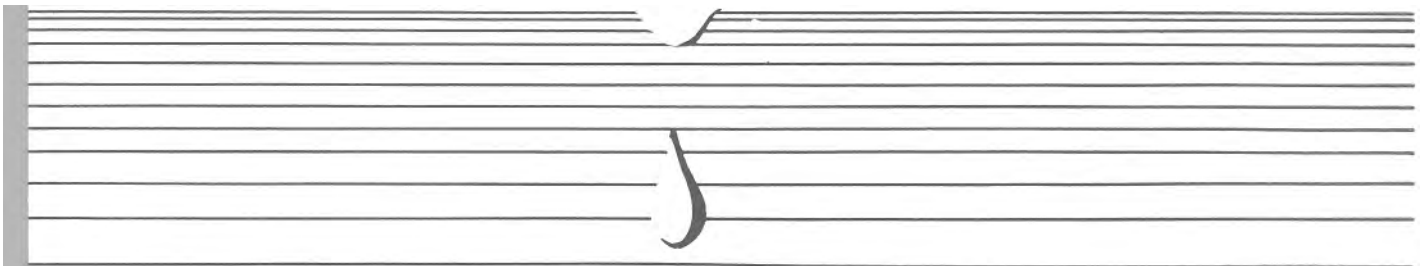


Training Guide

Corrosive Water: Testing and Treatment



Rural and Small Water Systems Training Guide

Corrosive Water: Testing and Treatment

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Although the production of this training guide has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement CT-901840-01-0 with amendments to the National Rural Water Association, it has not been subjected to the Agency's publications review process and therefore, it has not been approved for publication as an EPA document. The contents do not necessarily reflect the views and policies of EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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Acknowledgments

The National Rural Water Association extends its appreciation to the following people for their help in the preparation of this training guide:

Jerry Shands, National Rural Water Association
Kevin M. Ripp, The Kjell Corporation
Terry Engelhardt, The Hach Company
Terry Walker, National Rural Water Association
Bob Carroll, National Rural Water Association

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CORROSIVE WATER: TESTING AND TREATMENT

This NRWA Training Guide, "Corrosive Water: Testing and Treatment", reviews the effects and characteristics of corrosive water, and provides information on measuring pH, corrosiveness and rate of corrosion. It also offers courses of treatment and covers corrosiveness testing techniques.

Introduction

It is important for a water system to provide non-corrosive water throughout its distribution system. Corrosive water can cause two major problems for water systems.

It deteriorates distribution systems and metal plumbing materials by weakening pipes and fixtures, and the metals that leach into the water supply as a result of corrosion can affect the color, odor, taste, and safety of the water.

This training guide will examine the effects of corrosive water on pipes and other fixtures, and briefly mention the related health risks to humans. It will then discuss corrosion control methods using testing and the adjustment of water's acidity (pH) and carbonate levels.

Chapter 1

Corrosion and the Effects of Corrosive Water

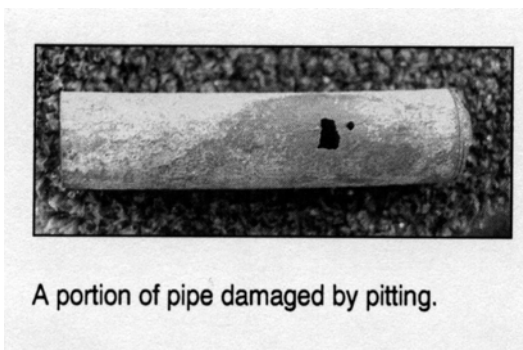
When piping materials deteriorate, the damage is called **corrosion**. Within piping materials, corrosion is caused by the physical and chemical effects of corrosive water.

It is important for the water system operator to understand how to inhibit the corrosiveness of water, to fight physical damage to the distribution system, and to protect consumer health.

It is also important for decision makers to know their responsibilities in providing non-corrosive water, so they can budget and plan to meet requirements.

Two common effects of corrosion are pitting and leaching.

Pitting is the formation of small pits or holes in pipe surfaces. The photo at left shows an example of pitting damage. In copper pipe, for example, pitting may occur when there is dissolved oxygen in water or a high free chlorine residual. A high free chlorine residual can lower water's pH level, causing it to be more acidic, and therefore more corrosive. This chlorine residual, combined with any oxygen already present, can create a strong oxidizing agent



Pitting can be caused by electrical currents or the presence of dissimilar metals in the water. Whatever the cause, the end results of pitting can be leaks or potential breakage of pipes and fixtures.

While pitting affects the physical condition of the distribution system and service lines, leaching can affect the physical condition of water and consumer health.

Leaching describes what happens when corrosive water begins to dissolve the metals used for piping. The water carries the dissolved (leached) metal in solution to the consumer's tap. This leached metal can alter the appearance, odor, and taste of water. For example, leached copper can turn water a blue-green color, and large amounts of copper in the water can cause a bitter taste.

Leached lead, however, presents no change in water's appearance, taste, or odor that consumers can detect, but can affect consumer health.

An excessive amount of lead is toxic to humans. It can damage the brain, liver and kidneys, and can contribute to anemia by interfering with the production of red blood cells. It also affects the nervous system by stripping protective coatings from the nerves.

The presence of lead in the human body is cumulative. Lead builds up in tissue and bone over time. It can take years for the body to rid itself of a single exposure to lead.

The United States Environmental Protection Agency (USEPA) has adopted an action level for lead of 0.015 milligrams per liter (mg/l) [15 parts per billion]. Refer to the USEPA's "Lead and Copper Rule" to determine specific regulatory requirements.

The EPA has adopted an action level for lead of 15 parts per billion.

When water reaches a temperature exceeding 70° Fahrenheit, corrosiveness increases.

Chapter 2

Characteristics of Corrosive Water

Corrosion control starts with providing non-corrosive water. To do this, you must be aware of the physical and chemical factors that affect water's corrosiveness.

Physical factors

Temperature is a physical factor that can affect water's corrosiveness. Corrosion is a chemical reaction which, like other chemical reactions, speeds up when temperature is increased. When water reaches a temperature exceeding 70° Fahrenheit, corrosiveness increases.

Normally, water leaves the ground at approximately 50-55° Fahrenheit. Once it is in the distribution system, a good temperature range for non-corrosive water is between 60-70° Fahrenheit. Below 60° Fahrenheit, the effectiveness of disinfection methods may be diminished, and either greater amounts of disinfection chemicals or longer contact times may be required for thorough disinfection.

