Purifying Water Supplies by Municipal Pre-Use Treatment

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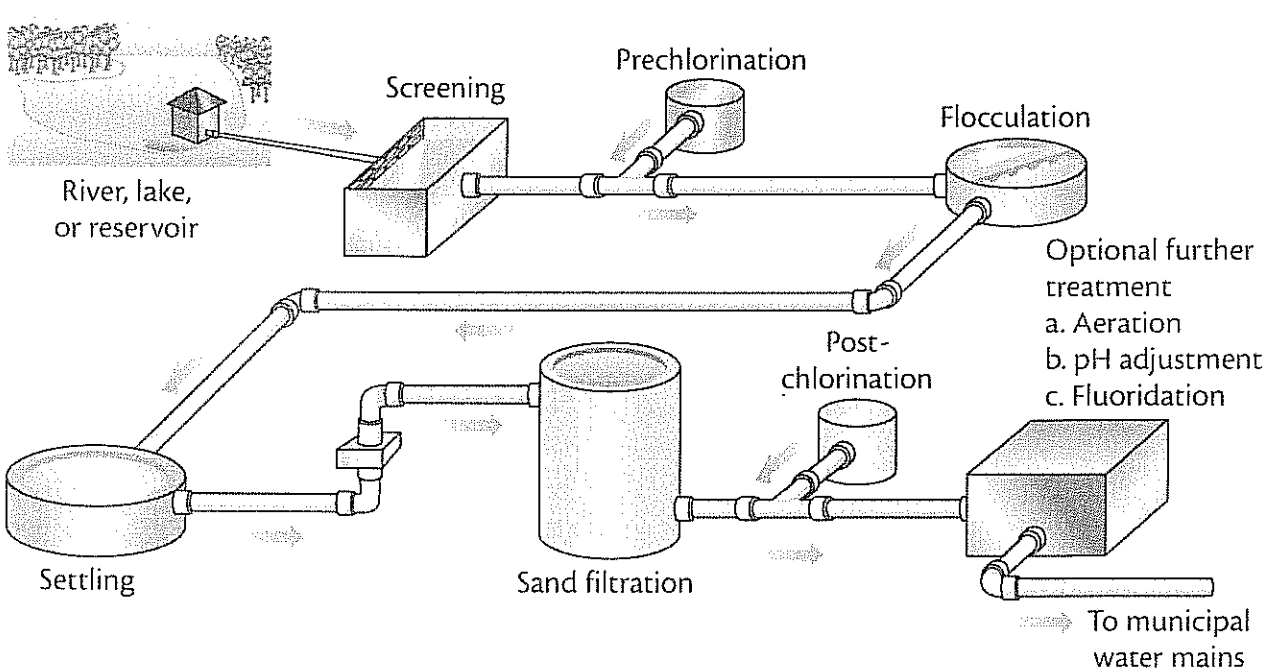
Today, many rivers—such as the Snake River in Riverwood—are both a source of municipal water and a place to release wastewater (sewage). Therefore, the water is cleaned twice, both before and after the water is used. *Pre-use purification,* often called *water treatment,* takes place at a municipal filtration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

A typical water-treatment process begins when intake water flows through metal screens that prevent fish, sticks, beverage containers, and other large objects from entering the water-treatment plant.

Plant operators may add chlorine, which is a powerful disinfecting agent, during the treatment process to kill disease-causing organisms. This step is known as *prechlorination.* Operators add crystals of alum—aluminum sulfate, $Al_2(SO_4)_3$—and slaked lime—calcium hydroxide, $Ca(OH)_2$—to remove suspended particles, such as colloidal clay, from the water. (Suspended particles can give water an unpleasant, murky appearance.) The alum and slaked lime react to form aluminum hydroxide, $Al(OH)_3$, which is a sticky, jellylike material that



Municipal Treatment: A human-made water-purification system. Surface water is commonly cleaned at a municipal water-treatment plant before being distributed to homes and businesses. Various steps in the cleaning process remove suspended materials, kill disease-causing organisms, and may remove odors or adjust pH levels.

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traps and removes the suspended particles, a process called *flocculation.* Operators then allow the aluminum hydroxide (holding trapped particles from the water) and other solids remaining in the water to settle to the tank bottom. They remove any suspended materials that do not settle out by filtering the water through sand.

In the *post-chlorination* step, operators adjust the chlorine concentration in the water to ensure that a low, but sufficient, concentration of chlorine remains in the water, thereby protecting the water from bacterial infestation.

