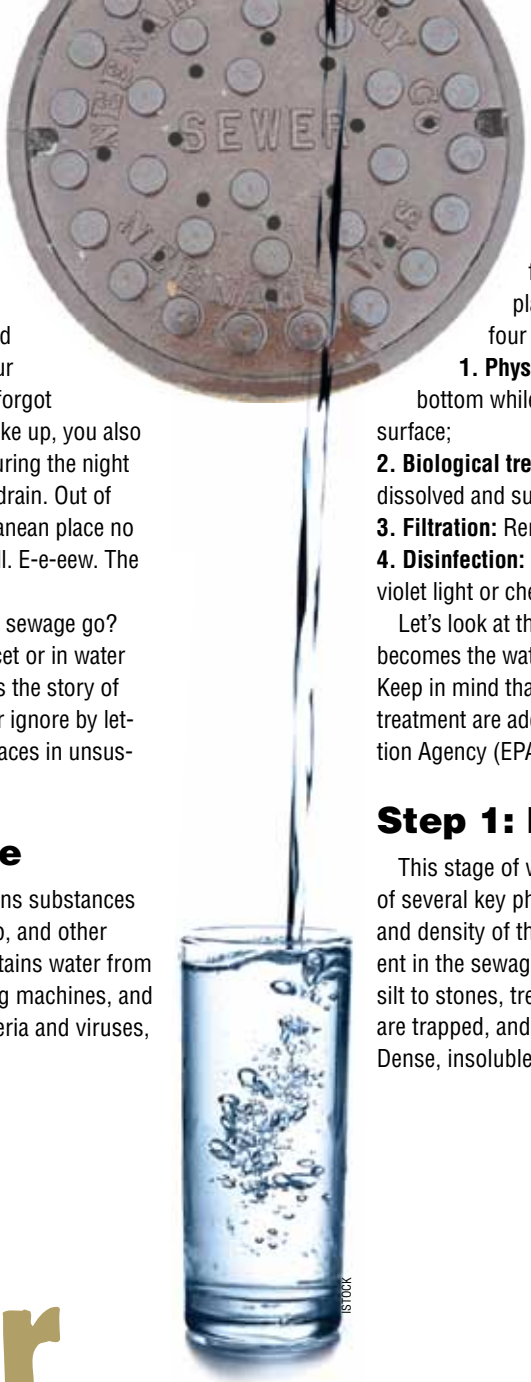
Is this Water Recycled Sewage?

By Gail Kay Haines



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You get up in the morning and stagger to a sparkling clean shower. Then, you power up your supercharged toothbrush and dress in your favorite clothes. Oops! We forgot the chore nobody mentions. After you woke up, you also eliminated wastes your body produced during the night and sent them gurgling down the toilet's drain. Out of sight and away they went, to that subterranean place no one wants to go to. Or even look. Or smell. E-e-eew. The sewer!

Which raises the question: Where does sewage go? Some of it comes back to your water faucet or in water bottles. How does this all happen? Here is the story of sewage, a substance that we would rather ignore by letting it stay underground but which resurfaces in unsuspected ways.

Recycling of sewage

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Sewage, also called wastewater, contains substances such as human waste, food, grease, soap, and other organic matter. Sewage from homes contains water from sinks, showers, bathtubs, toilets, washing machines, and dishwashers. Sewage also contains bacteria and viruses, mostly derived from human waste.

All of these substances are removed from sewage in wastewater treatment plants. Wastewater treatment happens in four stages (Fig. 1):

1. **Physical treatment:** Heavy solids settle to the bottom while grease and lighter solids float to the surface;
2. **Biological treatment:** Bacteria are used to remove dissolved and suspended matter;
3. **Filtration:** Remaining impurities are eliminated;
4. **Disinfection:** Remaining bacteria are killed with ultraviolet light or chemicals.

Let's look at these four stages to see how wastewater becomes the water you just drank at lunch or dinner. Keep in mind that additional processes for wastewater treatment are added to meet U.S. Environmental Protection Agency (EPA) standards for public water systems.

Step 1: Physical treatment

This stage of wastewater treatment takes advantage of several key physical properties—the size, solubility, and density of the waste material. Large particles present in the sewage, including anything from sand and silt to stones, tree branches, facial tissues, and socks, are trapped, and ultimately removed, by mesh screens. Dense, insoluble waste sinks to the bottom, and "liquid

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The Living Machine system is a patented product developed by Worrell Water Technologies, LLC. The Living Machine technology is a new approach to wastewater treatment employing the natural ecological process of a tidal wetland, enhanced by environmental science and information technology.

