POLICY STATEMENT Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of all Children

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

Prevention of Childhood Lead Toxicity

COUNCIL ON ENVIRONMENTAL HEALTH

abstract

Blood lead concentrations have decreased dramatically in US children over the past 4 decades, but too many children still live in housing with deteriorated lead-based paint and are at risk for lead exposure with resulting lead-associated cognitive impairment and behavioral problems. Evidence continues to accrue that commonly encountered blood lead concentrations, even those below 5 µg/dL (50 ppb), impair cognition; there is no identified threshold or safe level of lead in blood. From 2007 to 2010, approximately 2.6% of preschool children in the United States had a blood lead concentration ≥5 µg/dL (≥50 ppb), which represents about 535 000 US children 1 to 5 years of age. Evidence-based guidance is available for managing increased lead exposure in children, and reducing sources of lead in the environment, including lead in housing, soil, water, and consumer products, has been shown to be cost-beneficial. Primary prevention should be the focus of policy on childhood lead toxicity.

OVERVIEW AND INTRODUCTION

Primary prevention, reducing or eliminating the myriad sources of lead in the environment of children before exposure occurs, is the most reliable and cost-effective measure to protect children from lead toxicity. Very high blood lead concentrations (eg, >100 µg/dL) can cause significant overt symptoms, such as protracted vomiting and encephalopathy, and even death. Low-level lead exposure, even at blood lead concentrations below 5 µg/dL (50 ppb), is a causal risk factor for diminished intellectual and academic abilities, higher rates of neurobehavioral disorders such as hyperactivity and attention deficits, and lower birth weight in children. No effective treatments ameliorate the permanent developmental effects of lead toxicity. Reducing lead exposure from residential lead hazards, industrial sources, contaminated foods or water, and other consumer products is an effective way to prevent or control childhood lead exposure. Lead poisoning prevention education directed at hand-washing or dust control fails to reduce children's blood lead concentrations. However, pediatricians and parents should be aware of measures to reduce the toxic effects of lead on children, including the promulgation of regulations to screen or test older housing units for lead hazards

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DOI: 10.1542/peds.2016-1493

Accepted for publication May 5, 2016

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The author has indicated he does not have a financial relationship relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: The author has indicated he has no potential conflicts of interest to disclose.

To cite: AAP COUNCIL ON ENVIRONMENTAL HEALTH. Prevention of Childhood Lead Toxicity. *Pediatrics.* 2016;138(1):e20161493

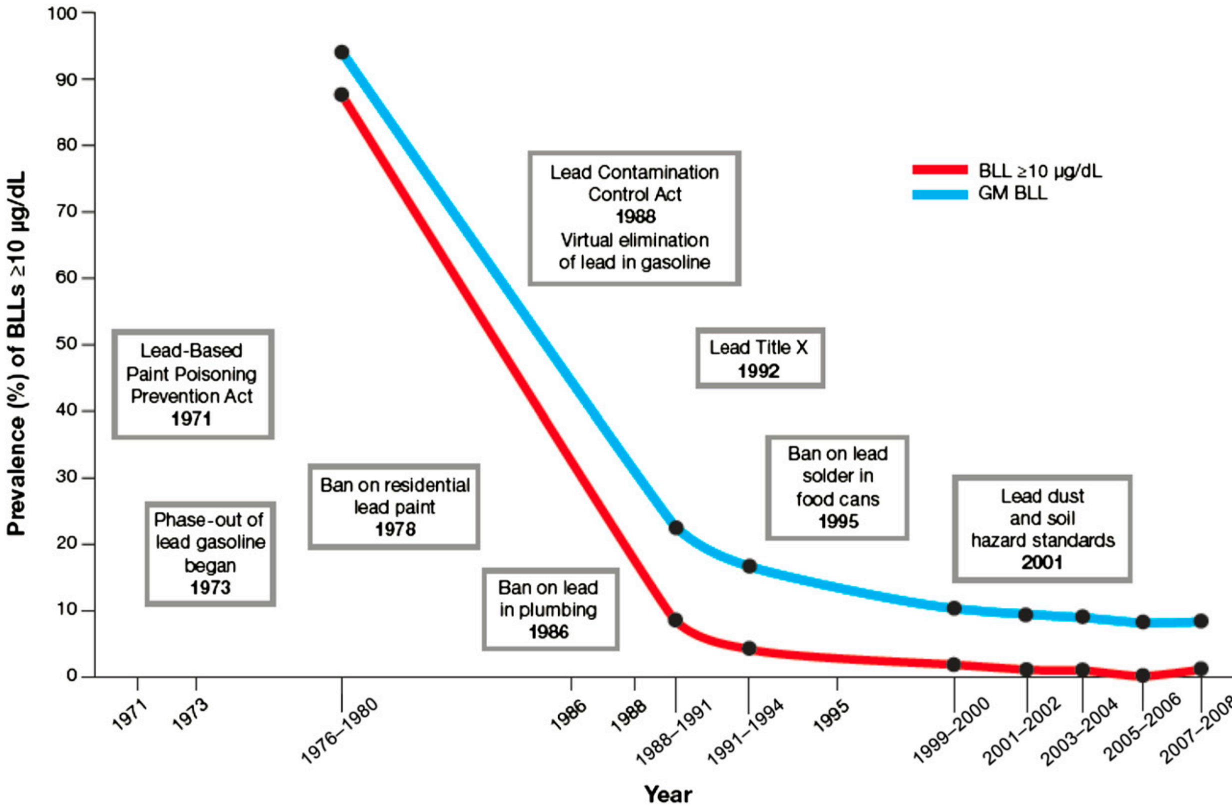

FIGURE 1
Timeline of lead poisoning prevention policies and blood lead levels in children aged 1–5 years, by year—NHANES, United States, 1971–2008. BLL, blood lead level; GM BLL, geometric mean blood lead level. Adapted from Brown et al.[1]

before occupancy and after major renovation and abatement; revision of federal standards to reduce allowable levels of lead in settled house dust, water, soil, cosmetics, and other consumer products; and enhanced protection for children who live in lead-contaminated communities or near lead-emitting industries.

SCOPE OF THE PROBLEM

Over the past 4 decades, blood lead concentrations among US children have declined dramatically since the elimination of lead from gasoline, paints, and other consumer products[1] (Fig 1, Table 1). From 1976 to 1980, blood lead concentrations among US children declined more sharply than anticipated after the phase-out of leaded gasoline.[2] In 1978, the US Consumer Product Safety Commission (CPSC) restricted the allowable content of lead in residential paint to 0.06% (600 ppm); in 2008, it was lowered to 0.009% (90 ppm).[3,4] There have also been significant reductions in tap water lead concentrations since the US Environmental Protection Agency (EPA) promulgated the Lead and Copper Rule.[5,6] Finally, use of lead solder in canned foods and other consumer products was banned. It is difficult to accurately apportion the decline in blood lead concentrations to specific sources, but the combined effect of these regulations clearly led to the dramatic reductions in children's blood lead concentrations.[1] The key to preventing lead toxicity in children is to reduce or eliminate persistent sources of lead exposure in their environment.

Prevention of low-level lead toxicity has historically focused on anticipatory guidance, screening children's blood for lead after exposure, and iron or calcium supplementation to reduce lead absorption.[7] Unfortunately, studies that evaluated the efficacy of parent education or provision of cleaning equipment to families failed to show significant reductions in children's blood lead concentrations.[8] Similarly, calcium and iron supplementation have not consistently been shown to be efficacious in reducing blood lead concentrations of children.[9,10] Collectively, these studies indicate that the focus of prevention should be on reducing the sources of childhood lead exposures rather than identifying children who have already been unduly exposed or attempting to ameliorate the toxic effects of lead exposure.

In 2005, the American Academy of Pediatrics (AAP) recognized that blood lead concentrations below 10 µg/dL (100 ppb) may impair cognition; no threshold for the toxic effects of lead was identified.[7] The AAP adopted a blood lead concentration >10 μg/dL (>100 ppb) as the "level of concern" recommended by the Centers for Disease Control and Prevention (CDC), which indicated the need for closer medical and public health management.[7] Extensive and compelling evidence now indicates that lead-associated cognitive deficits and behavioral problems can occur at blood lead concentrations below 5 μg/dL (50 ppb). In 2012, the US National Toxicology Program of the National Institutes of Health reported that, after other risk factors are accounted for, blood lead concentrations <5 μg/dL (<50 ppb) are strongly associated with intellectual deficits, diminished academic abilities, attention deficits, and problem behaviors (Table 2).[11] In that same year, the Advisory Committee on Childhood Lead Poisoning Prevention of the CDC concluded that there is no safe level of lead exposure and adopted the use of a reference value of ≥5 μg/dL (≥50 ppb) (based on the 97.5th percentile of blood lead concentrations from the National Health and Nutrition Examination Survey [NHANES]) to be used as a trigger to guide clinical and public health interventions.[12]

Low-level elevations in children's blood lead concentrations, even at concentrations below 5 μg/dL (50 ppb), can result in decrements in cognitive functions, as measured by IQ scores and academic performance.[13,14] For a given level of exposure, lead-associated IQ decrements are proportionately greater at the lowest blood lead concentrations. The IQ decrement associated with an increase in blood lead concentration from <1 μg/dL (<10 ppb) to 30 μg/dL (300 ppb) was 9.2 IQ points, but the decrement associated with an increase in blood lead concentration from <1 μg/dL (<10 ppb) to 10 μg/dL (100 ppb) was 6.2 IQ points.[14] The population impact of lead on intellectual abilities is substantial. Despite the dramatic reductions in blood lead levels, lead toxicity accounts for an estimated total loss of 23 million IQ points among a 6-year cohort of contemporary US children.[15]

Focusing efforts on children who have blood lead concentrations ≥5 μg/dL (≥50 ppb) is efficient but will fail to preserve the majority of lost IQ points in US children. The *prevention paradox* refers to the concept that most disease or disability occurs in low- to moderate-risk groups. Children who have blood lead concentrations ≥5 μg/dL (≥50 ppb) will, on average, experience

