SECTION D

WATER PURIFICATION AND TREATMENT

EDITORIAL

Attendance Urged at Special Council Meeting

A special town council meeting next Wednesday could result in important decisions affecting all citizens of Riverwood. The meeting will address two primary questions: Who is responsible for the fish kill? Who should pay the expenses of trucking water to Riverwood during the three-day water shutoff as well as any damages resulting from cancellation of the fishing tournament? These questions have financial consequences for all town taxpayers.

Those testifying at next week's public meeting include representatives of industry and agriculture, scientists taking part in the river-water analyses, and consulting engineers who have been studying the cause of the fish kill. Chamber of Commerce members representing Riverwood storeowners, representatives from the County Sanitation Commission, and officials of the Riverwood Taxpayer Association also will make presentations.

We urge you to attend and participate in this meeting. Many unanswered questions remain. Was the fish kill an "act of nature" or was it due to some human error? Was there negligence? Should the town's business community be compensated, at least in part, for financial losses resulting from the fish kill? If so, how should they be compensated and by whom? Who should pay for the drinking water brought to Riverwood? Can this situation be prevented in the future? If so, at what expense? Who will pay for it?

The *Riverwood News* will set aside part of its Letters to the Editor column in coming days for your comments on these questions and other matters related to the community's recent water crisis. For useful background information on water quality and treatment, we have prepared a special feature in today's paper that we think you will find useful.

WATER PURIFICATION THROUGH HYDROLOGIC CYCLE

BY RITA HIDALGO
Riverwood News Staff Reporter

The residents of Riverwood share a sense of relief that the Snake River fish-kill mystery has been satisfactorily solved. However, ensuring the quality of Riverwood's water supply is a long-term commitment.

To act wisely about water use, whether in Riverwood or in other communities, residents must know how clean the water is and how it can be brought up to the quality required. It should not take an emergency or crisis to focus attention on these concerns.

How do water-treatment methods address threats similar to those investigated in the recent fish-kill crisis? This article provides details on how natural water-purification systems work to ensure the safety of community water supplies—particularly in light of potential threats in the form of water contamination. A companion article in today's *Riverwood News* looks at municipal water-treatment methods—procedures that mimic, in part, water-purification processes found in nature's water cycle.

Until the late 1800s, Americans obtained water from local ponds, wells, and rainwater holding tanks. Wastewater and even human wastes were discarded into holes, dry wells, or leaching cesspools (pits lined with broken stone). Some wastewater was simply dumped on the ground.

By 1880, about one-quarter of U.S. urban households had flush toilets; municipal sewer systems were soon constructed. However, as recently as 1909, sewer wastes were often released without treatment into lakes and streams, from which water supplies were drawn at other locations. Many community leaders believed that natural waters would purify themselves indefinitely.

Waterborne diseases increased as the concentration of intestinal bacteria in drinking water rose. As a result, water filtering and chlorinating of water supplies soon began. However, municipal sewage—the combined waterborne wastes of a community—remained generally untreated. Today, with larger quantities of sewage being generated and with extensive recreational use of natural waters, sewage treatment is part of every municipality's water-processing procedures.

Nature's water cycle, the hydrologic cycle, includes water-purification steps that address many potential threats to water quality. Thermal

see Water Purification, page 5

Water Purification, from page 3

energy from the Sun causes water to evaporate from oceans and other water sources, leaving behind any heavy metals, minerals, or molecular substances that were in the water.

This natural process accomplishes many of the same results as distillation. Water vapor rises, condenses into tiny droplets in clouds, and—depending on the temperature—eventually falls as rain or snow. Raindrops and snowflakes are nature's purest form of water, containing only dissolved atmospheric gases. However, human activities release a number of gases into the air, making present-day rain less pure than it used to be.

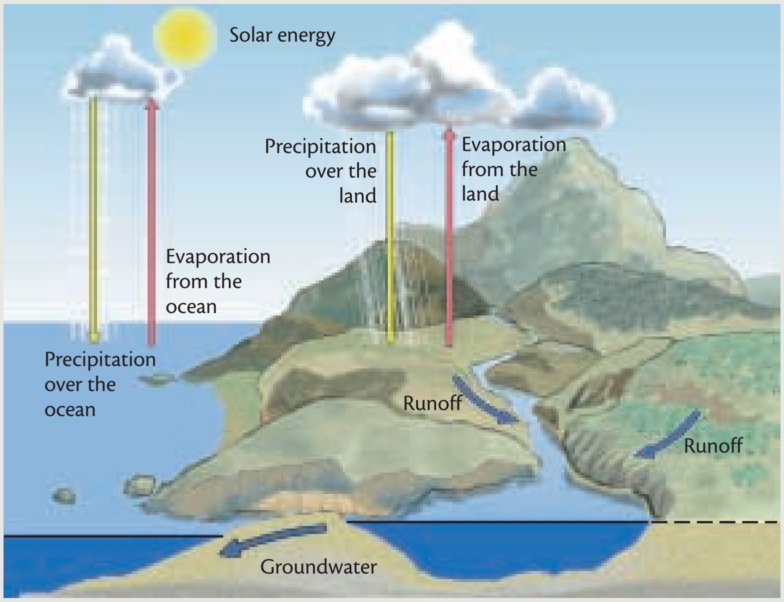
When raindrops strike soil, the rainwater collects additional impurities. Organic substances deposited by living creatures become suspended or dissolved in the rainwater. Located a few centimeters below the soil surface, bacteria feed on these substances, converting them into carbon dioxide, water, and other simple compounds. Such bacteria thus help repurify the water.

As water seeps farther into the ground, it usually passes through gravel, sand, and even rock. Waterborne bacteria and suspended matter are removed (filtered out). Thus three processes make up nature's water-purification system.

- **Evaporation,** then followed by **condensation,** removes nearly all dissolved substances.
- **Bacterial action** converts dissolved organic contaminants into a few simple compounds.
- **Filtration** through sand and gravel removes nearly all suspended matter.