Chemical factors

Chemical factors that affect water's corrosiveness include:

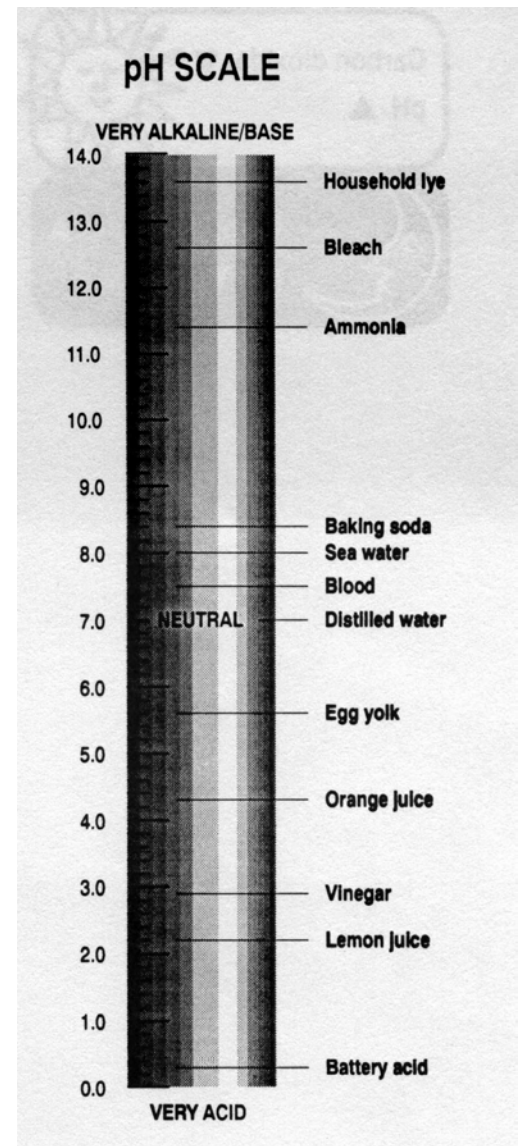
- **pH level**
- **Carbon dioxide**
- **Dissolved oxygen**
- **Chlorine**
- **Hardness**
- **Total Dissolved Solids (TDS)**

p^H is a value that expresses the intensity of acid or base of a substance. p^H is measured on a scale of 0 to 14. A p^H of 0 indicates extreme acidity; a p^H of 14 indicates extreme basic (alkaline) conditions. A p^H of 7 is considered neutral. If water has a p^H value between 0 and 7, it is considered acidic and potentially corrosive.

Carbon dioxide

The carbon dioxide level in water relates to its p^H level. In surface waters, increases and decreases in p^H are caused by changes in carbon dioxide used in photosynthesis and respiration of algae. During the day, organisms use sunlight and plant chlorophyll to convert carbon dioxide into oxygen, lowering the level of carbon dioxide in the water. This increases the water's p^H level. At night, respiration of algae increases the level of carbon dioxide in the water. This decreases the water's p^H level. As carbon dioxide levels in water increase, the p^H level decreases, which affects its acidity and corrosiveness.

Ground waters may be acidic because they contain large amounts of carbon dioxide. This carbon dioxide may be carried by rain which soaks into the soil, but is more likely to be carried by water that flows through plant roots and decaying vegetation beneath the soil. Ground water retains a high level of carbon dioxide because it is underground and the carbon dioxide has no means of release, through sunlight or plant life respiration, into the atmosphere.



Dissolved oxygen

The presence of dissolved oxygen in water speeds up corrosive reactions such as pitting. Since corrosion occurs only in the presence of oxygen, high levels of dissolved oxygen in water will increase its corrosiveness.

Chlorine

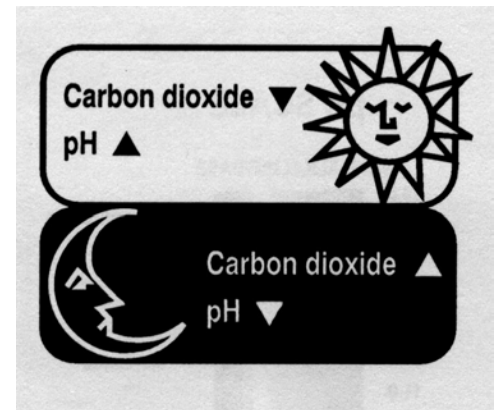
An excessive chlorine residual can lower water's pH level, causing it to be more acidic and more corrosive. A strong oxidizing agent, chlorine can add to whatever oxygen may already be present in water, increasing its potential corrosiveness.

Hardness

Calcium and magnesium compounds affect water's hardness or softness. Generally, hard water deposits minerals and soft water dissolves them. Hard water produces a scale in piping materials which protects them from corrosion. Water should only be hard enough to produce a light scale or film inside piping materials. If the water is too hard, it produces a heavy scale build-up that will restrict the velocity and amount of flow through pipes. Water hardness levels between 61 and 120 milligrams per liter as calcium carbonate (CaCO_3) may be beneficial in insulating piping materials from the corrosive effects of water.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) is the expression of the total concentration of dissolved mineral salts in water. These salts include calcium and magnesium carbonates, bicarbonates, chlorides, sulfates, iron and manganese. Like water hardness, the amount of TDS affects water's scale forming abilities. In order for water to be non-corrosive, it should have a TDS level between 50 and 500 milligrams per liter.



Of the factors that contribute to water's corrosiveness, pH and hardness are the most important in controlling lead leaching.

Physical and chemical factors are often interrelated. For example, some cold surface water supplies have high dissolved oxygen levels and thus are highly corrosive, even though their temperature is well below 70° Fahrenheit. A change in either a physical or chemical factor can affect the other factors that affect the corrosive potential of water.

Physical damage to piping materials and service lines due to the corrosive effects of water is a serious problem, but even more so are the health risks presented by lead leaching. Of the factors that contribute to water's corrosiveness, pH and hardness are most important in controlling lead leaching. You can test the pH and hardness of water at your site before it goes into the distribution system to determine if it is potentially corrosive. You can also determine the rate of corrosion. Then you can evaluate any need for and method of treatment.

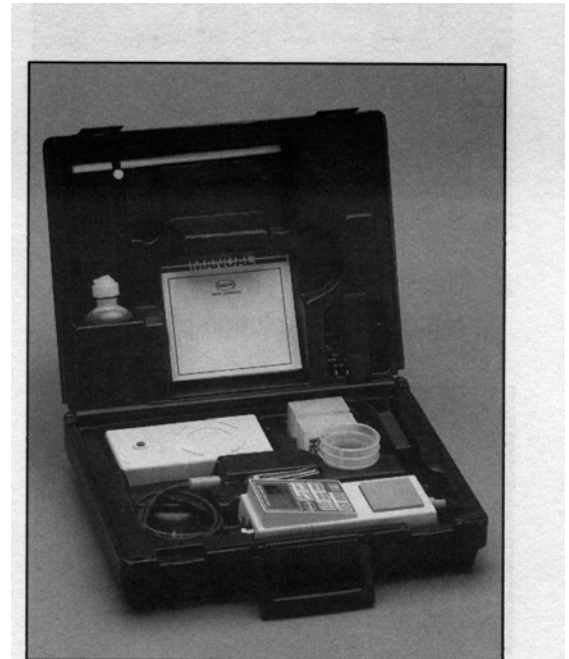
Chapter 3

Determining pH, Corrosiveness and Rate of Corrosion

pH

There are two basic approaches for measuring pH. One involves using a color comparator; the other involves using a pH meter. You should perform this test on-site instead of sending water samples to a lab for testing. Any change in temperature during transportation, the presence of oxygen in the sample container, or the presence of carbon dioxide (from exhaling on the sample) will affect the water's pH. Temperature fluctuations of more than 5° Fahrenheit will alter the pH of water.

