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Weaknesses in Federal Drinking Water Regulations and Public Health Policies that Impede Lead Poisoning Prevention and Environmental Justice

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ABSTRACT

The failure of the regulatory community to protect the residents of Flint, Michigan, from prolonged exposure to hazardous levels of lead in their drinking water has drawn public attention to long-acknowledged weaknesses in the implementation and oversight of the U.S. Environmental Protection Agency's (EPA's) Lead and Copper Rule (LCR). This rule defines the roles and responsibilities of water utilities in reducing consumer exposures to lead-in-water hazards. Despite this regulation, water-related lead poisoning cases have been documented in cities determined to be in regulatory compliance. This article presents preliminary results from an ongoing study that documents gaps and weaknesses in the rule and its implementation, oversight, and enforcement. We detail how the original intent of the LCR to protect public health has been undermined by inadequate lead-in-water monitoring and public education, as well as weak regulatory oversight and enforcement. We summarize how these issues contributed to the Flint debacle and are still being perpetuated today in other municipalities. Finally, we discuss how these factors may be thwarting the prevention of childhood lead poisoning in the United States, and contributing to disproportionate environmental burdens on low-income communities. This review is timely, in that it may prompt public involvement in the U.S. EPA's ongoing review and revision of the LCR.

INTRODUCTION

The Michigan Department of Environmental Quality (MDEQ) determined that Flint's water utility met regulatory requirements for lead in drinking water, after switching to a more corrosive water source in April 2014.[1] Despite other violations and regular boil water alerts, it took a concerted effort by citizens and outside scientists to reveal high water lead levels (WLLs), which were first detected in February 2015. The Flint Water Advisory Task Force (FWATF) reported incorrect implementation of regulations by the city's utility, inaccurate advice to the utility by state authorities, and lack of federal enforcement.[1] Ultimately, these actions doubled Flint's childhood lead poisoning rates.[2]

One reason behind this government failure was a lack of proper implementation and enforcement of a regulation called the Lead and Copper Rule (LCR) [40 C.F.R.

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[1]Flint Water Advisory Task Force (FWATF). *Final Report*. (State of Michigan: Commissioned by Office of Governor Rick Snyder, 2016).

[2]M. Hanna-Attisha, J. LaChance, R. Casey Sadler, and A. Champney-Schnepp. "Elevated Blood Lead Levels in Children Associated with the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response." *AJPH* 106 (2016): 283–290.

§ 141.80-91].[3] Promulgated in 1991 by the U.S. Environmental Protection Agency (EPA), the LCR aims to identify lead contamination at consumer taps from the distribution system and household plumbing; and requires remedial measures when high WLLs are widespread. Lead can leach from lead-bearing plumbing components,[4] like solder, galvanized piping, and ''lead-free'' brass fixtures (allowed to contain up to 8% lead).[5,6,7,8] The latter source is estimated to be in virtually all buildings built before 2010–2014, depending on the year when states revised regulations.[4,9] However, a primary contributor to water lead is lead service lines (LSLs),[7] present in an estimated 15–22 million homes built before 1986 (Fig. 1).[10] To ensure that drinking WLLs are minimized, the LCR outlines steps water utilities must take to (1) reduce water corrosivity; (2) monitor worst-case lead in tap water in high-risk homes; and (3) educate the public about potential or confirmed hazards.[5]

Small- and large-scale childhood lead poisoning due to water consumption has been documented not only in utilities that exceed regulatory requirements but also in those that meet them.[11,12,4,13,14,15,16] The EPA acknowledges that lead exposure from water may range from 5% to more than 50% of total lead exposure for children; and more than 85% for formula-fed infants.[3] Sufficient evidence exists that very low blood lead levels (BLLs) (<2 μg/dL) can impact academic achievement, attention, and behavior in children; reduce fetal growth; and decrease renal function in adults.[17] These facts reinforce the need to ensure that regulations governing tap water are protective of public health.

This review discusses weaknesses in the implementation and oversight of the LCR that delayed EPA's response to Flint, and almost allowed one of the worst known modern-day water-related crises in the United States to go undetected. Fewell ascribed EPA's delay to the following: ambiguities in EPA's emergency powers; EPA's deference to states out of a reluctance to fine municipalities and burden taxpayers; and conflicted LCR interpretations.[18] Edwards noted a lack of support for a robust LCR by agencies that should be advocates of the Rule—notably, the EPA and U.S. Centers for Disease Control and Prevention (CDC).[19] This review focuses on the weaknesses in LCR implementation by utilities and regulatory enforcement by government agencies that contributed to the crisis. Topics discussed include how inadequate monitoring protocols can underestimate drinking WLLs at consumer taps, and enable regulatory approval of utilities with widespread lead-in-water problems. Finally, we discuss how these issues may

FIG. 1. Part of a lead service line removed from a New Orleans home, Faubourg Treme (May 2, 2016). Credit: Adrienne Katner.

[3]U.S. Environmental Protection Agency (US EPA). ''Safe Drinking Water Act, National Contaminant Level Goals, and National Primary Drinking Water Regulations for Lead and Copper (LCR).'' *Federal Register* 56 (1991): 26460–26564.