Given appropriate conditions, people could depend solely on nature to purify their water. "Pure" rainwater is the best natural supply of clean water. If water seeping through the ground encountered enough bacteria for a long enough time, all natural organic contaminants could be removed. Flowing through sufficient sand and gravel would remove suspended matter from the water. However, nature's system cannot be overloaded if it is to work well.

If groundwater is slightly acidic (pH less than 7) and passes through rocks containing slightly soluble compounds such as magnesium and calcium minerals, a problem arises. Chemical reactions with these minerals may add substances to the water rather than removing them. In this case, the water may contain a relatively high concentration of dissolved minerals.



Your first laboratory activity in this unit (page 8) demonstrated that sand can act as a water filter.

CD-ROM WWW. **Section A: The Hydrologic Cycle**

Recall that the water cycle was first described on page 14.

D.2 MUNICIPAL WATER PURIFICATION

WATER PURIFICATION THROUGH MUNICIPAL TREATMENT

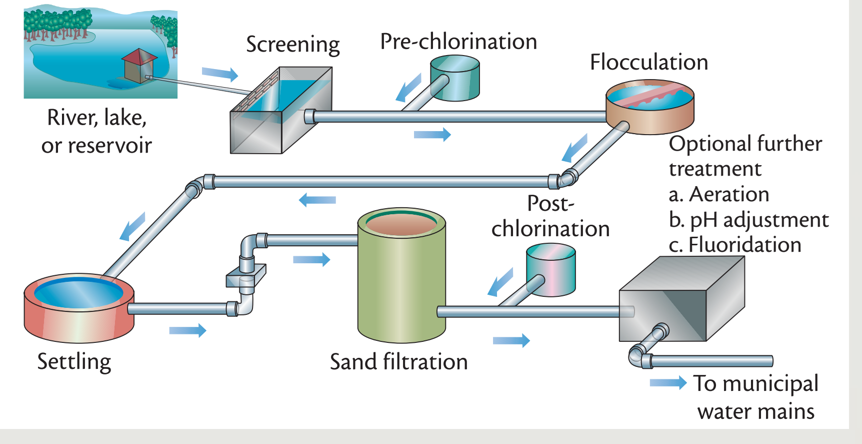
BY RITA HIDALGO
Riverwood News Staff Reporter

Today, many rivers—such as the Snake River in Riverwood—are both a source of municipal water and a place to release wastewater (sewage). Therefore, water must be cleaned twice—once before its use, and again after its use. Pre-use cleaning, often called **water treatment,** takes place at a municipal filtration and treatment plant. It is the focus of this article.

The steps in a typical water-treatment process begin when intake water flows through metal screens that prevent fish, sticks, beverage containers, and other large objects from entering the water-treatment plant.

Chlorine, a powerful disinfecting agent, is added early in the water-treatment process to kill disease-causing organisms that may be present in the water. This step is called **pre-chlorination.** Then crystals of alum—aluminum sulfate,

see Municipal Treatment, page 6



Municipal Treatment, from page 4

$Al_2(SO_4)_3$—and slaked lime—calcium hydroxide, $Ca(OH)_2$—are added to remove suspended particles such as colloidal clay from the water. These suspended particles can give water an unpleasant, murky appearance. The alum and slaked lime react to form aluminum hydroxide, $Al(OH)_3$, a sticky, jellylike material that traps and removes the suspended particles. This process is called **flocculation.** The aluminum hydroxide (holding trapped particles from the water) and other solids remaining in the water are allowed to settle to the tank bottom. Any remaining suspended materials that do not settle out are removed by filtering the water through sand.

In the **post-chlorination** step, the chlorine concentration in the water is adjusted to ensure that a low, but sufficient, concentration of residual chlorine remains in the water, thus protecting it from bacterial infestation.

Finally, depending on community regulations, one or more additional steps might take place before water leaves the municipal treatment plant. Sometimes water is sprayed into the air to remove odors and improve its taste. This process is known as **aeration.**

Water may sometimes be acidic enough to slowly dissolve metallic water pipes. This process not only shortens pipe life, but may also cause copper (Cu^{2+}) as well as cadmium (Cd^{2+}) and other undesirable ions to enter the water supply. Lime—calcium oxide, CaO, a basic substance—may be added to neutralize such acidic water, thus raising its pH to a proper level.

As much as about 1 ppm of fluoride ion (F^-) may be added to the treated water in a process called **fluoridation.** Even at this low concentration, fluoride ions can reduce tooth decay, as well as the number of cases of osteoporosis (bone-calcium loss) among older adults and hardening of the arteries.

WATER PURIFICATION

Building Skills 7

Refer to the two water-treatment articles by Ms. Hidalgo featured in the *Riverwood News* to answer these questions.

1. Compare natural water-treatment steps to the treatment steps found in municipal water systems.
   a. What are key similarities?
   b. What are key differences?
2. After reading the two water-treatment articles, a Riverwood resident wrote a letter to the *Riverwood News* proposing that the town's water-treatment plant be shut down. The reader pointed out that this would save taxpayers considerable money because "natural water treatment can take care of our needs just as well." Do you support the reader's proposal? Explain your answer.

Chlorine is probably the best known and most common substance used for water-treatment. It is found not only in community water supplies, but also in swimming pools. The following *Riverwood News* article provides background on chlorine's role in water treatment.

D.3 CHLORINATION OF WATER

CHLORINE IN PUBLIC WATER SUPPLIES

BY RITA HIDALGO
Riverwood News Staff Reporter

The single most common cause of human illness throughout the world is unhealthful water supplies. Without a doubt, chlorine added to public water supplies has helped to save countless lives by controlling water-borne diseases. When added to water, chlorine kills disease-producing microorganisms.

In most municipal water-treatment systems, **chlorination,** or chlorine addition, takes place in one of three ways.