A pH color comparator kit functions much like the one used in testing for free chlorine residuals (see **Gas Chlorination**, published by the National Rural Water Association). The comparator kit consists of a device with test tubes and a color disk. To determine the water's pH level, add the chemical reagent that accompanies the kit to a sample of your water. When the water changes appearance, it can be compared to the color disk, and the results indicate the water's pH.



A pH meter kit. Photo courtesy of Hach Company. Used by permission.

CORROSIVE WATER: TESTING AND TREATMENT

Although color comparators allow you to estimate your water's pH simply and inexpensively, the USEPA has specified that an electrometric method (using a pH meter) is the most accurate method for determining water's pH.

Contact a manufacturer's representative to find out which kit and chemical reagent your system should use for measuring pH.

Before you begin, read all instructions for operating a pH meter and make sure that the meter has been calibrated to manufacturer's specifications.

It is impossible to give instructions for each type of pH meter in this guide. The procedure described here is just one example of using a pH meter.

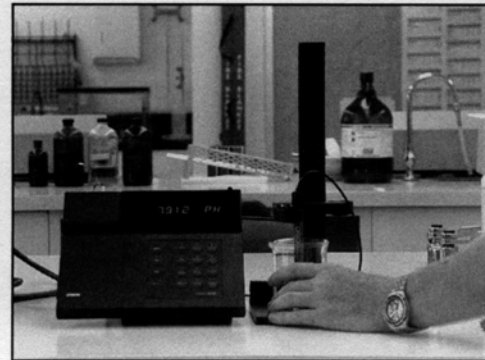
To begin, assemble the following materials:

- **Buffer solution labeled with specific pH**
- **Two clean, dry beakers**
- **A pH meter**
- **Distilled water**
- **A glass electrode**
- **A sample of your water**

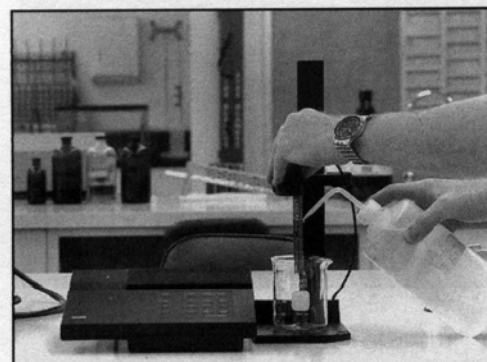
Before testing, make sure that all materials are about the same temperature. Also insure that the meter's electrode is well-seated and free from oily coatings. Then proceed as follows:



1. Pour buffer solution into beaker.



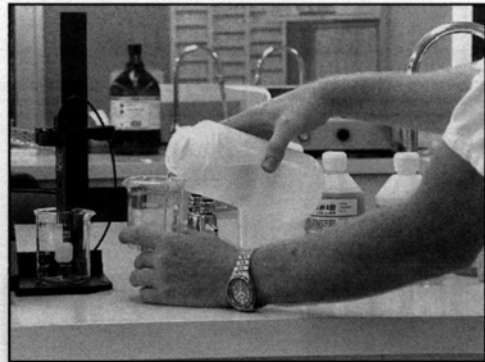
2. Standardize pH meter setting to match buffer solution pH.



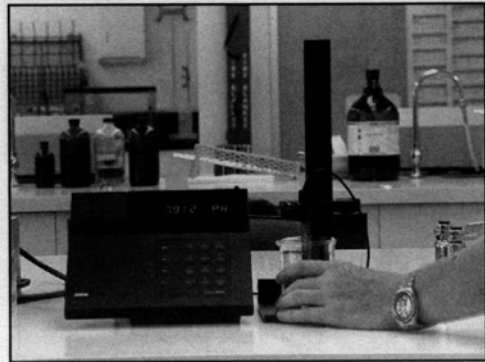
3. Rinse meter electrode.

1. Pour buffer solution into a clean, dry beaker.
2. Place the electrode of the pH meter into the buffer solution; meter until the reading registers exactly the same as the known pH of the buffer solution. (This process is called *standardizing* the meter.)
3. Rinse the electrode thoroughly with distilled water after you remove it from the buffer solution.
4. Pour a sample of your water into a clean, dry beaker.
5. Place the electrode of the pH meter into the water sample and record the reading as your water's pH.
6. Remove the electrode from the water sample and rinse with distilled water. Store the electrode in the buffer solution and be sure to turn the pH meter off when you are finished.

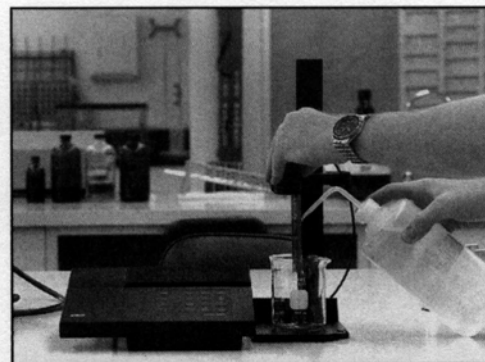
If your sample registers a pH lower than 7 with either the color comparator or the pH meter, your water is potentially corrosive, but other factors need to be evaluated to make this determination. You should test pH daily when practicing corrosion control, and whenever treatment procedures are changed.



4. Pour a sample of your water into a beaker.



5. Measure your water's pH.



6. Rinse meter electrode and store in buffer solution.

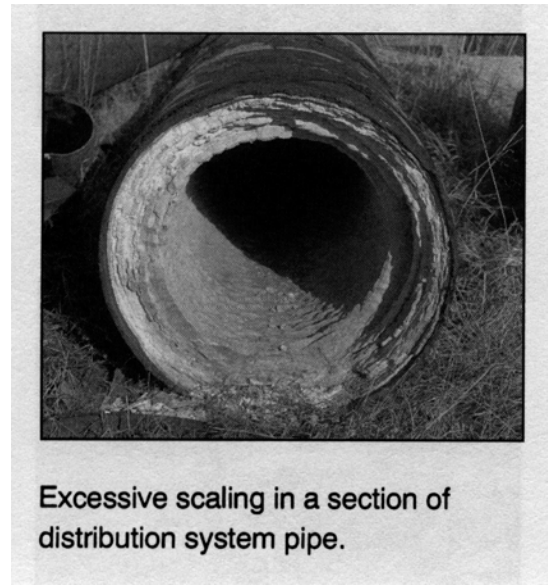
Corrosiveness

The *Marble Test*, the *Langelier Index (LI)* and the *Aggressive Index (AI)* are the corrosiveness indexes used most frequently in small water systems to measure water's scaleforming ability. Although these indexes do not measure water's corrosiveness, they are useful in predicting corrosiveness. Specifically, these indexes measure water's ability to dissolve or deposit calcium carbonate (CaCO_3). Calcium carbonate forms a protective scale inside piping materials and protects them from corrosive water.

Water's ability to form this scale combats its corrosiveness and limits potential lead leaching. Water that is saturated with calcium carbonate will form a thin scale that insulates piping materials from the corrosive effects of water; water that is undersaturated will not form a scale. Water that is supersaturated with calcium carbonate forms too much scale. This excessive scaling restricts and eventually blocks the flow of water, necessitating costly system maintenance. It is important to maintain a careful balance of pH and hardness to control corrosiveness and any resulting lead leaching without excessive scaling.