One or more additional steps may take place, depending on community procedures. Some plants spray water into the air to remove odors and improve its taste, a process known as *aeration.*

Water may sometimes be acidic enough to slowly dissolve metallic water pipes. This process not only shortens pipe life, but it may also cause copper (Cu^{2+}), as well as cadmium (Cd^{2+}) and other undesirable ions, to enter the home water supply. A plant may add lime—calcium oxide (CaO), a basic substance—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 known as *fluoridation.* Even at this low concentration, fluoride ions can reduce tooth decay.

Chlorine in Public Water Supplies

BY RITA HIDALGO
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The single most common cause of human illness in the world is unhealthful water supplies. Without a doubt, adding chlorine to public water supplies has helped save countless lives by controlling waterborne diseases. In water, chlorine kills disease-producing microorganisms.

In most municipal water-treatment systems, chlorination, which is the addition of chlorine to the water supply to kill harmful organisms, often takes place in several different ways:

- Chlorine gas, Cl_2, is bubbled into the water. This substance is not very soluble in water. Chlorine does react with water, however, to produce a water-soluble, chlorine-containing compound.
- A water solution of sodium hypochlorite, NaOCl, which is the active ingredient in household bleach, 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 household products sold as bleaching powder.

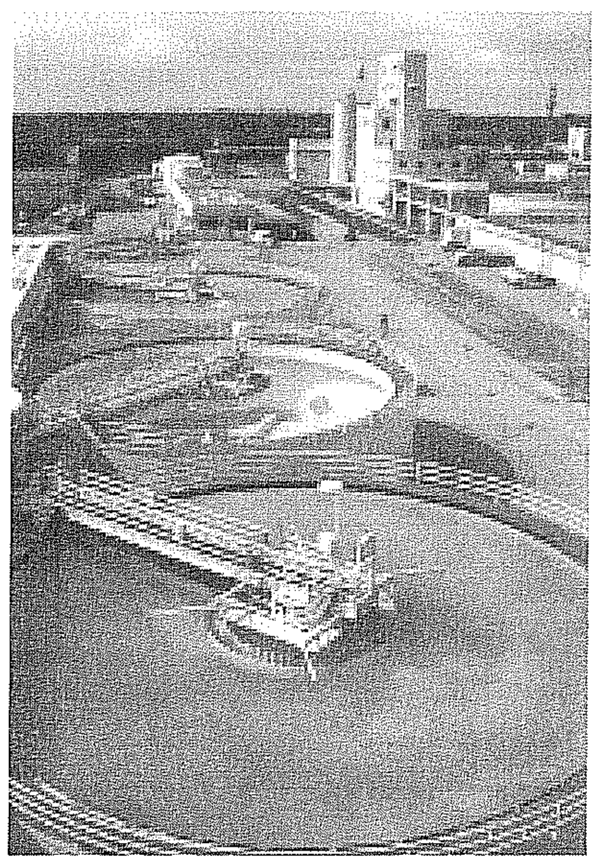
Regardless of how chlorination takes place, chemists believe that chlorine's most active form in water is hypochlorous acid (HOCl). This substance forms whenever chlorine, sodium hypochlorite, or calcium hypochlorite dissolves in water.

Unfortunately, a potential problem is 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 that, if in sufficiently high concentrations, can be harmful to human health.

One group of such substances is known as the *trihalomethanes* (THMs). A common THM is chloroform ($CHCl_3$), a *carcinogen*, which is a substance that is known to cause cancer.

Because of concern about the possible health risks associated with THMs, the Environmental Protection Agency has placed a current limit of 80 parts per billion (ppb) on total THM concentration in municipal water-supply systems.

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



Flocculator–clarifier units at a municipal water-treatment facility.