- *Chlorine gas, Cl_2, is bubbled into the water.* Chlorine gas, which is a nonpolar substance, is not very soluble in water. It does react with water, however, to produce a water-soluble, chlorine-containing compound.
- *A water solution of sodium hypochlorite, NaOCl, is added to the water.*
- *Calcium hypochlorite, $Ca(OCl)_2$, is dissolved in the water.* Available as both a powder and small pellets, calcium hypochlorite is often used in swimming pools. It is also a component of some solid products sold as bleaching powder.

Laundry bleach is a sodium hypochlorite solution.

Regardless of how chlorination takes place, chemists believe that chlorine's most active form in water is hypochlorous acid, HOCl. This substance forms whenever chlorine, sodium hypochlorite, or calcium hypochlorite dissolves in water.

Unfortunately, there is a potential problem associated with adding chlorine to municipal water. Under some conditions, chlorine in water can react with organic compounds produced by decomposing animal and plant matter to form substances harmful to human health.

One group of such substances is known as the trihalomethanes (THMs). A common THM is chloroform, $CHCl_3$, which is carcinogenic, or cancer causing.

Because of concern about the possible health risks associated with THMs, the Environmental Protection Agency has placed a current limit of 100 ppb (parts per billion) on total THM concentration in municipal water-supply systems.

Possible risks associated with THMs must be balanced, of course, against the disease-prevention benefits of chlorinated water.

D.4 CHLORINATION AND THMs

Making Decisions

Several options are available to operators of municipal water-treatment plants that would help eliminate the possible THM health risks highlighted in the newspaper article that you just read. However, each method has its disadvantages.

- Treatment-plant water can be passed through an activated charcoal filter. Activated charcoal can remove most organic compounds from water, including THMs. *Disadvantage:* Charcoal filters are expensive to install and operate. Disposal also poses a problem because used filters cannot be easily cleaned of contamination. They must be replaced relatively often.
- Chlorine can be completely eliminated. Ozone (O_3) or ultraviolet light could be used to disinfect the water. *Disadvantage:* Neither ozone nor ultraviolet light protects the water once it leaves the treatment plant. Treated water can be infected by the subsequent addition of bacteria—through faulty water pipes, for example. In addition, ozone can pose toxic hazards if not handled and used properly.
- Pre-chlorination can be eliminated. Chlorine would be added only once, after the water has been filtered and much of the organic material removed. *Disadvantage:* The chlorine added in post-chlorination can still promote the formation of THMs, even if to a lesser extent than with pre-chlorination. Additionally, a decrease in chlorine concentration might allow bacterial growth in the water.

Your teacher will divide the class into working groups. Your group will be responsible for one of the three options just outlined. Answer the following questions.

1. Consider the alternative assigned to your group. Is this choice preferable to standard chlorination procedures? Explain your reasoning.
2. Can you suggest alternatives other than the three given here?

BOTTLED WATER VERSUS TAP WATER

ChemQuandary 3

When people do not like the taste of tap water, think it is unsafe to drink, or do not have access to other sources of fresh water, they may go to a vending machine or a market to buy bottled water. This bottled water often comes from a natural source, such as a mountain spring, or it may be processed at the bottling plant.

Is this water any better for you than tap water? Could it actually be more harmful? What determines water quality, and how can the risks and benefits of drinking water from various sources be assessed?

As usual, answering challenging questions requires gathering reliable data and information, weighing alternatives, and making informed decisions. Working with a partner, answer the following questions:

1. In your view, what are the most important two or three factors or considerations to analyze in deciding whether to drink tap water or bottled water?
2. For each factor listed in your answer to Question 1, what factual information would you need to gather to establish the advantages and disadvantages of drinking bottled water rather than tap water?

D.5 WATER SOFTENING

Laboratory Activity

Introduction

Water containing an excess of calcium (Ca^{2+}), magnesium (Mg^{2+}), or iron(III) (Fe^{3+}) ions is called **hard water.** Hard water does not form a soapy lather easily. River water usually contains low concentrations of hard-water ions. However, as groundwater flows over limestone, chalk, and other minerals containing calcium, magnesium, and iron, it often gains higher concentrations of these ions, thus producing hard water. See Figures 31 and 32.

In this laboratory activity, you will explore several ways of softening water by comparing the effectiveness of three water treatments for