The Marble Test, the LI and the AI involve calculations based on water temperature, pH, alkalinity and hardness. These characteristics factor greatly into the determination of the corrosiveness of water. You can perform the Marble Test, the LI or the AI, or you can send water samples to a lab for testing.

See Appendices A, B and C for sample instructions of one method of performing these tests.



Rate of corrosion

Actual physical inspection of piping materials will reveal corrosion problems. Testing for pH and hardness levels provides a good indication of your water's potential corrosiveness. But to determine the rate at which piping materials are corroding, you can test the water using approaches such as the *Coupon Weight-loss* and *Loop System Weight-loss* methods.

The Coupon Weight-loss Method involves weighing a special piece of metal (the coupon) and placing it in the middle of a section of distribution system pipe for a period of time, usually a month. The corrosion rate is calculated based on the weight loss, density and surface area of the coupon over time.

The Loop System Weight-loss Method is essentially the same as the coupon method, but requires replacing an actual section of pipe with a weighed section. The corrosion rate is calculated in the same manner used for the Coupon Weight-loss Method.

The Coupon Weight-loss and Loop System Weight-loss Methods of testing are inexpensive and indicate the actual rate of corrosion in mils (thousandths of an inch) per year (mpy). They also allow you to monitor the effectiveness of corrosion control treatment. These methods of testing require time, however, and do not measure daily variations in the rate of corrosion. They also do not indicate the physical or chemical factors that are contributing to the water's corrosiveness.

Actual physical inspection of piping materials will reveal corrosion problems.

The Coupon Weight-loss and Loop System Weight-loss Methods of testing should be conducted only under supervision of an experienced engineer.

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If the tests you conduct indicate that your water is acidic with a pH of less than 7, and that your water is not saturated (that it dissolves calcium carbonate), your system faces corrosion and leaching problems.

The simplest and most economical solution is to treat the water chemically to reach a point of equilibrium.

For small water systems, the most practical and economical method of treatment generally involves adjusting pH and carbonate (alkalinity) levels.

Chapter 4

Treating Corrosive Water

Corrosive water requires timely treatment to prevent costly repairs due to corrosion, and to protect consumers from the dangerous effects of leached lead. This can be accomplished through pH and carbonate adjustment, or through addition of corrosion inhibitors. For small water systems, the most practical and economical method of treatment generally involves adjusting pH and carbonate (alkalinity) levels through the use of one of these chemicals:

- **Hydrated lime**
- **Soda ash**
- **Caustic soda**

As individual treatments, these chemicals are added **after** water is disinfected, but **before** it enters the distribution system. Each of these chemicals helps to raise pH while altering water hardness. Soda Ash will not substantially increase hardness.

Hydrated lime is often used to treat water that has low levels of alkalinity and hardness (see Appendix A, B or C for determining these values). Small water systems use hydrated lime because it has already been slaked. Slaking is a process which involves mixing the lime with water and heating the mixture before it can be fed into the water. This process requires expensive, specialized equipment, so it is generally more economical for small systems to buy hydrated lime.

Proper use of these chemicals (hydrated lime, soda ash and caustic soda) in raising pH has the added effect of adjusting carbonate levels so that water is saturated with calcium carbonate.

Hydrated lime is only slightly water soluble. It is usually fed using a dry feeder.

Soda ash is the common name for sodium carbonate. It is a white powder alkali that is often used in treating water with high levels of alkalinity and hardness. The water's high hardness will allow it to form calcium carbonate scale, but soda ash raises the pH so that the water achieves equilibrium. Soda Ash adds carbonates to water and increases pH without substantially increasing hardness. It is used to precipitate and remove non-carbonate hardness.

Soda ash is water soluble and generally fed using a solution feeder.

In general, lime and soda ash produce hardness compounds in their least soluble form. While dissolved hardness can be reduced to low levels, it is not completely eliminated by this process. Good dosage control is needed for best results since excess lime can actually increase hardness by contributing calcium to the water. When lime and soda ash are added to water, they react together to form caustic soda.

Caustic soda is the common name for sodium hydroxide and may also be used for water with high levels of alkalinity and hardness. It is a strong alkali, available as a solid or liquid.

Caustic soda burns the skin and becomes hot when mixed with water. To prevent burns, wear protective clothing, a respirator and goggles. Ventilate the working area.

Like soda ash, caustic soda is water soluble and generally fed by a solution feeder.

Proper use of the chemicals listed above in raising pH has the added effect of adjusting carbonate levels so that water is saturated with calcium carbonate.

The other means of treating corrosive water is to add corrosion inhibitors such as polyphosphates or orthophosphates. Unlike the chemical treatments discussed previously, polyphosphates and orthophosphates fight calcium carbonate scale formation but deposit a similar protective film of their own.

Polyphosphates and orthophosphates can be used in place of or as a supplement to pH and carbonate adjustment treatments.

Depending on price fluctuations due to supply and demand, corrosion inhibitors can be expensive methods of corrosion control, but they may also offer advantages over traditional methods of pH adjustment. You may wish to refer to the selected bibliography at the end of this guide for sources with detailed information on corrosion inhibitors.

The dosage of any chemical treatment and the feeding equipment required varies based on system size. Consider the cost of chemicals and safety precautions involved before embarking on any water treatment plan. Contact your state health department or your state rural water association for information on possible treatment programs.

Consider the cost of chemicals and safety precautions involved before embarking on any water treatment plan.

Corrosion Control Treatments

Chemical Treatment	Name and Formula	Use	Remarks
Hydrated lime	Calcium hydroxide (Ca(OH) ₂)	Low hardness, low alkalinity	Wear protective clothing
Soda ash	Sodium carbonate (Na ₂ CO ₃)	High hardness, high alkalinity	Wear protective clothing
Caustic soda	Sodium hydroxide (NaOH)	High hardness, high alkalinity	Burns skin; becomes hot when mixed with water. Wear protective clothing

Appendix A

The Marble Test

The Marble Test (Calcium Carbonate Stability test) measures whether water is saturated with calcium carbonate (CaCO_3) and has two general uses. It is valuable in checking the stability of a water that has been softened by the lime/soda ash process. It also determines the total alkalinity required by a water to prevent corrosion through the deposition of a protective coating of calcium carbonate in the mains.

It is a relatively simple laboratory procedure used to determine the necessary pH and alkalinity adjustments needed to achieve calcium carbonate equilibrium. The treatment of water to produce a protective calcium carbonate film on the inside of water pipes is based upon this adjustment of pH and alkalinity.

To save valuable time during testing, carefully read through the sample instructions below before proceeding. Also, be sure to read any kit manufacturer's instructions for performing specific segments of this test. Instructions may vary according to chemical reagents or kits used. There are currently over 45 kits available from various manufacturers. Contact your local supplier for more information on kits.

The Marble Test is a relatively simple procedure used to adjust pH and alkalinity to produce a protective film inside water pipes.

The following testing procedure serves only as an example.