[4]S. Triantafyllidou and M. Edwards. ''Lead (Pb) in Tap Water and in Blood: Implications for Lead Exposure in the United States.'' *Critical Reviews in Environmental Science and Technology* 42 (2012): 1297–1352.

[5]U.S. Environmental Protection Agency (US EPA). Lead and Copper Rule: Public Education and Other Public Information Requirements for Community Water Systems. EPA 816-F-08-019. EPA Office of Water, Washington DC, 2008.

[6]D.E. Kimbrough. ''Brass Corrosion as a Source of Lead and Copper in Traditional and All-Plastic Distribution Systems.'' *Journal of AWWA* 99 (2007): 70–76.

[7]A. Sandvig, P. Kwan, G. Kirmeyer, B. Maynard, D. Mast, R.T. Rhodes, S. Trussell, A. Cantor, and A. Prescott. *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues*. (AWWARF, 2008), 91229.

[8]C. Elfland, P. Scardina, and M. Edwards. ''Lead-Contaminated Water from Brass Plumbing Devices in New Buildings.'' *Journal of AWWA* 102 (2010): 66–76.

[9]K. Westerling. Are you ready for ''Lead Free'' 2014? *Water Online* (2013).

[10]D.A. Cornwell, R.A. Brown, and S.H. Via. ''National Survey of Lead Service Line Occurrence.'' *Journal of AWWA* 108 (2016): 68.

[11]Yanna Lambrinidou. ''Dissenting Opinion.'' EPA National Drinking Water Advisory Council's Lead and Copper Rule Work Group. October 2015.

[12]S. Triantafyllidou, J. Parks, and M. Edwards. ''Lead Particles in Potable Water.'' *Journal of AWWA* 99 (2007): 107–117.

[13]Marc Edwards, S. Triantafyllidou, and D. Best. ''Elevated Blood Lead in Young Children Due to Lead-Contaminated Drinking Water: Washington DC, 2001–2004.'' *Environmental Science & Technology* 43 (2009): 1618–1623.

[14]R. Renner. ''Mis-Lead.'' *Environmental Science & Technology* 40 (2006): 4333–4334.

[15]R. Renner. ''Out of Plumb: When Water Treatment Causes Lead Contamination.'' *Environmental Health Perspectives* 117 (2009): A543–A547.

[16]M.J. Brown, J. Raymond, D. Homa, C. Kennedy, and T. Sinks. ''Association Between Children's Blood Lead Levels, Lead Service Lines, and Water Disinfection, Washington, DC.'' *Environmental Research* 111 (2011): 67–74.

[17]National Toxicology Program (NTP). *NTP Monograph: Health Effects of Low-Level Lead*. (U.S. Department of Health and Human Services, NIH, 2012).

[18]B. Fewell. ''The Failure of Cooperative Federalism in Flint, Michigan.'' *Journal of AWWA* 10 (2016): 12–14.

[19]''Institutional Scientific Misconduct at U.S. Public Health Agencies: How Malevolent Government Betrayed Flint, MI.'' Testimony of Marc Edwards before the U.S. House Oversight Committee, February 3, 2016. https://oversight.house.gov/wp-content/uploads/2016/02/Edwards-VA-Tech-Statement-2-3-Flint-Water.pdf (Last accessed May 13, 2016).

perpetuate a misconception that drinking water contributes little to children's total lead exposure, which in turn may thwart childhood lead poisoning prevention efforts. This review is timely, in that it may prompt public involvement in the EPA's ongoing review and revision of the LCR, which is expected to be finalized between 2017 and 2018.

DISCUSSION

No enforceable health-based standard

The foundation of the LCR is the lead ''action level'' (AL) of 15 parts per billion (ppb). When more than 10% of tap water samples collected during a monitoring period exceed the AL, the utility is in exceedance and must implement remedial actions that may differ depending on the system size and status. These actions may include increased monitoring; optimization of corrosion control treatment (CCT); partial lead service line replacement (PLSLR); and public education. According to the EPA, the AL is merely a screening tool—not a health-based standard (the EPA health-based goal for lead in water is 0 ppb).[20] It was set based on several criteria, including limitations existing in 1991 for analytical detection of lead in water and the cost–effectiveness of lead removal treatments. The intent of the AL is to assess the corrosivity of the water and the performance of a utility's CCT, not to determine consumer exposure.[21] The AL was set at 15 ppb based on projections that 25% of all water systems in the 1990s would exceed it.[15]

Michigan recently proposed a lower AL value of 10 ppb.[22] The World Health Organization and Health Canada also selected this value, but this level was determined by limits in analytical sensitivity, treatment achievability, and cost.[23,24] Even a 10 ppb AL may not sufficiently protect fetuses, infants, and young children. Cumulative exposures to WLLs as low as 1 ppb are estimated to result in a 35% increase in BLL in children 1–5 years of age after 5 months of exposure;[25] and WLLs as low as 5 ppb may significantly increase BLLs in young women.[26] The scientific consensus asserts that there is no known safe level of exposure to lead.[27] However, even if the AL were lowered to 0 ppb, the Rule would still allow 10% of homes sampled by a utility to have any WLL—even those with WLLs classifying as hazardous waste (≥5000 ppb).[4]