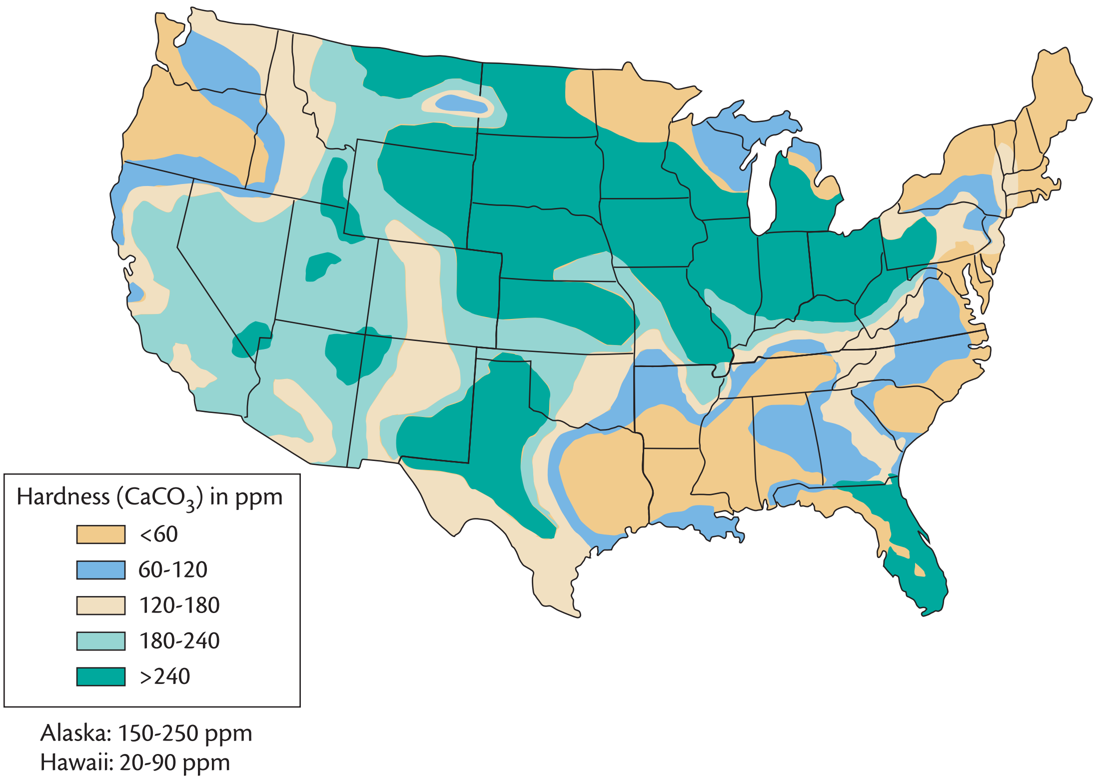


Figure 31 *U.S. groundwater hardness.*

Some Minerals Contributing to Water Hardness		
Mineral	**Chemical Composition**	**Chemical Formula**
Limestone or chalk	Calcium carbonate	$CaCO_3$
Magnesite	Magnesium carbonate	$MgCO_3$
Gypsum	Calcium sulfate	$CaSO_4 \cdot 2H_2O$
Dolomite	Calcium carbonate and magnesium carbonate combination	$CaCO_3 \cdot MgCO_3$

Figure 32 *The names, chemical composition, and chemical formulas for several minerals that contribute to water hardness.*

The "hardness" of water samples can be classified as follows:

Soft
< 120 ppm $CaCO_3$

Moderately hard
120–350 ppm $CaCO_3$

Very hard
> 350 ppm $CaCO_3$

removing calcium ions from a hard-water sample: sand filtration, treatment with Calgon, and treatment with an ion-exchange resin.

Calgon (which contains sodium hexametaphosphate, $Na_6P_6O_{18}$) and similar commercial products "remove" hard-water cations by causing them to become part of larger soluble anions. For example:

$$2\ Ca^{2+}(aq) + (P_6O_{18})^{6-}(aq) \longrightarrow [Ca_2(P_6O_{18})]^{2-}(aq)$$

$2\ Ca^{2+}(aq)$	+	$(P_6O_{18})^{6-}(aq)$	$\longrightarrow$	$[Ca_2(P_6O_{18})]^{2-}(aq)$
Calcium ion from hard water		Hexametaphosphate ion		Calcium hexametaphosphate ion

Calgon also contains sodium carbonate, Na_2CO_3, which softens water by removing hard-water cations as precipitates such as calcium carbonate, $CaCO_3$. The equation for the reaction is shown below. Solid calcium carbonate particles are washed away with the rinse water.

$Ca^{2+}(aq)$	+	$CO_3^{\ 2-}(aq)$	$\longrightarrow$	$CaCO_3(s)$
Calcium ion from hard water		Carbonate ion from sodium carbonate		Calcium carbonate precipitate

Another water-softening method relies on **ion exchange.** Hard water is passed through an ion-exchange resin such as those found in home water-softening units. The resin consists of millions of tiny, insoluble, porous beads capable of attracting cations. Cations causing water hardness are retained on the ion-exchange resin; cations that do not cause hardness (often Na^+) are released from the resin into the water to take the place of those that do. You will learn more about water-softening procedures after you have completed this laboratory activity.

Two laboratory tests will help you decide whether your hard-water sample has been softened. The first test is the reaction between hard-water calcium cations and carbonate anions (added as sodium carbonate, Na_2CO_3, solution) to form a calcium carbonate precipitate. The equation for this reaction is shown above. The second test is to observe the effect of adding soap to the water sample to form a lather.

Procedure

1. In your laboratory notebook, prepare a data table similar to the one shown on page 78.

DATA TABLE

Test	Filter Paper	Filter Paper and Sand	Filter Paper and Calgon	Filter Paper and Ion-Exchange Resin
Reaction with sodium carbonate (Na_2CO_3)				
Degree of cloudiness (turbidity) with Ivory soap				
Height of suds				

2. Prepare the equipment as shown in Figure 33. Lower the tip of each funnel stem into a test tube supported in a test-tube rack.
3. Fold four pieces of filter paper; insert one in each funnel. (In the following steps, funnels will be referenced, from left to right, as 1 to 4.)
4. Funnel 1 should contain only the filter paper; it serves as the control. (Hard-water ions in solution cannot be removed by filter paper.) Fill Funnel 2 one-third full of sand. Fill Funnel 3 one-third full of Calgon. Fill Funnel 4 one-third full of ion-exchange resin.
5. Pour about 5 mL of hard water into each funnel. Do not pour any water over the top of the filter paper or between the filter paper and the funnel wall.
6. Collect the filtrates in the test tubes. NOTE: The Calgon filtrate may appear blue because of other additives in the softener. They will not cause a problem. But if the filtrate appears cloudy, which means that some Calgon powder passed through the filter paper, use a new piece of filter paper and refilter the test-tube liquid.
7. Add 10 drops of sodium carbonate (Na_2CO_3) solution to each filtrate. Does a precipitate form? Record your observations. A cloudy precipitate indicates that the Ca^{2+} ion (a hard-water cation) was not removed.

