AWS Technical Report: Correcting or Reducing Corrosion in Home and Commercial Piping Systems

According to some estimates, corrosion costs the United States more than $1 billion a year. Copper corrosion in home plumbing systems is an extremely common phenomenon, which can have many causes. Besides actual piping failure, the telltale blue stains the oxidized copper leaves on sinks, tubs, and fixtures can identify copper corrosion. Often laundry and even blonde hair can be tinted blue. Copper can be toxic, and water-containing levels over 1.0 mg/L should not be used for drinking. If there are iron pipes present, the water can be colored rust or reddish, and contains metallic or sulfur odors, and sediment.

IRON PIPE NIPPLES CORRODED,
FILLED WITH RUST AND SLUDGE

COPPER PIPING CORROSION
WITH PIN HOLE LEAKS

Eventually corrosion can cause the piping to fail, in some cases in less than 10 years.

The main causes are:

- Low pH (acid water) or high pH (alkaline water) on private well systems.
- Other water chemistry causes, such as high levels of dissolved oxygen, high levels of salts dissolved in the water, and/ or corrosion-causing bacteria such as sulfate or iron bacteria.
- Electrochemical causes, such as improper grounding of electrical appliances to the copper piping.
- High velocity of water, relative to size of piping, causing hydraulic wear on the piping.
- Sand, sediment or other grit causing hydraulic wear on the piping.

Once corrosion starts in a piping, electrons can begin to flow between the corrosion sites, causing the copper to dissolve into the water. Since water contains oxygen, the copper ions "rust" or oxidize, to blue color. This same process happens in galvanized iron piping, causing rust stains and red water.

What can be done?

1. Identify the source and severity of the problem by inspection of the piping system and water analysis:

    - Check to see if there are unnecessary electrical appliances or wiring connected to the piping.

    - Check to see if the piping system properly grounded.

    - Verify to see that there is electrical continuity through out the piping system.

    - Check for pH and see if the water is corrosive, and/or perform a Langlier Index (see Table 2)

2. Correct or minimize the cause of the corrosion above.

3. Install a calcite neutralizer tank, or a soda ash feeder to raise the pH to 7.0 to 8.0 to correct for low pH and increase the alkalinity in the water.

4. Install a phosphate feeder before the copper piping. Phosphate will coat the piping and reduce or slow down the corrosion effects, by coating the interior surfaces of the piping with phosphate and causing an insulation surface to be built up.

Corrosion Background Information

Corrosion is "the deterioration of a substance or its properties due to a reaction with its environment." Corrosion in plumbing systems is due to physical and chemical reactions between the pipe material and water. Metals have a tendency to return to their natural state, with some metals being more active than others, and as a result are likely to enter their solutions (i.e. water in the case of pipe fixtures) if contact is made.

The process of corrosion can be described as electrochemical. As mentioned before, when a metal is placed into a solution it has a tendency to enter the solution as an ion or it may be the case that it combines with another element in the water already present to form another compound. At this point, electrons (electricity) will leave particular areas of the metal to travel to others to set up a type of current.

The electrons point of departure is called the "anode". The absence of electrons at this site will cause corrosion cells to appear around this area. The destination of these electrons is the "cathode" whose function is to carry the electrons through the solution and back to the anode. Dissolved oxygen in water solutions will react with whatever reaction products are initially present at both the anodic and cathodic regions, making it a major contributor in the internal corrosion of piping systems.

Anodic areas are nearly unavoidable because piping is never homogeneous in its makeup and therefore will have more active sites than others. Other possible anode formations could occur in pipes subject to stress cracks, differential oxygen concentrations caused by biological growth in pipes, as well as sediment deposits and corrosion product accumulation.

Homes in some areas are more likely to experience corrosion because of local building codes. This is because homeowners are mandated to "bond" their electrical systems with their plumbing in order to redirect stray current to the ground. This process is a contributing factor to "electrolysis"- the "decomposition into ions of a chemical compound in a solution by the action of an electric current passing through the solution"[2]. The process takes place when electrical current travels through the water and in doing so, aids in the development of corrosion sites in the piping.