Partial lead service line replacements

PLSLRs occur when a utility replaces the LSL from the water main in the street to a home's property line, replacement of the private portion of the LSL is the homeowner's responsibility. The LCR states that when more than 10% of high-risk homes sampled exceed the AL, utilities must install corrosion control and/or source water treatment, and must conduct costly PLSLRs on at least 7% of the total number of LSLs in their jurisdiction annually until the AL is met.[3] Utilities can opt to test LSLs in lieu of removing them—LSLs testing under 15 ppb are considered replaced. Utilities must also offer to replace the homeowner's portion of the LSL, but they are under no obligation to assume or subsidize the cost of the replacement.

PLSLRs present a public health risk and foster environmental injustice. Under the best conditions, they may slightly improve WLLs, but in most situations they elevate WLLs.[28,29,7,30,31,32] This is due to the physical

[20]U.S. Environmental Protection Agency (US EPA) National Drinking Water Advisory Council (NDWAC). Recommendations for Long Term Revisions to the Lead and Copper Rule. EPA-SAB-11-015. EPA Office of the Administrator, Science Advisory Board, 2015.

[21]M.J. Brown and S. Margolis. ''Lead in Drinking Water and Human Blood Levels in the United States.'' *MMWR Supplements* 61 (2012): 1–9.

[22]B. Dalbey. ''Nation's Toughest Lead Ware Rules Proposed in Michigan after Flint, Michigan Gov. Risk Snyder: Federal Rules are ''Dumb and Dangerous,'' Critics: ''Pure Michigan'' Needs to Do Better than Third World Countries.'' West Bloomfield Patch. April 15, 2016. http://patch.com/michigan/westbloomfield/nations-toughest-lead-water-rules-proposed-michigan-after-flint (Last accessed May 15, 2016).

[23]World Health Organization (WHO). Lead in Drinking Water: Background Document for Development of WHO Guidelines for Drinking Water Quality. WHO, Geneva, Switzerland. WHO/SDE/WHS/0.04/09/Rev/1. 2011. www.who.int/water_sanitation_health/dwq/chemicals/lead.pdf (Last accessed May 10, 2016).

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[25]G. Ngueta, B. Abdous, R. Tardiff, J. St. Laurent, and P. Levallois. ''Use of a Cumulative Exposure Index to Estimate the Impact of Tap-Water Lead Concentration on Blood Lead Levels in 1- to 5-Year Old Children (Montreal, Canada).'' *Environmental Health Perspectives* 124 (2016): 388–395.

[26]R. Fertmann, S. Hentschel, D. Dengler, U. Janssen, and A. Lommel. ''Lead Exposure by Drinking Water: An Epidemiological Study in Hamburg, Germany.'' *International Journal of Hygiene and Environmental Health* 207 (2004): 235–244.

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[29]Howard Frumkin. ''Important Update: Lead-based Water Lines.'' CDC.gov. January 12, 2010. www.cdc.gov/nceh/lead/waterlines.htm (Last accessed May 1, 2016).

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[31]C. Cartier. ''Impact of Treatment on Pb Release from Full and Partially Replaced Harvested Lead Service Lines (LSLs).'' *Water Research* 47 (2013): 661–671.

[32]U.S. Environmental Protection Agency (US EPA). SAB Evaluation of the Effectiveness of Partial Lead Service Line Replacements. EPA-SAB-11-015. EPA Scientific Advisory Board Drinking Water Committee, 2011.

disturbance of the line and the dislodging of the protective scale; and in some cases, galvanic corrosion, which can elevate WLLs for years or decades.[7,28,30,31,32,33,34] Most importantly, PLSLRs have been associated with elevated BLLs in young children.[16] Finally, many residents cannot afford to replace their LSL, which can cost up to $7000 per line. This means that the LCRs LSL replacement requirement offers differential public health protection on the basis of consumer income.

Inadequate oversight and enforcement

A 2006 U.S. Government Accountability Office (GAO) investigation of LCR oversight and enforcement found that states had not reported WLL data to the EPA for more than 30% of utilities; nor had states reported data on LCR implementation for more than 70% of utilities.[35] The GAO concluded that the EPA does not have the information it needs to evaluate ''how effectively the LCR is being implemented and enforced.'' The EPA's own record of enforcement was also low, enforcing less than one-tenth of the violation remedies it ordered in 1997.[36] Inadequate enforcement is a major concern given that one former Director of the EPA Office of Ground Water and Drinking Water stated he feared utilities were engaging in ''widespread fraud and manipulation.''[36] He went on to say, ''I fear for the safety of our nation's drinking water.''