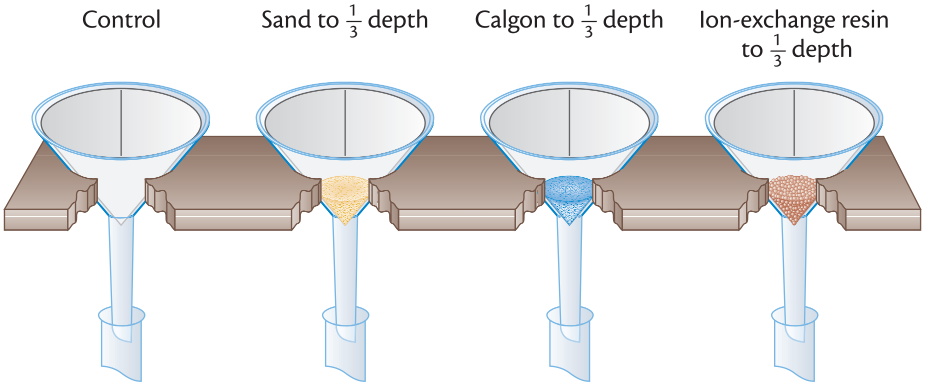


Figure 33 *Filtration setup.*

8. Discard the test-tube solutions. Clean the test tubes thoroughly with tap water and rinse with distilled water. Place the test tubes back in the test-tube rack as in Step 2. Do not empty or clean the funnels; they will be used in the next step.
9. Pour another 5 mL of hard-water sample through each funnel, collecting the filtrates in the clean test tubes. Adjust test tube liquid heights, if necessary, to make all filtrate volumes equal.
10. Add one drop of Ivory liquid hand soap (not liquid detergent) to each test tube.
11. Stir each test tube gently. Wipe the stirring rod before inserting it into another test tube.
12. Compare the cloudiness, or **turbidity,** of the four soap solutions. Record your observations. The greater the turbidity, the greater the quantity of soap that dispersed. The quantity of dispersed soap determines the cleaning effectiveness of the solution.
13. Stopper each test tube and then shake vigorously, as demonstrated by your teacher. The more suds that form, the softer the water. Measure the height of suds in each test tube and record your observations.
14. Wash your hands thoroughly before leaving the laboratory.

Questions

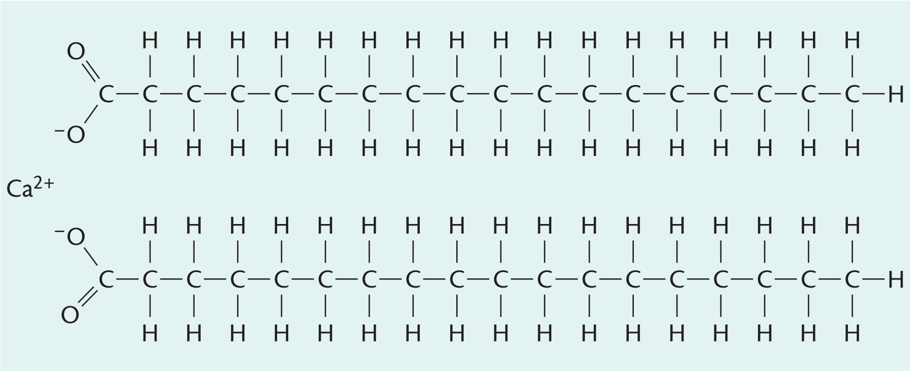
1. Which was the most effective water-softening method? Suggest why this method worked best.
2. What relationship can you describe between the amount of hard-water ion (Ca^{2+}) remaining in the filtrate and the dispersion (cloudiness) of Ivory liquid hand soap?
3. What effect does this relationship have on the cleansing action of the soap?
4. Explain the advertising claim that Calgon prevents "bathtub ring." Base your answer on observations made in this laboratory activity.

D.6 WATER AND WATER SOFTENING

Hard water causes some common household problems. It interferes with the cleaning action of soap. As you observed, when soap mixes with soft water, it disperses to form a cloudy solution topped with a sudsy layer. In hard water, however, soap reacts with hard-water ions to form insoluble compounds (precipitates). These insoluble compounds appear as solid flakes or a sticky scum—the source of a bathtub ring. The precipitated soap is no longer available for cleaning. Worse yet, soap curd can deposit on clothes, skin, and hair. The structural formula for this objectionable substance, the product of the reaction of soap with calcium ions, is shown in Figure 34 on page 80.

If hydrogen carbonate (bicarbonate, HCO_3^-) ions are present in hard water, boiling the water causes solid calcium carbonate ($CaCO_3$) to form. The reaction removes undesirable calcium ions and thus softens the water.

Figure 34 *Structural formula of a typical soap scum. This substance is calcium stearate.*



Hard Water & Soap Scum CD-ROM WWW.

However, the solid calcium carbonate produces rocklike scale inside tea kettles and household hot-water heaters. This scale (the same compound found in marble and limestone) acts as thermal insulation, partly blocking heat flow to the water. More time and energy are required to heat the water. Such deposits can also form in home water pipes. In older homes with this problem, water flow can be greatly reduced.

Fortunately, it is possible to soften hard water by removing some calcium, magnesium, or iron(III) ions. Adding sodium carbonate to hard water (as you did in the preceding laboratory activity) was an early method of softening water. Sodium carbonate (Na_2CO_3), known as washing soda, was commonly added to laundry water along with the clothes and soap. Hard-water ions, precipitated as calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$), were washed away in the rinse water. Water softeners in common use today include borax, trisodium phosphate, and sodium hexametaphosphate (Calgon). As you learned, Calgon does not tie up hard-water ions as a precipitate, but rather as a new, soluble ion that does not react with soap.

Figure 35 *In the 1960s and early 1970s, detergent molecules that were not decomposed by microorganisms caused some waterways to fill with sudsy foam, such as shown here. The development of biodegradable detergent molecules put an end to this unusual kind of water pollution.*

Most cleaning products sold today contain detergents rather than soap. Synthetic detergents act like soap but do not form insoluble compounds with hard-water ions. Unfortunately, many early detergents were not easily decomposed by bacteria in the environment—that is, they were not biodegradable. At times, "mountains" of foamy suds were observed in natural waterways. See Figure 35. These early detergents also contained phosphate ions (PO_4^{3-}) that encouraged extensive algae growth, choking lakes and streams. Because most of today's detergents are biodegradable and phosphate free, they do not cause these problems.