TABLE 1 Federal Lead Poisoning Prevention Policies

Policy or Legislation	Year	Comment
Lead Based Paint Poisoning Prevention Act	1971	First major lead-based paint legislation; addressed lead-based paint in federal housing.
Phase Out Lead in Gasoline	1973	US EPA regulated a phase-out of lead in gasoline.
Ban on Residential Paint	1978	CPSC banned lead paint in residential properties.
Safe Drinking Water Act	1986	US EPA banned use of lead pipes and lead solder in plumbing.
Housing and Community Development Act	1987	Highlighted the danger to children of lead-contaminated dust.
Lead Contamination Control Act	1988	Authorized CDC to make grants to state and local programs to screen children and to provide for education about lead poisoning.
Residential Lead-Based Paint Hazard Reduction Act, Title X	1992	Established primary prevention of lead poisoning as a national strategy.
Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing	1995, 2012	HUD established guidelines for evaluating and controlling residential lead-based paint hazards.
Ban Lead Solder in Food Cans	1995	FDA amended food additive regulations to ban lead solder from food cans.
Lead Safe Housing Rule	1999, 2012	Regulation issued by HUD setting forth new requirements for lead-based paint notification, evaluation, and remediation.
Hazard Standards for Lead in Paint, Dust and Soil	2001	US EPA established a definition of a lead-based paint hazard and standards for paint, dust, and soil in children's play areas.
Consumer Product Safety Improvement Act	2008	CPSC lowered the cap on lead in paint from 0.06% to 0.0009% and incorporated the Lead-Free Toy Act, setting limit on lead content in toys.
Lead Renovation, Repair and Paint Rule	2010	US EPA required contractors working on homes built before 1978 to be certified and follow lead safe guidelines.

TABLE 2 Effects of Low-Level Lead Exposure on Academic and Intellectual Abilities, Puberty, Kidney Function, Postnatal Growth, Hearing, and Other Health Endpoints

Blood Lead Concentration	Evidence Level	Health Effect
<5 μg/dL	Sufficient	Decreased academic achievement
		Lower IQ scores
		Attention-related behavior problems
		Antisocial behaviors
	Limited	Delayed puberty
		Decreased kidney function in children ≥12 y of age
<10 μg/dL	Sufficient	Delayed puberty
		Reduced postnatal growth
		Decreased hearing
	Limited	Hypersensitivity by skin prick test
	Inadequate	Asthma and eczema
		Cardiovascular effects
		Kidney function <12 y of age

From the US Department of Health and Human Services, National Institute of Environmental Health Sciences, 2012.

a lead-associated IQ deficit of 6.1 points, an IQ deficit much larger than that of children who have lower blood lead concentrations (Fig 2). Still, if the focus is only on reducing exposures for children who have a blood lead concentration ≥5 μg/dL (≥50 ppb), we will fail to preserve more than 20 million (>80% of total) of the 23 million IQ points lost among US children with lower lead exposure because there are so many more children who have low to moderate blood lead concentrations (Fig 2). No therapeutic interventions currently exist for low blood lead concentrations; therefore, prevention of exposure is paramount. For these reasons, this statement focuses heavily on how pediatricians can help *prevent* lead exposure in children.

Elevated blood lead concentrations can result in the development of behavioral problems in children, including inattention, impulsivity, aggression, and hyperactivity.[16–18] In a nationally representative study of 8- to 15-year-old US children, Froehlich et al[17] found that having a blood lead concentration >1.3 μg/dL (>13 ppb) was associated with an elevated risk for attention-deficit/hyperactivity disorder (ADHD). Children with a blood lead concentration in the lowest tertile (<0.7 μg/dL, or <7 ppb) exhibited, on average, 1 symptom of ADHD, whereas children with a blood lead concentration in the highest tertile (>1.3 μg/dL, or >13 ppb) exhibited 3 symptoms. Some critics have argued that these "subtle" shifts in behavioral symptoms are inconsequential, but this shift in the population distribution of ADHD symptoms led to an increase in the percentage of children who met criteria for ADHD from 5% to 13%. Approximately 1 in 5 cases of ADHD among US children have been attributed to lead exposure.[17]

Antisocial behaviors, including conduct disorder, delinquency, and criminal behaviors, can result from a variety of risk factors, but there is substantial evidence that lead toxicity is 1 of the major risk factors for their development.[16,19–22] Needleman et al[16] found that adolescents who had higher bone lead concentrations had higher scores for delinquency and aggression. In a meta-analysis of 16 studies, Marcus et al[22] concluded that lead exposure, measured via blood lead or bone lead concentrations, was a risk factor for conduct disorder. In 2 prospective longitudinal studies, higher childhood blood lead or tooth lead concentrations resulted in higher rates of self-reported delinquent behaviors and arrests or convictions.[20,21] Reyes[23] concluded that the reduction in population mean blood lead concentrations was the major risk factor associated with the decline in severe violent behaviors over the past 3 decades.

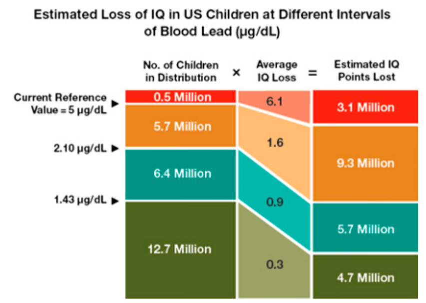

FIGURE 2

Prevention paradox. The majority of IQ points lost due to lead exposure occur in children who have low to moderate blood lead levels. Using the current reference value of 5 μg/dL, we will protect only 3.1 million IQ points (about 13% of the total). Adapted from Bellinger.[15]

Limited evidence implicates lead exposure in diminished kidney function in adolescents at low levels of exposure.[11] Using the NHANES, Fadrowski et al[24] found that, among 769 adolescents with a median blood lead concentration of 1.5 μg/dL (15 ppb), a doubling of the concentration led to a significant reduction in the glomerular filtration rate. It is not clear whether chronic, low-level lead exposure in childhood or adolescence is sufficient to result in chronic renal failure or whether it is the cumulative effect of a variety of risk factors that ultimately results in the development of chronic renal failure. Still, this study is consistent with others linking lead exposure with chronic renal failure in adults.[11]

Lead can cause spontaneous abortion, low birth weight, and reduced growth in children. In a case–control study of pregnant women in Mexico City with blood lead concentrations that ranged from 1.3 μg/dL (13 ppb) to 29 (290 ppb) μg/dL, the odds for spontaneous abortion increased by 1.8 for every 5-μg/dL (50-ppb) increase in maternal blood lead concentration.[25] Early studies that examined the association of prenatal lead exposure and low birth weight or preterm birth, measured via either maternal or cord blood lead concentrations, found inconsistent results. However, in a large cohort involving more than 34 000 live births, investigators found that a 5-μg/dL (50-ppb) increase in blood lead concentrations was associated with a 61-g decrement in birth weight.[26] The National Toxicology Program concluded that maternal blood lead concentrations <5 μg/dL (<50 ppb) are associated with lower birth weight.

PREVENTING LEAD TOXICITY

Despite historical reductions in children's blood lead concentrations, preventing childhood lead toxicity remains a major public health priority in the United States. Many children who live in older, poorly maintained housing or older housing that undergoes renovation are at high risk for lead exposure. In the NHANES conducted from 2007 to 2010, approximately 2.6% of preschool children in the United States had a blood lead concentration ≥5 μg/dL (≥50 ppb), which represents about 535 000 US children 1 to 5 years of age.[12] Children who lived in older housing units experienced an increased risk for having a blood lead concentration in excess of 5 μg/dL (50 ppb); 15% of US children who lived in housing units built before 1950 had a blood lead concentration ≥5 μg/dL (≥50 ppb), whereas 4.2% of children who lived in housing built between 1950 and 1978 had a blood lead concentration ≥5 μg/dL (≥50 ppb), compared with 2.1% of children who lived in housing units built after 1978.[27] No treatments have been shown to be effective in ameliorating the permanent developmental effects of lead toxicity.[28] Finally, the economic costs of childhood lead toxicity are substantial. Despite the historical reductions in blood lead concentrations, it has been estimated that the annual cost of childhood lead exposure in the United States is $50 billion.[29] For every $1 invested to reduce lead hazards in housing units, society would benefit by an estimated $17 to $221, a cost–benefit ratio that is comparable with the cost–benefit ratio for childhood vaccines.[30]

The key to preventing lead toxicity in children is identification and elimination of the major sources of lead exposure. Primary prevention of lead exposure is now widely recognized as the optimal strategy because of the irreversible effects of low-level lead toxicity.[7,12] The primary prevention approach contrasts with practices and policies that too often have relied predominantly on detection of lead exposure only after children develop elevated blood lead concentrations.

SOURCES AND VARIABILITY OF LEAD EXPOSURE

Lead ingestion and absorption are dynamic during the first 2 years of life. Blood lead concentrations of children who live in lead-contaminated environments typically increase rapidly between 6 and 12 months of age, peak between 18 and 36 months of age, and then gradually decrease.[31] The peak in children's blood lead concentrations stems from the confluence of normal mouthing behaviors and increasing mobility.[31] Younger children also absorb lead more efficiently than older children and adults.[32] Iron deficiency can also increase the absorption of lead.[33]

A large number of housing units in the United States contain lead-based paint. In a national survey of housing conducted in 2011, it was estimated that 37 million (35%) of 106 million housing units contain lead-based paint.[34] Lead-based paint is the most common, highly concentrated source of lead exposure for children who live in older housing.[35] Paint that was used on both the interior and exterior of houses through the 1950s contained higher concentrations of lead than that of houses built in later years.[34,35] The lead concentration in paint and other media can be measured by using a hand-held instrument called the x-ray fluorescence (XRF) spectrum analyzer or by chemically analyzing paint chips.

