *https://agrilifebookstore.org.*

- L-5451, *Drinking Water Problems: Iron and Manganese*
- L-5452, *Drinking Water Problems: Lead*
- L-5472, *Drinking Water Problems: Copper*

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Hermanson, R.E. 1991. *Corrosion from Domestic Water.* EB1581. Washington State University. Pullman, WA.

Oram, B. *Corrosion, Saturation Index, Balanced Water in Drinking Water Systems.* 2009. Wilkes University Center for Environmental Quality. Wilkes-Barre, PA.

Swistock, B.R., W.E. Sharpe, and P.D. Robillard. 2001. *Corrosive Water Problems.* F 137, Penn State University. University Park, PA.

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