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Drinking Water Problems: Corrosion

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One of the most common problems affecting domestic water supplies is corrosion, a chemical process that slowly dissolves metal, resulting in deterioration and failure of plumbing pipes, fixtures and water-using equipment. One type of corrosion attacks and gradually thins the entire metal surface, often causing red-colored stains in iron or steel plumbing systems or blue-green stains in copper and brass plumbing systems (***Figure 1***). Another type of corrosion attacks small areas where deep pits can develop and penetrate pipe or tank walls. This type of corrosion may not add significant amounts of iron or copper to the water, but can create small holes in a pipe or tank that destroy its usefulness, cause water leaks, and result in major water damage to a home or business ***(Figure 2)***. A third type of corrosion caused by the oxidation of metals involves conversion of copper or other base metal to an oxidized form in a process similar to the rusting of steel. It often results in reduced water flow through supply lines and destruction of water valves and other machined water flow control surfaces, thus resulting in internal and external leaks at valves and faucets. This type of corrosion does not necessarily occur due to the water chemistry, but is caused by exposure of the outside surface of the plumbing supply lines to soil or other corrosive environments.

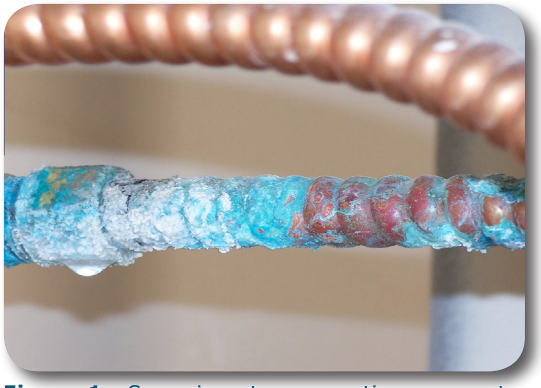

Figure 1. Corrosion at a connection on a water heater indicated by the blue-green color.

Especially in older installations and very new homes, two potentially toxic metals, copper and lead, may occur in tap water almost entirely because of leaching caused by corrosion. Elevated levels of copper can cause gastrointestinal problems and with long-term exposure result in liver and kidney damage. Elevated levels of lead can result in physical and mental development problems in children, and high blood pressure and kidney problems in adults. The US Environmental Protection Agency has established Primary Drinking Water Standards (http://water.epa.gov/drink/contaminants/index.cfm) for both copper (maximum contaminant level = 1.3 milligrams/liter) and lead (maximum contaminant level = 0.015 milligrams/liter). In addition, two other metals (iron and zinc) usually present because of corrosion can cause water to have a metallic taste. Laboratories and publications may report concentrations using units of milligrams/liter (mg/L) or parts per million (ppm), which are the same.

What are the causes of corrosion?

Corrosion is a natural process that occurs when metals are in contact with oxygen and react to form metal oxides. All water is corrosive to some degree as it contains some amount of dissolved oxygen. The rate of corrosion depends on a number of factors including acidity or low pH, electrical conductivity, oxygen concentration and water temperature. Each of these factors is explained in more detail in the next sections.

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

In addition to corrosion, dissolution of metals occurs when the water is extremely low in dissolved salts or in the presence of certain water-borne ions. All materials have a particular level of solubility and in the case of corroded plumbing, the concentration of the copper or other plumbing material metal is lower in the water than that material's solubility. As a result, the plumbing material is gradually dissolved. While this process is usually very slow, certain water-borne ions can react with and bind the recently dissolved metal allowing more rapid loss. While corrosion and dissolution are fundamentally different, the end result is similar; therefore, both are often discussed together under the general term, "corrosion".

Acidity or low pH

The pH value is used to measure acidic and alkaline materials in water. The pH scale ranges from 0 to 14, with a pH of 7.0 representing the neutral point where acid and alkaline materials are in balance. Water with pH values below 7.0 is dominated by acidic materials, while water with pH values above 7.0 is alkaline.

