Distribution

Causes and Cures of Distribution System Corrosion

by Kevin M. Ripp

Occasionally, I receive calls from concerned water users. One morning I received a call from a distressed mother of two. She said her children's naturally blonde hair was stained green and she had been trying to solve this problem all summer. Now, with school approaching, and green hair really not all that popular in the Midwest, she desperately needed to fix the problem.

After consulting the water supplier and evaluating the situation, we determined the green stains were the result of a low-alkalinity, corrosive water supply and copper plumbing. We decided to add a corrosion inhibitor to form a protective film over the copper. To do this, we installed continuous-feed equipment at the wellhouse prior to chlorination.

Testing revealed that the corrosion inhibitor, in addition to solving the green-hair dilemma, also lowered first-draw lead levels from 50 ppb (50 µg/L) down to 10 ppb (10 µg/L).

Corrosion and the Senses

A good operator can see, taste, and smell changes in water quality and has the "sixth sense" to detect differences in quality before they become problems. It is this sixth sense that makes the science of corrosion control an art in an effective treatment program.

Color. Iron corrosion stains bathroom vanities and white laundry with a familiar rust color. In homes, copper corrosion results in blue–green stains that show up in sinks, baths, and blonde hair.

Taste and odor. Corrosion can cause a metallic taste and sometimes a musty odor. At times this odor can be attributed to bacterial problems.

Costs of Corrosion

Economic costs. Corrosion can increase the operating expenses of a water distribution system. For example, when iron mains build up with tuberculation, flow rates and efficiency are reduced. This could lead to the premature replacement of mains. Fortunately, this kind of corrosion is easily seen and identified.

Health costs. Corrosive water can cause the leaching of lead and copper into a water supply. Unfortunately, lead leaching problems are not as visible as other types of corrosion problems. To determine lead leaching, the water must be tested for the presence of lead.

This article first appeared in the May 1991 issue and received the 1992 Opflow *Publications Award.*

Classifying Water

Before you start solving corrosion problems, you need to determine the type of water you are dealing with. Generally speaking, water can be classified into three categories: scaling, neutral, and corrosive.

Scaling typically indicates hard waters that are over-saturated with calcium carbonate. Scaling tendencies are easily noticed in hot water heaters.

Neutral water is in equilibrium. By adjusting the water to "slightly scaling," a protective eggshell crust forms in the water system. Forming this perfect eggshell coating is easier said than done.

Corrosive water tends to dissolve piping. Deposits of tuberculation in a cast-iron system are typical by-products.

Although it's easy to classify water qualities, it is important to remember that for every rule there is an exception. For example, in one water system an operator had a problem because of cast-iron corrosion. However, once the water was in the homeowner's house the hot water became scaling and plugged up the hot water heater.

In other examples, the water may become more corrosive in the home. This can result from higher velocity or the use of a home water softener or reverse-osmosis unit.

In some cases, water can be scaling in some parts and corrosive in other parts of the same system. Higher temperature and pressure can change a water from corrosive to scaling. Remember that corrosive water can and does change as it progresses through a water system.

Factors Affecting Corrosion

Corrosion is always the result of a combination of factors: physical, chemical, and biological.

Physical factors include flow and temperature. Low-flow, dead-end areas typically have higher rates of corrosion. This is why tuberculation problems tend to be worse in dead ends. On the other hand, erosion may cause corrosion in areas where water moves at extremely high velocities and at elbows. Corrosion tends to increase with higher temperatures—warmer summer months can result in higher corrosion rates, especially in surface water supplies.

Chemical factors include alkalinity, hardness, conductivity, dissolved oxygen, and the presence of sulfates or chlorides. Low alkalinity limits the formation of a calcium carbonate coating and provides little resistance to pH change. Low hardness offers little protection in the form of calcium carbonate.

Conductivity means the ability to transmit electricity. Some waters are more conductive than others. Because corrosion is an electrochemical process, the more conductive the water, the greater the potential for corrosion.

Dissolved oxygen at levels greater than 3 to 5 mg/L can encourage corrosion. High levels of sulfates and chlorides can increase the rate of corrosion. Chlorides are a common problem where there is saltwater intrusion. Chlorides form soluble corrosion by-products that can cause pitting problems.

Concerning biological factors, iron bacteria and sulfate-reducing bacteria can speed both corrosion and the formation of corrosion by-products. Slime growths in the system or a musty or stale taste to the water give notice of these problems.

Microbiologically influenced corrosion commonly refers to corrosion from iron-related bacteria and sulfate-reducing bacteria. Iron-related bacteria use iron as an energy source; sulfate-reducing bacteria use sulfate.

There are many different types of iron-related and sulfate-reducing bacteria. Iron-related bacteria may be noticed by reddish-brown, jelly-like slime that forms in the water system. Sulfur-related bacteria are commonly noticed through the hydrogen sulfide (rotten egg) odor that they produce.

Neither of these types of bacteria are harmful to health, but they do produce corrosion by-products and accelerate corrosion. And, they have a high degree of tolerance to normal distribution-system chlorine levels.

How Corrosive Is Your Water?

Judging the corrosivity of a water supply takes technical knowledge, testing, and practical observations. Two measurements of corrosivity are the Baylis curve and the Langelier calcium carbonate saturation index.

The Baylis curve (Figure 1) shows the relationship between the pH values and the alkalinity or the solubility of calcium carbonate. Note how the pH and the alkalinity can be changed to make the water noncorrosive.