The US Department of Housing and Urban Development (HUD) defines lead-based paint as an XRF reading ≥1 μg/cm^2 or 5000 ppm of lead in a paint chip.[36] The presence of *lead*-based *paint* is not as predictive of childhood lead exposure as a *lead paint hazard*. A lead paint hazard is defined by the EPA as "any condition that causes exposure to lead from contaminated dust, lead-contaminated soil, or lead-contaminated paint that is deteriorated, or the presence of accessible (or chewable) surfaces, friction surfaces or impact surfaces that would result in adverse human health effects."[37]

Age of the housing is a major determinant of lead paint hazards. For housing built from 1978 to 1998, 2.7% contained one or more lead paint hazards, whereas the prevalence of residential hazards increased to 11.4% of housing built from 1960 to 1977, 39% of housing built from 1940 to 1959, and 67% of housing units built before 1940.[34] Federal regulations for defining a lead paint hazard in house dust are obsolete. Federal agencies have set environmental lead standards to protect children from having a blood lead concentration ≥10 μg/dL (≥100 ppb), but it is now recognized that there is no safe level of lead exposure. Therefore, because the current standards for lead in house dust, water, and soil remain too high to protect children,[31,38] the percentage of housing that contains one or more lead paint hazards described above is an underestimate.

Lead-based paint is the major source of lead, but ingestions of lead-contaminated house dust and residential soil are the major pathways for exposure (Fig 3).[35–42] House dust, which can be contaminated by small particles of lead-based paint or track-in of lead-contaminated soil, is a major pathway of lead exposure for children who live in older, poorly maintained housing.[40] Ingestions of lead-contaminated house dust and soil are also the primary pathways of exposure for children who live in homes that were recently abated or renovated.[43–45]

Sampling house dust for lead hazards involves using a special wipe to sample a specified area, such as the floor, which is readily accessible to a child, or a window sill or window trough.[36] Windows are often more heavily contaminated than floors because exterior paints often contained higher concentrations of lead, and window troughs can act as reservoirs. Sampling house dust for lead is used to screen older housing units that may contain lead hazards at the time of purchase or rental and before occupancy; to conduct a full risk assessment that involves extensive sampling of settled dust in housing units that failed a lead hazard screen or where there is a high probability of a lead hazard;

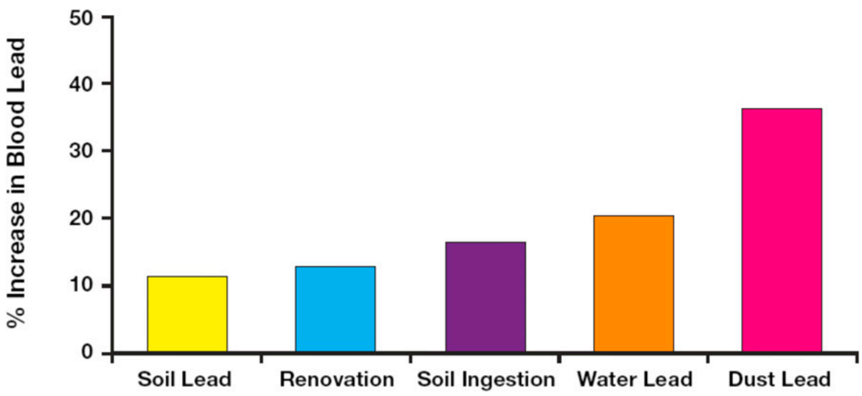

FIGURE 3
Contribution of lead exposure to children's blood lead concentrations. Adapted from Lanphear et al[31] and Spanier et al.[45]

TABLE 3 Common Sources of Lead Exposure

Source	Comment
House paint used before 1978 but especially before 1960	Deteriorated paint releases fine lead dust during home renovation.
Toys and furniture painted before 1976	
Painted toys made outside the United States	
Lead bullets, fishing sinkers, certain weights	Exposures often occur during practice in firing ranges.
Plumbing, pipes, and faucets	Lead leaches into drinking water when the pipes are connected with lead solder.
Soil contaminated by lead	Often in soil near highways and in yard of houses with exterior lead paint.
Hobbies involving soldering such as stained glass, jewelry making, pottery glazing, and miniature lead figures	Always check the labels.
Children's paint sets and art supplies	Always check the labels.
Pewter pitchers and ceramic dinner ware	
Storage batteries	
Parental occupation	Auto repair, mining, battery manufacture, pipe fitting and plumbing, welding, firing range use, ship building, painting, construction.
Folk remedies	Greta and Azarcon, Hispanic traditional medicines; Ghasard, an Indian folk medicine; and Ba-baw-saw, a Chinese herbal remedy, contain lead.
Cosmetics	Examples include Swad brand Sindoor, a cosmetic product used by traditional Hindus; Tiro, an eye cosmetic from Nigeria.
Candy from Mexico	Ingredient tamarind may contain lead.
Toy jewelry	A child died in 2006 after swallowing a metal heart charm that came with a purchase of shoes made by Reebok.

and to conduct clearance testing after repair or renovation of painted surfaces and after lead abatement, to verify that the housing unit is safe for occupancy (Table 3).[38]

Lead-contaminated soil is an important source of lead intake for children.[40,41] Lead-contaminated soil can directly contribute to children's blood lead concentrations via soil ingestion and indirectly from soil tracked indoors on shoes, which then contaminates house dust (Fig 3). Former mine and smelter communities present a particular risk to children for the ingestion of lead-contaminated soil, but lead in urban soil also is often heavily contaminated from the past use of leaded gasoline and paints. Other sources of lead in soil include weathering of lead-based exterior paint and nearby renovation or demolition activity. Soil testing is usually performed in areas where children play and the foundation perimeter. The EPA standards are 400 μg of lead per gram of soil for play areas and 1200 μg/g for the foundation perimeter.[37] Children's blood lead concentrations increase by approximately 3.8 μg/dL (38 ppb) for every 1000-ppm increase in soil lead concentration.[40]

Water is an important but often overlooked source of exposure for children, especially for infants who are formula fed.[5,46,47] Water typically contributes to approximately 20% of a child's blood lead concentrations if the water lead concentration exceeds 5 ppb (Fig 3).[31] The contribution of lead from water can be much higher for some children, especially for infants who ingest large quantities of tap water.[5,46,47] Children who reside in communities with lead service lines and inadequate anticorrosion control are also at increased risk for elevated blood lead concentrations.[48]

Phasing out leaded gasoline and creating stricter national air lead standards led to large reductions in the contribution of airborne lead to children's blood lead concentrations. Still, in some communities, such as those surrounding regional airports, airborne lead is an important source of lead exposure. Airborne lead is ingested primarily after it settles in house dust and soil where children play. Current sources of airborne lead include lead battery recycling operations, piston engine aircraft, and incinerators.[49] The contributions of airborne lead to children's blood lead concentrations are proportionately greater at the lower levels of exposure than at higher levels.[49]

Other sources of lead intake for children have been identified, such as nutritional supplements and folk medicines, ceramic dishware, and cosmetics[50–52] (Table 3).

Lead brought into the home from a worksite by a parent can also be a major source of exposure for some children.[53] Consumer products such as children's toys, lunch boxes, crayons, and lipstick that are contaminated with lead have received a great deal of attention. These products constitute a small source of lead intake for most children, but they can be the major source for an individual child. Moreover, because lead exposure is cumulative and there is no apparent threshold for the adverse effects of lead exposure, all sources of lead exposure should be eliminated. It is the responsibility of the relevant federal agencies, such as the CPSC and the Food and Drug Administration (FDA), to promulgate and enforce standards that will protect children from lead-contaminated consumer products.

TABLE 4 Federal Standards for Lead in House Paint, House Dust, Soil, Water, Air, and Candy

Source	Standard
1. Lead-based paint (XRF)	1 μg/cm^2
2. Paint containing lead applied after August 14, 2009	90 ppm by wt
3. Testing (full risk assessment) for dust lead hazards (by wipe sampling)	
a. Floors	40 μg/ft^2
b. Interior window sills	200 μg/ft^2
4. Screening test for dust levels (by wipe sampling) to determine whether a full risk assessment is indicated	
a. Floors	25 μg/ft^2
b. Interior window sills	125 μg/ft^2
5. Dust lead clearance levels after abatement (by wipe sampling)	
a. Floors	40 μg/ft^2
b. Interior window sills	250 μg/ft^2
6. Bare residential soil	
a. Children's playground area	400 μg/g
b. Yard other than play area	1200 μg/g
7. Drinking water systems	
Exceeded if lead is above this concentration in >10% of a drinking water system's tap water samples	15 ppb (0.015 mg/L)
8. Candy likely to be consumed by small children	0.1 ppb
9. National Ambient Air Quality Standards: http://www.epa.gov/ttn/naaqs/standards/pb/s_pb_history.html	0.15 μg/m^3

Other state or local standards may vary, and the most protective standard applies. FDA has not set a standard for lead in cosmetics.
1–7, adapted from HUD.[36]
8, from FDA Guidance for Industry, November 2006.

RESIDENTIAL STANDARDS FOR LEAD IN PAINT, DUST, AND WATER

Lead in Paint and Dust

Under section 403 of Title X, the US Congress mandated the EPA to promulgate residential health-based lead standards that are designed to protect children from lead toxicity.[37] Standards are necessary to identify lead hazards before a child is unduly exposed and to identify the source of lead exposure for children who have blood lead concentrations ≥5 μg/dL (≥50 ppb).[31] Unless performed carefully, attempts to reduce lead exposure, such as abatement, repair, or renovation, can result in increased contamination and elevation in a child's blood lead concentration.[43–45] Dust clearance tests, which involve collecting dust from floors or windows of a home by using a lead-free material that resembles a baby wipe, should be conducted after extensive repair, renovation, or abatement of older housing units to determine whether the housing intervention was sufficient to protect children from lead hazards, especially in housing units built before 1960.[27,34] Property owners are required to disclose possible presence of lead-based paint in properties built before 1978 and are required to provide the blue pamphlet from the EPA, HUD, and Consumer Product Safety Commission titled "Protect Your Family From Lead in Your Home" at the time of rental or sale.