Required Reagents and Equipment:

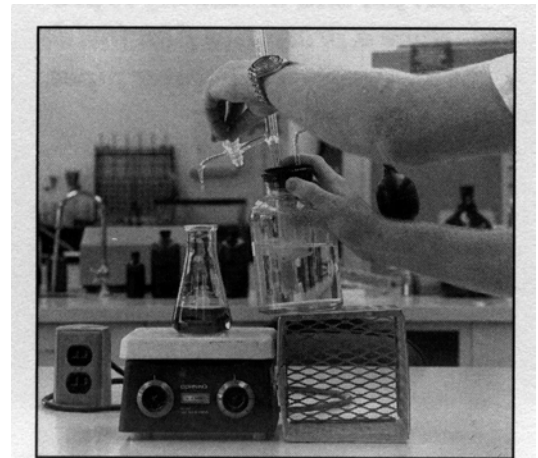
- Reagent grade calcium carbonate powder (CaCO_3)
- 300-milliliter Biochemical Oxygen Demand (BOD) bottle
- Whatman No. 50 filter paper
- Apparatus for determining alkalinity

Procedure:

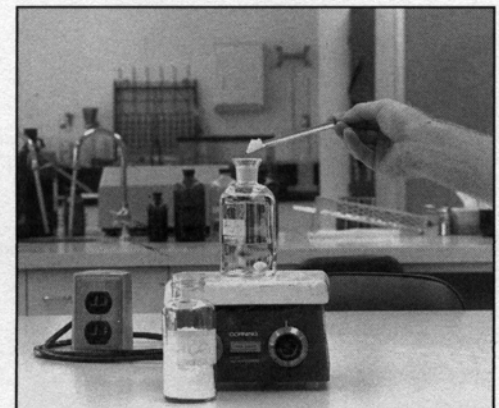
1. Determine the total alkalinity of water sample. (Refer to the sample procedure for determining alkalinity in Appendix B on page 26.)
2. Fill BOD bottle with another water sample. Be careful not to agitate the sample.

WARNING: The sample should be collected with as little splashing and aeration as possible to prevent the loss of dissolved carbon dioxide. The bottle should be stoppered to prevent the entrapment of air near the stopper.

3. Add an excess of calcium carbonate powder (CaCO_3), approximately 0.5 grams.



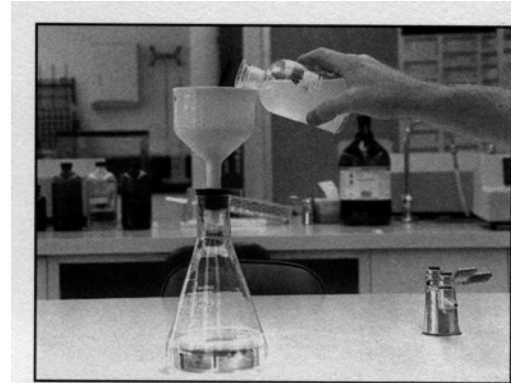
Determine sample alkalinity.



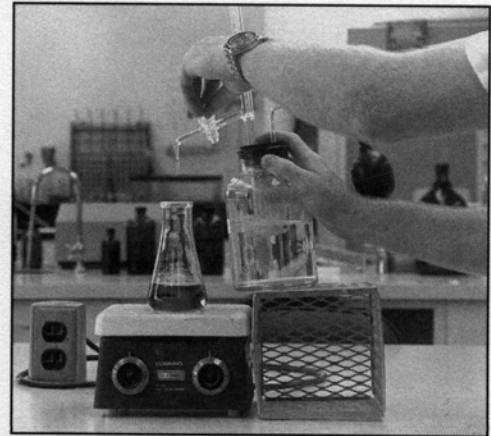
Add calcium carbonate (CaCO_3) to sample.

APPENDIX A

4. Carefully replace the stopper in the BOD bottle so that no air bubbles are left at the top.
5. Mix the powder and the water by shaking the bottle at frequent intervals (every 20 minutes) for at least two hours.
6. Allow the sample to settle overnight. During the first part of the settling, tap the bottle gently and twist the stopper so that the powder which adheres to the walls and to the stopper can be loosened and thereby enabled to settle to the bottom of the bottle.
7. With a 100 ml pipet, carefully remove two portions of the supernatant (the clear layer above the settled material) and place the samples in a clean container. Filter the withdrawn supernatant through filter paper, discarding the first 25 ml of the filtrate and saving the remainder.
8. Determine the total alkalinity of the filtrate. Make sure that the calcium carbonate powder is completely removed from the filtrate to avoid any error in the total alkalinity.
9. Subtract the filtrate's alkalinity value from the alkalinity value of the original sample.



Filter the sample.



Determine alkalinity of filtrate.

The difference in your initial and final alkalinity values indicates your water's potential for precipitating calcium carbonate.

Interpretation:

If the alkalinity of step 8 is greater than the alkalinity of step 1, the water is undersaturated and may be corrosive.

If the alkalinity of step 8 is less than the alkalinity of step 1, the water is supersaturated and may deposit a protective film or coating in the mains.

NOTE: Excessive saturation may cause reduced carrying capacities or even stoppage in mains.

If the alkalinity of both steps 8 and 1 is equal, the water is stable and in a state of calcium carbonate equilibrium.

Treatment Techniques:

Changes in the total alkalinity of the sample can be accomplished using the following chemical treatment dosages as a guideline:

1. Each 1mg/1 dose of pure lime (CaO) or 1.1 mg/1 dose of 90 percent commercial quicklime increases the total alkalinity by 1.79 mg/1 or reduces the carbon dioxide by 1.57 mg/1.
2. Each 1 mg/1 dose of pure hydrated lime, Ca(OH)₂, or 1.41 mg/1 dose of 93 percent commercial hydrated lime increases the total alkalinity by 1.35 mg/1 or reduces the carbon dioxide by 1.19 mg/1.

For additional information about treatment or further testing, contact your state rural water association.

The Langelier Index is the most commonly used method of estimating water's calcium carbonate saturation as an aid in monitoring water's potential corrosiveness. Use this method if you have regular access to the materials mentioned.

Appendix B

The Langelier Index (LI)

The Langelier Index (LI) gauges water's level of saturation with calcium carbonate (CaCO_3). This index serves as an aid in predicting water's corrosiveness.

The LI is the difference between water's actual (measured) pH and the calculated pH of saturation. The pH of saturation is based on values derived by measuring:

- **pH**
- **Temperature**
- **Total Dissolved Solids (TDS)**
- **Calcium Hardness**
- **Total alkalinity**

The following instructions for obtaining the measurements and values necessary for LI calculations serve as an example, and are based on the methods and solution strengths described in *Standard Methods for the Examination of Water and Waste Water*, Washington, D.C., APHA, AWWA, WPCA, 1989.

Carefully read through these instructions before proceeding, and be sure to read any test kit manufacturer's instructions before performing any tests. Instructions may vary according to chemical reagents or kits used.