The Langelier calcium carbonate saturation index determines the tendency of water to either scale or corrode piping and tanks. This method is based on the assumption that every water has a pH value at which it is stable—that is, it will neither deposit scale nor cause corrosion. This condition is termed saturation. The pH value, called saturation pH (pH_S), varies depending on calcium hardness, alkalinity, and temperature. After the pH_S is calculated, the Langelier index is found as follows:

$$\text{Langelier index} = pH - pH_S$$

If the pH is less than the pH_S, then the water is corrosive. If the pH is greater than the pH_S, then the water is likely to form scale. If the pH and pH_S are equal, the Langelier index is zero and, theoretically, the water is stable.

Measuring Corrosion Rates

Corrosion coupons can be used to measure corrosion rates. Coupons are pieces of metal, the same type of metal used in the water system. The coupons are set up in test racks, which are inserted in the pipes or tanks at various points in the distribution system. After a certain period of time, they are removed and tested or examined for types and amounts of corrosion.

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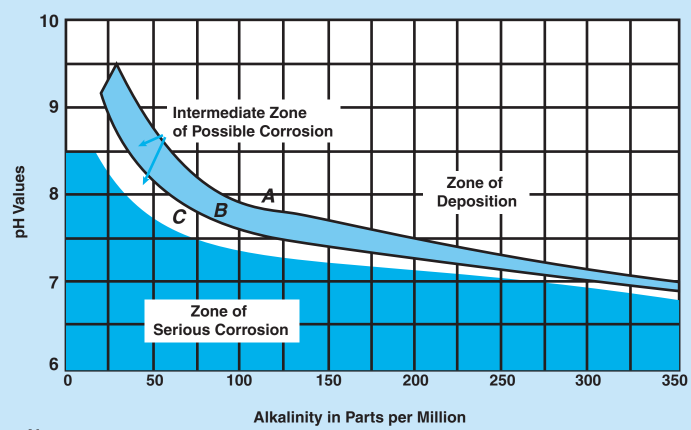
Figure 1. The Baylis curve.



Note:
A = Curve of values necessary to produce a coating of calcium carbonate.
B = Curve of calcium carbonate equilibrium.
C = Curve of values necessary to prevent iron stains.

Table 1 Proper Use of pH Adjustment Chemicals

Chemical	Feed Rates	Alkalinity Increase per Added 1 mg/L	Equipment
Caustic soda (NaOH) —50% solution	1–29 mg/L	1.25	Chemical feed pump
Soda ash (NaCO)	1–40 mg/L	0.94	Feed pump, solution tank
Lime (CaOH)	1–20 mg/L	1.35	Lime slaker
Sodium bicarbonate ($NaHCO_3$)	5–30 mg/L	0.59	Feed pump, solution tank

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While coupons provide a useful way to judge and compare rates of corrosion, they don't measure what is actually happening inside a 45-year-old main that doesn't at all resemble the coupons.

Testing. Analyzing water samples from the distribution system provides an accurate and practical way to monitor actual corrosion rates. By sampling and analyzing the water regularly, the metal content of the water can be monitored. The metal content indicates the rate of corrosion.

When lead leaching is the concern, obtaining first-draw, customer-service, and distribution samples is the best way to monitor.

What Inhibitor Is Right?

There are two ways to inhibit, or slow down, corrosion. They are adjusting the pH or adding a corrosion inhibitor. Sometimes, both are used.

Adjusting pH. If the water is corrosive and lead leaching is a problem, consider raising the pH to make the water more likely to form scale. Table 1 (page 27) lists several chemicals that can be used to raise pH. Using this chart in combination with the Baylis curve or the Langelier index, an operator can see how to change the water quality.

While each chemical listed raises the pH, each provides different sources of hydroxide (OH) or carbonate (CO_3) alkalinity. For example, only lime provides calcium, and it is the least expensive chemical per pound. However, it is also the most troublesome to feed. Liquid caustic soda can be fed easily and safely. However, long-term shortages of caustic soda will make it expensive.

Before adjusting the pH, other factors may need to be considered, such as trihalomethane formation at higher pH levels and the fact that disinfection by chlorination is most efficient between pH 7.2 and pH 7.5.

Chemical inhibitors. Chemical inhibitors may be used alone or with a pH adjustment program. Besides forming a film on the inside of distribution piping, some inhibitors also sequester minerals and buffer the water to help stabilize pH changes.

Sodium phosphates have been used for film formation, sequestration, and dispersion for more than 100 years. They can also be used to stabilize and buffer a pH-adjusted water. These phosphates generally work over a wide range of pH and under a variety of conditions.

Products such as sodium hexametaphosphate and sodium tripolyphosphate have been two traditional mainstays. Other powders and powdered blends are also available. Recently, many liquid-blended phosphates have shown the best performance and ease of application.

For waters below pH 8.0, zinc phosphates can be added for film formation. Zinc phosphates can be made of zinc orthophosphate or zinc polyphosphate; they come in liquid and powder forms. Maximum contaminant levels for heavy metals, such as for zinc in treatment sludge, have limited the use of zinc phosphates in some applications.

Silicates, more commonly known as "water glass," are known for the glasslike coatings they form in distribution systems. They can be blended with phosphates for corrosion reduction.

You Get What You Pay for

In general, with generic or proprietary compounds, you get what you pay for. Be sure to choose products that have a good history and are approved by the National Sanitation Foundation to ensure you are buying a quality product.

Conclusion

The costs of a corrosion control program are easily offset by the savings. A corrosion control program allows a distribution system to last longer and operate more efficiently. This efficiency allows water operators to save time because of fewer customer complaints; less need to flush hydrants; and more efficient valve, water main, and meter performance.

In unlined ductile, galvanized, or cast-iron pipe, certain products can remove existing corrosion by-products. This cleaning can often result in lower electrical pumping costs and improved chlorine residuals. Remember, when dealing with corrosion, the cleaner the water system—the better the corrosion control.

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