Steps to Take to Correct Corrosion by Electrical Currents or Factors

Continuity of a piping system can be important. If there are dielectric unions on the water heater and corrosion is evident, a jumper wire should be joined between the inlet and outlet piping to provide electrical continuity of the piping.

If a plastic filter housing, plastic water softener bypass or any other type of insulating part or device that interrupts the electrical continuity of the piping is present, jumper wires and proper grounding clamps should be installed by a qualified electrician.

Other preventative measures to reduce or slow down the corrosion include upgrading electrical grounds, raising the pH of the water by installing a neutralizing filter, and /or by using phosphate feeder can coat the interior of the piping and provide protection against corrosion.

CAUTION: DO NOT ATTEMPT TO WORK ON ELECTRICAL GROUNDS yourself. Use a qualified electrical contractor or electrician and follow all local building codes and the National Electrical Code.

Other Corrosion Factors

Factors that might lead to corrosion include water characteristics, size of home, improperly constructed piping systems, and improper grounding.

Characteristics of Water that Affect Piping Corrosion

Flow Velocity: The flow velocity of water can lead to corrosion in piping. High velocity waters combined with other corrosive characteristics can lead to a more rapid deterioration of materials. High velocity waters can also affect pipe corrosion by increasing the rate at which dissolved oxygen comes into contact with metal surfaces. The transport of corrosion products may also be increased with higher water velocities. On the other hand, extremely low velocities can contribute to stagnation, which may form pitting and biological growth.

Temperature: The temperature of water has complex and varied effects on corrosion. Reaction rates increase in warm temperatures so that if you take nothing else into consideration, how water is generally more corrosive than cold water.

Water Chemistry: The relationship between the pH, alkalinity, and carbon dioxide in water is important to understand because imbalances in the three can lead to metal corrosion. pH is a measure of the concentration of hydrogen ions in water. These ions are responsible for accepting the electrons transported when a metal corrodes, therefore the measurement of pH is very useful in determining corrosion levels. Alkalinity is a measure of the water's ability to neutralize acids. Low alkalinity, with low pH combined, can equal a corrosive water condition.

Field and Laboratory Analysis

To determine corrosion, the first step is a physical inspection of the piping. Signs of pipe corrosion include:

- Blue stains from copper on pipes and fixtures, or rust stains if on iron piping.
- A toilet flush tank with blue, rust or green stains indicating corrosion.
- A metallic taste indicating the presence of iron or zinc corrosion from iron pipes
- Holes in pipes, as well as leaks and clogs. These problems can lead to a reduction of water pressure, the structural failure of pipes, and corrosion products becoming lodged into the water.
- Odors from bacterial activity.

There are many causes and signs of corrosion in the field that can be observed, see Table 1 for the more common symptoms and causes.

Table 1. Typical Problems Related to Corrosion:

Problem	Potential Cause
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of iron in raw water.
Bluish stains on fixtures	Corrosion of copper lines
Black water	Sulfide corrosion of copper or iron lines
Foul taste and/or odors	By-products from microbial activity
Loss of water pressure	Excessive scaling, tubercle build-up from pitting corrosion, leak in system from pitting or other type of corrosion
Loss of water pressure	Build-up of sand or grit from the water source, or corroded distribution piping outside the home or plumbing system
Lack of hot water	Build-up of mineral deposits in hot water system
Short service life of household plumbing	Rapid deterioration of pipes from pitting or other types of corrosion

Water Testing for Corrosion

To determine the corrosion potential for the water, the "Langlier Saturation Index" can be used. To calculate the saturation it is necessary to determine the alkalinity, pH, calcium hardness (or total hardness), conductivity and total dissolved solids content of the water. The saturation index is then determined based on a particular water temperature, typically 25 C.

In addition, it is recommend having the water checked for evidence of testing the water for lead and copper. This is conducted by determining the lead and copper content of the water after the water has been left in the piping overnight.

If your piping is newer than 10 – 20 years old, it is unlikely you have leaded pipes. Copper testing can be done inexpensively, by using a home test kit. If your piping is copper, and it tests positive for copper residual during a "first-draw" test, then you likely have corrosion occurring.

