

# DON'T DRINK — THE — WATER

## IN BRIEF

**More communities** are finding high levels of perfluorochemicals (PFCs) in drinking water. The EPA recommends concentrations stay below 70 parts per trillion. **PFC molecules**, used to manufacture many consumer products, are everywhere because they do not break

down. They accumulate in the human bloodstream. **Studies show** possible correlations between high PFC levels and weakened immune systems, enlarged livers, and more, but no direct causation has been shown. **Scientists are having** a difficult time determining what

levels may be dangerous because potential health effects vary among species in animal studies and are hard to isolate in human studies. No “unsafe” limits have been declared, leaving residents and municipalities uncertain whether to take corrective actions.

HEALTH

More communities  
are emerging  
as hotspots for  
drinking water  
tainted with PFCs,  
but scientists and  
regulators are  
struggling to  
determine how  
much is unsafe

*By Charles Schmidt*



# SPRAWLING OVER A MANICURED SUBURBAN LANDSCAPE

in Portsmouth, N.H., the Pease International Tradeport office park encompasses 250 companies, a golf course and a pair of day care centers. Nearly 10,000 people arrive here for work every day. But belowground lies a toxic legacy. Until 1988, the site was a U.S. Air Force base, where fire crews during routine training exercises would torch old planes in a field, then douse the flames with chemical foam. At the time, it did not seem to matter that the foam sank into the soil. But it contaminated groundwater. Pease workers and their children have been drinking for decades.

Three years ago scientists sampled the drinking water at Pease and detected perfluorochemicals, or PFCs—compounds in the foam that could snuff out fuel fires. The concentrations were up to 35 times higher than what the U.S. Environmental Protection Agency says is okay to drink. PFCs have been used for decades in hundreds of products, and they are now widely dispersed in soils and groundwater around the planet. Virtually everyone in the industrial world has some of the particles in their blood from drinking water or eating crops, meat and fish. Of even more concern, the chemicals can accumulate at high levels in local environments where they were manufactured or used to make products. People who live in these hotspots can have concentrations in their bodies that are much higher than average.

The number of hotspots is rising. In May 2016, citing emerging evidence that the compounds are especially toxic to children developing in the womb and breastfeeding infants, the EPA dropped its health advisory level for PFCs in drinking water to a new low: 70 parts per trillion, or a little more than half a teaspoon in 20 Olympic-sized swimming pools. Communities in more than two dozen states have since reported PFCs exceeding the new threshold. With all this attention, more towns are looking and finding they have a problem.

The discoveries are fueling fears that the nation's drinking water, already threatened in many places by lead and other chemicals, is not adequately protected. PFCs are a rising concern because they are still being discovered widely and because the amounts ingested in drinking water add to the accumulated exposures from other sources, such as food and consumer products. Between 2013

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and 2015 the EPA looked for PFCs in every water utility around the country that served more than 10,000 people, along with a sample of 800 water systems that served fewer. Sixty-six utilities serving a combined six million Americans had on at least one occasion detected PFCs in their water at levels over the EPA's new threshold.

Many states are taking action. This past summer health officials advised 100,000 residents in northern Alabama to avoid PFC-contaminated tap water until a temporary supply was brought online. In Bucks and Montgomery counties in Pennsylvania, officials had as of October closed 22 public and 150 private drinking-water wells serving 100,000 people. In Ohio and West Virginia, 3,500 people have sued DuPont, a major PFC manufacturer, claiming that releases from its Washington Works chemical plant on the states' common border drove up rates of cancer and other illnesses. More than a year ago state officials told residents in Hoosick Falls, N.Y., to not drink the water but have not yet fully resolved the problem. "We think we're just scratching the surface in terms of how many communities are affected by PFCs," says David Andrews, a senior scientist at the Environmental Working Group in Washington, D.C. "We expect the numbers are enormous."

High PFC levels in blood raise health fears not just for cancer but also for immune system suppression and reproductive problems. But precisely how particular levels affect human health is not clear, and that is driving pitched debates over the amounts that people can consume safely.