According to the FWATF, all levels of government share responsibility in the Flint debacle.[1] The primary enforcement authority over drinking water regulations lies with the state, but EPA retains oversight authority and authority over certain enforcement provisions. Michigan officials gave the utility inaccurate CCT guidance and did not ensure high-risk homes were targeted for sampling and sampled correctly. When the MDEQ failed to enforce LCR requirements within 30 days after being alerted to violations by the EPA, Section 1414 of the Safe Drinking Water Act (SDWA) authorized the EPA to issue an administrative order or commence a civil action. No such order was sent—the EPA only exercised its emergency powers on January 21, 2016—11 months after learning about the lack of CCT and biased sampling (February 27, 2015), and 7 months after detecting excessively high WLLs (June 24, 2015).[1]

Absent, ineffective, or adverse corrosion control methods

The primary reasons for Flint's lead crisis were the absence of CCT ''in contradiction to long-standing policy,'' and the failure of MDEQ to enforce the LCRs CCT requirement.[1] In a similar event, Washington D.C. switched disinfectants from chlorine to chloramine between 2001 and 2004, which when coupled with a failure to implement CCT, resulted in corrosive conditions that increased lead leaching and caused a significant increase in miscarriages, fetal deaths, and childhood lead poisoning.[13,37,38] EPA's failure to address LCR enforcement weaknesses following D.C. may have contributed to Flint's repeat of history. New research suggests that even when CCT is applied appropriately, high WLLs may still arise.[39,40]

Inappropriate sampling or sample processing

A list of current LCR monitoring practices used by utilities that can underestimate WLLs at consumer taps is presented in Table 1. Perhaps the weakest LCR provision is the requirement that only 100 samples per year are needed for utilities serving more than 100,000 customers. If certain criteria are met, states can reduce this to 50 samples every 3 years. Since so few samples are collected, one or two results can ''mean the difference between passing and failing.''[41] Even with optimized practices, it is easy to miss high WLLs because particulate lead release is sporadic.[41] One EPA official stated: ''It's a real crapshoot as to what's going to come out of the tap and whether it will be healthy or not.''[41] If the current LCR scheme is to work, utilities must make sure to sample the highest risk homes (homes with either LSLs or lead solder and copper), as required by the Rule. However, some utilities cannot document that their sample sites met these criteria.[41] One nationwide review estimated that if utility monitoring practices really

[33]J. St. Clair, C. Cartier, S. Triantafyllidou. B. Clark, and M. Edwards. ''Long-Term Behavior of Simulated Partial Lead Service Line Replacements.'' *Environmental Engineering Science* 33 (2016): 1–12.

[34]U.S. Environmental Protection Agency (US EPA) Science Advisory Board (SAB). Drinking Water Committee Augmented for the Review of the Effectiveness of Partial Lead Service Line Replacements. EPA-SAB-11-015. EPA Office of the Administrator, Science Advisory Board, 2015.

[35]U.S. Government Accountability Office (US GAO). Drinking Water: EPA Should Strengthen Ongoing Efforts to Ensure That Consumers Are Protected from Lead Contamination. GAO-06-148. Report to Congressional Requesters. Washington DC, 2006.

[36]C.D. Leonnig, J. Becker, and D. Nakamura. Lead Levels in Water Misrepresented across U.S.: Utilities Manipulate or Withhold Test Results to Ward off Regulators. Washington Post, October 5, 2004. www.washingtonpost.com/wp-dyn/articles/A7094-2004Oct4html (Last accessed May 15, 2016).

[37]M. Edwards. Experiences and Observations from the 2001–2004 DC Lead Crises. Testimony before the U.S. House of Representatives Committee on Science and Technology, 111th Congress: Preventing Harm-Protecting Health: Reforming CDC's Environmental Public Health Practices.

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Table 1. Weaknesses in the U.S. Environmental Protection Agency's Lead and Copper Rule's Monitoring Requirements and Oversight

