drugging the waters

HOW AN AGING POPULATION AND OUR GROWING ADDICTION TO PHARMACEUTICALS MAY BE POISONING OUR RIVERS

by elizabeth royte

NORMAN Leonard moved to Heritage Village, a sprawling retirement community in western Connecticut, 11 years ago. Its green-gabled condominiums and Capes were well maintained, and the landscapers hadn't skimped on the rhododendrons. A retired CPA, Leonard considers himself, at age 80, to be in pretty decent shape: He plays platform tennis on the grounds and hikes often in nearby forests and reserves. But still, he takes five different drugs a day to manage his blood pressure, acid reflux, and high cholesterol. Heritage Village is home to about 4,000 residents with similar medical profiles, who take an average of six drugs a day.

And that's a healthy population. In a convalescent home a few miles away, Patricia Reilly, age 88, wheels herself each morning toward a low shelf. With a glass of water and small cups of applesauce at the ready, she prepares to take her morning medicines: nine different types that treat heart disease, acid reflux, renal stones, a chronic urinary-tract infection, chronic constipation, migraine headaches, depression, allergic rhinitis, degenerative arthritis, and intermittent vertigo. The 120 residents of River Glen Health Care Center, where the average age is 90, take an average of eight drugs a day; the most common among them target high cholesterol, high blood pressure, depression, and diabetes. Once swallowed, Reilly's medications will bring her some relief, but their biological activity won't stop once they leave her body.

When residents of Heritage Village and two other nearby retirement communities flush their toilets, wastewater laced with traces of prescription drugs rushes through a series of pipes into the Heritage Village treatment plant. This flushing is the main pathway by which pharmaceuticals enter the environment. Hospitals and nursing homes routinely dump unused or expired pills down the toilet, and consumers have been advised to do the same; effluent from pharmaceutical manufacturers also ends up at municipal wastewater treatment plants. Through a process of settling and aeration, the Heritage Village plant separates liquids from solids, treats the liquid portion with disinfectant, and then discharges this effluent into a mini-creek that meanders between the third green and the seventh tee of the Heritage Village golf course. Making its way through a riparian band of oaks and maples, the creek fans out into the Pomperaug River, which loops without further interruption through the town of Southbury.

The water of the Pomperaug looks no different upstream or down, but studies conducted by the U.S. Geological Survey on other rivers suggest that the Pomperaug below the effluent creek carries the signatures of drugs consumed by anyone plumbed into the Heritage Village system. The effect of those drugs on the environment, and possibly on those who drink water pumped from those streams, is only beginning to be understood.

Deep pools and fast riffles make the Pomperaug a favorite trout fishing spot. Right: A few of the drugs taken daily by a patient at a nearby nursing home.

photographs by masood kamandy

We are a nation obsessed with pharmaceuticals. We spend vast sums to manage our health, and we pop pills to address every conceivable symptom. Some elderly Americans take as many as 30 drugs a day, some of them merely to counteract the effects of others. Prescription drug sales rose by an annual average of 11 percent between 2000 and 2005. Americans now fill more than three billion prescriptions a year; nationwide, more than 10 million women take birth-control pills, and about the same number are on hormone-replacement therapy.

The rate at which prescriptions are dispensed is only going up as the population ages. Already, those over 65 fill twice as many prescriptions per year as do younger Americans. Inevitably, more drugs will be headed into waterways like the Pomperaug. Our rivers—already stressed by pollutants, groundwater pumping, reduced flows, and overburdened wastewater treatment plants that dump raw sewage—will be ever less able to cope.

Alarmed by data that showed trace levels of pharmaceuticals in European streams, researchers in the United States have begun to survey our nation's waterways. In 2002, the U.S. Geological Survey (USGS) published the results of its first-ever reconnaissance of man-made contaminants. Using highly sensitive assays, the agency found traces of 82 different organic contaminants—fertilizers and flame retardants as well as pharmaceuticals—in surface waters across the nation. These drugs included natural and synthetic hormones, antibiotics, antihypertensives, painkillers, and antidepressants.

Now that science has documented the presence of free-flowing pharmaceuticals, researchers are faced with another, far more difficult, pair of questions: What does this mean for the environment, and what does it mean for us? Early evidence of harm to aquatic organisms is giving researchers grounds for real concern.

Dr. Allison MacKay and her students sample the waters of the Pomperaug.