Most existing lead standards fail to protect children (Table 4). In 1978, the CPSC set the maximum paint lead concentration at 0.06% (600 ppm), because there was evidence that paint could be manufactured with this lower level of contamination.[3] Similarly, the EPA's action level of 15 ppb of lead in water, which is used to regulate water systems in the United States, is routinely (but erroneously) used as a health-based standard; it was not intended as a health-based standard, nor does it adequately protect children or pregnant women from adverse effects of lead exposure.[5,31] In 1988, the HUD established a postabatement floor dust standard of 200 μg/ft^2 because there was evidence that it was feasible to attain, not because it was demonstrated to be safe or protective. In 2001, the EPA promulgated residential lead standards of 40 μg/ft^2 for floors and 250 μg/ft^2 for window sills.[37] Unfortunately, these standards, which failed to protect children from having a blood lead concentration ≥10 μg/dL (≥100 ppb) when they were first promulgated, dictate the levels of lead contamination considered "normal" or "low," and they provide an illusion of safety.[38,40] At a floor standard of 40 μg/ft^2, the current EPA standard for floors, 50% of children were estimated to have a blood lead concentration ≥5 μg/dL (≥50 ppb); 5% of children have a blood lead concentration ≥5 μg/dL (≥50 ppb) at a median floor dust lead level of 1.5 μg/ft^2 (Fig 4).[42]

Scraping, sanding, or construction during painting, repair, renovation, or abatement of older housing can result in lead contamination of a child's environment.[41,43–45,54] In a controlled study of children with baseline blood lead concentrations

<22 μg/dL (<220 ppb), Aschengrau et al[41] reported a 6.5-μg/dL (65-ppb) *increase* in blood lead concentrations for children whose homes had undergone paint abatement. Clark et al[44] reported that 6-month-old infants were 11 times more likely to have a ≥5 μg/dL (≥50 ppb) increase in blood lead concentrations after abatement compared with older children. Spanier et al[45] reported that routine renovation of older housing was associated with a 12% higher mean blood lead concentration. These studies indicate that the levels of lead-contaminated dust generated by lead hazard control work or housing renovations can result in excessive lead exposure and absorption for children unless there is sufficient cleanup and clearance testing after the work is completed. The HUD has published technical guidelines and regulations for workers involved in lead-based paint abatement or remediation of housing.[36]

In 1992, the US Congress mandated the EPA to promulgate regulations to protect children from lead exposure resulting from housing repairs and renovation.[37] In 2011, the EPA finalized recommendations for the Lead Renovation, Repair and Painting Rule.[54] Unfortunately, the EPA failed to recommend the validated wipe-sampling method for clearance testing. Instead, it used an unvalidated cloth test, which should not be confused with the validated wipe sampling test. The white cloth test assumes that if dust is visible on a white cloth (ie, the "white glove test"), it contains a lead hazard; conversely, if there is no visible dust, it does not contain a lead hazard.[54] Although it would be valuable to have a quick test to identify the presence of a lead hazard, the white cloth test is not a validated tool and is not a reliable way to quantify the presence of a lead hazard.

Lead hazard control work can result in sizable reductions in the magnitude of dust lead loading when proper procedures are followed and cleanup and postwork clearance testing are performed. In 1 study, dust lead levels (measured as micrograms of lead per area) immediately after professional abatement were 8.5 μg/ft^2, 8.0 μg/ft^2, and 21 μg/ft^2 for floors, interior window sills, and window troughs, respectively, representing reductions of more than 80% compared with preabatement levels.[55] In another study of more than 2600 housing units, postabatement dust lead levels were 12 μg/ft^2, 31 μg/ft^2, and 32 μg/ft^2 for floors, window sills and window troughs, respectively.[56] These levels were achieved with dust clearance testing set at 100 μg/ft^2 or higher, but floor dust lead levels below 5 μg/ft^2 can be achieved by following a specific protocol. In 1 unpublished study of more than 160 housing units built before 1978, 1 group found that it is possible to routinely meet floor lead levels below 5 μg/ft^2 after housing renovations costing an average of $5600 (B. Lanphear, MD, MPH, Simon Fraser University, unpublished data).

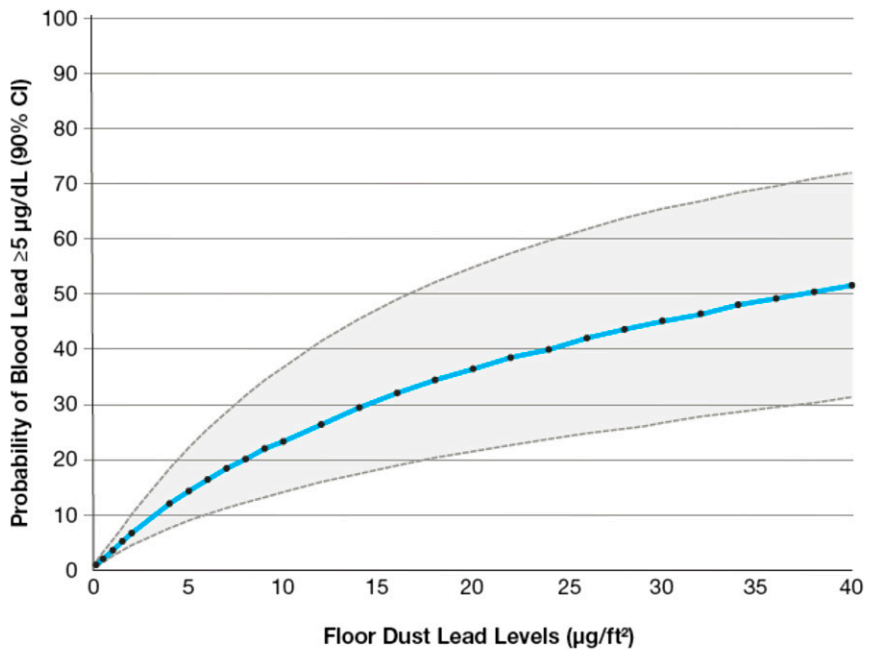

FIGURE 4
Estimated probability of blood lead concentrations ≥5 μg/dL for children living in pre-1978 housing by floor dust lead level, NHANES, 1999–2004. CI, confidence interval. Adapted from Dixon et al.[42]

Lead in Water

The primary sources of lead in water, which can be dissolved or particulate, consist of lead service lines, lead solder, and brass fittings that contain high concentrations of lead.[5] Plumbing installed before 1986, the year a federal ban was issued on using lead pipe and lead solder and a maximum lead content of 8% by weight for brass plumbing was established, is more likely to contain higher concentrations of lead.[5] Lead services lines that are being replaced, are undergoing maintenance, or are damaged can release particles of lead that can be ingested.[57] Partial service line replacement, which is sometimes performed to minimize the cost of service line repair by water authorities, fails to reduce lead exposure.[57] Proper maintenance and ultimately full replacement of water service lines will be necessary to eliminate lead intake from water, but it must be performed with proper precautions. In the interim, water filters that are certified by the National Sanitation Foundation for lead removal can effectively reduce water lead concentrations. The EPA recommends running the cold water of residential units for up to 2 minutes to flush the lead leached from pipes out of the plumbing system, but flushing is useful only in housing units without lead service lines.[58–61] In housing units without lead service lines, and where the primary source is brass fittings or lead-soldered joints, a 1-minute flush may be sufficient, depending on the length of plumbing; for housing units with lead service lines, flushing may *increase* lead exposure, again depending on the length of the lead service lines.[58–61]

Drinking fountains in older schools can be an important source of lead exposure.[5] Unfortunately, there are no regulations for evaluating lead contamination of school drinking fountains in most states.

Implementation of the Lead and Copper Rule has significantly reduced tap water lead levels. In 1991, the US EPA set an action level for lead in water of 15 μg/L or (15 ppb).[6] Communities in which >10% of water samples taken from various taps throughout the system exceed 15 ppb are considered to be out of compliance and are required by the EPA to take action to reduce lead levels using corrosion control methods or replacement of lead service lines. The action level is used as an administrative tool to evaluate community-level exposure; it is not a health-based standard. The maximum contaminant level goal, the value the EPA deems acceptable for health, is 0.

Testing Asymptomatic Children for Elevated Blood Lead Concentrations

In the primary care office, primary prevention begins with education and counseling. Ideally, environmental assessments, such as screening older housing units, occurs before a child is born so that parents can identify and hire trained workers to abate environmental lead exposure hazards.[12] It is especially important to conduct an environmental assessment for lead if a family resides in a housing unit built before 1960 that has undergone recent renovation, repair, or painting or if it is poorly maintained.

Screening questionnaires frequently used in the primary care setting fail to identify children who have elevated blood lead concentrations,[62] but they may be useful as a tool to identify lead hazards in children who have a blood lead concentration ≥5 μg/dL (≥50 ppb). In addition, public health agencies often use other methods of targeting children who should be screened with a blood lead test on the basis of community and residential characteristics, such as older housing. Blood lead surveillance data can be used to identify cities, communities, or housing units at higher than typical risk for lead poisoning. Technologies using geographic information system–based analyses and surveillance from electronic medical records are important tools to identify at-risk children who should have their blood lead concentration measured.

In 1991, the CDC recommended universal blood lead testing for all children.[63] In 2005, the AAP recommended that states and cities formulate their own lead screening recommendations on the basis of local data because of the wide variation in lead exposure.[7] The AAP, consistent with the CDC, recommended universal screening of children's blood for lead if they lived in communities with more than 27% of housing built before 1950 or a prevalence of blood lead concentrations ≥10 μg/dL in children 12 to 36 months old of 12% or greater.[7,12,63,64] Screening is not efficient after 36 months of age unless specific high-risk factors are identified; the likelihood of a child having a blood lead concentration >10 μg/dL after 36 months of age is low.[65] These recommendations now need to be updated to conform to with our new understanding of lead toxicity.[11,12]

A detailed evaluation and follow-up of children who have blood lead concentrations <10 μg/dL (<100 ppb) is now indicated. Current federal regulations for clinical laboratory testing through the Clinical Laboratory Improvement Amendments of 1988[66] permit an allowable laboratory error in blood lead proficiency testing programs of ±4 μg/dL (±40 ppb) for blood lead concentrations ≤20 μg/dL (≤200 ppb). This range of error can result in children being misclassified and cause additional anxiety or false comfort when blood lead concentrations within the margin of error erroneously are interpreted as going up or down. The majority of laboratories analyzing blood lead reference materials routinely achieved laboratory error of ±2 μg/dL (±20 ppb) at blood lead concentrations ≤20 μg/dL (≤200 ppb).[67] Changing the allowable laboratory error to tighter performance requirements, such as ±2 μg/dL (±20 ppb), could decrease misclassification of children and lead to better allocation of health care resources.