If you live in a hard-water region, your home plumbing may include a **water softener.** Hard water flows through a tank containing an ion-exchange resin similar to the one that you used in the water-softening laboratory activity. Initially, the resin is filled with sodium cations (Na^+). Calcium and magnesium cations in the hard water are attracted to the resin and become attached to it. At the same time, sodium cations leave the resin and dissolve in the water. Thus undesirable hard-water ions are exchanged for sodium ions, which do not react to form soap curd or water-pipe scale. Figure 36 illustrates this process.

It may not be economical to soften water of hardness less than about 200 ppm $CaCO_3$.

CD-ROM WWW. **Water Softening by Ion Exchange**

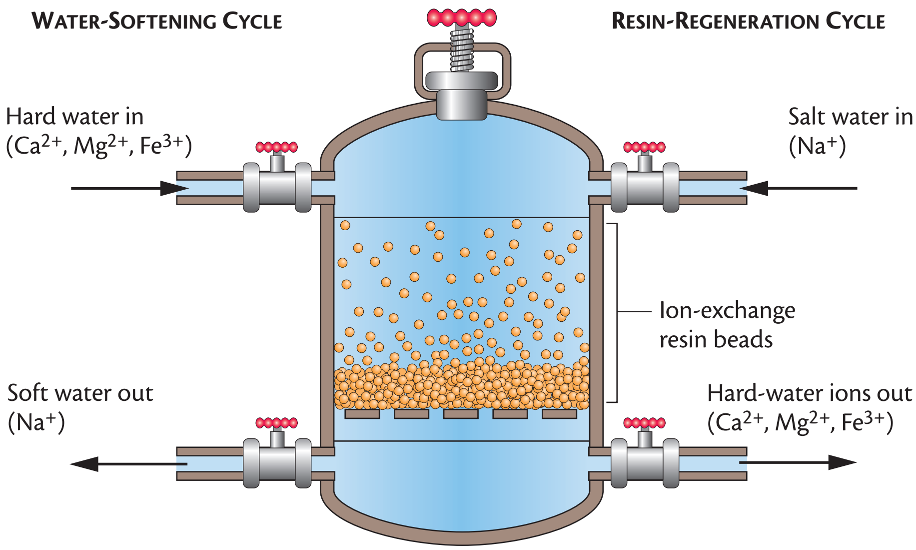


Figure 36 *Ion-exchange water-softener cycles.*

A water-softening unit typically uses from 5 to 6 pounds (2 to 3 kg) of sodium chloride (salt) for one regeneration.

As you might imagine, the resin eventually fills with hard-water ions and must be **regenerated.** Concentrated salt water (containing sodium ions and chloride ions) flows through the resin, replacing the hard-water ions held on the resin with sodium ions. Released hard-water ions wash down the drain with excess salt water. Because this process takes several hours, it is usually completed at night. After the resin has been regenerated, the softener is again ready to exchange ions with incoming hard water.

CD-ROM WWW. **Questions & Answers**

Water softeners are most often installed in individual homes. Other water treatment is done at a municipal level, both in Riverwood and in other cities.

CHEMISTRY AT WORK

Purifying Water Means More Than Going with the Flow

When you drink from a water fountain, do you ever wonder where the water comes from? In some parts of the country, drinking water is provided by people such as **Phil Noe.**

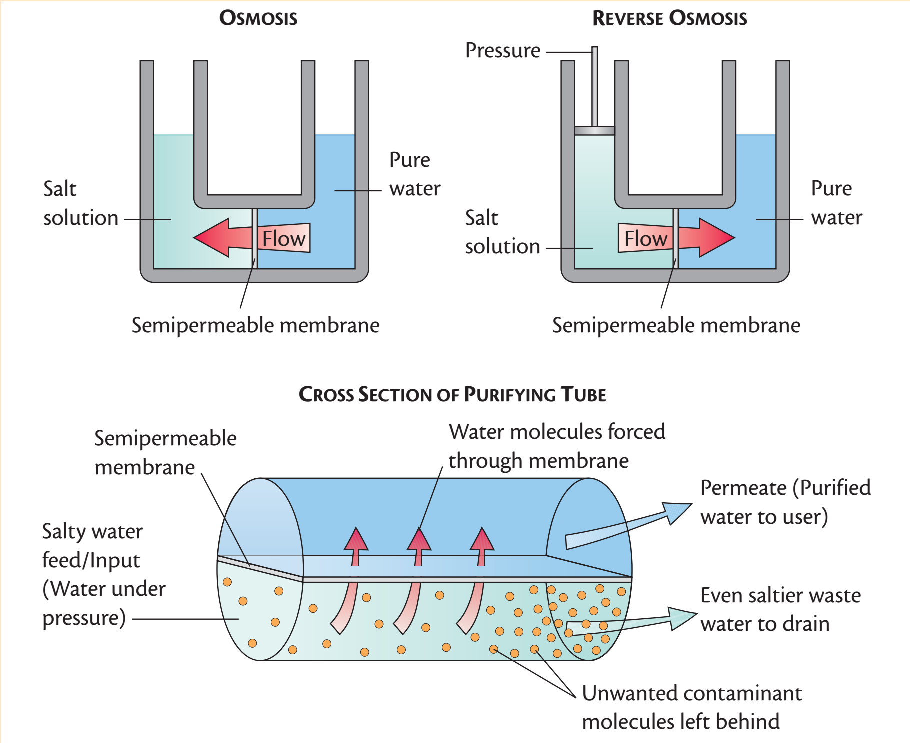
"We have a limited supply of fresh water," says Phil, "so we've built a plant that lets us use water from our aquifers."

Phil is Production Manager at Island Water Association (IWA), which provides water for Florida's Sanibel and Captiva Islands. "We have a limited supply of fresh water," says Phil, "so we've built a plant that lets us use water from our aquifers." Aquifers are underground layers of permeable (porous) sand and limestone that contain large quantities of water.