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On a dull November morning, two graduate students from the University of Connecticut shiver on the steep banks of the Pomperaug. Monotonously, repetitively, they plunge plastic jars two feet down into the beer-colored water. Five-minute intervals tick away on a stopwatch. "Is it here yet?" asks Dan Seremet. He's now midstream, his fleece cuffs dripping onto his chest waders. Raquel Figueroa, squatting in a drift of crisp oak leaves, slips a vial of water into a portable fluorometer, closes the gizmo's cover, taps a button, and answers, "Point one nine."

So, no. It isn't here yet.

Five minutes pass, Raquel shouts in her tiny voice, "Go!" and Dan, maneuvering over slippery rocks, dips his jar again. Two hours pass, in five-minute chunks, and the fluorometer, which detects and measures specific particles in the water, rises only to 0.65 parts per billion (ppb).

"Maybe we're in the wrong river," Dan sighs. Raquel doesn't bother to answer. She logs the time and the concentrations. She dumps out samples. She painstakingly removes a bittersweet vine holding her leg prisoner. "Next time we should bring pruners," she says to no one in particular. Then, "Go!" Dan dips.

In 30 minutes, the fluorometer rises to 2.45. Nothing to get excited about: When the half cup of fluorescent magenta dye—poured into the Pomperaug two miles upstream and two hours earlier—flowed past the previous monitoring station, the reading peaked at just over 4 ppb. "Uh-oh," says Raquel when she takes the next reading. "We're down to 2.301." In another five minutes it is 2.25.

"I guess that was the peak," says Dan, his voice the opposite of a peak, as he clambers out of the streambed. He and Raquel pack up their bottles and log books, the fluorometer, a tape measure, and a flow meter (basically a pair of spinning blades on a stick, used to measure the water's velocity), then drive downstream to do it all again with the boss, at the last of four monitoring stations.

The boss is Allison MacKay, an environmental engineer who specializes in aquatic chemistry at the University of Connecticut. MacKay had risen at four o'clock in the morning and loaded her car with gear, plus the sleepy Dan and Raquel, then drove west to Southbury. By eight, she had poured her dye into the Pomperaug at the point where it receives the Heritage Village effluent. (Invisible to the naked eye, the dye is nontoxic and will degrade in sunlight over three days.) With her grad students MacKay is tracking the dye's progress down a six-mile stretch. The concentration of the dye, read by the fluorometer, will tell her both the rate at which the Pomperaug flows and the rate at which a particular contaminant is diluted as it flows downstream—two useful bits of information when you're studying the movement of contaminants from a single source. MacKay and her helpers are also taking water samples that will later be analyzed for the presence of the same 82 organic contaminants originally assayed by the USGS.

In a turquoise parka and insulated pants, MacKay kneels on the sandy bank. Her cheeks are pink in the cold air. If there is any fun to be had along a New England river in November, this crew refuses to acknowledge it. There are no observations on flora or fauna, no chit-chat, no stone skipping or stick building. MacKay is all business, and her students follow her lead. For eight hours (no lunch break) they collect water and measure the river's depth, width, and velocity.

"The USGS does grab samples," says MacKay, rapidly punching a series of numbers into her calculator and plotting points on a hand-drawn graph. Grab samples are like snapshots, a single moment in a single place in a stream. "Their studies established the presence of drugs in our waterways, but no one in this country has looked at the temporal and spatial distribution or the environmental degradation rates of pharmaceuticals in surface water. That's what I'm doing." Among the factors that influence the compounds' fate are sunlight, temperature, flow rate, microorganisms in the sediment, minerals, and other chemicals in the water. If concentrations of any particular contaminant decrease, MacKay explains, she'll set up controlled lab experiments to see where, when, and how it happened: Was it the sun degrading the compound, a change in temperature, or an organism that might have consumed it? If aquatic life is suffering, she continues, researchers will need to know what concentrations they're being exposed to at different points in the stream.

> In Boulder Creek, female white suckers outnumber males by more than five to one, and 50 percent of males have female sex tissue

This stretch of the Pomperaug makes an ideal laboratory for MacKay's study: It is wadeable, and it has only one significant input of both water and prescription compounds—the Heritage Village treatment plant. The river is also a paradigm of the nation's threatened waterways, of the large- and small-scale changes that our growing population has wrought. Still, to drive the country roads of Southbury and its neighboring villages is to marvel at what hasn't changed in the past 200 years. Well-kept colonial houses still flank water mills; nineteenth-century farm fences decorously sag. The stream banks are, for the most part, intact. Trout congregate in deep pools. Though some of its meanders and oxbows were mechanically straightened more than half a century ago, the river still flows past horse farms and hemlock glades and rolling hills.