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A reverse osmosis system, such as the one shown here, is used in a sewage treatment plant to filter inorganic salts that remain in the water.

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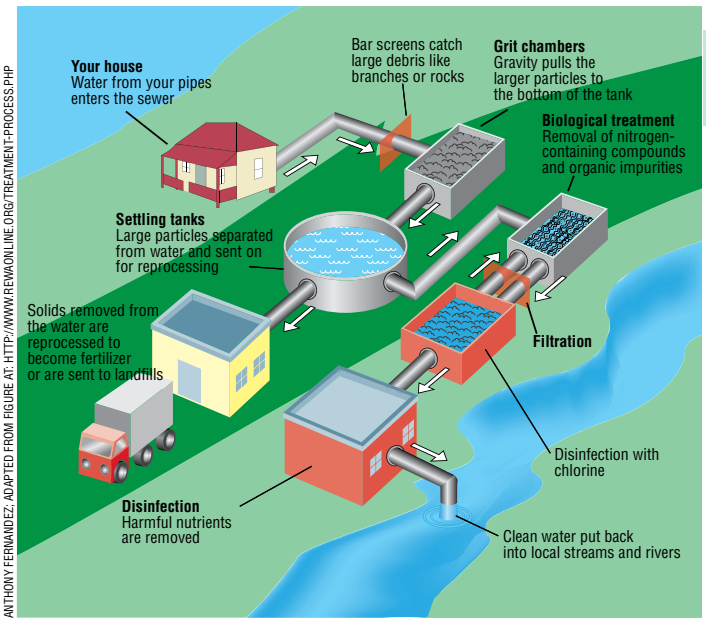
Aerial view of settling tanks at a sewage treatment plant. Large pieces of materials settle at the bottom of these tanks and are later removed and reprocessed.

grease"—which includes oils, waxes, and soaps—forms a layer lighter than water at the top and is skimmed off. The skimmed substances are sent to the landfill, and the sunken material becomes solid waste called sludge.

What remains in the water are microscopic particles that are suspended as colloids. These particles, which have diameters ranging from 0.001 to 1 micrometer, consist of groups of molecules or ions that are bound together, but they do not break up and dissolve as individual ions or molecules. The removal of these colloidal particles is particularly important because they include viruses and bacteria. Later stages of treatment will facilitate the removal of these substances from water.



ANTHONY FERNANDEZ; ADAPTED FROM FIGURE AT: HTTP://WWW.REWAONLINE.ORG/TREATMENT-PROCESS.PHP

Figure 1. The various steps of the wastewater treatment process

Step 2: Biological treatment

While we often think about bacteria as substances that might cause harm, bacteria are actually used in the wastewater treatment process to remove certain dissolved and suspended contaminants from water. One of the most important ways in which bacteria are used is to convert nitrogen-containing compounds into nitrogen gas (N_2) that is then bubbled out of the water into the atmosphere. This process occurs in two stages: nitrification and denitrification.

One of the most common nitrogen-containing compounds present in wastewater is ammonia (NH_3). First, nitrifying bacteria convert ammonia into nitrate ions (NO_3^-) in a two-step process:

$$2\ NH_3 + 3\ O_2 \rightarrow 2\ NO_2^- \text{ (nitrite ion)} + 2\ H^+ + 2\ H_2O$$

$$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^- \text{ (nitrate ion)}$$

Then, denitrifying bacteria convert the nitrate ions into nitrogen. This is a reaction that requires a substance to be oxidized. Methanol (CH_3OH) is one of the best choices for such a substance because it is usually present in wastewater. Methanol is converted to carbon dioxide (CO_2) in the following reaction:

$$6\ NO_3^- + 5\ CH_3OH + 6\ H^+ \rightarrow 5\ CO_2 + 3\ N_2 + 13\ H_2O$$

Therefore, the denitrification process removes both nitrates and organic matter (carbon-based compounds) from the wastewater. At the end of this process, the bacteria sink to the bottom, leaving clear water at the top.