Monitoring issue[a]	*LCR provisions or guidelines*	*Impact on underestimation of WLLs*	*Examples*
Insufficient sample size	LCR: Utilities serving >100,000 people collect 100 samples/year from high-risk homes.[b]	States can grant reductions to no more than 50 samples every 3 years.	When Flint did not meet its 100-sample target in 2015, the MDEQ reduced the number of samples required for Flint.[c,d]
Sampling of low-risk homes	LCR: Systems must sample high-risk "Tier I" sites (50% with LSL, 50% with copper pipe or lead solder.)	U.S. GAO determined that some U.S. utilities were testing sites that were not high risk; and documentation proving high risk was lacking.[e]	Flint, Philadelphia, Boston, and Detroit did not collect all samples from highest risk homes and/or were unable to document that homes sampled met required criteria.[c,f,g]
Low-flow sample collection	Guidance: Urge states and utilities against low-flow collection.[h]	WLLs are lower when collected at low flow vs. high flow. High flow mobilizes particulate lead and is more typical of natural use.[h–l]	Water utilities in Columbus, OH, and South Burlington, VT, have instructed consumers to collect water at low flow.[m]
Prestagnation flushing	Guidance: Urge states and utilities against prestagnation flushing.[h]	Negates "the intent of the rule to collect compliance samples under 'worst-case' conditions, which is necessary for statistical validity given the small number of samples collected for" the LCR.[n]	MDEQs prestagnation flushing was a "serious concern" as it "could provide a false sense of security to the residents of Flint."[n] MDEQ indicated it had no intention of disallowing such practices.[o] Other utilities that used this practice: Boston, MA; Chicago, IL; Philadelphia, PA; Columbus, OH; South Burlington, VT; Rhode Island; Mount Pleasant, SC[m]
Upper limits on stagnation times	LCR and clarification memo:[p] No outer limit on stagnation times (time water sits unused before sampling).[b]	Upper limits on stagnation times may underestimate lead levels that may take more than 24 hours to equilibrate,[q] and may not reflect water use in buildings such as schools and daycares.	Cities such as Boston, MA, and Portland, OR, have implemented maximum stagnation periods.[m] New Orleans, LA, used an upper limit of 12 hours in sampling instructions for several years after 2005.[r]
Aerator cleaning and removal	Guidance: Aerators should not be cleaned/removed before sampling.[h,s]	Shown to significantly reduce the amount of lead capture in regulatory samples.[t]	Philadelphia, PA; Chicago, IL; Greenville NC; and Durham, NC, have advised either aerator removal or cleaning.[n,u]
First draw samples	LCR: Utilities are required to collect first sample after 6-hour stagnation period.[b]	Can "systematically miss the high lead levels and potential human exposure." About 84% of lead in first draw samples is from home plumbing and misses lead from LSLs.[j,v]	All utilities (required)

(*continued*)

Table 1. (Continued)

Monitoring issue[a]	*LCR provisions or guidelines*	*Impact on underestimation of WLLs*	*Examples*
Inadequate processing	Guidance: EPA Method 200.8.[v]	On average, 27% of lead not quantified using EPA protocols. When samples are not shaken, up to 99.9% of lead is undetected; if samples are not digested in original bottle, up to 100% of lead is undetected.[k] EPA reported large loss of soluble lead and digestion was inconsistent with some particulates.[w]	Delays in detection of hazardous WLLs occurred in Washington D.C., due to inappropriate monitoring practices.[a]

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[b]U.S. Environment Protection Agency (US EPA). Safe Drinking Water Act, National Contaminant Level Goals, and National Primary Drinking Water Regulations for Lead and Copper (LCR). Federal Register 56 (1991): 26460–26564.

[c]''Is Philadelphia testing its drinking water correctly?'' NBC News, Lisa Riordan Seville, February 19, 2016.

[d]Marc Edwards. ''Commentary: MDEQ Mistakes and Deception Created the Flint Water Crisis.'' Flint WaterStudy.org (Last accessed September 30, 2015).

[e]U.S. Government Accountability Office (US GAO). 2006. Drinking Water: EPA Should Strengthen Ongoing Efforts to Ensure That Consumers Are Protected from Lead Contamination. GAO-06-148. Report to Congressional Requesters. Washington DC.

[f]''Thirst for Truth: Who's to Blame for Flint's Water Crisis?,'' YouTube video, posted on September 23, 2015, posted by ''American Civil Liberties Union (ACLU),'' May 4, 2016.

[g]C.D. Leonnig, J. Becker, and D. Nakamura. Lead Levels in Water Misrepresented across U.S.: Utilities Manipulate or Withhold Test Results to Ward off Regulators. Washington Post, October 5, 2004. www.washingtonpost.com/wp-dyn/articles/A7094-2004Oct4.html (Last accessed May, 15, 2016).

[h]US EPA. Memo to State Commissioners, and State and Local Partners from Mark Rupp, Deputy Associate Administrator, Office of Intergovernmental Relations; Gina McCarthy, Administrator for the US EPA; Joel Beauvais, Deputy Assistant Administrator, Office of Ground Water and Drinking Water, US EPA. Washington DC, February 29, 2016.

[i]M.A. Del Toral, A. Porter, and M.R. Schock. ''Detection and Evaluation of Elevated Lead Release from Service Lines: A Field Study.'' *Environmental Science & Technology* 47 (2013): 9300–9307.

[j]C. Cartier, R.B. Arnold, Jr., S. Triantafyllidou, M. Prevost, and M. Edwards. ''Effect of Flow Rate and Lead/copper Pipe Sequence on Lead Release from Service Lines.'' *Water Research* 46 (2012): 4142–152.

[k]B. Clark, S. Masters, and M. Edwards. ''Profile Sampling to Characterize Particulate Lead Risks in Potable Water.'' *Environmental Science & Technology* 48 (2014): 6836–6843.

[l]M. Schock. ''Causes of Temporal Variability of Lead in Domestic Plumbing Systems.'' *Environmental Monitoring and Assessment* 15 (1990): 59–82.

[m]J. Glenza and O. Milman. ''Water Utilities Serving American Cities Use Tests That Downplay Contamination.'' *The Guardian* March 6, 2016. (Last accessed May 10, 2016).

[n]US EPA Region 5. 2015. Memo from Miguel del Toral, Regulations Manager, US EPA Region 5 Ground Water and Drinking Water Branch, to Thomas Poy, Chief, Ground Water and Drinking Water Branch. WG-15J. June 24, 2015.

