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Lead: A Lurking Threat in Drinking Water

Millions of people in the United States are exposed to lead from their drinking water.[1] Lead is a dangerous neurotoxin that can harm every major system of the human body. Young children are especially vulnerable to lifelong health and developmental consequences from exposure. Although drinking water had been long dismissed as a less significant source of exposure than paint or dust,[2] the water crisis in Flint, Michigan has deepened the public's awareness about the threat of lead in drinking water. Increasing evidence shows that lead in drinking water can pose an enormous health risk[3] — and one that too often goes unnoticed and untreated. It is long overdue to eliminate all lead from our drinking water systems.

How does lead enter drinking water?

Lead enters tap water from the pipes and plumbing that deliver the water to the faucet. Water rarely has significant levels of lead at the source.[4] After leaving the treatment plant,[5] the metal leaches into water through contact with lead pipes, lead solder, and brass or bronze plumbing fixtures.[6] Corrosive water causes the lead plumbing to release lead particles into the water. However, water can be treated through corrosion control to build up a mineral scale within the pipe, which coats the inside of the lead pipe so that the water has essentially no contact with the metal and does not become contaminated with lead.[7] In addition to drinking water, contaminated water is dangerous to cook with, as lead can be absorbed and concentrate in foods like pasta or vegetables.[8]

Who is affected?

Although now banned,[9] an estimated 6.1 million lead service lines, which are the pipes that connect water mains to homes, are still in use in the United States, delivering water to between 15 and 22 million people.[10] Lead in drinking water is most common in the Northeast and Midwest regions of the United States due to their higher quantities of lead service lines.[11] The aging infrastructure, including older housing, is the most likely cause for this trend.[12]

Children are much more vulnerable to lead-contaminated water because they absorb lead at much higher rates than adults.[13] Infants are especially vulnerable to lead exposures if contaminated water is used in their formula.[14] In addition to infants and children, people with diets low in calcium or iron, as well as those not consuming enough calories or eating infrequent meals, are also more vulnerable to absorbing lead.[15] Poverty can be a risk factor for lead.[16] Elevated lead levels disproportionately impact children with low-socioeconomic status, and the effects can perpetuate or even exacerbate existing inequalities.[17] Childhood lead exposure can result in lifelong health and cognitive problems, and one study found that it is associated with downward social mobility for those affected.[18]

As with many environmental health issues, lead is more prevalent in communities of color. The Agency for Toxic Substances and Disease Registry reported that of children with elevated blood lead levels between 1997 and 2001, 60 percent were African American, compared to 16 percent Hispanic and 17 percent non-Hispanic white, showing a clear pattern in which African-American children are much more likely to have high lead levels in their blood.[19] In addition, violations of water quality standards have been shown to be significantly higher in communities of color living in high poverty, revealing structural inequality in drinking water systems.[20]

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How does lead affect human health?

Lead-containing water can pose serious health risks.[21] Ingesting lead can cause lifelong health problems. Lead is a neurotoxin, meaning it can attack the central nervous system, particularly in children.[22] The effects of this include lowered IQ scores, increased learning disabilities, hyperactivity or attention deficit disorders, speech or hearing impediments, seizures, aggression and behavioral issues.[23]

Lead can also cause anemia, as well as kidney malfunction or failure.[24] In pregnant women, high lead levels are associated with "instantaneous abortion, premature labor, stillbirth, infant mortality, low birth weights, and developmental issues in the infant".[25] While some of these health risks are only present at high levels of lead, low levels are enough to impact cognition in children.[26]

What regulations exist?