Gather the following material

- Measured samples of your water in clean beakers
- pH meter or pH comparator kit
- Celsius thermometer (if you do not have a Celsius thermometer, you can use a Fahrenheit thermometer and convert the results using the formula shown below)
- Conductivity meter
- Buffer solution
- Hardness titrant (EDTA or CDTA)
- Indicator solution
- Alkalinity indicator reagent
- Magnetic stirrer
- Stir-bar

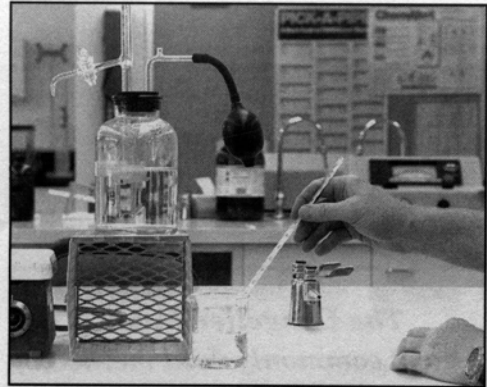
1. Record sample temperature in degrees Celsius. If you do not have a thermometer that measures Celsius, measure the temperature in degrees Fahrenheit and convert the measurement based on the following formula:

$$C = \frac{(F - 32) \times 5}{9}$$

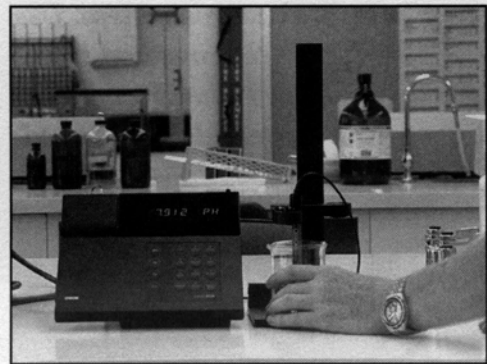
where:

C = the temperature in degrees Celsius.

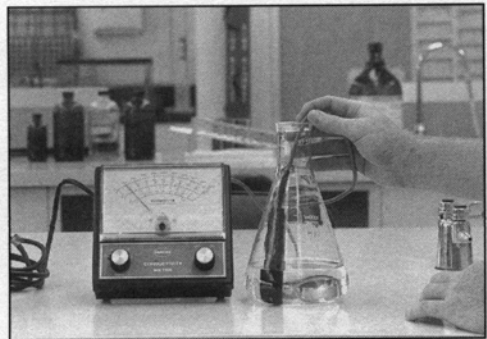
F = the temperature in degrees Fahrenheit



1. Measure sample temperature.

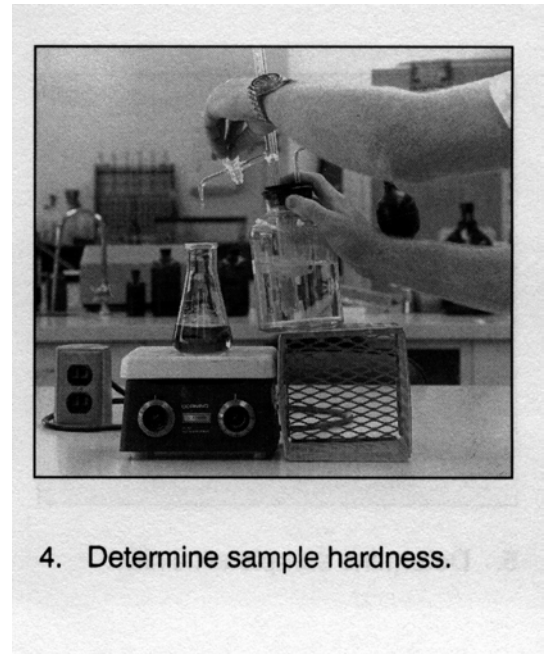


2. Measure sample pH using a pH meter or a color comparator.



3. Estimate sample TDS using a conductivity meter.

2. Measure sample pH using either a pH meter or a color comparator kit. See *page 10* for a discussion of this process. Record the result.
3. Estimate sample TDS using a conductivity meter. A conductivity meter measures water's ability to carry electrical currents. Follow manufacturer's instructions when using a conductivity meter.
 - a. Measure the conductivity of your sample in microohms/centimeter.
 - b. Multiply this figure by 0.9 (the ratio of conductivity to TDS) and record the result in milligrams per liter (mg/l).
4. Measure sample calcium hardness. Hardness can be measured by an EDTA (ethylenedinitrilo)-tetraacetic acid disodium salt) or CDTA (disodium 1,2 cyclohexanediaminetetraacetic acid) titration as indicated below:
 - a. Add two ml of buffer solution to your sample.
 - b. Add two drops indicator solution to the sample.
 - c. Titrate (add titrant to the water a drop at a time) until the sample loses its reddish color and becomes a pure blue color, indicating that it has reached its end point.
 - d. Record the amount of titrant used in milliliters. Then calculate hardness based on the following formula:



$$H = \frac{(T \times 1,000)}{S}$$

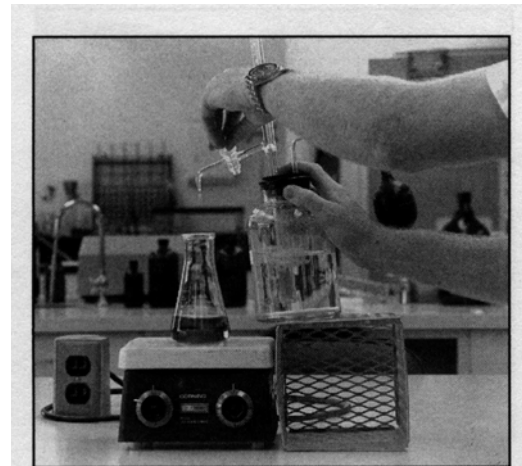
where:

H = Calcium Hardness in mg/1 as CaCO₃,

T = amount of titrant used (ml)

S = Size of sample (ml)

5. Measure the total alkalinity of your sample. Total alkalinity can be measured by titration as follows:
 - a. Measure a 100 ml sample of your water into a clean, dry beaker.
 - b. Put the stirrer bar into the beaker and stir sample slowly.
 - c. Measure sample pH using either a pH meter or color comparator kit.
 - If the sample pH is **less than 8.3**, titrate sample to pH 4.5 with a standard 0.02 N sulfuric acid solution. *Consult manufacturer's instructions on preparation of solution.* Record the amount of acid used and calculate total alkalinity according to the formula in d. below.
 - If the sample pH is **greater than 8.3**, titrate the sample with a standard 0.02 N sulfuric acid solution to a pH of 8.3. Record the amount of titrant necessary to reach this point. Next, titrate the sample further to a pH of 4.5, still using the acid solution. Add together the amounts used for both the first and second titrations, and use this total to calculate alkalinity.



5. Determine sample alkalinity.

NOTE: Only **one** of the totals you arrive at in these procedures is necessary to calculate alkalinity for the LI

d. Calculate total alkalinity based on the following formula:

$$T = \frac{A \times 0.02N \times 50,000}{\text{ml of sample}}$$

where:

T = Total alkalinity in mg/l as CaCO₃

A = total ml of titrant used in titration

Use the following formula to calculate LI:

$$LI = pH - pH_s$$

where:

pH = the measured or actual pH of a water sample and

pH_s = the value at which water is saturated with calcium carbonate.

To determine the value for pH_s , the following formula is used:

$$pH_s = A + B - C - D,$$

where:

A = the value selected from Table A, page 36 that corresponds with the sample's *temperature*

B = the value selected from Table B, page 36 that corresponds with the sample's *Total Dissolved Solids (TDS)*

C = the value selected from Table C, page 36 that corresponds with the sample's *total alkalinity*.