[o]Flint Water Advisory Task Force (FWATF). *Final Report*. State of Michigan: Commissioned by Office of Governor Rick Snyder, 2016.

[p]US EPA. 2004. Lead and Copper Rule: Clarification of Requirements for Collecting Samples and Calculating Compliance Fact Sheet. EPA 810-F-04-001. EPA Office of Water, Washington DC.

[q]D.A. Lytle and M.R. Schock.''Impact of Stagnation Time on Metal Dissolution from Plumbing Materials in Drinking Water.'' *Journal of Water Supply Research and Technology-Aqua* 49 (2000): 243–257.

[r]New Orleans Sewerage and Water Board (S&WB). Instructions for collecting water sample. New Orleans, LA. (2009, 2010, 2013).

[s]US EPA. 2006. Management of Aerators during Collection of Tap Samples to Comply with the Lead and Copper Rule. WSG 178. EPA Drinking Water Protection Division, Office of Ground Water and Drinking Water, Washington DC.

[t]S. Triantafyllidou, J. Parks, and M. Edwards. ''Lead Particles in Potable Water.'' *Journal American Water Works Association* 12 (2007): 107–117.

[u]A. Sandvig, P. Kwan, G. Kirmeyer, B. Maynard, D. Mast, R.T. Rhodes, S. Trussell, A. Cantor, and A. Prescott. Contribution of service line and plumbing fixtures to lead and copper rule compliance issues. *AWWARF* (2008) 91229.

[v]US EPA Method 200.8. Determination of Trace Elements in Waters and Wastes By Inductively Coupled Plasma–Mass Spectrometry Revision 5.4 Environmental Monitoring Systems Laboratory, Office of Research and Development, US EPA, Cincinnati, Ohio.

[w]US EPA. Effectiveness of the Preservation Protocol within EPA Method 200.8 for Soluble and Particulate Led Recovery. EPA/600/R-13/222. 2013. US EPA Office of Research and Development. Cincinnati, OH.

LCR, Lead and Copper Rule; WLLs, Water lead levels; MDEQ, Michigan Department of Environmental Quality; U.S. GAO, United States Government Accountability Office; OH, Ohio; VT, Vermont; MA, Massachusetts; IL, Illinois; PA, Pennsylvania; SC, South Carolina; OR, Oregon; LA, Louisiana; D.C., District of Columbia; EPA, Environmental Protection Agency; LSL, lead service line.

captured worst-case conditions, ~50%–70% of utilities with LSLs would exceed the AL.[42]

Current sample processing protocols can also miss up to 99.9% of lead in water.[4,43,44] Sample processing methods are good at characterizing soluble lead, but not particulate lead. This is a concern as particulate lead is often the predominant form of lead in LCR compliance samples[45] and water systems.[46,47] If ingested, lead particles can lodge in the intestine and can serve as a long-term endogenous source.[12] Thus, WLLs, exposures, and risks are commonly underestimated.

Differences in site selection and sample collection may account for discrepancies between Flint's 2015 LCR compliance samples and samples collected independently. The latter set of samples did not support the utility's claim that Flint's water met regulatory requirements—30% of 48 tap water samples exceeded the AL.[1] At least one home exceeded EPA's standard for hazardous waste (>5000 ppb).[48] These results, had they been obtained by Flint, would have triggered the LCR remediation requirements. It was later discovered that Flint used a flawed compliance sampling protocol and sampled low-risk homes.[1,49] Officials with MDEQ later acknowledged this shortcoming with a statement that program staff ''made a mistake.''[50]

Unlawful exclusion of high WLLs

The EPA has stipulated that samples can only be invalidated if (1) there is a laboratory error; (2) a sample is damaged; (3) a sample site did not meet selection criteria; or (4) a sample was tampered with [40 C.F.R. § 141.86(f)].[3] However, utilities often use this provision to request that states invalidate high WLL results, even when none of the invalidation criteria is met. For example, the MDEQ invalidated two high lead results in Flint's 2015 LCR report to meet LCR requirements.[51] Washington D.C. did the same in 2001,[37] as did New Orleans in 2009 for its 2007 sampling round.[52] According to one EPA official, New Orleans' invalidations did not meet LCR criteria,[53] which the utility said were due to infrequent prior water use and line repairs at the homes in question.[54] However, these circumstances were indicative of city-wide conditions, as people were still returning home to rebuild after Hurricane Katrina. The state originally denied the invalidation,[55] yet regional EPA officials allowed the state to approve the invalidations,[56] which, in turn, enabled the state to approve a reduction in the water utility's monitoring frequency.[54]

Delayed or no alerts

Utilities have 60 days to notify the public about an AL exceedance, compared with 30 days for most other SDWA violations.[5] One coauthor of this article and member of the EPA National Drinking Water Advisory Council's (NDWAC) LCR Working Group noted: ''By the time comprehensive education is mandated, many consumers have been needlessly exposed to elevated levels of lead for prolonged periods of time.''[11] Sometimes, utilities do not alert the public within the required time. Between 2001 and 2004, Washington D.C. was in violation of the AL, but the public was only alerted in 2004.[37]

When utilities do not exceed the AL, requirements for public education are even less stringent. For example, utilities routinely conduct PLSLRs; repair LSLs, water meters, water mains, shut-off valves; and conduct street excavations. While these activities can increase WLLs,[57]

[42]R. Slabaugh.''Optimized Corrosion Control: An Estimate of National Impact'' [(Power Point Presentation). AWWA Water Quality Technology Conference (WQTC), New Orleans, LA; November 16–20, 2014].