The issue of lead poisoning has captured public attention for a long time. Lead contamination of drinking water, however, was not addressed until the implementation of a 1986 amendment to the Safe Drinking Water Act (SDWA) that banned all lead pipes in plumbing.[27]

Following that amendment, the Lead and Copper Rule (LCR) was added to the SDWA in 1991. This rule requires utilities to monitor lead levels in their water by sampling homes at high risk for lead due to lead plumbing materials. The samples collected by the utility must be first-draw water, meaning that the water sampled has been left standing in the pipes for at least six hours.[28] The U.S. Environmental Protection Agency (EPA) has set 15 parts per billion (ppb) of lead as an action level for these samples. If more than 10 percent of the samples exceed this level, then the utility must implement corrosion control.[29]

If a utility continues to violate regulations even with corrosion control, they must begin replacing lead service lines at a rate of 7 percent of total lead service lines per year until they are no longer in violation, or testing lead service lines in place of physically replacing those not in exceedance.[30] Utilities that exceed the EPA action level are also required to educate the public and institutions serving vulnerable populations, such as schools and childcare facilities, about the health effects of lead and what they can do to limit their exposure.[31]

The Lead and Copper Rule is inadequate. The health-based standard is zero. To best protect human health, drinking water should have no lead. The EPA's enforceable regulation, however, is not based on health risks, but rather on feasibility for the utility.[32] The LCR can also underestimate lead in water — different protocols may be used when sampling, such as using cold water or taking samples using flow rates, and the standard analytical methods can dramatically undermeasure lead in water samples by failing to capture all the particulate lead that settles or sticks to the sampling containers.[33]

How many violations are there?

Lead-in-water violations are widespread. About 3 million people are served by water systems that violate the lead-in-water rule, according to a report from 2017 by the U.S. Government Accountability Office (GAO). In total, 1,430 water systems, or 2 percent of the systems subject to this regulation, exceeded the 15 ppb lead action level between 2014 and 2016. Even more concerning, 18 percent of the systems in violation were schools or daycare systems.[34]

What are the requirements for schools?

There are no federal laws that mandate testing for lead in school drinking water specifically,[38] except when a school has its own water system. However, 7 states and the District of Columbia require lead testing in school districts, and 13 others support voluntary testing in schools through funding programs.[39] While the EPA provides resources

The Need to Ban Partial Lead Service Line Replacements

Most lead pipes are service lines that deliver water from a water main to a home. Too many utilities decide to replace only the part of the lead service line that is on public or utility property, leaving in place the portion of the lead line that brings water from the property line to the home. This is called a partial lead service line replacement, and it puts the burden of replacing the rest of the line on homeowners, who may be unaware of the problem or unable to afford replacement.

Recent studies have found that partial service line replacements are unsafe.[35] Partial replacements have been shown to cause increases in lead levels for 4 to 18 months after the replacement. This could be due to the disturbance made by the replacement, causing the pipe scale — or built-up minerals that coat the inside of a pipe — to release lead. Not only that, but by replacing the lead with a copper pipe, this practice can create a galvanic cell, leading to galvanic corrosion. This electrochemical process causes metal — in this case lead pipes that remain in place — to corrode, releasing lead and creating higher or inconsistent lead levels in the water.[36]

A study in Washington, D.C. found that children in homes with partial lead service line replacements had the same risk of having elevated blood lead levels as children in homes with lead service lines that had not been replaced, demonstrating that this practice was ineffective and did not reduce health risks.[37]

and guidance for states and school districts, school districts have expressed the need for more in-depth guidance on testing and remediation methods and costs.[40]

The GAO estimated that in 2016 to 2017 only 43 percent of school districts tested for lead in school drinking water, of which 37 percent found elevated lead levels.[41] In the same survey, it was reported that 41 percent of schools did not test for lead and 16 percent were unsure if they had, representing a total of 18 million students in grades K-12 at risk.[42]

Notable cases:

Flint, Michigan: The water crisis in Flint shined a national spotlight on the dangers of lead in our drinking water. In 2014, the water supply for the city of Flint, Michigan was switched from the Detroit Water and Sewerage Department to the Flint River, a decision made by a state-appointed emergency manager without city council approval.[43] This decision led to a health crisis that persists in Flint to this day, and one that has disproportionately affected African-American and socioeconomically disadvantaged residents.[44]

The water utility did not implement corrosion control despite warnings of high lead levels from residents, state and federal officials, and scientists.