Case Management of Children With a Blood Lead Concentration at or Above Reference Value

The AAP is adopting the current reference value of ≥5 μg/dL (≥50 ppb) for case management.[12] The CDC recommended that the 97.5th percentile of blood lead concentrations derived from the combination of the 2 most recent cycles of NHANES data be used to identify children who have unacceptably high exposure and to set public health goals.[12] The CDC will reconsider the reference value for children's blood lead concentrations every 4 years.[12]

After confirmatory testing, it is important to monitor children who have blood lead concentrations

TABLE 5 AAP Recommendations on Management of Childhood Lead Exposure and Poisoning

Lead Level	Recommendation
<5 μg/dL (<50 ppb)	1. Review laboratory results with family. For reference, the geometric mean blood lead concentration for US children 1–5 y old is <2 μg/dL (<20 ppb); 2.5% have a blood lead concentration ≥5 μg/dL (≥50 ppb). 2. Repeat the blood lead concentration in 6–12 mo if the child is at high risk for lead exposure or if risk profile increases. Follow all local and state lead screening recommendations. 3. For children initially screened before 12 mo of age, consider retesting in 3–6 mo for children at high risk; lead exposure may increase as mobility increases. 4. Perform routine assessment of nutrition and physical and mental development and assess risk factors for iron deficiency. 5. Provide anticipatory guidance about common sources of environmental lead exposure: paint in homes or child care facilities built before 1960, soil near roadways, take-home exposures related to adult occupations, and imported spices, cosmetics, folk remedies, and cookware.
5–14 μg/dL (50–140 ppb)	1. Perform steps as described above for blood lead concentrations <5 μg/dL (<50 ppb). 2. Retest venous blood lead concentration within 1–3 mo to verify that the lead concentration is not rising. If it is stable or decreasing, retest the blood lead concentration in 3 mo. Refer patient to local health authorities if such resources are available. Most states require elevated blood lead concentrations be reported to the state health department. Contact the CDC at 800-CDC-INFO (800-232-4636) or www.cdc.gov/nceh/lead or the National Lead Information Center at 800-424-LEAD (5323) for resources regarding lead poisoning prevention and local childhood lead poisoning prevention programs. 3. Take a careful environmental history to identify potential sources of exposures (see #5 above) and provide preliminary advice about reducing or eliminating exposures. Take care to consider other children who may be exposed. 4. Provide nutritional counseling related to calcium and iron. Encourage the consumption of iron-enriched foods (eg, cereals, meats). Encourage families to sign up for the Special Supplemental Nutrition Program for Women, Infants, and Children, if eligible. 5. Screen for iron sufficiency with adequate laboratory testing (complete blood cell count, ferritin, C-reactive protein) and provide treatment per AAP guidelines. Consider starting a multivitamin with iron. 6. Perform structured developmental screening evaluations at child health maintenance visits, because lead's effect on development may manifest over years.
15–44 μg/dL (150–440 ppb)	1. Perform steps as described above for blood lead concentrations 5–14 μg/dL (50–140 ppb). 2. Confirm the blood lead concentration with repeat venous sample within 1–4 wk. 3. Abdominal radiography should be considered for children who have a history of pica for paint chips or excessive mouthing behaviors. Gut decontamination may be considered if leaded foreign bodies are visualized on radiography. Any treatment of blood lead concentrations in this range should be provided in consultation with an expert. Contact local pediatric environmental health specialty unit (www.pehsu.net or 888-347-2632) or local or regional Poison Control Center (www.aapcc.org or 800-222-1222) for guidance.
>44 μg/dL (>440 ppb)	1. Follow guidance for blood lead level 15–44 μg/dL (150–440 ppb) as listed above. 2. Confirm the blood lead concentration with repeat venous lead level within 48 h. 3. Consider hospitalization or chelation therapy (managed with the assistance of an experienced provider). Safety of the home or child care facility with respect to lead hazards, isolation of the lead source, family social situation, and chronicity of the exposure are factors that may influence management. Contact your regional pediatric environmental health specialty unit or Poison Control Center or the CDC for assistance.

Modified from Pediatric Environmental Health Specialty Unit. Medical Management of Childhood Lead Exposure and Poisoning (http://www.pehsu.net/_Library/facts/medical-mgmnt-childhood-lead-exposure-June-2013.pdf).

≥5 μg/dL (≥50 ppb). The pediatrician should inform the local or state health department and request an inspection of the child's house to identify and remediate any lead hazards (Table 4). Screening children for iron deficiency and insufficient dietary calcium intake is also important.[7] A detailed description of the diagnosis and treatment of significant lead toxicity (ie, ≥45 μg/dL [≥450 ppb]) is beyond the scope of this policy statement, but guidance is available in an earlier publication of the AAP[7] and through the Pediatric Environmental Health Specialty Units Web site (www.pehsu.net) (Table 5). Children who have elevated blood lead concentrations need to be monitored until environmental investigations and remediation are complete and blood lead concentrations decline.[12]

The AAP recognizes that environmental investigations will typically be conducted by local or state health or environmental departments to identify sources of lead exposure for a child who has a blood lead concentration ≥5 μg/dL (≥50 ppb). In many cases, however, the pediatrician can provide clues about possible sources of lead intake by taking a careful history.

Case management involves a thorough investigation of potential sources of lead poisoning in a child's environment, including paint, house dust, water, and soil. Case management also includes a questionnaire and visual inspection for other potential sources of lead exposure, including antique furniture, toys, ethnic folk remedies, and consumer products such as imported food, cosmetics, and ceramics.[12,50–52] It can include testing deteriorated paint on furniture, such as a crib, taking dust samples from child care settings or a family member's house, and taking soil samples from a child's play area.

SUMMARY AND RECOMMENDATIONS

Lead toxicity results in substantial, population-level effects on children's intellectual abilities, academic abilities, problem behaviors, and birth weight. Pediatricians may be well equipped to advocate for more stringent regulations to reduce sources of lead exposure and prevent childhood lead exposure. The AAP recognizes the importance of a variety of educational, enforcement, and environmental actions to reduce the number of children who are exposed to lead hazards and concur with recent detailed recommendations for prioritization of primary prevention of lead toxicity.[7,12,68–70] The AAP offers the following recommendations for government as well as pediatricians, other health care providers, and public health officials.

Recommendations for Government

1. The federal government should expand the resources currently offered by the HUD to local and state governments for lead hazard control work.
2. The federal government should provide both financial and nonfinancial resources and technical guidance through the CDC, the EPA, and the HUD to state and local public health agencies as well as environmental and housing agencies engaged in childhood lead poisoning prevention efforts.
3. The US EPA and HUD should review their protocols for identifying and mitigating residential lead hazards (eg, lead-based paint, dust, and soil) and lead-contaminated water from lead service lines or lead solder and revise downward the allowable levels of lead in house dust, soil, paint, and water to conform with the recognition that there are no safe levels of lead.
4. The federal government should resume and expand its vital role in providing federal public health leadership in childhood lead poisoning prevention work through the CDC. Allocation of additional resources would be necessary to accomplish this goal.
5. The Centers for Medicare & Medicaid Services, which is responsible for regulating clinical laboratory testing through the Clinical Laboratory Improvement Amendments of 1988,[69] should expeditiously revise current regulations for allowable laboratory error permitted in blood lead proficiency testing programs from ±4 μg/dL (±40 ppb) to ±2 μg/dL (±20 ppb) for blood lead concentrations ≤20 μg/dL (≤200 ppb).[12] In the future, when feasible, allowable laboratory error permitted in blood lead proficiency testing programs should be reduced even more, to ±1 μg/dL (±10 ppb) for blood lead concentrations ≤20 μg/dL (≤200 ppb).
6. The federal government should continue to conduct the NHANES and provide national data on trends in blood lead concentrations. These newer data should be used by the CDC to periodically formulate a new reference value and guide clinical and public health interventions.
7. The federal government should continue to regularly survey children and adolescents in the NHANES for ADHD and conduct disorder by using validated diagnostic surveys from the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* to examine the association of lower blood lead concentrations with these conditions.
8. Local or state governments, in consultation with pediatricians, should develop policies and regulations requiring the remediation of lead-contaminated housing and child care facilities, including the elimination of lead hazards during transfer of rental units or renovation or demolition of older housing.
9. State and local governments should collect, analyze, and publish blood lead test results performed in their jurisdictions and should regularly publish reports of age of housing and other risk factors for children having blood lead concentrations ≥5 μg/dL (≥50 ppb). These reports should be readily available to pediatricians, health care providers, and the public.
10. Federal, state, and local governments should provide resources for environmental evaluations and case management of children who have blood lead concentrations ≥5 μg/dL (≥50 ppb), in conjunction with the child's primary care provider.
11. State and local governments should take steps to ensure that water fountains in schools do not exceed water lead concentrations of 1 ppb.

Recommendations for Pediatricians, Health Care Providers, and Public Health Officials

1. Pediatricians are in a unique position to work with public health officials to conduct surveys of blood lead concentrations among a randomly selected,

representative sample of children in their states or communities at regular intervals to identify trends in blood lead concentrations. These periodic surveys are especially important for children who live in highly contaminated communities, such as smelter communities or regions with a historically high prevalence of lead exposure.

2. Pediatricians, heath care providers, and public health officials should routinely recommend individual environmental assessments of older housing,[12] particularly if a family resides in a housing unit built before 1960 that has undergone recent renovation, repair, or painting or that has been poorly maintained.

3. Pediatricians and public health officials should advocate for the promulgation and enforcement of strict legal standards based on empirical data that regulate allowable levels of lead in air, water, soil, house dust, and consumer products. These standards should address the major sources of lead exposure, including industrial emissions, lead paint in older housing, lead-contaminated soil, water service lines, and consumer products.

4. Pediatricians should be familiar with collection and interpretation of reports of lead hazards found in house dust, soil, paint, and water, or they should be able to refer families to a pediatrician, health care provider, or specialist who is familiar with these tools.