[43]B. Clark, S. Maters, and M. Edwards. ''Profile Sampling to Characterize Particulate Lead Risks in Potable Water.'' *Environmental Science & Technology* 48 (2014): 6836–6843.

[44]S. Triantafyllidou, C.K. Nguyen, Y. Zhang, and M. Edwards. ''Lead (Pb) Quantification in Potable Water Samples: Implications for Regulatory Compliance and Assessment of Human Exposure.'' *Environmental Monitoring and Assessment* 185 (2013): 1355–1366.

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[47]Y. Wang, H. Jing, V. Mehta, G.J. Walter, and D.E. Giammer. ''Impact of Galvanic Corrosion on Lead Release from Aged Service Lines.'' *Water Research* 46 (2012): 5049–5060.

[48]A. Mantha and S. Roy. ''Hazardous Waste Levels of Lead Found in a Flint household's water.'' Flintwaterstudy.org. August 24, 2015. http://flintwaterstudy.org/2015/08/hazardous-waste-levels-of-lead-found-in-a-flint-households-water/ (Last accessed May 8, 2016).

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[50]Michigan Department of Environmental Quality (MDEQ). ''DEQ Director Dan Wyant Issues Statement About Flint Drinking Water.'' MDEQ. October 19, 2015. www.michigan.gov/deq/0,4561,7-135—367529—,00.html (Last accessed June 9, 2016).

[51]Michigan Department of Environmental Quality (MDEQ). ''Lead and Copper Report and Consumer Notice of Lead Result Certificate for Community Water Supply.'' Flintwaterstudy.org. 2015. http://flintwaterstudy.org/wp-content/uploads/2015/09/Revised-LCR-Report-Flint-2015-9-30-2015.pdf (Last accessed May 4, 2016).

[52]Letter from Sean Nolan, Louisiana Department of Health and Hospitals (LDHH), LCR Rule Manager to Vincent Fouchi, S&WB Water Purification Superintendent. Re: LCR—Confidence Sample Results, Corrected Version, August 19, 2009.

[53]Email from Lisa Donahue, EPA Region 3 to Hillol Ray, US EPA Region 6, Re: New Orleans CCR, August 7, 2009.

[54]Letter from Vincent Fouchi Jr., S&WB Water Purification Superintendent to Sean Nolan, Louisiana Department of Health and Hospitals (LDHH), LCR Rule Manager, Re: LCR—Request for Invalidation, March 16, 2009.

[55]Letter from Sean Nolan, Louisiana Department of Health and Hospitals (LDHH), LCR Rule Manager to Vincent Fouchi Jr., S&WB Water Purification Superintendent Re: LCR—Request for Invalidation of Sample(s), April 24, 2009.

[56]Email from Mark McCasland, US EPA Region 6, to Karen Irion, Chief Engineer, LDHH, Re: New Orleans Lead, August 10, 2009.

[57]M.A. Del Toral, A. Porter, and M.R. Schock. ''Detection and Evaluation of Elevated Lead Release from Service Lines: A Field Study.'' *Environmental Science & Technology* 47 (2013): 9300–9307.

utilities are not required to notify residents about the risk. In New Orleans, for example, we documented cases in which residents alleged they were subjected to PLSLRs without information about potential WLL increases. This is a concern as WLLs as high as 120 ppb were observed 2 days after a PLSLR.[58] Recently, Chicago and Philadelphia residents who were not warned about risks of high WLLs after street work filed a class action lawsuit against city officials, citing ''negligent and reckless conduct.''[59]

Lack of transparency

Two GAO reports identified several weaknesses in public education and utility transparency.[35,60] In many states, it is extremely difficult to get information from the utility or state on site selection procedures, sampling protocols, WLL results, invalidations, LSL locations, and other information a consumer needs to make an informed decision. As researchers, we have also experienced great difficulty, delay, and cost in trying to obtain documents from utilities about lead in water. The EPA responded to criticisms about the lack of transparency in February 2016 by issuing a memo to regulators to increase utility transparency and allow public access to critical documents, such as sample results, sampling protocols, and inventories of LSLs.[61]

