

Safeguarding Children's Health: Time to Enact a Health-Based Standard and Comprehensive Testing, Mitigation, and Communication Protocol for Lead in Drinking Water

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Lead was a known toxin before the Roman Empire, yet exposure remains a public health concern today. Although there is no safe lead exposure level, a health-based drinking water standard has not been established. The Clean Water for Carolina Kids Study highlights the need for a health-based standard.

For millennia, lead's physicochemical properties, such as high density and resistance to oxidation, along with its relative abundance, have made this element desirable for a wide variety of industrial uses, including plumbing, pigmentation, and solders [1]. Because of this widespread industrial utility, occupational and general environmental exposure to this element has occurred throughout history, and the dangers of lead exposure have been described since antiquity [2, 3].

Lead accumulates in soft tissues and bone and exposure causes many adverse health effects. Some of these include reduced intelligence quotient (IQ); encephalopathy, which impacts attention, concentration, and motor skills; peripheral nerve damage; impaired cardiovascular health; and decreased kidney function [4]. Exposure to lead is particularly detrimental to children because of long-term impacts on lifelong intellectual abilities and an increased risk for juvenile delinquency [5-7]. It is important to note that a safe blood lead level threshold to prevent the adverse infant and childhood development health outcomes associated with lead exposure has not been identified [8].

Lead is a ubiquitous, multimedia environmental pollutant with several sources contributing to overall exposure. Beginning in the 1970s, lead concentrations in air, dust, and soil began to drastically decline in the United States, largely from phasing out lead as a gasoline additive and restricting the lead content in paint [9]. The US Environmental Protection Agency (EPA) has considered drinking water as a secondary lead exposure source, accounting for up to 20% of total exposure nationally, with deteriorating paint and contaminated dust and soil as the major sources [10].

However, in some areas, water may account for a much higher percentage of total exposure. Factors affecting the risk of lead exposure in water include geographic location, housing characteristics, water source and treatment, and socioeconomic status. An increasing body of evidence indicates that people living in lower socioeconomic status communities, including rural areas and peri-urban neighborhoods excluded from municipal water services (also known as extraterritorial jurisdictions), have poorer water quality, including higher levels of lead, than adjacent neighborhoods [11, 12]. In addition, a recent review described several cases in which contaminated tap water was a major contributor to the lead levels in children's blood in the United States [13].

The recent water crisis in Flint, MI, illustrates the potential for lead-contaminated drinking water to serve as the predominant exposure pathway for this toxic element, as well as the disproportionate impact that socioeconomically disadvantaged communities bear from environmental contamination [14]. (Flint's population is disproportionately African American and among the poorest communities in the United States.) As the extent of the Flint water crisis became more apparent, a growing number of geographic locations and school systems around the country voluntarily tested their water to determine lead levels. New York City, NY; Washington, DC; Newark, NJ; villages in Ohio; and Portland, OR, have all recently conducted lead testing and have detected measurable levels of lead in municipal buildings and public schools [15-19].

EPA's National Primary Drinking Water Regulations include a combination of legally enforceable water quality standards, known as maximum contaminant levels (MCLs), and requirements for use of specific water treatments

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intended to protect the public by limiting contaminants in drinking water [20]. The maximum contaminant level goal (MCLG) is a non-enforceable public health goal that states the level at which a contaminant in drinking water is not expected to cause an increased health risk. EPA set the MCLG for lead in drinking water at 0 parts per billion (ppb) because any amount of lead is harmful to human health. Unlike most other inorganic chemicals with an MCLG, lead does not have an MCL. An MCL is an enforceable standard that considers the MCLG and the feasibility (considering the laboratory detection limit and costs of treatment technologies) of regulating the level of a contaminant that is allowed in drinking water. In the absence of an MCL, steps have been taken to improve lead in drinking water using a treatment technique—a required process that helps reduce the level of a contaminant in public drinking water supplies. The standard also requires testing for a small subset of tap water samples for public water users. If more than 10% of the samples exceed 15 ppb of lead, which is denoted as the “treatment-based action level,” the standard requires the water utility to implement corrosion control measures.