After pumping the brackish, undrinkable water up from the Suwanee Aquifer to IWA's processing plant, Phil and his co-workers remove almost all of the salt and minerals, producing water that is more pure than many mountain streams. The process that accomplishes this task is known as reverse osmosis. The accompanying illustration is a comparison of osmosis with reverse osmosis. The amount of pressure applied in reverse osmosis must exceed the osmotic pressure, which tends to move the water from a region of higher vapor pressure to one of lower vapor pressure. Because osmotic pressure depends only on the concentration of the salt solution, it is known as a colligative property.

Aquifers are located at depths ranging between 700 and 900 feet. Water pumped up from these aquifers contains an average of 3000 ppm total dissolved solids (TDS). Feed water is pumped through hundreds of feet of pipes containing salt-filtering membranes. In the process, the purified water, called the permeate, separates from the salts and other dissolved solids. Eventually, the water is purified to levels as low as 100 ppm TDS.

Because Florida is subject to hurricanes and other tropical storms, Sanibel Island's water system maintains



Osmosis occurs naturally when water in a dilute solution passes through a semipermeable membrane into a concentrated solution. In reverse osmosis, pressure must be applied to a concentrated solution to force water through a semipermeable membrane into a dilute solution.

After filtering to remove the larger solids, the water passes through equipment where reverse osmosis is used to produce purified water.

Saving up for a windy day.

15 million gallons of purified water in storage. As a result, island customers can manage without the plant in operation during brief periods of severe weather with no more inconvenience than several weeks without lawn sprinklers.

Eighty percent of IWA's feed water is converted into drinkable water. The remaining 20% is pumped out into the Gulf of Mexico. This water, a salt solution, is lower in salt and mineral concentrations than the gulf water itself and is harmless to marine life.

Web Search . . .

- Use the World Wide Web to search for other communities that rely on reverse osmosis for all or part of their water supply.
- Most communities use rivers, lakes, or wells to supply their water needs. Search the Web for information about municipal water-supply systems that use alternative water-purification processes in addition to reverse osmosis.
- What other kinds of water purification systems are in use in the United States?
- Use the Web to gather information about the cost of water for household use in various parts of the United States. Is there a connection between the cost of water and the location of the community? For example, is water more expensive in the desert than it is near the ocean?

Aquatic wildlife is unaffected by the salt water left over from the reverse osmosis process.

SECTION SUMMARY

Reviewing the Concepts

- **Water can be purified through the actions of the hydrologic cycle or through municipal treatment.**

1. Explain how water can be purified through the actions of the hydrologic cycle.
2. How are the properties of aluminum hydroxide related to the process of flocculation?
3. Why is calcium oxide (CaO) sometimes added in the final steps of municipal water treatment?

- **Chlorination is commonly used to treat and purify water for human consumption. The benefits of chlorine treatment can be weighed against its risks.**

4. What advantages does chlorinated drinking water have over untreated water?
5. What are some disadvantages of using chlorinated water?
6. Water from a clear mountain stream may require chlorination to make it safe for drinking. Explain why.

- **Hard water contains relatively high concentrations of calcium, magnesium, or iron cations. Such water can be softened by removing most of these ions as precipitates or complexes.**

7. What is the origin of the expression "hard water"?
8. When a sample of well water was mixed with a few drops of sodium carbonate solution, a precipitate formed. What does the formation of a precipitate indicate about the water sample?
9. Hard water often tastes better than distilled water. Explain.
10. Which source in a given locality would probably have harder water, a well or a river? Explain.

Connecting the Concepts

11. A simple test for the hardness of water is to add soap to the sample and shake it. Explain how measuring the quantity of soap suds formed can be used to assess the hardness of water.
12. Explain how hard water can interfere with the processes of a water-treatment plant.

Extending the Concepts

13. How much water would you have to drink to get your minimum daily requirement of calcium from water that contains 300 ppm calcium carbonate?
14. Explain why hard water stains in old sinks are found more often around hot-water faucets than around cold-water faucets.
15. Investigate the reasons why sodium-based ion-exchange resins have been banned in some municipalities.

PUTTING IT ALL TOGETHER

FISH KILL—FINDING THE SOLUTION

FISH KILL CAUSE FOUND

MEETING TONIGHT

BY ORLANI O'BRIEN
Riverwood News Staff Reporter

Mayor Edward Cisko announced at a news conference held early today that the cause of the fish kill in the Snake River has been determined. The details of the accidental cause will be released at a town council meeting tonight. As of today, levels of all dissolved materials in the river are normal and the water should be considered safe.

Accompanying Mayor Cisko was Dr. Harold Schmidt of the Environmental Protection Agency. Dr. Schmidt performed dissections on fish taken from the river within a few hours of their death. He also directed the team that analyzed accumulated river-water data in efforts that led to determining the cause of the fish kill. Dr. Schmidt gave assurances that the town's water supply is "fully safe to drink."

Mayor Cisko refused to elaborate on reasons for the accident. However, he invited the public to the special town council meeting scheduled for 8 P.M. tonight at Town Hall. The council will discuss events that caused the fish kill and how costs associated with the three-day water shutoff will be paid. Several area groups, as well as invited experts, plan to make presentations at tonight's meeting.

TOWN COUNCIL MEETING

Meeting Rules and Penalties for Rule Violations

CD-ROM WWW. **Putting It All Together**

1. The order of presentations is decided by council members and announced at the start of the meeting.
2. Each group will have a specified time for its presentation. Time cards will notify the speaker of time remaining.
3. If a member of another group interrupts a presentation, the offending group will be penalized 30 seconds for each interruption, to a maximum of one minute. If the group has already made its presentation, it will forfeit its rebuttal time.