D = the value selected from Table D, page 36 that corresponds with the sample's *calcium hardness*.

Example:

Find the pH_s and LI of water with the following measurements:

$$pH = 7.8$$

$$\text{Temperature} = 25^\circ C$$

$$\text{TDS} = 100 \text{ mg/l}$$

$$\text{Total Alkalinity} = 100 \text{ mg/l}$$

$$\text{Calcium Hardness} = 50 \text{ mg/l}$$

STEP 1.

Match the measurements with their corresponding values from the tables on page 36:

The value for *temperature* (A) = 2.00

The value for TDS (B) = 9.77

The value for total *alkalinity* (C) = 2.00

The value for *calcium hardness* (D) = 1.30

STEP 2.

Calculate the pH_s by replacing the letter variables with their corresponding values:

$$\begin{aligned} \text{pH}_s &= A+B-C-D \\ &= 2.00+9.77-2.00-1.30 \\ &= 8.47 \end{aligned}$$

STEP 3.

Calculate the LI of your sample by subtracting the value for pH_s from the pH you recorded:

$$\begin{aligned} \text{LI} &= \text{pH} - \text{pH}_s \\ &= 7.8 - 8.47 \\ &= -0.67 \end{aligned}$$

An LI of 0 is the optimum value for your water if it is to produce a thin scale to protect against corrosion and lead leaching.

If the LI value is **greater than** 0, your water is supersaturated and may tend to form too much calcium carbonate scale. If the LI value is **equal to** 0, your water is saturated; it will neither deposit nor dissolve calcium carbonate. If the LI value is **less than** 0, your water is undersaturated and tends to dissolve calcium carbonate.

An LI of 0 is the optimum value for your water if it is to produce a thin scale to protect against corrosion and lead leaching.

For information about necessary treatment or further testing, contact your state rural water association.

Appendix C

The Aggressive Index (AI)

The Aggressive Index (AI) is a simplified variation of the Langelier Index (LI). The AI also estimates the solubility of CaCO_3 in water, but its values are derived from measuring:

- **pH**
- **Calcium Hardness**
- **Total alkalinity**

Carefully read through these sample instructions before proceeding. Be sure to read the manufacturer's instructions for performing the specific segments of this test; instructions may vary according to chemical reagents or kits used. The methods and solution strengths used in this sample procedure were derived from *Standard Methods for the Examination of Water and Waste Water*, Washington, D.C., APHA, AWWA, WPCA, 1989.

Use the Aggressive Index as a simplified version of the Langelier Index to estimate the solubility of calcium carbonate in your water.

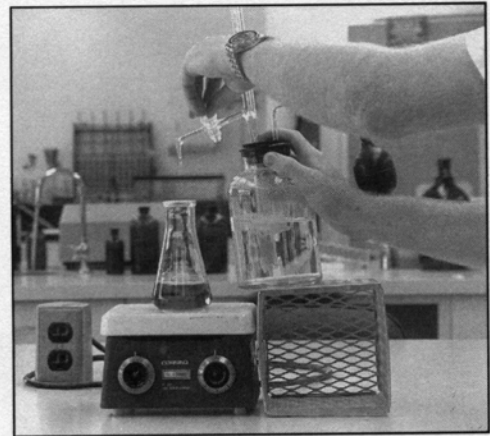
Gather the following materials:

- **Measured samples of your water in clean beakers**
- **pH meter or pH comparator kit**
- **Buffer solution**
- **Hardness titrant (EDTA or CDTA)**
- **Indicator solution**
- **Alkalinity indicator reagent**
- **Magnetic stirrer**
- **Stir-bar**

1. Measure sample pH using either a pH meter or a color comparator kit. See page 10 for a discussion of this process. Record the result.
2. Measure sample calcium hardness. Calcium hardness can be measured by an EDTA ((ethylenedinitrilo)-tetraacetic acid disodium salt) or CDTA (disodium 1,2 cyclohexanediaminetetraacetic acid) titration as indicated below:
 - a. Add two ml of buffer solution to your sample.
 - b. Add two drops of indicator solution to your sample.
 - c. Titrate (add titrant to the water a drop at a time) until the sample loses its reddish color and becomes a pure blue color, indicating that it has reached its end point.
 - d. Record the amount of titrant used in milliliters. Then
 - e. calculate hardness based on the following formula:



1. Measure sample pH using a pH meter or color comparator.



2. Determine sample hardness.

$$H = \frac{(T \times 1000)}{S}$$

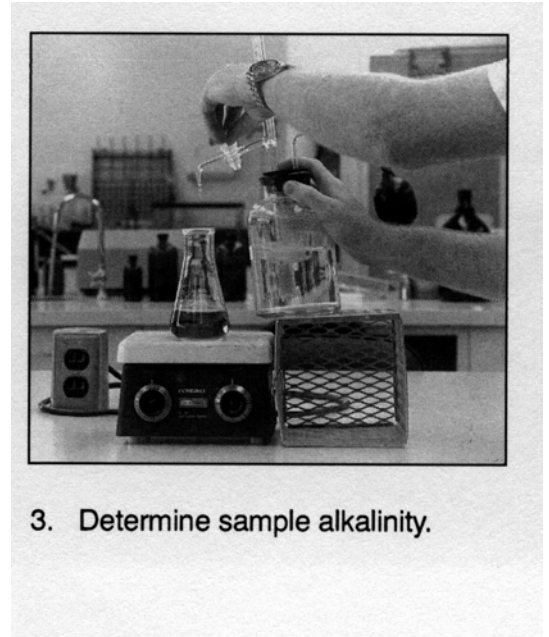
where:

H = Calcium Hardness in mg/l as CaCO₃

T = amount of titrant used (ml)

S = Size of sample (ml)

3. Measure the total alkalinity of your sample. Total alkalinity can be measured by titration as follows:
 - a. Measure a 100 ml sample of your water into a clean, dry beaker.
 - b. Put the stirrer bar into the beaker and stir sample slowly.
 - c. Measure sample pH using either a pH meter or color comparator kit.
 - If the sample pH is **less than 8.3**, titrate sample to pH 4.5 with a standard 0.02 N sulfuric acid solution. *Consult manufacturer's instructions on solution preparation.* Record the amount of acid used and calculate total alkalinity according to the formula in d. below.
 - If the sample pH is **greater than 8.3**, titrate the sample with a standard 0.02 N sulfuric acid solution to a pH of 8.3. Record the amount of titrant necessary to reach this point. Next, titrate the sample further to a pH of 4.5, still using the acid solution. Add together the amounts used for both the first and second titrations, and use this total to calculate alkalinity.



3. Determine sample alkalinity.

NOTE: Only **one** of the totals you arrive at in the procedures above is necessary to calculate total alkalinity for the LI.

d. Calculate total alkalinity based on the following formula:

$$T = \frac{A \times 0.02N \times 50.000}{\text{ml of sample}}$$

where:

T = Total alkalinity in mg/l as CaCO₃

A = total ml of titrant used in titration.

Use the following formula to calculate AI:

$$AI = pH + C + D,$$

where:

pH = the measured or actual pH of a water sample,

C = the value selected from Table C, *page 36*, that corresponds with the sample's *total alkalinity*.

D = the value selected from Table D, *page 36*, that corresponds with the sample's *calcium hardness*.