For water testing, use a first draw sample. The first draw sample is the first one-liter of water collected from a cold water tap which has been shut off for at least six hours. This is the sampling procedure EPA is requiring community water systems to use to determine compliance with the new action levels. Samples are then analyzed for copper, and in some cases lead.

It is strongly recommended that a homeowner or new homeowner have of the water tested at least once every few years.

Corrosion Index (Langlier Saturation Index)

The Langlier Saturation Index is a means of evaluating water quality data to determine if the water has a tendency to be corrosive or scale forming. In order to use this index, the following laboratory analysis is needed: pH, conductivity, total dissolved solids, alkalinity, and total hardness. This can give you an idea of the corrosion potential of the water. However, in certain cases corrosion can still be occurring even if the water is has a neutral Langlier Index.

If you have copper piping, and a first-draw sample (after the water has sat in the pipes for 12 hours or more) tests positive for high levels of copper (over .2 ppm for instance), then you have corrosion occurring no matter what the Langlier Saturation Index indicates.

In manipulating the data, the actual pH of the water is compared to the theoretical pH (pHs) based on the chemical analysis. The Saturation Index =

$$\text{Saturation Index} = \text{pH} - \text{pHs}$$

The Saturation Index is typically either negative or positive and rarely 0. A Saturation Index of zero indicates that the water is "balanced" and is neither scale forming or corrosive. A negative SI indicates that the water is corrosive. Corrosive water can react with the household plumbing and metal fixtures resulting in the deterioration of the pipes and increased metal content of the water. This reaction could result in aesthetic problems, such as bitter water and stains around basins or sinks, and in many cases elevated levels of toxic metals.

A positive Saturation Index indicates that water may be scale forming. The scale, typically a carbonate residue, could clog or reduce the flow in pipes, cause buildup on hot water heaters, impart an alkali taste to the water, reduce the efficiency of the water heaters, and cause other aesthetic problems. Table 1 presents a typical range of SI that may be encountered in a drinking water and a description of the nature of the water and general recommendations regarding treatment.

Table 2 Saturation Index Calculation Chart

Temp deg F = T	**Calcium Hardness = H**	**Total Alkalinity = A**
32° = **0.0**	5 = **0.3**	5 = **0.7**
37° = **0.1**	25 = **1.0**	25 = **1.4**
46° = **0.2**	50 = **1.3**	50 = **1.7**
53° = **0.3**	75 = **1.5**	75 = **1.9**
60° = **0.4**	100 = **1.6**	100 = **2.0**
66° = **0.5**	150 = **1.8**	150 = **2.2**
76° = **0.6**	200 = **1.9**	200 = **2.3**
84° = **0.7**	300 = **2.1**	300 = **2.5**
94° = **0.8**	400 = **2.2**	400 = **2.6**
105° = **0.9**	800 = **2.5**	800 = **2.9**
128° = **1.0**	1000 = **2.0**	1000 = **3.0**

pH ___ + T ___ + H ___ + A ___ - 12.1 = Langlier Index

Example:
pH = 6.8 Temperature ("T") = 53 Hardness = 75 ppm Alkalinity = 100

(6.8 + .3 + 1.5 + 2.0) – 12.1 = - 1.5 Langlier Index is - 1.5

If Index is less than -0.5 the water is Corrosive

If Index is between -0.5 and +0.5 the water is Balanced

If Index is greater than +0.5 the water is Scale Forming

Use the chart above (Table 2) to calculate the Saturation Index of your water, and then view the chart below (Table 3) to see where your water is on the Langlier Scale:

Table 3 Saturation Index and Recommendations

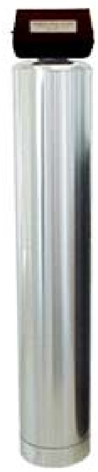
Saturation Index	Description	General Recommendations
-5	Severe Corrosion	Treatment Recommended
-4	Moderate/ Severe Corrosion	Treatment Recommended
-3	Moderate/Severe Corrosion	Treatment Recommended
-2	Moderate Corrosion	Treatment Should be Considered
-1	Mild Corrosion	Treatment Should be Considered
-0.5	Mild Corrosion/Near Balanced	Treatment Probably Not Needed
0	Balanced	Treatment Probably Not Needed
0.5	Near Balance	Treatment Probably Not Needed
1	Mild Scale Forming	Some Aesthetic Problems; Consider Treatment
2	Mild Scale Forming	Some Aesthetic Problems; Consider Treatment
3	Moderate Scale Forming	Treatment Should be Considered
4	Severe Scale Forming	Treatment Recommended
5	Severe Scale Forming	Treatment Recommended