## INDESTRUCTIBLE MOLECULES

MANUFACTURED FOR DECADES in large quantities, PFCs were developed commercially in the 1940s by the Minnesota Mining and Manufacturing Company, now 3M. PFC molecules look like a zipper, with a backbone of carbon atoms interlaced with fluorine atoms, and they form durable and impenetrable films. When applied as a coating, say on rain jackets, carpets and even computer microchips, the hard but slick films helped water, oils and dirt slide off. They were also used as manufacturing aids in making products for cooking and food storage, such as nonstick pans, pizza box liners and popcorn bags. The chemicals allowed other coatings, such as Teflon, for instance, to spread evenly over surfaces that would come in contact with food. Companies tried to remove PFCs after the coatings were applied, but studies disagree over whether the removal processes were successful, meaning PFCs could have remained in coatings of nonstick pans, for example, and been released when the pans were heated on home stoves.

Over time many companies made and used the chemicals. More than 3,000 varieties remain on world markets today. But the structural stability that makes PFC-based coatings so useful to industry also has a health and environmental downside. Carbon-fluorine bonds—which are wholly unnatural—are not readi-





ANDREA AMICO'S husband and children have elevated PFCs in their blood. He worked at the Pease International Tradeport, where the compounds were found in drinking water; the kids went to day care there.

ly digested by microbes, broken down by the sun, or metabolized to anything else in soils, plants or the bodies of humans or animals. Most PFC molecules ever made still linger somewhere on the earth. Scientists have detected PFCs in polar bears, whales, fish and the produce that winds up on American dinner plates. "Nothing in the environment can degrade them," says Ian Cousins, a chemist and professor at Sweden's Stockholm University. "PFCs can only be diluted and dispersed."

For years PFC production was dominated by long-chain compounds that had backbones of eight carbon atoms or more. The two most widely manufactured compounds were perfluorooctanoic acid (PFOA), also called C8, which had been used to make Teflon and Gore-Tex, and perfluorooctane sulfonic acid (PFOS), formerly a key ingredient in Scotchgard fabric protector and many firefighting foams. Unlike other widespread chemical pollutants that build up in fatty tissue—think dioxin or DDT—PFCs accumulate in blood and then pass from the body in urine. But long-chain PFCs are reabsorbed in the kidneys, allowing them to circulate in the blood for years.

That is why, by the early 2000s, most of the major PFC manufacturers in the U.S., Europe and Japan joined in EPA-coordinated efforts to voluntarily phase the long-chain PFCs out of production; 95 percent were to be gone by 2010 and the rest by 2015. Certainly older products hanging around homes may contain the chemicals.

Some companies not in the voluntary program continue to produce or import and use long-chain PFCs. Chinese companies still make up to 500 tons of PFOA and PFOS a year. The firms that have stopped using the long-chain molecules have adopted alternatives, including short-chain PFCs that flush out of the body. Because they do not linger in blood, short-chain PFCs are arguably less harmful to people, but they still persist in the environment. In May 2015 more than 200 scientists signed a warning called the Madrid Statement, cautioning that there is little public information about the chemical structures, properties, uses or biological effects of the short-chain PFCs now on the market, used in making treated upholstery and other products.

Cousins says that before the voluntary phase-out of the long chain PFCs, food packaging and treated fabrics accounted for most PFOS and PFOA exposure. Now most of the general public's exposure comes from fish or produce contaminated by PFCs. With the decline in commercial sources, levels in blood have fallen accordingly. In 1999, when the Centers for Disease Control and Prevention first began to look, PFOA amounts in American blood averaged just over five nanograms per milliliter (ng/mL). By 2012, according to the CDC's most recently published data, those levels had been cut by more than half. The average PFOS levels in blood fell even more dramatically, from 30 ng/mL to just over 6 ng/mL during the same period in the U.S.

Those averages are little solace, however, for people who live in the growing list of hotspots with PFC-contaminated drinking water. There blood levels can spike off the charts. In June, New Hampshire officials reported results from a study at Pease showing that the nearly 1,600 people tested—a quarter of them children who attended the on-site day care centers—had average PFC levels far higher than current national averages. Extraordinarily high blood levels were measured in people living near DuPont's chemical plant in Wood County, West Virginia. PFOA levels among the 70,000 local residents there averaged 28 ng/mL, but half had levels of 82 ng/mL or more, "and the most highly exposed people had PFOA levels greater than 1,000 ng/mL," says Kyle Steenland, an epidemiologist and professor at Emory University's Rollins School of Public Health. Most likely hundreds of thousands of U.S. residents live in PFC hotspots near military installations, chemical plants and wastewater-treatment facilities, not to mention millions more outside the country.

