

# Drugs down the drain

Remnants of everything in your medicine cabinet can now be found in the water supply. Alan Dove asks, should you be worried?

Six a.m.: the tingly foam of toothpaste runs in rivulets through millions of drains in the city and into its sewers. Seven a.m.: soap and shampoo mingle in a frothy deluge and seep into the watershed. Ten a.m.: a pulse of unabsorbed caffeine heads toward the waterways when the citizens relieve themselves after a morning cup of coffee.

The city's sewers each day soaks up its citizens' routines, taking in a steady stream of products. Toothpaste and shampoo may be harmless enough, but the waste also collects a wide array of medicines people take. Most drugs are poorly absorbed and metabolized by the body, so it is not unusual that the majority of a drug would end up intact in the urine. Because all water goes through toilets at some point, these artificial compounds, some quite difficult to break down, can eventually find their way into the city's water supply—even bottled water.

Until recently, few tests could detect drugs at the low levels they are found in sewers, but more sensitive techniques are now allowing scientists to track these compounds through the ecosystem.

What they've found is that medicines and personal-care products are nearly ubiquitous in the water supply. There are on average nearly 20 different drugs in a waste stream, says Dana Kolpin, a research hydrologist at the US Geological Survey's Iowa Water Science Center in Iowa City. "Every wastewater treatment plant we've looked at to date," he says, "we've found stuff."

Only the most naive environmentalist would argue that all chemicals are bad and, so far, most experts are hesitant to sound a general alarm about pharmaceuticals in wastewater. The field is still in its infancy, however, and recent discoveries have started to fuel concern about this unanticipated source of pollution. If the trend continues as it is expected to, it will pit clean drinking water and modern medicines, two cornerstones of the revolutions in public health, at direct odds with each other.

## Fluoride to fluoxetine

The list of compounds in wastewater—and by extension in the environment downstream—is a veritable medicine cabinet, stocked with common over-the-counter drugs such as ibuprofen, exotic cancer chemotherapies

and everything in between. The blockbuster antidepressant Prozac (fluoxetine) has appeared everywhere from Canadian lakes to Texas fishing streams. An analysis of the Po River in northern Italy even allowed researchers to quantify local cocaine use, with the surprising finding that residents nearby consume about 3,000 pounds of the illicit drug each year<sup>1</sup>. Traces of prescription heart medications and caffeine have even found their way into the Atlantic Ocean.

Most of the drugs appear in concentrations of a few parts per trillion in streams, making it difficult to isolate them from water. At those doses, the risk they pose is probably small, but experts note that some drugs persist in the environment and might accumulate over time.

In Europe, water-quality institutes have been tracking pharmaceutical pollutants for more than a decade, partly because countries such as Germany and Switzerland do not chemically disinfect wastewater. Instead, those countries rely on physical filtration and sedimentation systems to remove biological contaminants. The technique effectively removes potential pathogens, but it seems to leave many chemicals intact.

Most of the European work has focused on the most potent drugs from a biochemical perspective—such as antibacterials, antibiotics and endocrine-active compounds, which include natural and synthetic steroids. These compounds often accumulate in the food chain,

and laboratory and field studies suggest that they may be able to feminize the males of some species, rendering them infertile.

Because pharmaceutical compounds are tested for human toxicity at doses several orders of magnitude higher than those found in wastewater, the direct medical impact on people of this pollution stream is harder to assess. "This is definitely more of an ecological topic with regards to risk assessments," says Michael Dodd, a postdoctoral fellow at the Swiss Federal Institute of Aquatic Science and Technology.

But there could be an indirect effect by promoting resistance to antibiotics. Apart from antibiotics in urine, waste streams have in recent years acquired a substantial flow of the disinfectant triclosan, as soap manufacturers have added this chemical to a vast collection of 'antibacterial' products. By giving pathogens a diluted preview of newer antimicrobials, the water streams might allow them to develop resistance even before encountering a host.

## Soap and sanitation

Sewers are notorious for their ability to trigger epidemics, and some cities in developing countries still weather regular bouts of cholera and diarrhea. Making sure that all human excrement gets disinfected before entering the watershed is a difficult, but necessary, task.

But many US cities pool raw sewage and rainwater from the streets and then subject the combined stream to treatment. In the case of heavy rainfall, runoff from the streets can surpass the treatment capacity, sending raw waste overflowing into surrounding waterways, where it can be pulled back into the drinking water system.

Regular tests for the intestinal bacterium *Escherichia coli* can identify serious overflows, but the test is insensitive and slow. But in an example of a drug in wastewater proving to be beneficial, a



**Bad chemistry:** Common medicines and the compounds into which they break down are entering the food chain—and could affect your health.

common heart medication found in most waste streams has provided the solution<sup>2</sup>.

Scientists at the University of California in Berkeley were looking for methods to test whether pharmaceutical compounds were breaking down after their discharge into the environment. But they first had to determine whether the compounds are degraded in the wastewater treatment plants. They chose Inderal, a popular treatment for high blood pressure that is found in most sewers. Inderal (propranolol) exists as a mixture of two mirror-image isomers, or enantiomers. The researchers found that in treated wastewater, one enantiomer of Inderal degrades faster than the other, but in untreated waste, the two degrade equally fast.