The terms alkalinity and pH often are confused. Total alkalinity is a measure of the total bases in water that can neutralize acid. This includes bicarbonates, carbonates, hydroxides, and even some phosphates and silicates. Alkalinity is reported in units of milligrams per liter (mg/L) of calcium carbonate.

Groundwater can be acid 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 other acid-forming materials such as decaying organic matter (vegetation).

In areas where underground strata contain limestone (calcium carbonate) or dolomite (calcium magnesium carbonate), the acid is neutralized and the water is usually alkaline, with pH values between 7 and 8, and "hard" (due to the carbonates). Where limestone or dolomite is not present underground, the percolating water will retain its acidity and groundwater will typically have pH values between 6 and 7.

For ideal corrosion control, water should have moderate alkalinity (40 to 70 mg/L) and a pH between 7.0 and 8.2. Water with pH values 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 (electrical conductivity)

The ability of water to conduct electricity is affected by its ionic concentration. Dissolved soil minerals in water separate into charged particles called ions that can conduct electricity. Pure water does not conduct electricity. Thus, electrical conductivity is only a problem when water has a high mineral concentration. Water containing sodium salts (soft water) is more corrosive than water containing calcium or magnesium salts (hard water), because hard water minerals tend to coat the inside of pipes and reduce the potential for corrosion.

Several different types of metals are often used in a plumbing system. When two different metals are in contact with each other and a solution that conducts electricity, a galvanic cell is created. The cell generates electricity and one metal dissolves or corrodes in proportion to the electricity produced. Galvanic corrosion occurs at or very near the joint between the two metals.

Plumbing systems using galvanized pipe often have brass values. Likewise, copper plumbing often has solder joints and valves made of a different metal alloy. Any dissimilar metal connections such as these represent potential sites for galvanic corrosion if the water has high amounts of dissolved minerals.

Dissolved oxygen and other gases

Oxygen dissolved in water is one of the most common and important corrosive agents. When water is exposed to air, some of the oxygen in the air is absorbed. Oxygen dissolved in rain and surface water is usually consumed as water seeps into the ground. As a result, deep wells usually are free of dissolved oxygen. In contrast, shallow wells and surface water often have a higher dissolved oxygen concentration. Dissolved oxygen also may be introduced into water when a pneumatic pressure tank is used. In addition to oxygen, the presence of hydrogen sulfide also can result in significant corrosion of metals. The presence of high levels of dissolved gases can be observed by dispensing water into a clear glass. In extreme cases, the water may initially have a pale white (milky) appearance due to the presence of very small air bubbles.

Water temperature

Corrosion is more likely and more rapid at higher water temperatures. The rate of corrosion increases by a factor of three to four as water temperature rises from 60°F to 140°F. Above 140°F, the rate of corrosion doubles for every 20°F increase in water temperature.

How do I know if there is a corrosion problem?

Most people first realize they have corrosive water because of its negative effects. The most common symptoms are:

- The cold water has a bitter taste when you first draw it in the morning, and flushing the line by running the water for a few seconds improves taste.
- Blue-green stains in sinks and/or at the joints of copper piping.
- Water leaks in floor, wall or ceiling areas as a result of pin-size or larger holes in metal pipes.

Many water-testing laboratories, including the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory in College Station, Texas, offer routine tests for irrigation and/or livestock water uses. Results showing elevated levels of copper, iron or zinc can be an indication of on-going corrosion in a water system. However, these tests are only indicators of a potential problem, and more detailed testing is often needed to confirm that corrosion is occurring and why.

Special laboratory testing is needed to more specifically determine the causes and severity of corrosion potential. The Langelier Saturation Index (LSI) is one method for predicting if water is likely to be corrosive. In order to use the index, a laboratory must measure pH, electrical conductivity, total dissolved solids, alkalinity and total hardness. The LSI typically is either negative or positive and only rarely zero. An LSI value of 0 indicates that the water is "balanced" and unlikely to be corrosive, values above 0 indicate the water will tend to form a carbonate scale, while negative values indicate that the water has a greater corrosive potential. A typical reporting range for the LSI is -1=Mild Corrosion Potential to -5=Severe Corrosion Potential.