After the switch, Flint residents complained about the color, odor and taste of their water.[45] Tests showed that Flint water not only violated bacterial water standards but also contained high levels of disinfection byproducts and lead. The water utility did not implement corrosion control despite warnings of high lead levels from residents, state and federal officials, and scientists.[46] In 2015, lead tests done on Flint's water exceeded 25 ppb in the majority of samples, with some reaching over 100 ppb or even 1,000 ppb.[47] However, the emergency manager and state officials repeatedly insisted that the water was safe to drink.[48]

In a study that helped expose the crisis, the percent of children with elevated blood lead levels was found to have more than doubled after the water-source change, with even greater increases in areas of the city shown to have extremely high lead levels in the water.[49] On October 16, 2015, Flint finally changed its water supply back to the Detroit Water and Sewerage Department.[50]

As of 2019, Flint had a different mayor, Michigan had a different governor, and many lead service lines had been replaced. According to the state, the water was reportedly safe, but for Flint residents, the crisis was not yet over. With trust in the government at a low and the trauma of the public health crisis still fresh, even the new mayor of the city encouraged residents to avoid unfiltered tap water.[51] In 2019, the Michigan Attorney General dismissed the criminal cases associated with the disaster, effectively restarting the investigation and leaving the Flint crisis unresolved.[52]

Washington, D.C: Before Flint, there was Washington, D.C. Starting in November 2000, Washington, D.C. experienced one of the most well-known public health crises related to lead contamination in drinking water.[53] In response to a new EPA regulation addressing disinfection byproducts, the D.C. Water and Sewer Authority changed its water treatment plan and began using chloramine.[54] This new treatment changed the water chemistry, which, combined with the enormous quantity of lead service lines in the District of Columbia — about 25,000 residencies have lead service lines — caused the concentration of lead in the water to rise drastically.[55]

This spike in lead contamination led the utility to violate the LCR and endanger D.C. residents. A study showed that children, especially younger children, living in D.C. during that time in houses with lead service lines had significantly higher levels of lead in their blood over the four years that chloramine was used to treat the water than before or after.[56]

Flint, Michigan, 2016. Water filtration pickup station for residents with extremely high levels of lead in the water. / PHOTO COURTESY OF USDA

Similar to Flint, the D.C. Water and Sewer Authority downplayed the health risks of lead,[57] and although the agency first found elevated lead levels in 2002, the public did not learn about the scale of the crisis until the *Washington Post* broke the story two years later in January 2004.[58] In June 2004, the EPA found that the agency had broken the lead-in-water rule by failing to properly notify the public about elevated lead levels, withholding test results and delaying an effective response.[59]

A 2010 Congressional report found that even the U.S. Centers for Disease Control and Prevention may have misled the public about the health risks, prompting allegations of a cover-up.[60] The D.C. Water and Sewer Authority took steps to remediate the situation including increasing testing, replacing lead service lines (see box on page 3 for information about the failure of the partial lead service line replacements), and distributing water filters, and the Washington Aqueduct, the city's water provider, began using orthophosphate, a corrosion control.[61] Lead levels fell.[62] Since then, under new leadership, the authority has undergone rebranding as DC Water in an attempt to clean up its image after its mismanagement of the lead crisis.[63]

Madison, Wisconsin: Unlike Washington, D.C. or Flint, the city of Madison, Wisconsin serves as an example for municipalities facing issues of lead in their water. After the LCR went into effect in 1991, Madison discovered that its water exceeded the lead action level of 15 ppb and began to investigate how it could solve the problem. A chemical engineer hired by the city performed numerous water tests with different phosphate treatments, which are widely recognized as an effective form of corrosion control to prevent lead from leaching into tap water.