Figure 37 *View of a city council meeting in session in Austin, Texas. Open meetings such as this encourage citizen involvement in discussions of local issues and in related decision-making challenges.*

Town Council Members: Background Information

Your group is responsible for conducting the meeting in an orderly manner. Be prepared to:

1. Decide and announce the order of presentations at the meeting. Groups presenting factual information should be heard before groups voicing opinions.
2. Decide how the presentation area will be organized: where town council members controlling the meeting will be located, where the presenters will present, and where the groups and observers will be positioned.
3. Explain the meeting rules and the penalties for violating those rules.
4. Recognize each group at its assigned presentation time.
5. Enforce established presentation time limits by preparing time cards with "one minute," "30 seconds," and "time is up" written on them. These cards, placed in the speaker's line of sight, can serve as useful warnings.
6. Control the rebuttal discussions and open-forum speeches.
7. Summarize the options when testimony has been completed.
8. Conduct a vote of all town council members.
9. Report the results of the vote and future actions mandated by it.

Power Company Officials: Background Information

The power plant includes a dam and reservoir that ensure an adequate supply of cooling water. Your company's engineers control the rate of water release from the dam into the Snake River.

Normally, only relatively small volumes of water are released at any particular time. However, releasing large quantities of water from the dam is a standard way of preventing flooding. The last time such a large volume of water was released from the dam was 30 years ago. A fish kill was reported then, but the cause remained unknown. On that occasion, Riverwood and surrounding areas had experienced an unusually wet summer.

The dam, constructed in the 1930s, had the most current design of that time. Since then, its basic structure has not been modified.

Agricultural Cooperative Representatives: Background Information

Cooperative members in the Snake River valley include farmers and ranchers managing a variety of crops and livestock. Your cooperative assumes a proactive role in informing its members of current best practices and regulations regarding the use of agrochemicals and the management of wastes and runoff from fields and pastures.

Heavy rains present a problem for farmers. Although the rain is good for crops, it can wash away recently applied fertilizers and pesticides. This is not only expensive, but it can cause problems if these substances wash into the watershed.

Mining Company Representatives: Background Information

Riverwood began as a mining town on the Snake River, which provided early residents with a source of water. Your company intensely mined the hills surrounding Riverwood in the 1930s and 1940s. The important metals that came from this area included zinc and silver. The by-products of mining and processing the metal ores were collected in storage ponds built in accordance with the specifications and regulations of that time.

In seasons with average rainfall, the runoff from the waste ponds contains heavy-metal ions at levels within the values specified by your company's EPA permit. Your company monitors effluent values and keeps the ponds secured. Your company's structural engineers are responsible for upkeep of storage ponds at abandoned mine sites. However, during heavy rainfall, some underground settling in the mines and avalanches in hilly areas of the Snake River have been noted.

Scientists: Background Information

You are responsible for explaining how the analyzed data support the proposed cause of the fish kill. You should be prepared to explain what the data mean and why data fluctuations are noted from month to month or year to year. You may be called on to explain concepts such as pH, solubility of molecular and ionic substances, units of concentration, water-purification techniques, the hydrologic cycle, and other water-related concepts. It is important that you help council members and other attendees understand how the analyzed data document the cause of the fish kill.

Consulting Engineers: Background Information

Your consulting firm was hired to do a detailed examination of the cause of the fish kill. Your task was to determine whether accident, human error, negligence, or an unforeseen circumstance was responsible for the Riverwood crisis. In addition, you were asked to prepare scenarios or suggest improvements that would prevent recurring fish kills.

Your presentation should include the proposed solutions, the costs and benefits of each solution, and a detailed analysis of the cause. It is understood that you may not be familiar with cost analyses of major projects; however, you should try to make feasible estimates.

Chamber of Commerce Members: Background Information

Canceling the annual fishing tournament cost you and other Riverwood merchants a substantial sum of money. Close to one thousand out-of-town tournament participants were expected. Many would have rented rooms for at least two nights and eaten at local restaurants and fast-food establishments. In anticipation of this business, extra food supplies and support services were ordered. Fishing and sporting goods stores stockpiled extra fishing supplies. Some businesses have applied for short-term loans to help pay for their unsold inventories.

Local churches and the high school planned family social activities as revenue makers during the tournament weekend. For example, the school band scheduled a benefit concert that would have raised money to send band members to the spring band competition.

People are likely to remember the fish kill for many years. Tournament organizers predict that future fishing competition revenues in Riverwood will be substantially reduced due to this year's adverse publicity. Thus total financial losses resulting from the water emergency may be much higher than most current estimates predict.

You should be able to discuss how merchants and businesses were affected by this event and summarize the availability of support (as well as lack of support) to help resolve the issues.

County Sanitation Commission Members: Background Information

You are responsible for the protection and safety of the Snake River water supply. You are the group that completes most of the routine water testing for the supply of drinking water in Riverwood. It is important to know what the standards that specify the quality of drinking water mean and to explain how the water testing is done. You should be able to report maximum contamination levels (MCLs) for hazardous water contaminants. You should also know the allowable limits or expected ranges for other analyzed water data.

Riverwood Taxpayer Association Members: Background Information

Your organization is concerned about the financial effects of the fish kill on Riverwood citizens. Thus some of the important questions to be answered at the town council meeting should be addressed in your presentation. These questions include:

- Who will pay for the water brought into Riverwood during the water shutoff?
- Will taxes be increased to compensate local businesspeople for their financial losses? (Keep in mind that local merchants themselves are likely to be Riverwood taxpayers!)
- If the organization responsible for the fish kill takes measures to prevent its recurrence, will the costs be passed on to consumers? If so, how?

Because your presentation may be influenced by the testimony of other groups, you may find it useful to obtain their written briefs before the council meeting, if possible.

LOOKING BACK AND LOOKING AHEAD

The Riverwood water mystery is solved! In the end, scientific data provided the answer. And now human ingenuity will provide strategies for preventing the recurrence of such a crisis. In the course of solving the problem, the citizens of Riverwood learned about the water that they take for granted—abundant, clean water flowing steadily from their taps—and probably gained a greater appreciation for it.

Although Riverwood and its citizens exist only on the pages of this textbook, their water-quality crisis could be very real. The chemical facts, principles, and procedures that clarified their problem and its solution have applications in your own home and community.

Although the fish-kill mystery has been solved, your exploration of chemistry has only just begun. Many issues related to chemistry in the community remain, and water and its chemistry are only one part of a larger story.