5. Pediatricians, women's health care providers, and public health officials should be familiar with federal, state, local, and professional recommendations or requirements for screening children and pregnant women for lead poisoning.[12,68,69]

6. Pediatricians and other primary care providers should test asymptomatic children for elevated blood lead concentrations according to federal, local, and state requirements. Immigrant, refugee, and internationally adopted children also should be tested for blood lead concentrations when they arrive in the United States because of their increased risk.[71,72] Blood lead tests do not need to be duplicated, but the pediatrician or other primary care provider should attempt to verify that screening was performed elsewhere and determine the result before testing is deferred during the office visit.

7. Pediatricians and other primary care health providers should conduct targeted screening of children for elevated blood lead concentrations if they are 12 to 24 months of age and live in communities or census block groups with ≥25% of housing built before 1960 or a prevalence of children's blood lead concentrations ≥5 µg/dL (≥50 ppb) of ≥5%.

8. Pediatricians and other primary care providers should test children for elevated blood lead concentrations if they live in or visit a home or child care facility with an identified lead hazard or a home built before 1960 that is in poor repair or was renovated in the past 6 months.[7,12]

9. Pediatricians and primary care providers should work with their federal, state, and local governments to ensure that a comprehensive environmental inspection is conducted in the housing units of children who have blood lead concentrations ≥5 µg/dL (≥50 ppb) and that they receive appropriate case management.

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ABBREVIATIONS

AAP: American Academy of Pediatrics
ADHD: attention-deficit/hyperactivity disorder
CDC: Centers for Disease Control and Prevention
CPSC: Consumer Product Safety Commission
EPA: Environmental Protection Agency
FDA: US Food and Drug Administration
HUD: Department of Housing and Urban Development
NHANES: National Health and Nutrition Examination Survey
XRF: x-ray fluorescence

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Prevention of Childhood Lead Toxicity

COUNCIL ON ENVIRONMENTAL HEALTH

Pediatrics 2016;138;
DOI: 10.1542/peds.2016-1493 originally published online June 20, 2016;

Flint, MI Filter Challenge Assessment

Attachment: ATSDR Letter to U.S. EPA Administrator
June 22, 2016
Prepared by U.S. EPA in coordination with the Unified Command Group

MDHHS Michigan Department of Health & Human Services
Genesee County Health Department Your Health. Our Work.

Filter Challenge Assessment Summary

Executive Summary:

In January, 2016, the U.S. Environmental Protection Agency (EPA) initiated an assessment program to evaluate the efficacy of Brita and Pur Brand filters that are NSF certified to remove lead. These filters were distributed to residents who use the Flint Drinking Water system for consumption. The Unified Command Group (UCG) was specifically concerned about levels of lead in excess of 150 ug/L (or parts-per-billion, ppb) that may be entering these filters.

During its initial assessment, EPA collected samples of both filtered and unfiltered water from over 200 taps. Analysis revealed that these filters, when installed and operating properly, effectively reduce lead. Additionally, the maximum and average concentration of lead were exceptionally low, with most data showing lead through the filters at levels too low to be detected. The average concentration of lead through filters was just under 0.3 ug/L. (Note: approximately 80% of all results were below the detection level for lead. To calculate the average, the method detection limit was used when there was no detection.)

In mid-April, EPA briefed the UCG and requested that the health agencies review the data summary and determine if the filtered water was safe for consumption for all populations. The Agency for Toxic Substances and Disease Registry (ATSDR) recommended additional sampling at locations of full lead service lines and/or at risk populations, targeting homes with a lead service line and confirmed residency of a child less than 6 years of age (based on the Michigan Medicaid database) and homes with the highest Michigan Department of Environmental Quality (MDEQ) lead water results. ATSDR provided locations for EPA to collect samples at least 50 additional locations. The resulting data from this expanded sampling was nearly identical to the previous assessment. Lead levels in filtered water averaged less than 0.3 ug/L and all sample results were well below EPA's action level.

On June 22, 2016, ATSDR provided a summary of their review of EPA's data (attached). Their conclusion is that the Brita and Pur filters distributed in Flint are effective in consistently reducing the lead in tap water, in most cases to undetectable levels, and in all cases to levels that would not result in a significant increase in overall lead exposure. ATSDR also reported that the filter test data supports the conclusion that the use of filtered water would protect all populations, including pregnant women and children, from exposure to lead-contaminated water.

Background:

In January, 2016, as sample data from MDEQ's Residential Sampling Program was being reviewed, it became apparent that concentrations of lead in a small number of samples (less than 1%) were greater that 150 ug/L. The NSF certified filters (Brita and Pur) were rated to remove lead to 150 ug/L or less. During initial discussions with field staff and subject matter experts, it was largely believed that these filters were likely effective at levels much higher than 150 ug/L based on (1) a study conducted by Virginia Tech University (Deshommes, 2010) and (2) the belief that the high level lead was due to particles containing high lead content as opposed to soluble lead (these particles are believed to be effectively trapped by the filters). However, out of an abundance of caution, the UCG advised a number of precautions until the filters could be further evaluated. EPA immediately proposed a "Filter Grab" sampling procedure to evaluate the filters at the tap in the City of Flint water distribution system.

Methodology:

The objective of the Filter Grab assessment was to determine if lead contamination in water in the Flint Distribution System, specifically in residential homes, is effectively removed or reduced to safe levels.

Sample locations were established by three methods:

1. Locations where MDEQ residential results indicated concentrations >150 ug/L (coded FG)
2. Locations where residents requested EPA to sample at their homes (coded FGW & FGC)
3. Locations where CDC/ATSDR requested samples at locations of full lead service lines and/or at risk populations (coded FH)

Samples were collected in accordance with the Quality Assurance Project Plan (QAPP), as described below:

Three samples are taken at the kitchen faucet and analyzed for total metals including lead:

1. Filtered Water, Existing Faucet Filter - One grab sample was collected through the existing water filter (if present). The type (brand) of the filter, status of the filter indicator, and available information from the resident regarding the time since the filter or cartridge was installed are all noted.
2. Unfiltered Water- The filter was removed, and an unfiltered water sample was collected as the first grab sample following removal of the filter and/or aerator. No cleaning or flushing was conducted prior to the unfiltered water grab sampling.
3. Filtered Water, New Faucet Filter- Following the collection of the unfiltered sample, a new filter or new filter cartridge was installed, and the water was allowed to run through the new filter for approximately two minutes. Following installation and flushing of the new filter or replacement filter cartridge, a grab sample was collected through the newly installed filter.

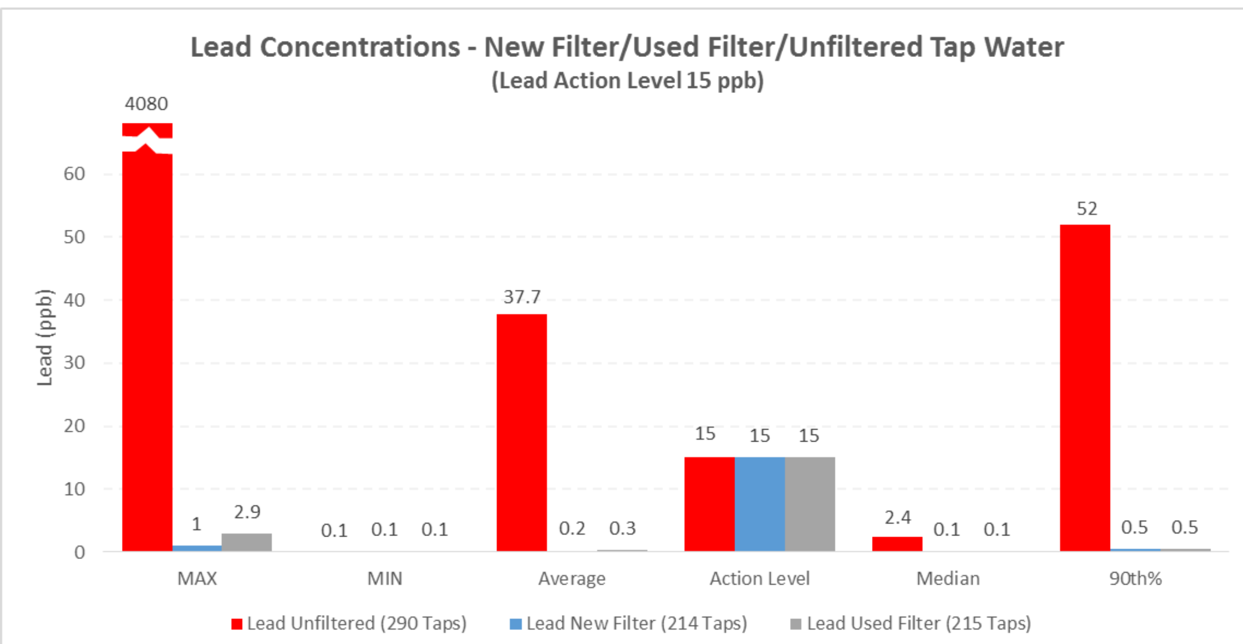
For each grab water sample, one 1,000-mL HDPE bottle was collected and field preserved (HNO3 to pH<2) for analysis of total metals including lead. Samples were then packed and shipped to the selected EPA laboratory or the PHILIS Contract Laboratory, for analysis as described in Appendix J of the QAPP.

If an expired filter was observed, based on filter indicator light or other indicators, a new filter was installed and flushed per field procedures described above. In those cases, an additional sample was collected from the expired filter.