## TOXIC UNCERTAINTIES

DETERMINING WHETHER such levels are dangerous is tricky. "I'm always asked, 'How are PFCs going to affect me?'" says Patrick Breyse, director of the CDC's National Center for Environmental Health in Atlanta. "But there's no easy answer. Our ability to measure them outstrips our ability to interpret what they do to the human body."

One reason for the uncertainty is that the data on PFC toxicity are all over the map. PFCs cause myriad effects in animals, but species also vary from one to the next in their toxic susceptibility to the chemicals. Certain levels cause harm in certain species yet do not in others. Likewise, the evidence on humans diverges from study to study. Some show harms that others do not, "making it very inconsistent," says Benjamin Chan, state epidemiologist in the New Hampshire Department of Health and Human Services. "People want to compare their own blood levels with those causing effects in a particular human study, but the quality

of each study individually isn't very high," he says. "We need to look at the weight of the evidence in the literature as a whole to gauge what the science says about health effects from PFCs, and that gets confusing quickly."

Scientists have known since at least 2000 that PFCs cause liver, testicular and pancreatic cancer in exposed rats, although those cancers do not appear in monkeys. Enlarged livers, suppressed immune systems, neurological changes, obesity and delays in mammary gland development have been documented in different kinds of animals. The EPA based its new health advisory on evidence that mice born to PFC-exposed mothers are prone to low birth weights, skeletal problems and accelerated puberty.

Whereas researchers can feed PFCs to animals under controlled conditions in the laboratory, they cannot do so with people. Instead they have to study them epidemiologically, which means trying to determine if communities with higher levels of exposure also have higher rates of disease. Epidemiology also requires that researchers contend with potentially complicating factors—smoking, poor diets, other chemical exposures—that can obscure any PFC effects. Steenland says the best opportunities come from studying large groups of highly exposed people, among whom changes in the frequency of certain diseases, such as cancer, can be more easily detected. One example is the population next to DuPont's chemical plant in West Virginia, which discharged PFOA into the Ohio River for over 50 years and polluted groundwater for miles around to levels reaching 3,000 parts per trillion or more.

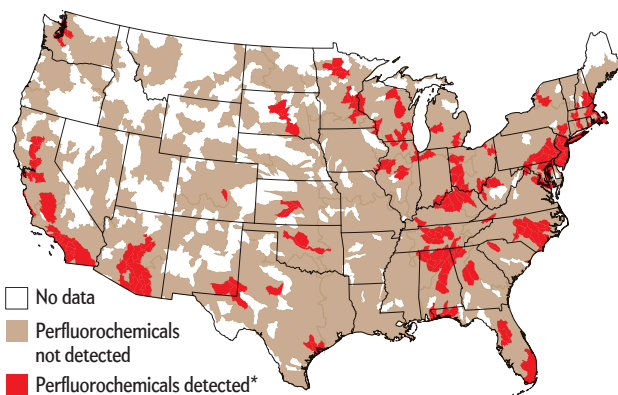
Under settlement terms from a 2004 class action lawsuit against the company, DuPont agreed to fund a \$35-million investigation into the potential health consequences. The ensuing C8 Science Panel enrolled 69,000 local residents and ultimately revealed "probable links" between PFOA exposures in drinking water and six different diseases: kidney and testicular cancers, ulcerative colitis, thyroid disease, hypercholesterolemia and pregnancy-induced hypertension.

Steenland, who co-directed the study, says the odds are better than 50-50 that PFOA exposure and those illnesses are related. "But that's a far cry from saying that PFOA actually *causes* any of those conditions," he adds. "Our data are fairly strong, but one large study isn't definitive. We need to establish the links in other populations to reach more convincing conclusions."