One can't help thinking the Pomperaug is privileged to run through a stronghold of the well-to-do. All American rivers are, at some level, endangered, but this one's remaining virtues are particularly obvious. Not only is there plenty worth saving here, there are also plenty of stakeholders eager to do the saving, among them a mild-mannered, semiretired internist named Marc Taylor, who happens to live just a few miles downstream from MacKay's sampling sites.

Taylor is the medical director of the River Glen Health Care Center, where Patricia Reilly lives, but he spends an inordinate amount of time fretting—in public meetings and in private telephone calls with scientists, politicians, city planners, and conservation groups—about the health of his river. "I'm concerned about pharmaceuticals in the river because I am a doctor," says Taylor, who speaks in precisely measured sentences, "and because I know these drugs are bioactive." That is, they can enter the bioprocesses of aquatic organisms.

As chairman of the Pomperaug River Watershed Coalition, Taylor has watched with increasing concern as developers cut streets into nearby hillsides, shopping centers supplant farms and orchards, and waves of the elderly flock to four planned communities within the town limits. "As the population of the watershed goes up," says Taylor, sitting in his basement office surrounded by maps of the region, "more groundwater is being pumped. We've got three public water companies drawing water from wells sunk near the Pomperaug." With a few computer keystrokes, Taylor pulls up real-time data from a gauging station on the river. This afternoon's flow is 250 cubic feet per second. Last summer it dropped to 8 cubic feet per second—one of the lowest flow rates in the river's recorded history. Some small streams in the Pomperaug watershed now completely disappear in the summer.

The Pomperaug's peril is not unique. "Across the nation rivers are stressed," says Katherine Baer, advocacy director for American Rivers, which is based in Washington, D.C. "As drought becomes more common, there is less water in streams for aquatic life. Everywhere we see more development, sprawl, and increased population. So we get higher pollution loads. Pharmaceuticals, which become more concentrated with low water, are only increasing the burden."

At the present time, in a project unrelated to its study of contaminants, the USGS is making hydrologic models of how water enters, moves through, and leaves the Pomperaug watershed. The Pomperaug River Watershed Coalition is studying water quality, the dilution of treated wastewater, and, with the help of Allison MacKay, the environmental fate of compounds left behind after drugs have been metabolized by our bodies, as well as that portion of the drugs that passes through us without being absorbed.

According to the Environmental Protection Agency, which is putting together a database of literature on so-called emerging contaminants, those metabolites are virtually everywhere, from the iconically dirty Chicago River to the iconically pristine headwaters of Boulder Creek in Colorado. They're in the intakes and outflows of water facilities in both urban and rural areas, in groundwater, mountain streams, surface water, and domestic wells. And while levels of pharmaceuticals are sometimes infinitesimally low, their supplies are continually replenished. As a result, organisms that constantly bathe in a chemical broth are beginning to reveal some alarming abnormalities.

In Boulder Creek, David Norris, an environmental endocrinologist at the University of Colorado at Boulder, found that female white suckers, bottom-feeding fish that grow up to a foot long, outnumber males by more than five to one, and that 50 percent of males have female sex tissue. Similar intersex changes have been found in flat-head chubs and smallmouth bass. The cause, Norris suspects, is exposure to estrogen. Like most pharmaceuticals, hormones aren't designed to break down easily. They're supposed to have an effect at low dosages with chronic use, and they only partly dissolve in water.

"I'm worried for fish populations, and I'm worried for human populations," says Norris. "The levels found in Boulder Creek are low in absolute terms, but they aren't low on the biological level. You could have six chemicals below the no-effect level, but all together they are above the no-effect level." In lab tests, frogs and rats have developed infections and deformities after being exposed to multiple pollutants at extremely low levels. Since exposure to only one compound is rare in the modern world, sorting out "mixture effects" is a daunting but critical research area. The estrogenic compounds in drinking water, Norris says, are "adding to the general exposure of the human population to environmental estrogens in our foods, and in containers that hold our foods. They all work through the same mechanisms." In the United Kingdom, hormones in the environment have been linked with lowered sperm counts and gynecomastia—the development of breasts in men.