Example:

Find the AI of water with the following measurements:

$$pH = 6.5$$

$$\text{Total Alkalinity} = 100 \text{ mg/l}$$

$$\text{Calcium Hardness} = 50 \text{ mg/l}$$

STEP 1.

Match the measurements with their corresponding values from the LI/AI tables on *page 36*. $pH = 6.5$
The value for *total alkalinity* (C) = 2.00 The value for *calcium hardness* (D) = 1.30

STEP 2.

Calculate the sample's AI by adding all values:

$$\begin{aligned} \text{AI} &= pH+C+D \\ &= 6.5+2.00+1.30 \\ &= 9.8 \end{aligned}$$

If the AI value is **greater than 12**, your water is non-aggressive (not corrosive). If the AI value is **in the range** of 10-11.9, your water is moderately aggressive. If the AI value is **less than 10**, your water is very aggressive (corrosive). An AI above 12 is the optimum value for your water.

For information about necessary treatment or further testing, contact your state rural water association.

If the AI value is less than 10, your water is very aggressive (corrosive). An AI above 12 is the optimum value for your water.

Langelier and Aggressive Index (LI/AI) Tables

TABLE A

Water Temperature °C	Value for A
0	2.60
4	2.50
8	2.40
12	2.30
16	2.20
20	2.10
25	2.00
30	1.90
40	1.70
50	1.55
60	1.40
70	1.25
80	1.15

TABLE B

Total Dissolved Solids (TDS) milligrams/Liter	Value for B
0	9.70
100	9.77
200	9.83
400	9.86
600	9.89
1000	9.90

TABLE C

Total Alkalinity milligrams/Liter as CaCO ₃	Value for C
10	1.00
20	1.30
30	1.48
40	1.60
50	1.70
60	1.78
70	1.84
80	1.90
100	2.00
200	2.30
300	2.48
400	2.60
500	2.70
600	2.78
700	2.84
800	2.90
900	2.95
1000	3.00

TABLE D

Calcium Hardness milligrams/Liter as CaCO ₃	Value for D
10	0.60
20	0.90
30	1.08
40	1.20
50	1.30
60	1.38
70	1.44
80	1.50
100	1.60
200	1.90
300	2.08
400	2.20
500	2.30
600	2.38
700	2.44
800	2.50
900	2.55
1000	2.60

Langelier Index (LI) Formulas

$$LI = pH - pH_s$$

$$pH_s = A + B - C - D$$

Indications:

- LI > 0 Water is supersaturated
- LI = 0 Water is saturated
- LI < 0 Water is undersaturated

Aggressive Index (AI) Formula

$$AI = pH + C + D$$

Indications:

- AI > 12 Water is non-aggressive
- AI = 10–11.9 Water is moderately aggressive
- AI < 10 Water is very aggressive

Glossary

Aggressive Index (AI): A method used to predict the corrosiveness of water, based on the water's pH level, alkalinity, and hardness.

Alkalinity: A measure of water's ability to neutralize acid.

Calcium carbonate (CaCO₃): One of the materials deposited by water that can form a protective scale inside piping materials to prevent corrosion.

Carbon dioxide (CO₂): An odorless, colorless gas that affects water's corrosiveness. It is closely related to the pH of water. Water with a high level of carbon dioxide will have a correspondingly low pH and a greater potential for corrosiveness.

Caustic soda (NaOH): Common name for sodium hydroxide. It is a strong alkali used to adjust pH and carbonate levels in water to control corrosion. Caustic soda burns the skin. To prevent burns, wear protective clothing, a respirator and goggles.

Corrosion: The deterioration of a substance as a result of physical and chemical reactions.

Corrosion inhibitors: Substances that control or prevent corrosion-in this instance-of piping materials, by creating a protective film between water and piping or fixture interiors.

Corrosive: The physical and chemical characteristics of a substance that enable it to cause deterioration of another substance.

Coupon: A section of pipe inserted into a distribution system or service line to assist in measuring rate of corrosion.

Coupon Weight-loss Method: A means of measuring rate of corrosion in millionths of inches per year (mpy) through the use of a physical sample immersed in the water system or service lines.

Dissolved Oxygen: Oxygen present in water.

Hardness: The level of calcium and magnesium in water. Water with adequate hardness produces a light scale which protects plumbing materials from corroding.

Hydrated lime (Ca(OH)₂): A fine powder used to adjust pH and carbonate levels in water to control corrosion.

Langelier Index (LI): A method used to measure water's saturation with calcium carbonate, based on water pH, temperature, Total Dissolved Solids (TDS), hardness and total alkalinity. It is a means of predicting the corrosiveness of water.

Leaching: Occurs when corrosive water reacts with metal plumbing materials. Metals leach into water when corrosive water deteriorates metal pipe and solder.

Lead: A heavy, bluish-white metal that was used extensively for pipes and solder until the United States Environmental Protection Agency (USEPA) banned its use in piping drinking water supplies in 1986. Lead is toxic and considered a health hazard.

Loop: A section of pipe weighed and fitted into a distribution system or service line to provide evidence of corrosion.

Loop System Weight-loss Method: A means of measuring rate of corrosion in millionths of inches per year (mpy) through the use of a physical sample fitted into water system or service lines.

Marble Test: A procedure used to measure the saturation of water with calcium carbonate, based on the water's pH, alkalinity and hardness.

Orthophosphates: Chemical treatments that inhibit corrosion through formation of a protective film in piping interiors.

pH: A value which expresses how acidic or how basic a substance is. The pH scale ranges from 0 to 14. A pH of zero means the water is very acidic and a pH of 14 means the water is very basic (alkaline). A pH of 7 means the water is neutral. A change on the pH scale of a whole number represents a 10-fold change in the strength of the acid or base, i.e. a pH of 3 is 10 times more acidic than a pH of 4.

Photosynthesis: A process in which organisms convert carbon dioxide into oxygen with the help of plant chlorophyll and the sun. Photosynthesis causes changes in the pH of surface waters, such as oceans and lakes.

Pitting: Corrosion damage caused by the formation of small holes in pipe surfaces. Pitting is usually caused by water that has dissolved oxygen, high chlorine residuals, or metals dissimilar to those used in piping construction.

Polyphosphates: Chemical treatments that inhibit corrosion through formation of protective film in piping interior.

Saturation: The condition in which a substance remains in solution without precipitate. In this instance, saturation refers to the tendency of water to neither deposit nor dissolve calcium carbonate.

Soda ash: Common name for sodium carbonate. It is a white powder alkali used to adjust pH and carbonate levels in water to control corrosion.

Supersaturated: The condition of a substance in which some materials precipitate from solution. In this instance, supersaturation refers to the tendency of water to deposit calcium carbonate.

Titration: In this instance, a procedure used to measure hardness and total alkalinity. Specific chemical reagents are added to water samples until noticeable changes occur in each sample.

Total Dissolved Solids: The total concentration of dissolved mineral salts in water. These salts include calcium and magnesium carbonates, bicarbonates, chlorides, sulfates, iron and manganese.

Undersaturation: The condition in which a substance can continue to be dissolved in solution. In this instance, undersaturation refers to the tendency of water to dissolve calcium carbonate.

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