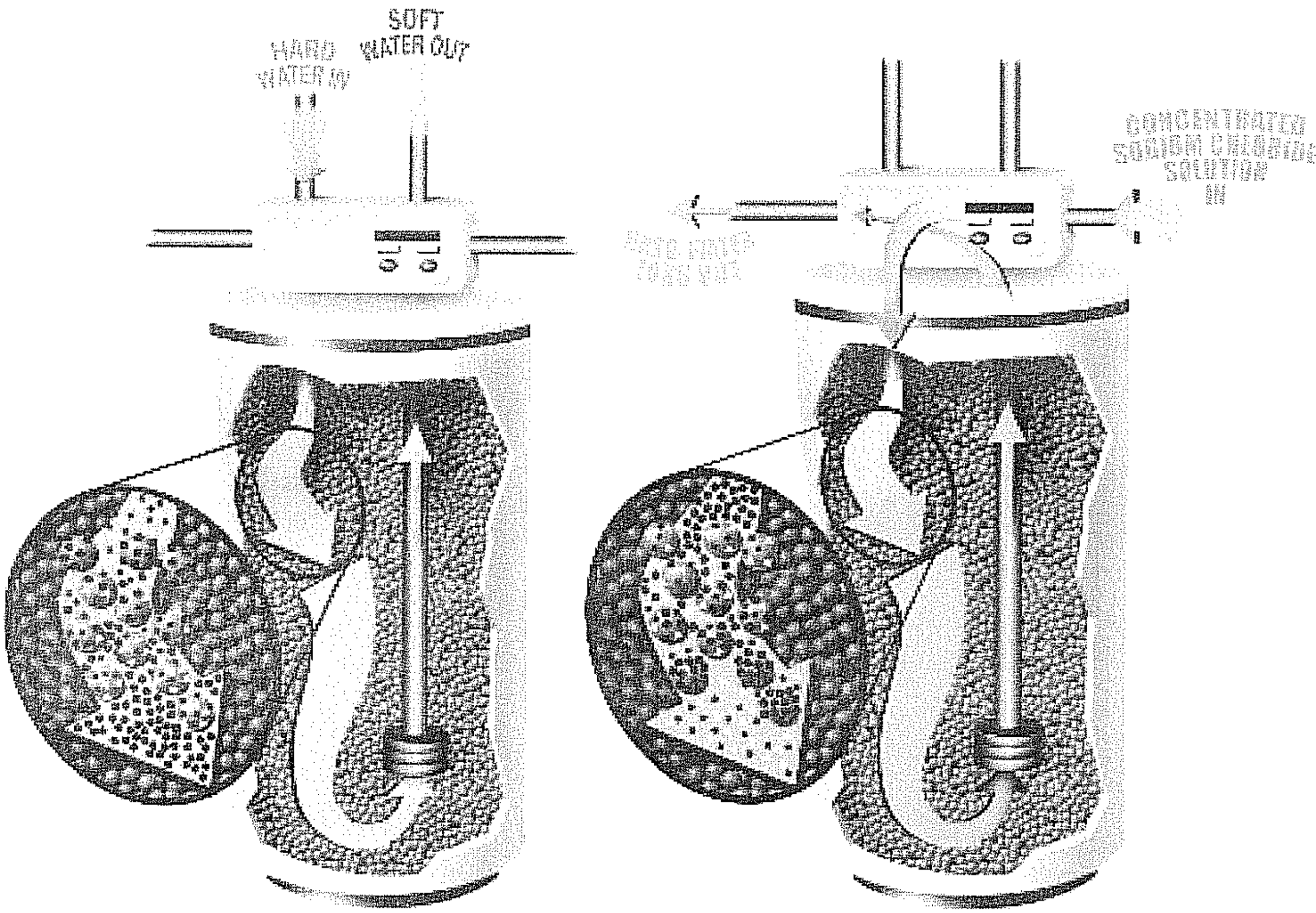


Figure 1.68 **Home Water Softener.** *Hard water, containing excess calcium (Ca^{2+}), magnesium (Mg^{2+}), or iron(III) (Fe^{3+}) cations, prevents soap from lathering easily and can cause scale to build up inside pipes. Thus, where hard water poses a problem, many people install home water softeners. Water softeners contain ion-exchange resin, depicted here as orange beads.* Left: *Initially, sodium ions (Na^+, depicted as black dots in the magnified portion) are attached to the resin. As hard water flows into the tank, hard-water cations such as Mg^{2+} and Ca^{2+} (yellow triangles and red squares) become attached to the resin, releasing Na^+ ions into the water. This softened water flows through pipes to faucets, water heaters, and washing machines.* Right: *Eventually, all Na^+ ions are replaced by hard-water ions; no further ion exchange can occur. Then, the resin is "recharged" with Na^+ ions (black dots) by passing concentrated sodium chloride solution through the system. This displaces hard-water ions (yellow triangles and red squares) from the resin; they flow from the water softener into a drain. Thus, regenerated resin—with Na^+ ions again attached—is ready to soften hard water again.*

Purifying Water Through the Hydrologic Cycle

BY RITA HIDALGO
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Riverwood residents want to know how clean their water is. It should not take a crisis to focus attention on their concerns.

This article provides details on how natural water-purification systems work. A companion article in today's *News* examines municipal water-treatment methods—procedures that mimic, in part, water-purification processes at work 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, and municipalities were constructing sewer systems. 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 chlorination soon began. However, municipal sewage—the combined waterborne wastes of a community—remained generally untreated. Today, sewage treatment is part of every U.S. 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 energy from the Sun causes water to evaporate from oceans and other water sources. Dissolved heavy metals, minerals, or molecular substances do not evaporate and, thus, are left behind.

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 today's rain less pure than it used to be.