A Baylor University researcher found tiny amounts of Prozac in liver and brain tissue of channel catfish and black crappie captured in a creek near Dallas that receives almost all of its flow from a wastewater treatment plant. The creek also connects to a drinking water supply. A University of Georgia scientist found that tadpoles exposed to Prozac morphed into undersize frogs, which are vulnerable to predation and environmental stress. The EPA reports that antidepressants can have a profound effect on spawning and other behaviors in shellfish and that calcium-channel blockers (used to relieve chest pain and hypertension) can dramatically inhibit sperm activity in some aquatic organisms. Even at extremely low levels, ibuprofen, steroids, and antifibrotics—a class of drugs that helps reduce the development of scar tissue—block fin regeneration in fish. According to a report by the Scientific Committee on Problems of the Environment, a worldwide network of scientists and scientific institutions, and the International Union of Pure and Applied Chemistry, more than 200 species—aquatic and terrestrial—are known or suspected to have experienced adverse reactions to such endocrine disruptors as estrogen and its synthetic mimics. (See "Hundreds of Man-Made Chemicals Are Interfering With Our Hormones and Threatening Our Children's Future" by Gay Daly, *OnEarth*, Winter 2006.)

podcast DR. MARC TAYLOR TALKS ABOUT HIS WORK ON THE POMPERAUG AT www.onearth.org/podcasts.

Marc Taylor worries about the health of his aging patients—and of the nearby Pomperaug River.

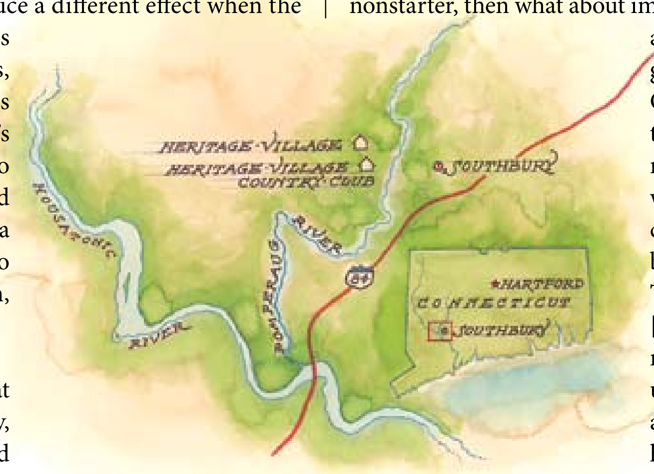
"As a doctor, I'm concerned about pharmaceuticals in the river because I know these drugs are bioactive."

Experts say pharmaceuticals have probably been in the environment for as long as we've been using them. We're discovering them now because analytical methods sensitive at the parts-per-trillion level and lower were only recently developed. Surely the technology is a boon to society, but it opens a Pandora's box of questions. We know that low concentrations of some pharmaceuticals are affecting aquatic organisms, but what are they doing to humans? What happens when organisms are exposed to multiple chemicals at the same time? What happens when they bioconcentrate in living creatures or accumulate in sediment?

Traditionally, toxicologists have assessed environmental and health risks one chemical at a time, focusing on such end points as birth defects or cancer. More recently, scientists have begun to examine effects from combinations of chemicals, an approach that more closely mimics the way organisms are exposed to chemicals in the environment. Looking at end points that include immune and reproductive system dysfunctions and neurological, cognitive, and behavioral effects, researchers are finding that mixtures of chemicals can lead to effects at much lower levels than do single chemicals, and that low-level exposure can often induce results not seen at higher levels. Nearly every week, results of new studies on emerging contaminants appear in toxicology and environmental health journals.

"It may seem impossible to figure out what's happening," says Christian Daughton, chief of the environmental chemistry branch of the EPA's National Exposure Research Laboratory in Las Vegas, "but technology has a way of leapfrogging. Less than a decade ago no one thought you could map the human genome. Analytical chemistry progresses at a fast rate. Remember, we're only talking about this now because we developed the technology to find these compounds."