In Flint, elevated lead concentrations were found in tap water after the city switched its water source to save money under bankruptcy and failed to take adequate measures to decrease the corrosivity of the new water source. As occurred in Flint, the erosion of piping, water fixtures, and solder can cause the release of dissolved lead and lead particles into the tap water. Under EPA’s 1991 Lead and Copper Rule, with recent short-term revisions in 2007, public water systems should identify systemic water quality concerns and address them via corrosion control, potential lead service line replacement, and educational awareness [21]. However, most of the buildings that use public water supplies, including households, schools, and child care facilities, are currently not tested for lead at the tap. Furthermore, the Lead and Copper Rule does not apply to water systems serving fewer than 15 service connections or 25 people. In 2006, the EPA published voluntary guidance entitled 3Ts for Reducing Lead in Drinking Water in Schools and Child Care Facilities [22]. This guidance includes a protocol for Training, Testing, and Telling, but the recommendations do not follow a health-based standard. In fact, the guidance only recommends that water sources at schools be taken out of service if the lead level exceeds 20 ppb, which is 5 ppb greater than the treatment-based action level for public water supplies.

Despite these efforts, the growing list of geographic locations that have voluntarily tested and found lead in children’s drinking water indicates that more must be done.

To gain a greater understanding of the potential risk posed to young children from lead in drinking water at North Carolina child care centers, RTI International initiated the Clean Water for Carolina Kids (CWCK) study in 2017 [23]. The child care providers participating in the CWCK study were all licensed by the State of North Carolina and were connected to public water supply systems. The pro-

viders helped to collect study samples using a citizen science approach that included training and support by RTI researchers. RTI’s quantitation limit for all tested samples was 0.1 ppb lead, which is a consistently achievable and scientifically defensible quantitation threshold with careful sample preparation and analysis by inductively coupled plasma mass spectrometry (ICP-MS).

The CWCK study results indicate that approximately 75% of the samples collected contained measurable values of lead, with most ranging between 0.1 and 3 ppb. However, only 1% of the samples exceeded the treatment-based action level of 15 ppb that would require public utilities to take corrective action [23]. Because the participating child care centers were connected to public water systems regulated under the Lead and Copper Rule, these results do not reflect the water quality at all child care centers in the area. A more comprehensive study that also includes schools relying on unregulated water sources (such as private wells) and an expanded study area would better elucidate the water quality differences between public and unregulated water supplies and further characterize the significance of socioeconomic variability and population density. According to the EPA, approximately 98,000 public schools and 500,000 child care facilities obtain water from unregulated sources [24].

Indeed, lead appears to be a more prevalent concern in well water compared with municipal water supplies. For example, a recent study of unregulated private wells in Wake County found that 28% of tap water samples inside homes relying on these sources contained lead at concentrations above the 15 ppb treatment-based action level [25]. This prevalence is comparable to the prevalence of elevated lead in Flint during the recent water crisis; during the crisis, 6% to 32% of houses had elevated lead, depending on the neighborhood [26].

Although the health effects of early life exposure to lead are devastating, there is promising evidence to indicate that successful and timely interventions can reverse many of the negative outcomes [27]. In the CWCK study, RTI demonstrated that low-cost, feasible solutions to eliminating lead exposure in drinking water below laboratory detection limits are possible. Longer-term solutions must also be evaluated to remove the source of lead in fixtures and piping with higher amounts. The disparity between the treatment-based action level (15 ppb) and the health-based MCLG (0 ppb), and the fact that most buildings are not tested, poses 2 fundamental questions:

1) Can lead concentrations in drinking water be eliminated or reduced to below laboratory detection limits to meet the health-based MCLG for individual buildings and homeowners in a cost-effective manner? The CWCK study suggests that the answer to this question is yes. Most utilities have a laboratory detection limit of 3 ppb, and the RTI laboratory ICP-MS quantitation limit is 0.1 ppb, which shows that it is feasible to detect lead near the MCLG of 0, and certainly

below the 15 ppb treatment-based action level. Utilities typically offer free testing, and private laboratory testing services for lead are also inexpensive. It is also feasible to reduce costs using citizen scientists for sample collection with minimal training. Furthermore, there are low-cost mitigation measures that can eliminate detectable lead at the tap in most cases without service line replacement. These include the implementation of “clean water habits” (such as using only cold water for drinking and cooking), designating specific outlets for drinking and cooking, and the implementation of point-of-use water treatment with appropriate maintenance [28-30].

