Drugs Down the Drain

The drugs you swallow, the water you drink

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By Cynthia Washam

You don't need a prescription to get a dose of antidepressants, painkillers, female hormones, and antibiotics. Unfortunately, they're all there in the water you drink, along with a mixture of other commonly used prescription and over-the-counter drugs.

But don't count on them to cure a headache, infection, or the blues. "The highest concentration of any pharmaceutical we detected in U.S. drinking water is approximately 5 million times lower than the therapeutic dose," says Shane Snyder, a professor of chemical and environmental engineering at the University of Arizona, Tucson, Ariz.

Scientists wonder if even those minute doses, taken day after day, year after year, might put us at risk. Let's look at the facts.

Disturbing facts

One scientist who has been taking a close look at the health effects of medical drugs in freshwater is Herb Buxton, coordinator of the U.S. Geological Survey's Toxic Substances Hydrology Program. Buxton admits that he and other scientists don't know the health effects of long-term exposure to these trace quantities of pharmaceutical drugs from drinking water, but they are concerned, especially after seeing how these dissolved substances harm fish. Recent studies revealed traces of several common pharmaceuticals in the brains, livers, and muscles of freshwater fish. In another study, fish exposed to synthetic female hormones from birth control pills developed both male and female reproductive organs. Yet another study showed that minnows exposed to antidepressants lost their instinct to avoid predators.

Scientists believe such small traces of pharmaceuticals have no effect in humans, but they admit more studies must be done before water contaminated with pharmaceuticals can be deemed completely safe. "Decades ago, we could only detect contaminants at parts-per-million levels," Snyder told a U.S. Senate subcommittee. "Years ago, we advanced to parts per billion. We are now able to detect compounds at the parts-per-trillion level, and are breaching the parts-per-quadrillion boundary level in some cases."

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Meds go with the flow

When you take a drug, your body uses only a portion of the active ingredients. The rest is excreted. So, you are releasing some of the drug into the sewer system every time you flush the toilet. Bathing also carries pharmaceuticals down the drain to the sewer system. Consider all of the medicinal gels, creams, and lotions we put on our skin that wash away as we shower.

Wastewater from homes and businesses travels through underground pipes to a sewage treatment plant, where it is treated to remove harmful bacteria and toxins. The disinfected solids that remain after treatment are taken to farms, where they are used as fertilizer.

The liquid discharge from sewage treatment plants, called effluent, is released into rivers, lakes, and reservoirs, where the water eventually is taken up by water treatment plants. Water treatment plants are the facilities that treat water, groundwater, or surface water to remove bacteria and other contaminants and produce drinking water for human consumption. Similar to the wastewater treatment plants, the water treatment plants may not be able to remove pharmaceuticals still present in the water, and these pharmaceuticals may, therefore, end up in your tap water.

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Pharmaceutical drugs flushed down the toilet (left) and soap going down the sink (right) end up in wastewater but are not completely eliminated from it. Some of it shows up in tap water.

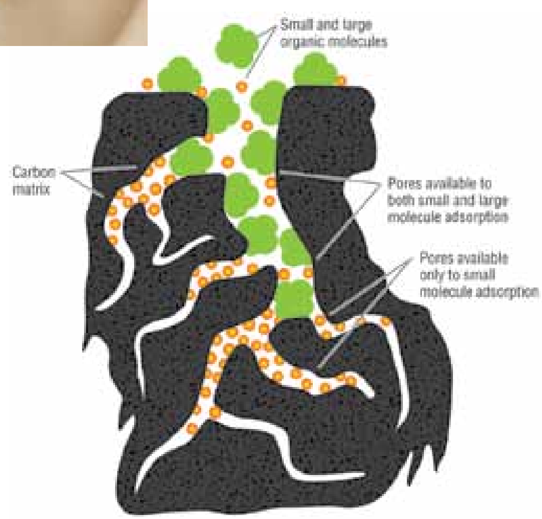

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Figure 1. Molecular structure of an activated carbon filter

Drugs escape disinfection

After discovering female hormones in freshwater, scientists began to wonder what other drugs are contaminating our streams.

To answer that question, in 1999 and 2000, scientists from the U.S. Geological Survey sampled water from 139 streams in 30 states. They found that 80% of the waterways contained detectable levels of pharmaceuticals, insecticides, and fire retardants.

Surprisingly, some of the most widely used prescription drugs did not turn up in waterways, while other seldom-used drugs were among the top contaminants. Why?

Some pharmaceuticals are detectable in streams and others are not because of the chemistry of wastewater treatment. Treatment plants normally disinfect wastewater with chlorine (see article "Is this Water Recycled Sewage?" by Gail Kay Haines on p. 8 of this issue). Chlorine completely removes some drugs, while others escape chlorine treatment.

Another drawback to disinfection with chlorine is that it can react with pharmaceuticals and personal-care products to form more toxic compounds. The antibacterial agent known as triclosan, found in countless household products, reacts with chlorine in tap water to produce chloroform. The U.S. Environmental Protection Agency (EPA) lists chloroform as a probable human carcinogen. Triclosan's toxic potential led the California city of Palo Alto to ban soap containing triclosan at city facilities.