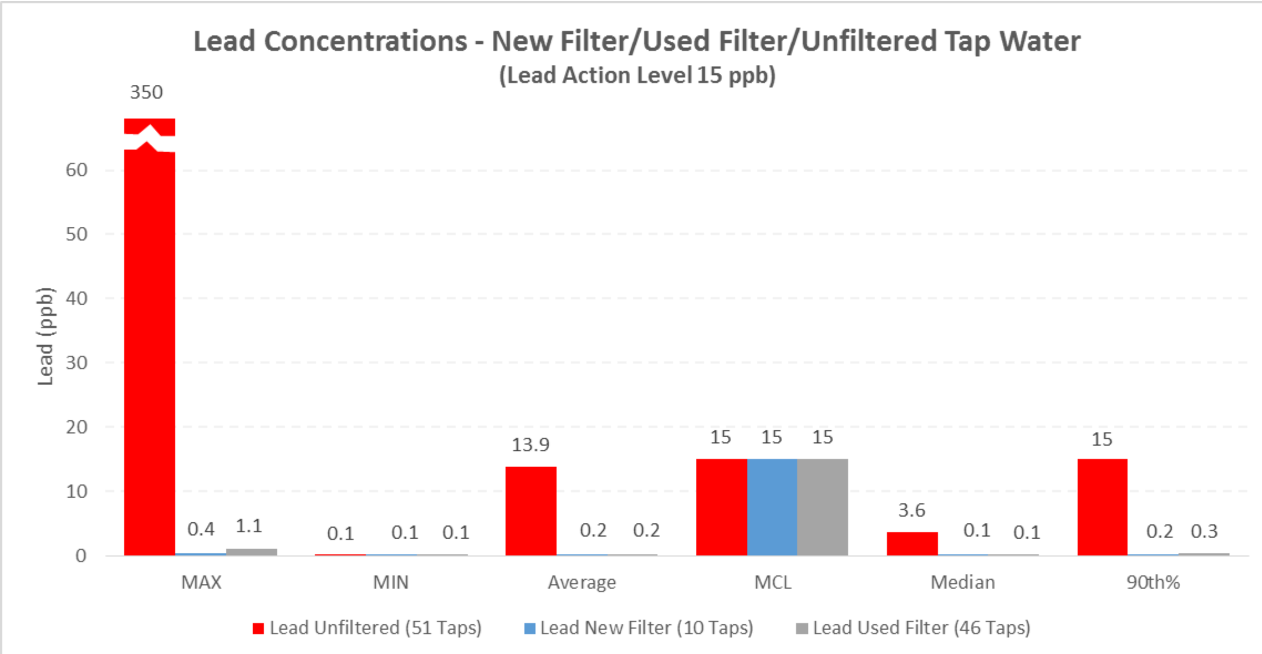
Results:

Raw data can be found on EPA's project web site: www.epa.gov/flint. The following tables and graphs summaries EPA's data for both filtered and unfiltered water.

Filter Grab (FG, FGC & FGW) Sample Results



*Health Request Filter Grab Sample Results**



*FH samples only included existing filter samples and unfiltered samples (no 'new' filter sample was collected unless the filter was already expired (in those cases, new and used filter samples were collected). In addition, in FH samples, the unfiltered portion was collect via the by-pass valve as opposed to removing the entire filter.

Conclusions:

EPA and ATSDR evaluated the resulting data and reported to the UCG. The following conclusions were drawn:

1) The field data collected by EPA indicate that the use of distributed Brita and Pur point-of-use faucet filters, when installed and maintained properly, are effective at removing lead. The resulting average concentration of filtered water is less than 1 ppb.

2) ATSDR reports that consuming filtered water at these lead levels would not cause significantly increased blood lead levels.

3) ATSDR continues to support the multi-agency recommendation to use filtered water for cooking and drinking. The filter test data supports the conclusion that the use of filtered water would protect all populations, including pregnant women and children, from exposure to lead-contaminated water (see attached letter from Patrick N. Breysse to EPA Administrator McCarthy).

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Centers for Disease Control
and Prevention (CDC)
Atlanta GA 30329-4027

June 22, 2016

Dear Administrator McCarthy:

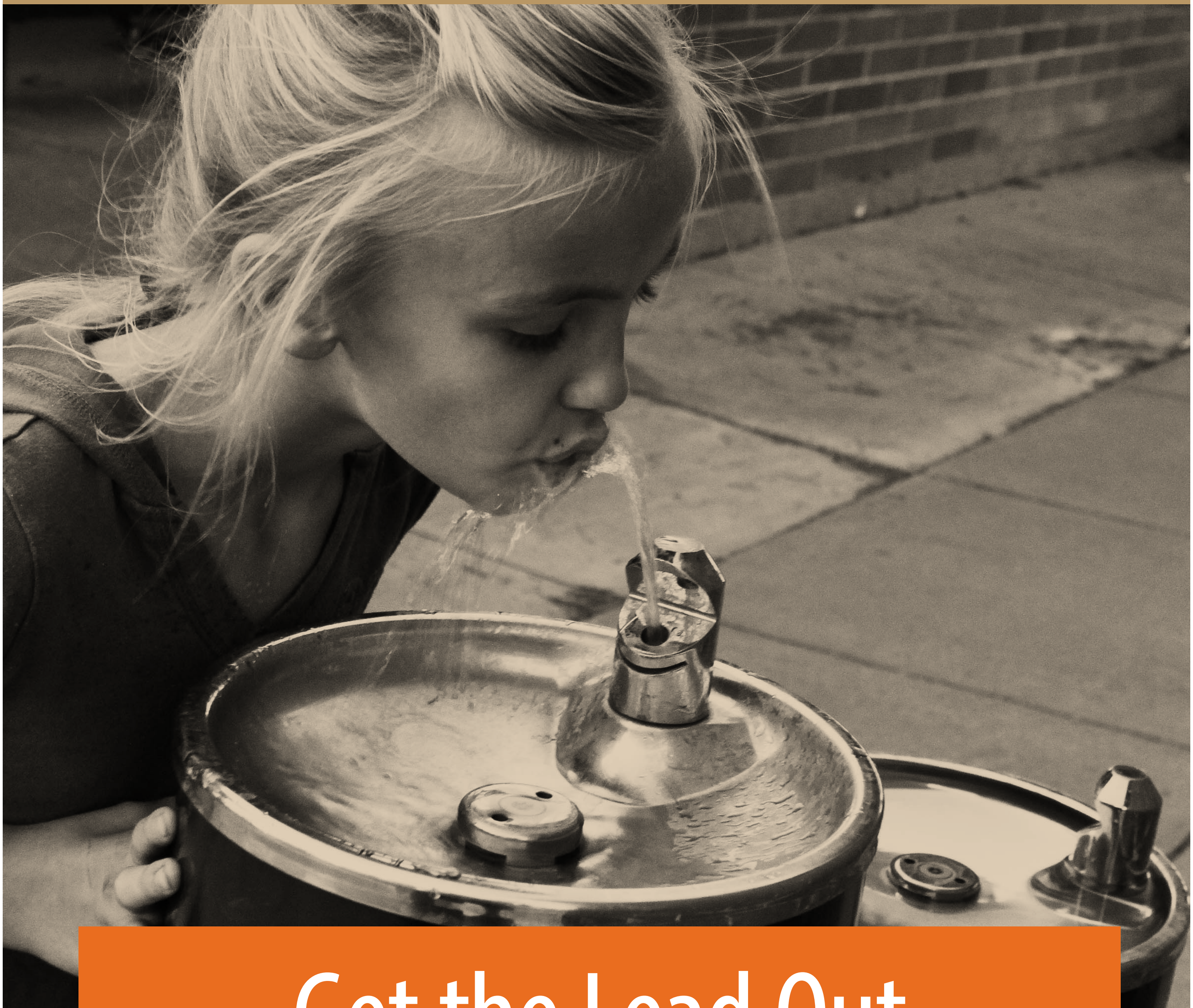
The Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR) appreciates the close working relationship established in the past with the U.S. Environmental Protection Agency, which has been strengthened as we work on objectives for the health and safety of the citizens of Flint, Michigan.

EPA conducted additional water filter tests in the households of Flint residents that included pregnant women, nursing and bottle-fed children, and children under six. CDC requested this additional sampling to ensure that those Flint residents most vulnerable to health impacts of potential lead exposure were adequately represented in water testing. We appreciate EPA's collaboration in conducting these tests in addition to EPA's previously collected samples.

After reviewing the findings of all of the water filter tests taken, including those done for more vulnerable residents, CDC concurs with EPA that when using an approved and properly installed and maintained water filter, it is safe for residents of Flint to drink filtered tap water, including pregnant women, nursing and bottle-fed children, and children under six.

Sincerely,

Patrick N. Breysse, PhD, CIH
Director
National Center for Environmental Health
Agency for Toxic Substances and Disease Registry
Centers for Disease Control and Prevention



Get the Lead Out

Ensuring Safe Drinking Water for Our Children at School

ENVIRONMENT AMERICA
RESEARCH & POLICY CENTER

U.S. PIRG
Education Fund

Get the Lead Out

Ensuring Safe Drinking Water for Our Children at School

Written by:

John Rumpler and Christina Schlegel

Environment America Research & Policy Center

February 2017

Acknowledgements

Environment America Research & Policy Center and U.S. PIRG Education Fund thank Marc A. Edwards, PhD, Environmental Engineering at Virginia Tech; Yanna Lambrinidou, PhD, anthropologist at Virginia Tech Department of Science and Technology in Society; Professor David Bellinger, Harvard School of Public Health; Sylvia Broude, Executive Director of Toxics Action Center; Dr. Daniel Faber, Northeastern University; Tony Dutzik, senior policy analyst at Frontier Group; and Steven G. Gilbert, PhD, DABT for their review of this report. Thanks also to Dr. Faber and the students in his Environmental Sociology class at Northeastern for their research assistance.

The authors bear responsibility for any factual errors. The recommendations are those of Environment America Research & Policy Center. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

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Design: Meltzer Design

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Table of Contents

Executive Summary

Over the past two years, the tragedy of Flint, Michigan has stunned the nation. We watched the drinking water of an entire city become contaminated with lead. And now we know this toxic threat extends well beyond Flint to communities across the country. In fact, test results now show that lead is even contaminating drinking water in ***schools and pre-schools*** — flowing from thousands of fountains and faucets where our kids drink water every day.

In all likelihood, the confirmed cases of lead in schools' water are just the tip of the iceberg. Most schools have at least some lead in their pipes, plumbing, or fixtures. And where there is lead, there is risk of contamination.

The health threat of lead in schools' water deserves immediate attention from state and local policymakers for two reasons. First, **lead is highly toxic and especially damaging to children** — impairing how they learn, grow, and behave. So, we ought to be particularly vigilant against this health threat at schools and pre-schools, where our children spend their days learning and playing.