2) Is there a health imperative to move away from a treatment-based action level and enact a health-based regulatory structure that aims to eliminate or minimize exposure to lead in drinking water for children, pregnant and nursing women, people with illnesses, and the general population?

In the CWCK study, approximately 75% of voluntary samples from licensed child care providers contained measurable lead, but only approximately 1% exceeded the treatment-based action level of 15 ppb. There is a gap in the goal

for lead exposure, which is 0 ppb, and this treatment-based action level for public utilities. It has been understood that lead in drinking water is a threat to children’s health and public health for thousands of years. We have the current ability to eliminate or minimize this threat using modern sample collection and laboratory testing protocols, low-cost mitigation approaches, and effective communication techniques. To safeguard both children’s health and public health overall, a health-based standard must be considered with comprehensive testing, mitigation, and communication protocols for lead in drinking water that reflects the current state-of-the-science. The North Carolina General Assembly should continue to examine the risk of lead exposure and opportunities to mitigate this risk. **NCMJ**

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References

1. Sloane K, Fry R. Priority environmental contaminants: understanding their sources of exposure, biological mechanisms, and impacts on health. In: Fry R, ed. *Systems Biology in Toxicology and Environmental Health*. Cambridge, MA: Academic Press; 2015:117-169.
2. Nriagu J. A history of global metal pollution. *Science*. 1996;272(5259):223-224.
3. Needleman H. Low level lead exposure: history and discovery. *Ann Epidemiol*. 2009;19(4):235-238.
4. Skerfving S, Bergdahl I. Lead. In: Nordberg G, Fowler B, Nordberg M, Friberg L, eds. *Handbook on the Toxicology of Metals*. 3rd ed. Cambridge, MA: Academic Press; 2007:599-643.
5. Miranda ML, Kim D, Galeano MA, Paul CJ, Hull AP, Morgan SP. The relationship between early childhood blood lead levels and performance on end-of-grade tests. *Environ Health Perspect*. 2007;115(8):1242-1247.
6. Sampson R, Winter A. Poisoned development: assessing childhood lead exposure as a cause of crime in a birth cohort followed through adolescence. *Criminology*. 2018;56(2):269-301.
7. Aizer A, Currie, J. Lead and juvenile delinquency: new evidence from linked birth, school, and juvenile detention records. National Bureau of Economic Research website. <http://www.nber.org/papers/w23392>. Accessed May 31, 2018.
8. Centers for Disease Control and Prevention. Lead in drinking water and human blood lead levels in the United States. Atlanta, GA: Centers for Disease Control and Prevention; 2012. <https://www.cdc.gov/mmwr/pdf/other/su6104.pdf>. Accessed May 31, 2018.
9. Bellinger DC. Lead contamination in Flint – an abject failure to protect public health. *New Engl J Med*. 2016;374(12):1101-1103.
10. United States Environmental Protection Agency. 3Ts for reducing lead in drinking water in schools and child care facilities: revised guidance. <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20017JVA.txt>. Published December 2005. Accessed May 31, 2018.
11. Delpla I, Benmarhnia T, Lebel A, Levallois P, Rodriguez, MJ. Investigating social inequalities in exposure to drinking water contaminants in rural areas. *Environ Pollut*. 2015;207: 88-96.
12. Stillo F, MacDonald Gibson J. Exposure to contaminated drinking water and health disparities in North Carolina. *Am J Public Health*. 2017;107(1):181-185.
13. Triantafyllidou S, Edwards M. Lead (Pb) in tap water and in blood: implications for lead exposure in the United States. *Crit Rev Environ Sci Tech*. 2012;42(13):1297-1352.
14. Gostin LO. Lead in the water: a tale of social and environmental injustice. *JAMA*. 2016;315(19):2053-2054.
15. Taylor K. Lead tests on New York City schools' water may have masked scope of risk. *NYTimes.com*. <https://nyti.ms/2bZE06C>. Published August 31, 2016. Accessed May 31, 2018.
16. Stein P. D.C. launches lead-testing blitz of water sources at schools, recreation centers. *WashingtonPost.com*. <https://www.washingtonpost.com>