More study may also be needed to determine harmful effects of even low exposure to children's developing immune systems. When a child is inoculated with a vaccine intended to fight a disease such as measles, the body reacts by producing antibodies—foot soldiers that learn to recognize the pathogen. If, later, the child contracts the actual pathogen, his or her immune system is already prepared to fight it and can rapidly build up a counterattack. Evidence suggests that PFCs might impede the body's response to vaccines, rendering them less effective. In 2012 Harvard University scientists reported in a high-profile study that antibody levels mobilized by diphtheria and tetanus vaccines dropped off steadily with increasing PFC exposures. They conducted the study in the Faroe Islands, where the population gets most of its PFCs from a marine diet that includes whale meat. Pregnant women and chil-

## Hotspots ABOUND

More than six million U.S. residents are exposed to perfluorochemicals in their public drinking-water supplies that exceed recommended levels, according to EPA test data, analyzed by Xindi Hu of Harvard University and her colleagues. Data for municipalities under 10,000 people and for private wells have not yet been taken, so the numbers could rise.



dren had PFC levels similar to those of the general U.S. population. Philippe Grandjean, a professor in the Harvard T. H. Chan School of Public Health who led the study, says it suggests that those levels could make it harder for children to resist infectious diseases.

Andrew Rooney, acting director of the Office of Health Assessment and Translation at the National Institutes of Health, says studies with mice show the same thing: both PFOA and PFOS suppress antibodies in the animals. "We're talking apples to apples," he says. "And the fact that we see similar immune effects in animals and humans increases confidence in the results. We expect a less effective response to vaccines among people who have more PFCs in their bodies."

Still, the animal evidence on antibody suppression is so far limited to mice; neither rats nor monkeys experience that effect when dosed with PFCs. Scientists from the C8 study looked for evidence of antibody suppression in the highly exposed communities in Ohio and West Virginia and found that antibody levels were slightly suppressed for one of three flu strains for a single flu vaccine that was evaluated, but they could not detect any evidence of increased colds or flu in the population. Tony Fletcher, an epidemiologist at the London School of Hygiene & Tropical Medicine, and a C8 study co-director, says it is unclear why the C8 and Grandjean studies produced such divergent findings. "You would expect a greater response when the exposure levels are high," he says.

Epidemiology is a slow process. Steenland says results trickling in from other studies around the world will lend clarity. But health officials trying to set exposure levels can work only with the data they have, and they often disagree over interpretation. New Jersey officials, for instance, recently undercut the EPA by proposing a much lower drinking-water standard for PFOA of 14 rather than 70 parts per trillion. They argued that the lower standard would protect against enlarged livers and delays in mam-

SOURCE: "DETECTION OF POLY- AND PERFLUOROALKYL SUBSTANCES (PFAS) IN U.S. DRINKING WATER LINKED TO INDUSTRIAL SITES, MILITARY FIRE TRAINING AREAS AND WASTEWATER TREATMENT PLANTS," BY XINDI C. HU ET AL. IN ENVIRONMENTAL SCIENCE & TECHNOLOGY LETTERS, VOL. 3, NO. 10, OCTOBER 11, 2016

mary gland development, which are the most sensitive effects seen at the lowest doses in mice. When I asked the EPA why it did not do the same, a spokesperson replied by e-mail that the agency does not consider changes in rodent liver weights to be adverse and that, moreover, liver enlargement might result from a biological response that humans do not share. The spokesperson also wrote that delays in mammary gland development do not prevent the animals from lactating normally or from adequately feeding pups. Yet Grandjean is advocating for an even lower drinking-water standard of one part per trillion, which he says is necessary to protect against immunological effects in children.

## REGULATORY DYSFUNCTION

BURDENED BY INCONCLUSIVE DATA, insufficient funding and staffing shortages, a frequently hostile Congress, and competing interests of environmental groups and industry, the EPA's attempts to set enforceable standards for drinking-water contaminants can grind nearly to a halt. "Chemical health assessments are often delayed indefinitely without being completed," says Andrews of the Environmental Working Group. "And the EPA has to finish those assessments before it can set regulatory standards under the Safe Drinking Water Act (SDWA)." In fact, the EPA has not set an enforceable standard for any contaminant under the act for 20 years. Its health advisory for PFCs—which are still unregulated by the agency—amounts to little more than a cautionary threshold. Water utilities do not actually have to sample for PFCs, although with the growing publicity, many now are.

Meanwhile other unregulated drinking-water contaminants are drawing mounting scrutiny, including 1,4 dioxane, chromium 6 and perchlorate, an oxidizer in rocket propellants that the EPA was supposed to be regulating under the SDWA by August 11, 2014. Plagued by internal disputes over the chemical's toxicity, the EPA missed that deadline and was subsequently sued by the Natural Resources Defense Council. Erik Olson, an attorney with the council, complains that the studies imposed on the EPA by the SDWA consume too many resources and provide too many opportunities for industry meddling. "The EPA just gets boxed in," he says. In an e-mail, EPA officials said they were "evaluating PFOA and PFOS as in accordance with processes required under the SDWA," but they would not comment on whether a standard was imminent.