Parsing the downstream effects of pharmaceutical compounds is an exceedingly complicated task. For one thing, more than 100 new drugs—both prescription and over-the-counter—are introduced each year. Researchers are confronted with long latency periods for some human diseases, making it difficult to connect an illness or disorder with long-ago exposures. Some of the drugs in our waterways act upon more than one hormonal pathway; some may end up in humans through multiple exposures (for example, antibiotics from both food and water); and exposure to mixtures of contaminants may lead to an adverse effect using one particular recipe, but produce a different effect when the ratio of those same ingredients is changed. "For many of these drugs, the mechanism of action for humans is unknown," says Daughton. "So it's difficult to anticipate what's going to happen to them after they've entered the environment. There isn't even a database for all published work to show their presence, their location, and their concentration."



MAP BY MIKE REAGAN

This fall, when water flows are at their lowest, Allison MacKay, accompanied by Raquel and another grad student, hopes to inch down the riverbanks once again to capture small pieces of the Pomperaug. MacKay knows her study is just the beginning of a very long process, but it is fundamental to an understanding of drugs in our waterways. "The power of knowing about the fate of these compounds is to use it in a predictive way," MacKay says. "Once we know what's happening, we can say, 'I'm going to release this, and this is when it will degrade.' I don't know about drugs, but pesticides have been reformulated to degrade faster and be less bioaccumulative in waterways."

Could manufacturers reformulate pharmaceuticals in a similar way? "There's a trade-off in terms of having molecules break down readily versus having a stable molecule that does its work as a medicine and has a reasonable shelf life," says Thomas White, a technical consultant to the Pharmaceutical Research and Manufacturers of America (PhRMA), which represents brand-name drug manufacturers and accounts for 80 percent of all drug sales in the United States. "We've looked at studies of 26 compounds and there doesn't appear to be any human health risk." Because there is no accepted methodology for evaluating interactions among active pharmaceutical ingredients, the studies that PhRMA reviewed, which came from a variety of sources, considered drugs singly, not in combination. The PhRMA review included antibiotics, cardiovascular drugs, and antidepressants, but not estrogen or steroids. "Hormones," White concedes, "are a class of drug that would be a problem: They're designed to affect the human endocrine system. Their fate effects are under study now."

Marc Taylor, like many health-care professionals, thinks a good first step for getting drugs out of waterways is to persuade hospitals and nursing homes to abandon their policy of flushing unused drugs down the toilet. A handful of states and municipalities have launched pharmaceutical take-back programs, in which consumers bring unwanted or expired medications to an official collection site. Drugs are then either returned to manufacturers or disposed of by incineration. But creating a national return policy is more complex than it sounds. "You've got federal and state regulations, the governing boards of pharmacies, and the Drug Enforcement Agency," says Daughton. "Everyone has to get together."

Even if the federal government did devise such a policy, it would deal only with unused drugs, not with those actually swallowed and then flushed, which is the primary pathway to the environment. If redesigning drugs to break down sooner in the environment is a nonstarter, then what about improving wastewater treatment? "We already have the tools and technology to take out everything," says Lynn Orphan, former president of the Water Environment Federation, which represents operators of municipal wastewater treatment plants. "We can use activated carbon or membrane filters, which have tiny pores. There's reverse-osmosis filtration [which removes organic contaminants] and exposure to ozone or to ultraviolet light. Sometimes it's just a matter of extra retention time in holding tanks."

But Hugh Kaufman, a senior policy analyst on waste issues at the EPA, says, "Some of those technologies have been demonstrated to work in a laboratory, but they haven't been scaled up for day-to-day use. The cost of putting them in place, plus their operation, is astronomical—hundreds of millions over the lifetime of a plant."

Standing in his backyard, Marc Taylor can, with little effort, toss a stone into the riffles of the Pomperaug. The water is so clear that he could, if he wanted, easily retrieve it. He continues to swim in the river and to drink from it—his well water comes from the Pomperaug aquifer.

As he awaits the results of MacKay's study, Taylor says, "I'll keep prescribing the medications that Patricia Reilly and my other patients need." In a philosophical mode, he continues, "The public will have to get used to the reality that the drugs and chemicals we use all go somewhere and have potential effects. The environmental fate of all consequential drugs and chemicals should be known. It's worth studying because this problem is only going to get worse as the population ages." For now, he says, "we'll have to rely on the health of the fauna in our rivers to get hints about the consequences to people. The fish and the amphibians are our canaries."

Elizabeth Royte, a regular contributor to OnEarth, *is the author of* Garbage Land: On the Secret Trail of Trash *(Little, Brown).*