Another common index is the Ryzner Stability Index (RSI). An RSI greater than about 6.5 indicates water that is probably corrosive, with higher values being increasingly corrosive.

Only selected laboratories offer determination of a saturation or stability index for estimating corrosion potential of water. Individuals should contact the laboratory to discuss costs and sample collection and handling methods before obtaining water samples for testing.

How can corrosion be controlled?

Eliminating corrosion completely is generally not possible, but it often can be reduced to acceptable levels by water treatment. The appropriate treatment method depends entirely on the type and causes of corrosion.

If acidity is the only problem present, a neutralizing filter is usually the best approach. These filters contain calcium carbonate (limestone) chips, marble chips, magnesia (magnesium carbonate) or other alkaline materials that dissolve as the neutralization process occurs. The acid-neutralizing filter is usually installed after the pressure tank. Raw water flows through the filter and as it contacts the media, its pH is increased and corrosivity decreased. The process will increase the hardness of the water, but this is necessary for proper corrosion control. Also, the resistance of the neutralizing material may lower water pressure. The tank must be routinely refilled with neutralizing material as it is dissolved. The rate of refilling can range from weeks to months depending on the water corrosivity, volume of water use, and the type of neutralizing material. Backwashing typically is required to remove trapped particles and oxidized metals.

Another method for neutralizing acidic water is to inject a sodium hydroxide (NaOH) or sodium carbonate (soda ash - Na_2CO_3) solution using a chemical feed pump before the pressure tank. Individuals on a low sodium diet should investigate the use of potassium hydroxide (KOH) instead of the sodium salts. This treatment system is simple and inexpensive and does not increase water hardness. Since the unit is installed ahead of the pressure tank, there is no reduction in water pressure that sometimes occurs with neutralizing filters. The rate of injection should be adjusted to produce treated water with a pH of 7.5 to 8.0. There is significant maintenance including filling solution tanks and maintaining the feed pump. Soda ash is preferred over sodium hydroxide, because it is safer to handle. Sodium hydroxide is extremely caustic and must be handled using accepted safety practices. Generally, it should be handled only by trained individuals.

Removing high levels of dissolved salts from water requires the use of a reverse osmosis system. These systems may require additional pretreatment, and whole house systems require large storage tanks. Reverse osmosis systems also will increase overall water use by 30-200%, and generate wastewater with concentrated salts. Reverse osmosis can remove 80-95% of salts from the water entering the system. In some cases, treated water may actually be so low in total dissolved salts that it too results in corrosion of plumbing components. As a general recommendation, reverse osmosis water should be transferred and dispensed through non-metallic pipe and fixtures. Because there are few feasible methods for removing high levels of dissolved salts from whole house water systems, homeowners may choose to utilize food-grade polyphosphate or silicate compounds that can be fed into water systems to control corrosiveness. These materials deposit a thin protective film on the inner surface of the pipe which limits contact with the water. The film re-dissolves slowly, and the feeding of the materials should be maintained at proper levels. Initially, old corrosion deposits can loosen and flush through the system making the "red water" problem appear to be worse. A higher feed rate will clean the system and establish a protective film. The feed rate then can be lowered to maintain the protective film.

In many cases, little can be done to reduce dissolved oxygen in small water systems. Using a flexible "membrane" or a floating disc in the pressure tank will minimize exposure of the water to air. This type of pressure tank also will nearly eliminate pressure tank water logging, a common problem with highly air-entrapped water. However, injection of polyphosphate or silicate compounds may be necessary to prevent damage to the water system over the long term. If space is available, a large capacity, semi-open storage tank can be used to reduce super-saturation, similar to the way air bubbles escape from a drinking glass. This approach requires tank sizing two times greater than the daily use rate and since the water is no longer pressurized, chlorination is required prior to end use.