When raindrops strike soil, the rainwater collects impurities. Organic substances deposited by living creatures become suspended or dissolved in the rainwater. 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 filtered out. Thus, three processes make up nature's water-purification system.

- Evaporation, 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.

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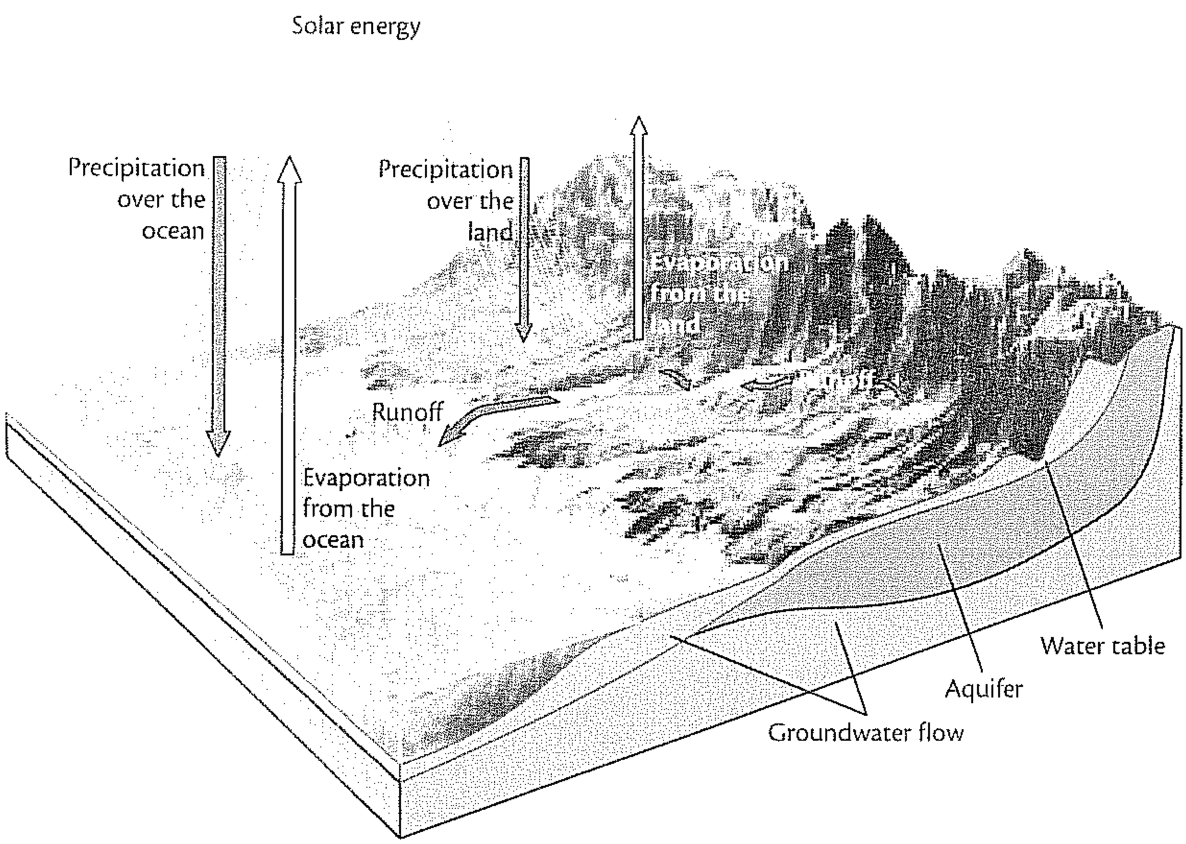
Given appropriate conditions, people could depend solely on nature to purify their water. *Pure* rainwater is the best natural supply of clean water. If water seeping through the ground encountered enough bacteria for a long enough period of time, all organic contaminants could be removed. Flowing through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

If slightly acidic groundwater (pH less than 7.0) passes through rocks that contain slightly soluble compounds, such as magnesium and calcium minerals, chemical reactions with these minerals may add substances to the water rather than remove substances in the water. In this case, the water may contain an increased concentration of dissolved minerals.



Hydrologic Cycle: Earth's water-purification system. The Sun provides energy for water to evaporate (yellow arrows). Evaporation leaves behind minerals and other dissolved substances. Water vapor condenses and falls as precipitation (red arrows), which runs off the land (blue arrows) to join surface water sources (lakes, streams, and rivers) or groundwater sources beneath Earth's surface. Both surface water and groundwater are sources of municipal and agricultural water. Any water—when returned to the surface—can evaporate and continue flowing through the hydrologic cycle. Throughout the cycle, evaporation, bacterial action, and filtration purify water.