However, instead of lowering lead levels the engineer found that the treatments were actually causing them to increase by up to four times the initial amount. Not only that, but the phosphate treatments would create issues in the city's lakes by causing an increase in phosphorous in wastewater, which could lead to unwelcome algae and weed growth and would require an expensive removal system. Instead, the engineer recommended that Madison begin replacing all of its lead service lines — about 8,000 in total.[64]

To replace the entire lead service line instead of just the utility-owned portion, Madison had to provide customers with financial assistance so that the city could require them to replace their portion of the lead pipes as well. The city reimbursed customers up to $1,000 for the replacements, which averaged $1,400, with loans available for low-income customers.[65] Between 2001 and 2011, Madison replaced all of the lead pipes in the city, with

Consumer tips: What can you do to protect yourself from lead in your drinking water?

First, find out if you have lead in your drinking water:

- Read your local consumer confidence report, a water quality report issued annually by water utilities, to see if your water system is in violation of any water quality regulation.[72] The report may be mailed with your water bill or posted on the utility's website.
- Check whether your school district has tested for lead in water.
- Check your service line. If your home was built before 1986, it could have a lead service line.[73] You can identify lead services lines by finding the pipe connected to your water meter and scratching it. Shiny silver, soft metal that is not magnetic means your service line is lead. If that test is not possible, you can check with your landlord, utility or a plumber.[74]
- Request a test kit from your water utility. Many large water utilities provide free lead testing.
- Call your local health department or another EPA-certified water testing laboratory to test your water yourself, if your utility doesn't offer that service or if you have a private well.[75]

If you get the results and find out that there is lead in your drinking water, you should filter the water before drinking. When choosing a filter, ensure that it is certified to the NSF/ANSI standards 53 or 58, indicating that the filter is certified to reduce lead.[76]

Generally, carbon, distillation and reverse osmosis filters can safely filter out lead.[77] Models include pitcher filters, faucet-mounted filters, countertop filters, plumbed-in filters and whole-house filters.[78] Pitcher and faucet-mounted filters are usually the most inexpensive and range from $20 to $50, while more extensive filters can be between $50 and $900.[79]

Other ways to reduce lead in tap water include using the coldest-possible water for any human consumption (including drinking and cooking) and cleaning faucet aerators every two weeks to prevent lead from building up.[80]

approximately 5,500 residents participating in the program.[66] Although the replacements cost the city over $15 million, officials estimated that the long-term costs of water treatment and phosphorous removal would have been higher had they decided to rely solely on corrosion control instead.[67]

Madison's success story might not have been possible everywhere, however; the city's generally well-off residents may have been more willing and able to pay for lead service line replacements than residents of many low-income communities facing lead contamination in their water systems.[68] Not only that, but legal issues in requiring residents to replace the privately owned portions of their service lines can arise, with only a few states having passed legislation that enables programs like these.[69]

A few other cities have since followed Madison's example and fully replaced their lead service lines, including Lansing, Michigan, which in 2016 finished replacing its 12,150 lead service lines.[70] Meanwhile, many other cities have taken steps in that direction by either instituting programs or setting public goals to do so.[71] With increasingly aging infrastructure and today's awareness of the negative health effects of even low levels of lead, programs like these will certainly become more popular.

Conclusions and recommendations

Lead is a dangerous water contaminant. All levels of government must step up to pass policies that ensure that our drinking water is lead free.

Local utilities

- Locate and remove all lead service lines;
- Offer free lead testing of homes;
- Expand public notification of any lead findings; and
- Provide free lead filters if the system finds elevated lead levels in any home.

States

- Ban partial lead service line replacement and require total replacement;
- Require and provide financial assistance to test for, and filter out if necessary, lead in the water of public schools and daycares; and
- Set up a compliance schedule to eliminate all lead plumbing in schools and daycares.

Federal government

- The EPA must strengthen the Lead and Copper Rule to reduce the action level for lead in water, improve water sampling methods to enhance accuracy and consistency, and strengthen remediation requirements for violators.
- Congress should provide federal funding to local governments and schools to comply with stronger lead testing and remediation efforts. The Water Affordability, Transparency, Equity and Reliability (WATER) Act, a bill introduced in Congress, would provide sufficient support for local projects to address lead contamination of drinking water in schools, homes and public water systems.

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