Corrosion on the outside of supply lines?

The outside of plumbing also can be subject to corrosion. The most common problem is when copper or galvanized supply lines come in contact with highly acidic or basic soil. These conditions can occur from the oxidation of acid-producing soil materials exposed during trenching or alkali created from the burning of construction materials, trees or old buildings. Modern water systems often use plastic-jacketed, flexible copper tubing. Care should be used when installing this piping to ensure no tears or cuts occur, otherwise the cut jacket can potentially localize/concentrate corrosion problems. Aboveground, corrosion of the exterior of plumbing is often the result of a highly corrosive environment. This may include areas where hazardous materials are stored, mixed or used, for example swimming pool systems that use concentrated hydrochloric acid (muriatic acid). If allowed by local plumbing codes, supply lines comprised of PVC, CPVC, or PEX are recommended in potentially corrosive environments.

What if toxic metals are the only concern?

In many cases, water corrosivity is not severe enough to cause leaks in the plumbing, but does cause undesirable increases in copper and/or lead in the water. In this case, various options are available to reduce or eliminate the metals from drinking water. Since copper and lead normally accumulate in the water as it sits in contact with the metal plumbing, the most simple and inexpensive solution is to flush the plumbing system by running the water for at least one minute before drinking the water. This draws fresh water from the pressure tank or well that has not had sufficient contact with the plumbing system to accumulate metals. Flushing is only necessary if the water has been in contact with the plumbing for at least one hour. If this method is used, a water sample should be collected after running the water for one minute and analyzed for copper and lead to ensure levels are reduced to safe concentrations. To conserve water, flush the plumbing system in the morning and fill a container with drinking water for use during the day. In more recent home construction, lead within the plumbing system is restricted entirely to the brass components. Therefore, most lead contaminated water will be dispensed upon opening the valves. By allowing the water to run for several seconds, all of the dissolved lead from the brass fixture will bypass human contact.

If excessive lead and copper persist after flushing, or if flushing is an undesirable method, there are numerous alternatives for reducing lead and copper in water. Unlike the neutralizing filters and chemical injection units discussed above that treat all of the water entering the home, smaller point-of-use devices can be used to remove the metals at individual taps. Reverse osmosis, activated alumina filters or distillation are all acceptable methods that can be used to treat only the water that will be used for drinking and cooking.

Can corrosion be prevented?

Since corrosive water attacks the plumbing system, one way to correct or prevent the problem is to install plumbing components that are resistant to corrosion. Most often this involves replacement of copper pipe or substandard plastic pipe with approved plastic pipe. The use of PEX plumbing has gained wide acceptance in recent years. Unlike PVC which can become damaged during freezing, many manufacturers of PEX claim high heat tolerance, the ability to freeze solid many times with no damage and single jointless supply runs from the whole-house water manifold to the end-use fixture. Approved plastic pipe is directly stamped with “NSF” (National Sanitation Foundation) and “Drinking Water” on the side. Since local plumbing and building codes vary, these local codes should be consulted prior to replacement or installation of plumbing materials.

Additional notes on plumbing system design and materials

In some cases, leaks in copper plumbing systems are caused from excessive water velocity. If the water velocity is too great, the water can erode the copper pipe, especially when it passes through 90-degree fittings. Excessive water velocity occurs when the demand for water downstream in the plumbing system is too great for the diameter of the supply line. Over time, the erosive nature of water wears down the copper and leaks occur, almost always in angle fittings. This type of leak is caused by poor system design and not by corrosion, thus the prevention methods listed above will not solve this problem.

In rare cases, improper or faulty manufacturing of copper piping can result in materials that are more subject to corrosion. While uncommon, this problem can result in pinhole leaks that occur relatively soon after the system is put into service.

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