- post.com/news/education/wp/2016/05/03/d-c-launches-lead-testing-blitz-in-water-sources-at-schools-rec-centers/?noredirect=on&utm_term=.1aebd8162f24. Published May 3, 2016. Accessed May 31, 2018.
17. Superville DR. New Jersey to require all public schools to test water for lead. EdWeek.com. http://blogs.edweek.org/edweek/District_Dossier/2016/05/new_jersey_to_require_all_publ.html. Published May 2, 2016. Accessed May 31, 2018.
 18. Pérez-Peña R. Lead in Ohio villages' water went uncurbed for months, state says. NYTimes.com. <https://www.nytimes.com/2016/01/27/us/lead-in-ohio-villages-water-went-uncurbed-for-months-state-says.html>. Published January 26, 2016. Accessed May 31, 2018.
 19. Roth S. 99% of Portland schools have high lead levels. KGW.com. <https://www.kgw.com/article/news/health/99-of-portland-schools-have-high-lead-levels/283-268102018>. Published September 6, 2016. Accessed May 31, 2018.
 20. United States Environmental Protection Agency. National Primary Drinking Water Regulations. EPA website. <https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations>. Published May 2009. Accessed May 31, 2018.
 21. United States Environmental Protection Agency. Lead and Copper Rule. EPA website. <https://www.epa.gov/dwreginfo/lead-and-copper-rule>. Published October 10, 2007. Accessed May 31, 2018.
 22. United States Environmental Protection Agency. 3Ts for Reducing Lead in Drinking Water in Schools and Child Care Facilities. EPA website. <https://www.epa.gov/dwreginfo/3ts-reducing-lead-drinking-water-schools-and-child-care-facilities>. Published October 2006. Accessed June 2, 2018.
 23. Killenberg S. Is there lead in the water at your child care center? RTI will test to find out. NewsObserver.com. <http://www.newsobserver.com/news/local/article165395237.html>. Published August 4, 2017. Accessed May 31, 2018.
 24. United States Environmental Protection Agency. Lead in drinking water in schools and childcare facilities. EPA website. https://www.epa.gov/node/116045_. Updated May 17, 2018. Accessed May 31, 2018.
 25. Stillo F, Macdonald Gibson J. Racial disparities in access to municipal water supplies in the American South: Impacts on children's health. *International Public Health Journal*. In press.
 26. Hanna-Attisha M, LaChance J, Sadler RC, Champney Schnepf A. Elevated blood lead levels in children associated with the flint drinking water crisis: a spatial analysis of risk and public health response. *Am J Public Health*. 2016;106(2):283-290.
 27. Billings SB, Schnepf K. IZA Institute of Labor Economics. Life after lead: effects of early interventions for children exposed to lead. Bonn, Germany: IZA Institute of Labor Economics; 2017. <http://ftp.iza.org/dp10872.pdf>. Accessed May 31, 2018.
 28. RTI International. Clean Water for Carolina Kids. Information on Lead in Drinking Water. Research Triangle, NC: RTI International; 2017 https://www.rti.org/sites/default/files/brochures/rti_cwck_drinking_water.pdf. Accessed June 2, 2018.
 29. RTI International. Clean Water for Carolina Kids. Safe Drinking Water in North Carolina Childcare Centers. Research Triangle, NC: RTI International; 2017 https://www.rti.org/sites/default/files/brochures/rti_cwck.pdf. Accessed June 2, 2018.
 30. RTI International. Clean Water for Carolina Kids. Point-of-Use Water Treatment and Bottled Water Guidance. Research Triangle, NC: RTI International; 2017 https://www.rti.org/sites/default/files/brochures/rti_cwck_wt_bwg_0.pdf. Accessed June 2, 2018.