Treatment Options: Calcite Media Neutralizers & Soda-Ash Feeders

If the pH is low, or the water is low in alkalinity or hardness, you can change the corrosive chemistry of the water by raising the pH, increasing the alkalinity and/or increasing the calcium hardness.

- Calcite neutralizers raise pH, hardness and alkalinity.
- Soda ash feeders raise pH and increase alkalinity but not hardness.

TYPICAL CALCITE NEUTRALIZER (SHOWN ABOVE, STAINLESS STEEL TANK ON THE FAR RIGHT) INSTALLED IN COMBINATION WITH AN IRON FILTER SYSTEM AND WATER SOFTENING SYSTEM



NEUTRALIZER MEDIA FILTER

SODA ASH FEEDER. YELLOW SOLUTION TANK (DIMENSIONS: 24" X 36") WITH METERING PUMP, SHOWN INSTALLED NEAR WELL HEAD BEFORE STORAGE TANK (STORAGE TANK NOT SHOWN)

Calcite Neutralizers

One of the most convenient methods to raise pH, hardness and alkalinity is to use a calcite neutralizer filter.   These filters will typically raise the pH of the water to 7.0 to 8.0 and add 30 to 100 ppm of hardness depending on the alkalinity and water hardness.

In neutralizer filters, acidic waters slowly dissolve the calcium and magnesium media on contact as the water flows through the filter, raising the pH of the water and increasing the alkalinity. This eliminates the effects of corrosive water chemistries and can help to prevent corrosion of piping and fixtures.

The size of the system is directly proportional to the flow rate of the water, in gallons per minute. The higher the flow rate, the larger the system required.

The filters usually have an automatic backwash feature, where the calcium mineral media is periodically backwashed water. This keeps the media clean and also allows the filter to remove sediment from the water.

If there is also iron in the water, in some cases, you can use a Birm (a type of iron filter media) blend filter as a combination acid neutralizer and iron filter, all in one tank.

Under the right conditions there is little maintenance. Periodically, and depending on raw water pH and the amount of water used, additional mineral is easily added to the filter tank. This is typically once a year for the average home.

Properly sized, the system produces a very low-pressure drop at service flow rates, usually around five psi.

Soda Ash Feeders

Metering pumps are used to inject a small amount of soda ash (sodium carbonate) into the water, usually in conjunction with a contact tank. For best results, allow 10 minutes contact with the water for pH adjustment to occur.
For home wells, when the metering pumps are wired to turn on and start pumping soda ash solution, when the well pump is energized or running.
Soda ash is bought dry, usually in 25 or 50 lb bags and mixed with soft or pure water in the solution tank. When a saturated solution is achieved (approximately 1 pound per 5 gallons of water), a solution of between 50 and 500 ppm are injected, depending on the pH, alkalinity and flow rate of the water.
Usually the pH must be checked on-site and the metering pump adjusted

Phosphate Feeders

Phosphate feeders contain crystals of sodium hexametaphosphate which allow addition of 1 to 5 ppm of phosphate into the water. This phosphate then coats the interior surfaces of the piping or plumbing, slowing down or arresting corrosion. In addition to the crystal by-pass feeder style, which uses a phosphate crystal encased in a filter cartridge canister, there are also liquid phosphate solutions available. Zinc-orthophosphate is commonly used by municipal water systems to correct aggressive or corrosive water conditions in their distribution systems.

In some cases, phosphate cartridge filters are used after neutralizers, water softeners or other treatment systems.

Questions? Contact us at (831) 476-0515 or email us at office@advanced-water-systems.com or visit us online at www.advanced-water-systems