“Serendipitously, it turned out that we had a tracer which told us whether the compounds had been through a wastewater treatment plant,” says David Sedlak, professor of civil and environmental engineering at the University of California in Berkeley.

A field test of the new technique revealed that raw sewage leaks—and the associated health risks—may be more common than previously believed. “When we employed this tool in surface waters, we found that there were a number of locations where the pharmaceutical was coming from raw sewage, and not from [treated] effluent,” says Sedlak.

The researchers are now looking into other common drugs in wastewater, in the hope of developing a panel of standardized tests that could indicate sewage overflows quickly and reliably.

### Fish pharming

Assessing the risks to people from pharmaceutical waste is a high priority, but ecologists are also concerned about what these drugs could do to other organisms. There is no question that at least some drugs move from wastewater into the food chain: the invasive zebra mussels of US freshwater lakes contain detectable amounts of fluoxetine, for instance, as do at least some species of freshwater fish. Other compounds, particularly steroid hormones, could be responsible for feminizing some male fish and disrupting reproduction<sup>3</sup>.

Researchers in the field are also starting to ask how the ecosystem affects the drugs, and whether the chemicals might break down into dangerous compounds.

“The analytical methods are pretty much focused on the parent [compound], so if there are conjugates or if there are other degradation products, you’re not going to see those,” notes William MacCrehan, a research chemist at the US National Institute of Standards and Technology in Gaithersburg, Maryland.

MacCrehan and his colleagues have discovered that acetaminophen—one of the most abundant drugs in wastewater streams and the active ingredient in the fever reducer Tylenol—reacts readily with the chemicals in standard chlorine-based water treatments<sup>4</sup>.

The byproducts include benzoquinone, a compound the US Occupational Safety and Health Administration warns “may be fatal if swallowed, inhaled or absorbed through the skin.” The researchers note, however, that the

complete treatment might further degrade the chemicals into hydroquinone, which is commonly prescribed as a topical skin-bleaching agent.

Turning a nonprescription painkiller into a prescription dermatology drug is certainly a novel use for a sewage plant, but the bigger question is what happens to the breakdown products after they are released into streams. “It’s so early in the game nobody knows what they’re going to do in the environment,” says MacCrehan.

At least one entrepreneur is taking an unusual tack and trying to harness the drugs in waste streams (see sidebar), and other groups are trying to find ways to cut down on this source of pollution. For instance, researchers at the Swiss institute are working on a product they call the NoMix toilet, which would separate urine into its own waste stream. Because urine carries the majority of secreted drugs, the approach would allow cities to isolate the chemicals more easily.

If the concerns over the chemicals grow, the timeline of a typical day might have to accommodate an entry more along these lines—five a.m.: sanitation truck stops in front of a house and picks up several sealed containers of yellowish liquid.

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## Toilet maker mines medicines from waste

Drugs in the water supply might be a frightening concept for most people, but to Earl Braxton, it presented a business opportunity. In 1991, Braxton watched doctors dispose of needles after a chemotherapy treatment and noticed that they took special care to avoid letting the drugs slip into the waste stream. “I realized right away that there was a hell of a business there,” says Braxton.

Braxton is president of the Michigan-based Pharmaceuticals.org, a drug-development firm with an unusual parent company: portable-toilet maker Porta-John Systems, Inc., which Braxton also heads.

Despite the care lavished on the needles, the majority of the cancer drug leaves the hospital in the body of the patient, and eventually enters the sewer system. Braxton says he was surprised to learn that even people who have not taken any drugs secrete copious amounts of potentially useful compounds. The clot-buster enzyme urokinase occurs naturally in human urine, for instance, but pharmaceutical companies spend a lot of money making it in cultured cells.

Braxton has no formal research training, but armed with some basic biochemistry equipment, he easily isolated urokinase from urine. He has also successfully purified such biotechnology blockbusters as erythropoietin and human growth hormone from human waste.

“I had a major pharmaceutical company tell me there’s no such thing as cheap protein, and I was pumping out protein by the drum-full,” Braxton says.

Urine-derived drugs are not unheard of—Wyeth’s Premarin, isolated from the urine of pregnant mares, is a highly successful treatment for the symptoms of menopause. And Braxton certainly had access to billions of gallons of urine. But he quickly discovered that drug makers find human urine harder to stomach.

With only a slight adjustment in their techniques, Braxton’s company began isolating small-molecule drugs from urine, hoping that companies would be more interested in selling these recycled synthetic compounds. Braxton says his affinity column-based process, for which he has filed patents, can easily isolate many over-the-counter and prescription drugs. The work has not reached peer-reviewed journals, however. “It works,” Braxton says, but, “I’m Earl Braxton, toilet pumper, who the hell’s going to publish it?”—AD



Entrepreneur Earl Braxton (inset) has patented his drug-purifying methods.