Inappropriate exposure reduction messages

Flushing water is one of the only low-cost ways that low-income families, who cannot afford pipe replacements or treatment systems, can take to reduce WLLs. The EPA had required utilities to recommend flushing for 30 seconds to 2 minutes or until water becomes cold, on outreach materials—this information is still available on government, utility, and nongovernmental organization websites [40 CFR §141.154.d.1].[62,63] However, several studies call into question the sustainability and effectiveness of these guidelines.[4,26,34,44,57] Over half the sites sampled in New Orleans (58%, $n=258$) had higher WLLs after at least one of these recommended flush times, thereby potentially increasing exposures.[64] The EPA now allows systems to tailor flushing directions to their system, with state approval (71 FR 40828, July 18, 2006).[5] Despite this flexibility and industry knowledge of the inconsistent effectiveness of flushing, utilities and government officials still distribute the ''30 seconds to 2 minutes or until water becomes cold'' recommendation to the public.[65]

CONCLUSION

Accumulating evidence of low-dose lead impacts on the neurological development of fetuses and children and widespread acknowledgment that there is no safe level of lead underscore the need for renewed attention to lead in drinking water.[17] However, ill-designed compliance monitoring protocols, and biased sampling of an insufficient number of sites of low or undocumented risk, present the danger that WLLs reported by utilities may be invalid, unreliable, and unrepresentative of worst-case concentrations.[4,66] Despite explicit government guidelines on how to collect and process samples, utilities are permitted by regulators to ignore these guidelines because they do not carry the weight of law. However, even legal provisions are sometimes ignored or advantageously ''misinterpreted,'' as we saw in Flint.[1] The MDEQ failed the public when it did not enforce LCR provisions or intent, which is to ''prevent known or anticipated adverse effects on the health of persons to the extent feasible'' [40CFR1§141.86].[3] This resulted in underdetection of WLLs, misinformation, false security, adverse health consequences, and potential societal costs.

Prolonged inadequate monitoring of lead in water may have led us to underestimate the scope and magnitude of both low-dose, but chronic, and acute exposure routes, which, in turn, may be perpetuating a reliance on inadequate interventions for childhood lead poisoning prevention in the United States. Existing interventions of education and dust control have proved ineffective in reducing population-level BLLs[67]; yet, interventions for lead in drinking water are rarely implemented, despite the fact that filters certified to remove lead are readily

[58]J. Parks and M. Edwards. *Interim Report: Evaluation of Lead in Tap Water in New Orleans, LA*. (Virginia Polytechnic Institute and State University, 2016).

[59]O. Milman. ''Chicago Residents Blame City for Water Contamination in Class-Action Lawsuit.'' *The Guardian*. February 18, 2016. www.theguardian.comus-news/2016/feb/18/chicago-class-action-lawsuit-water-contamination-lead-pipes (Last accessed May 9, 2016).

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available, relatively cheap, and highly effective.[68] Today, the CDC still recommends that lead poisoning prevention programs analyze WLLs from homes of lead-poisoned children, ''when no other source of lead is found,'' or when the utility ''is not in compliance with LCR.''[21,69] Even when public health programs do test water, one EPA official noted that they often do so in a haphazard way that makes the data useless.[70]

If the LCR is to be successful and public trust renewed, the EPA should coordinate with health agencies, affected communities, and independent scientists; also, insist on timely alerts and transparency. The EPA NDWAC presented its recommendations for LCR revisions recently[20]; but these did not go far enough to ensure public protection.[11] Recommendations included the following: voluntary requests for samples versus targeting high-risk sites; unenforceable long-term LSL replacement goals; continuing to base decisions about water safety and remediation on a 90th percentile AL exceedance; and continuing PLSLRs. The EPA will continue to solicit public input on LCR revisions through 2017—public involvement and engagement are critical during this review.

The FWATF concluded that Flint suffered an environmental injustice.[1] Composed primarily of minority and low-income residents, Flint was disproportionately impacted by an environmental hazard; lacked access to information needed to make public-health-protective decisions; denied ''involvement in the government decision-making process''; and deprived of state representation and protections entitled to all consumers by the federal government. State officials were described as ''callous and dismissive'' of community concerns; one regional EPA official even went so far as to say: ''I'm not so sure Flint is the community we want to go out on a limb for.''[1] One encouraging outcome of this event, however, is Michigan's renewed commitment to the halting of PLSLRs; supporting innovative strategies to finance full replacement of all LSLs; increasing public transparency, education, and assistance[71]; and mandating guidance and training on environmental justice.[1] These actions, if they become law, may alleviate some of the disparate impacts on low-income communities that arise directly from existing LCR provisions, which mandate PLSLRs, or indirectly from ''lax and myopic compliance practices.''[1] This success speaks to the power of engaged citizens and ethically motivated individuals in bringing this crisis to the nation's attention, spurring a public discussion of the gaps and weaknesses in our regulatory system.[1]

The fight for the right to safe drinking water is not limited to Flint—it is a national problem. Low-income and minority communities disproportionately suffer from the lowest quality water[72]; are less likely to afford treatment systems and LSL replacements[73]; and are most likely to live in high-risk areas, with failing infrastructure and high levels of legacy lead.[74] Small rural communities lack financial and technical support; suffer higher per capita infrastructure costs and less oversight; and are victims to more than 90% of U.S. drinking water violations.[75,76] Without policies to address disparities in access to quality water and chronic and acute exposures to lead in water, efforts to eliminate childhood lead poisoning may stagnate or fail and injustice will endure.

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