For decades the EPA was hamstrung by the very law that allows it to regulate—and, in some cases, ban—industrial chemicals at the point of production. When the Toxic Substances Control Act (TSCA) was enacted in 1976, it grandfathered every one of the more than 60,000 industrial chemicals that were already in commerce at the time—including PFCs. The TSCA instead directed the EPA to focus on new chemicals, giving existing chemicals a regulatory pass. Charlie Auer, currently an attorney in Washington, D.C., directed the EPA office that administers the TSCA. He says he bypassed the law when coordinating the voluntary efforts to pull PFOA and PFOS off the market: "The fact that long-chain PFCs are largely out of commerce and that human blood levels have fallen from levels seen before the EPA got involved shows that a lot of progress was achieved despite the manifest weaknesses in the TSCA at the time. The problem of PFC production and use was largely solved within about 15 years—which is pretty fast for any regulatory scheme given how hard it is to get things done these days."

Last June, Congress finally amended the TSCA to give the EPA more authority over existing chemicals. In an e-mail, EPA officials

stated that they would "consider PFCs for risk evaluations" under the amended law. But they also said they would not prioritize PFCs for evaluation, because the EPA had already spearheaded efforts to remove long-chain PFCs from the market.

The regulatory and scientific uncertainties mean residents in towns across the U.S. remain unclear about what levels of PFCs in drinking water may be safe or not and whether they need to take corrective action or not. Andrea Amico just wants to know what PFCs are doing to her family's health—especially her children's. An occupational therapist, Amico lives in Portsmouth, N.H. Her husband worked at Pease for seven years before the contamination was discovered there, and her two children attended the local day care. Her husband and children all have elevated PFCs in their blood. In 2015 Amico launched a community action group called Testing for Pease, which is urging CDC officials to launch a long-term health study with roughly 350 children exposed to PFCs at Tradeport. "Some of these children started drinking PFC-contaminated tap water with powdered formula when they were just six weeks old," Amico says. "We don't know what's going to happen to them. We need a plan to get answers."

That plan, Amico says, should include what is called a longitudinal study with blood sampling and medical monitoring until the children become adults. There are too little pediatric data on PFC effects, Amico emphasizes, and too few long-term studies. She and others from the Pease community say they want to contribute to research by being tracked over time because no one can tell them if their exposures will eventually be harmful.

But at a September meeting with the Pease community, officials from the Department of Health and Human Services' Agency for Toxic Substances and Disease Registry (ASTDR) balked. Breyse, who is also director of ASTDR, explained that although his organization would consider a cross-sectional study to investigate changes in cholesterol levels, immunity, thyroid hormones and other effects at a single time point, a longitudinal study wasn't practical because the group of exposed children at Pease is too small to identify health changes with statistical confidence. The better approach, Breyse says, would be to incorporate the Pease children into a larger national study of exposed communities from around the country. "Right now we're trying to figure out what that study would look like," Breyse says. "And at the same time, we're trying to address individual community concerns."

What concerns Amico most is not knowing. "This is affecting us all personally," she says. "I lose sleep at night wondering how these exposures are going to affect my kids." ■

### MORE TO EXPLORE

#### Changing Interpretation of Human Health Risks from Perfluorinated

Compounds. Philippe Grandjean and Richard Clapp in *Public Health Reports*, Vol. 129, No. 6, pages 482–485; November–December 2014.

**Perfluorinated Chemicals (PFCs).** Factsheet. National Institute of Environmental Health Sciences, July 2016. [www.niehs.nih.gov/health/materials/perfluorinated\\_chemicals\\_508.pdf](http://www.niehs.nih.gov/health/materials/perfluorinated_chemicals_508.pdf)

**Immunotoxicity Associated with Exposure to Perfluorooctanoic Acid or Perfluorooctane Sulfonate.** National Toxicology Program. U.S. Department of Health and Human Services, September 2016. <http://ntp.niehs.nih.gov/pubhealth/hat/noms/pfoa/index.html>

### FROM OUR ARCHIVES

**Gauging the Effects of Lead.** Ellen Ruppel Shell; July 2016.