Searching for a solution

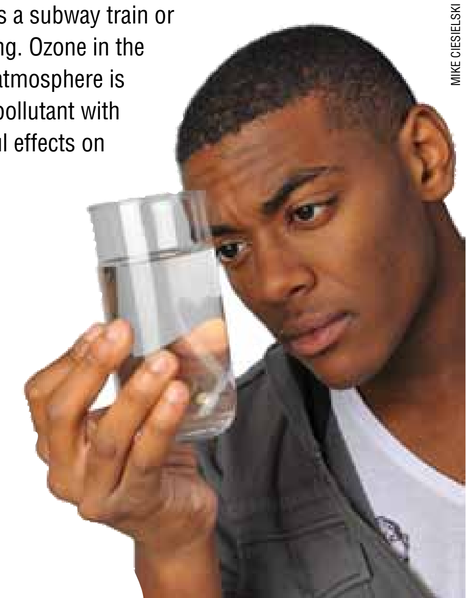
Scientists are looking for solutions to remove pharmaceuticals from drinking water and are attacking the problem on several fronts. Some have found that simply adjusting the pH, or acidity level, of water being treated can improve the effectiveness of chlorine against some drugs. The anticonvulsant carbamazepine, for example, is removed more thoroughly by chlorine when the water pH is low.

Activated carbon, also called activated charcoal or coal filter, may be helpful in removing unwanted chemicals from drinking water. Activated charcoal is a form of carbon that has been processed to make it extremely porous; as a result, it has a very large surface area available for adsorption (Fig. 1). The ever-present pores simply trap and bind large molecules. You have probably seen activated carbon in pour-through and faucet-mounted water filters used in the home, or used it in a fish tank.

Unfortunately, charcoal filters are expensive to install and operate. Disposal also poses a problem because it is hard to clean contamination from used filters. So, filters must be replaced relatively often.

Another water treatment process that eliminates many of the drawbacks of chlorine and removes 80% of all pharmaceuticals within 5 minutes is ozone treatment.

Ozone (O_3) is a molecule composed of three oxygen atoms, and is a toxic, light-blue gas. Its strong odor is noticeable around sources of significant electrical discharge, such as a subway train or lightning. Ozone in the lower atmosphere is an air pollutant with harmful effects on



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certain plants and the respiratory systems of animals; however, the ozone layer in the upper atmosphere is beneficial, preventing potentially damaging ultraviolet light from reaching the Earth's surface.

Ozone is produced when oxygen (O_2) molecules are dissociated by an energy source into oxygen atoms, which then collide with an oxygen molecule.

$$3\ O_2\,\text{(gas)} + \text{energy (electrical discharge)} \rightarrow 2\ O_3\,\text{(gas)}$$

Most wastewater treatment plants generate ozone from dry air by electrical charges. The ozone is then bubbled up through the water being treated.

Ozone gas is highly reactive and cannot be stored for an extended period of time. For that reason, ozone used in water treatment must be generated at the plant just before it is pumped into the water. Ozone reacts with organic molecules, including phenols in pharmaceuticals.

Ozone is a more potent disinfectant than chlorine and works over a wide range of temperature and pH levels. It is popular among environmentalists because it leaves no chemical residue in treated water. But the lack of a residual effect leaves water susceptible to contamination after treatment.

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Many municipalities abandoned ozone treatment 20 years ago because of its high energy cost. Newer technology, though, enables treatment plants to operate more efficiently. An ozone water-treatment plant being built in Las Vegas, Nev., is the first in the country designed specifically to remove pharmaceuticals from tap water.

What to Do with Unused Medications

For generations, the toilet was considered the best place for unused medications. It kept them from getting into the mouths of pets, children, and garbage-scavenging drug addicts. Nobody realized flushing doesn't make drugs disappear.

Now we know flushed pharmaceuticals often re-emerge in freshwater bodies. To minimize the environmental risk, the U.S. Fish and Wildlife Service and drug manufacturers created guidelines for disposing of medications that have expired or are no longer needed:


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- **Never flush or pour drugs down the drain unless the accompanying patient instructions advise you to.**
- **Some pharmacies and hazardous-waste collection sites sponsor take-back programs when people can return unused drugs for safe disposal. Call your local pharmacy or waste-removal service for more information.**
- **If you must dispose of drugs at home, remove them from their original containers and mix with an unappetizing substance such as sawdust, kitty litter, or coffee grounds. Better yet, crush the pills first. Then put the mixture in a sealed plastic bag or container before throwing it in the garbage. Also, remove the label from the original bottle or use a permanent marker to block out the prescription number and all personal information. This discourages illicit refills.**

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Other potential remedies to remove pharmaceuticals from drinking water include such novel approaches as cultivating bacteria to gobble up drugs. Kung-Hui Chu, an assistant professor of environmental engineering at Texas A&M University, College Station, Texas, discovered that a bacterial strain named KC8 thrives on estrogen—a female sex hormone. Now, Kung-Hui and colleagues are trying to figure out how to introduce the strain into wastewater treatment.

Better water treatment, drug-gobbling bacteria, and consumer efforts might go far toward minimizing pharmaceuticals in water. But they will never remove every trace, Snyder said.

"Ultimately, it will come down to people deciding how pure they want their water to be," Snyder added. "The most economical solution might be to provide two types of water: pure drinking water and less pure water for bathing, the toilet, and washing clothes."

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