Step 3: Filtration

The decomposition of organic substances usually results in the production of inorganic salts, many of which remain in the water. These salts can be removed using filtration techniques such as reverse osmosis.

Osmosis is a process in which water moves across a semipermeable membrane from an area of low solute concentration to high solute concentration. This process requires no energy input.

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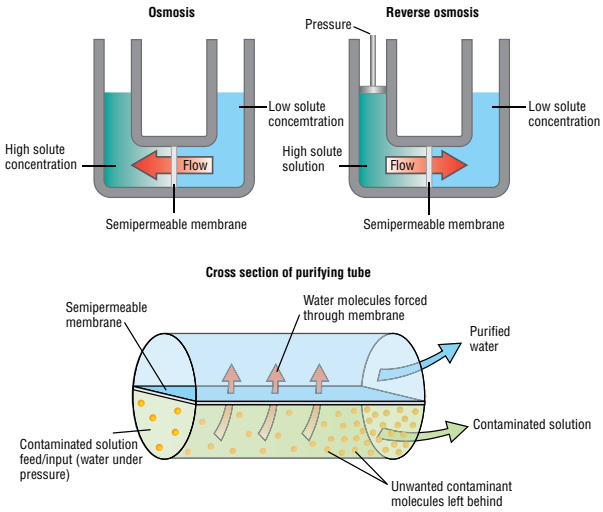

Figure 2. How reverse osmosis works

ILLUSTRATION BY ANTHONY FERNANDEZ, BASED ON FIGURE (P. 100) IN "CHEMISTRY IN THE COMMUNITY", W.H. FREEMAN, 5TH ED

Reverse osmosis uses pressure to force water to move in the opposite way. This process uses a membrane through which ions cannot travel (Fig. 2). The surface of the membrane is about 0.2 micrometers thick and is relatively nonporous. Because only water can go through the membrane, the liquid on the other side of the membrane is pure water. On the other side of the membrane, the contaminated solution becomes more and more contaminated in salt and is eventually discarded.

Water filtered by various methods can be pumped through special purple pipes—the international color for recycled water—and used for city irrigation, parks and roof gardens, a boat-washing station, and all of the sanitation for the wastewater treatment plant itself.

This water is used differently depending on the needs of the local areas. For example, Portland, Ore., has turned its airport into a "living building," where its own wastewater irrigates, flushes, and even provides heat for lobbies and offices.

Santa Rosa, Calif., injects 12 million gallons of treated water into mile-deep cracks in the Earth to re-supply dried-up geysers. Hot, underground rocks boil the water, and the steam generates enough electricity to power 200,000 homes, eliminating millions of tons of potential air pollution.

Step 4: Disinfection

In some wastewater treatment plants, the water is further disinfected before being released into bodies of natural water. Chlorine (Cl_2) is a common water disinfectant.

Chlorine has been used to disinfect drinking water since 1897. When chlorine is added to water, it quickly hydrolyzes to form hypochlorous acid (HOCl) and hydrochloric acid (HCl):

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Of the two acids, hypochlorous acid is the most potent disinfectant. It kills disease-carrying bacteria by penetrating their outer layer.

One major drawback of chlorine is that it reacts with organic matter to create cancer-causing byproducts called trihalomethanes.

Ozone (O_3) is also used in some municipalities to disinfect wastewater because it is very effective at killing viruses and bacteria.

Ready to drink it?

The final product is probably cleaner than most tap water, and safe as the safest bottled product. But does this sanitized sewer water feed directly into homes? Actually, no. Treatment plants throughout the United States often put fully treated water into bodies of water so that it is filtered down as rainwater. This process is called recharging. The waters blend and become one fresh, clean source.

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After water has been filtered in a wastewater treatment plant, you can use a home water filter to remove calcium and magnesium, known to cause "scales" inside pipes, water heaters and tea kettles.

This water percolates into the ground to enhance the water supply. Months later, it works through the soil and becomes actual drinking water again.

Recharging has been occurring for the past 30 years. According to the EPA, every major body of water in the United States contains some purified wastewater.

Now that we know what happens to our wastewater, we may feel good about the fact that it is reused to irrigate fields or heat buildings. But are we ready to drink it? We don't even know whether the water we drink every day has been recycled. Since most of us are still healthy after drinking it, well, that may be the evidence we were looking for!

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Check out the video podcast on sewage recycling at: www.acs.org/chemmatters

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