Second, **current regulations are too weak to protect our children from lead-laden water at school.** Federal rules only apply to the roughly *ten percent* of schools and pre-schools that provide their own water. Moreover, these rules only require remediation when testing confirms lead concentrations in excess of 15 parts per billion, even though medical and public health experts are unanimous that there is no safe level of lead for our children. The error of this approach is compounded by the fact that testing, even when properly done, often fails to detect maximum lead levels in water coming out of the tap.

Unfortunately, so far most states are failing to protect children from lead in schools' drinking water. Our review of 16 states' laws and regulations finds:

- Several states have no requirements for schools and pre-schools to address the threat of lead in drinking water; and
- Of the few states with applicable laws, most follow flaws in the federal rules — relying on testing instead of prevention, and using standards that allow health-threatening levels of lead to persist in our children's water at school.

More specifically, when assessed in terms of protecting children from lead in water at school, these states' policies earned the following grades:

State	Grade
Washington, DC (proposed)	B
New York	C
New Jersey	C-
Illinois, Massachusetts	D
CA, CT, GA, FL, MD, ME, PA, OH, OR, TX, WA, WI	F

Given the high toxicity of lead to children, the most health-protective policy is simply to "get the lead out" of our schools and pre-schools. This involves proactively removing lead-bearing parts from schools' drinking water systems — from service lines to faucets and fixtures — and installing filters certified to remove lead at every tap used for drinking or cooking. Because all this prevention work will take time to complete, schools should also immediately begin regular and proper testing of all water outlets used for drinking or cooking and promptly remove from service those outlets where lead is detected. And schools should provide the public with easy access to all testing data and the status of remediation plans.

The promise and viability of this "get the lead out" approach can be seen in municipal and voluntary programs across the country. Madison, Wisconsin and Lansing, Michigan have removed all lead service lines from homes, and New York City has replaced them at schools. Seattle has adopted a somewhat more protective standard for lead in water. And Washington, D.C. is considering an ordinance that would not only set the standard for lead at one part per billion for schools but also require installing certified filters at all outlets used for drinking or cooking in schools.

Recommendations

The science now makes clear that there is no safe level of lead exposure for our children. To ensure safe drinking water for our children, we need policies that will "get the lead out" at school and pre-school.

States and communities should:

- Proactively "get the lead out" of schools and early childhood programs by removing lead service lines, lead-bearing plumbing, fixtures, etc.
- Install and maintain filters certified to remove lead on taps and fountains used for cooking and drinking
- Adopt a 1 ppb standard for lead in schools' drinking water, consistent with recommendations of the American Academy of Pediatrics
- Require testing at all water outlets used for drinking or cooking at all schools annually, using protocols designed to capture worst-case lead exposure for children
- Immediately remove from service any faucet or fountain used for drinking or cooking where testing indicates lead in the water
- Disclose all available information about lead in water infrastructure, test results, and remediation plans/progress both onsite and online
- Provide funding to remove lead in schools' water infrastructure

The federal government should:

- Enforce and strengthen federal rules to protect drinking water from lead - e.g. the Lead and Copper Rule
- Propose major funding to help states and communities remove lead in water infrastructure — including lead service lines and plumbing/fixtures in schools
- Marshal the authority of all relevant federal agencies to protect public health from contamination of drinking water

And of course, we should fully protect all sources of drinking water from pollution.

Introduction

As our nation rushed through more than a century of unprecedented economic growth, we allowed several toxic health threats to become embedded into the fabric our lives. One of the more enduring and pervasive of these threats has been the use of lead. While the toxic nature of lead has been known for centuries, we allowed manufacturers to put it in our paint, plumbing, gasoline, and many other products.

For the past few decades, public health officials have been working to undo the damage. Banning lead in gasoline immediately removed a major source of toxic air pollution. Barring lead in paint stopped a major threat to children's health from becoming even worse, but we are still cleaning up the damage from millions of homes with lead paint, as well as related lead in dust and soil.

Yet until recently, few Americans paid as much attention to another pervasive pathway for this potent toxin: the delivery system that brings drinking water right to our faucets.

Over the past two years, many Americans have watched in horror and disbelief as an enormous tragedy unfolded in Flint, Michigan. Through a combination of appalling decisions and denials, an entire city had its water contaminated with high levels of lead. Between 6,000 and 12,000 children were exposed to lead in Flint.[1] In addition to acute symptoms and other illnesses, by one estimate, these children will lose 18,000 future healthy years combined.[2]

While Flint is an extreme case, it is hardly alone. In fact, thousands of communities across the country have lead in their drinking water. A review of data by USA Today found that nearly 2,000 water systems across the 50 states had levels of lead in their water in excess of U.S. Environmental Protection Agency (EPA) standards over four years.[3] And the contamination is likely even more widespread. More than 18 million people get their drinking water from systems that violated federal rules for lead in 2015 alone, according to a review of data from EPA's Safe Drinking Water Information System by researchers at the Natural Resources Defense Council.[4]

And now we know that lead is even contaminating the water at many of our schools and pre-schools — the places our children go each day to learn and play.

Lead in Schools' Water: A Threat to Children's Health

"Anything above zero is harmful. Just like crack cocaine and heroin, there's no safe amount."[5]

—Ron Saff, MD, who coordinated lead tests at Florida schools

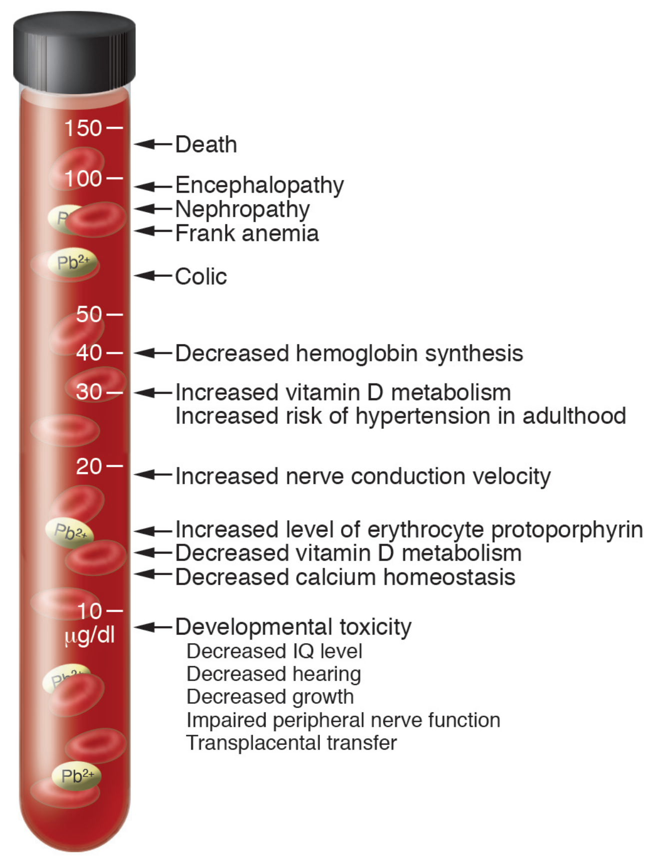
Lead is Harmful to Children — Even at Low Levels

Lead is a potent neurotoxin. It is particularly damaging to children for several reasons. Children absorb as much as 90 percent more lead into their bodies than adults. Once ingested, lead flows from the blood to the brain, kidneys, and bones. Yet children's organs and bones are immature and more vulnerable than adults'; they also have an incomplete blood-brain barrier.[6]

"We see learning difficulties, hyperactivity, developmental delays," said Marcie Billings, a pediatrician with Mayo Clinic in Rochester, Minn. "Any damage is irreversible."[7]

We have known for some time that high levels of lead can cause severe health impacts — including anemia, kidney disease, abnormal brain function and even death. (See Figure 1)

Figure 1: Adverse Effects of Lead at Low Levels [8]



Yet the medical science now confirms that even *low levels of lead* can cause permanent damage to our children. According to EPA, "In children, low levels of [lead] exposure have been linked to damage to the central and peripheral nervous system, learning disabilities, shorter stature, impaired hearing, and impaired formation and function of blood cells."[9]

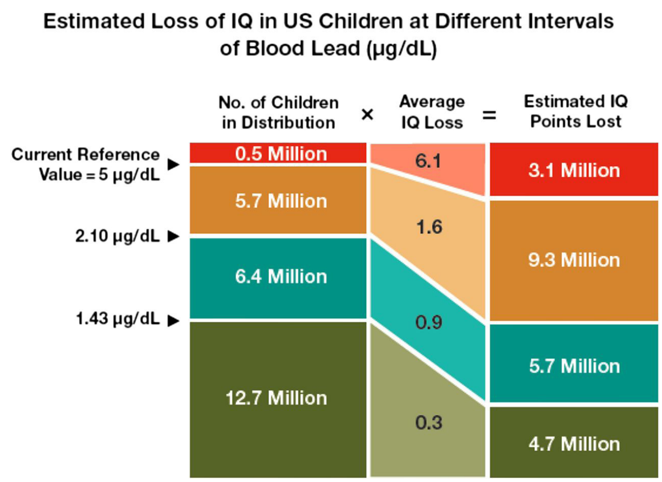
Of particular alarm for schools, the data now links low lead levels with long-term loss of learning in our children. For example, a Wisconsin study found that 3,757 fourth-graders with relatively low lead levels in their blood "scored significantly lower on reading and math tests than those without elevated blood-lead levels"- an adverse effect that persisted for these children seven to eight years later.[10]

Lead poses additional risks for children with other health conditions. For example, last year OPB.org ran a profile on nine-year old Abigail Harper in Portland, Oregon. Abigail has kidney disease, and high or prolonged exposure to lead can damage kidneys. Last school year, Abigail was hospitalized multiple times for extremely high blood pressure. Doctors were mystified, and ran a barrage of tests. During the same time, the Portland Public School District had begun testing lead levels at its schools. When Abigail's school (Creston) was tested, the results confirmed taps with elevated levels of lead. Doctors also found high levels of lead in Abigail's blood.[11]

Last summer, the American Academy of Pediatrics concluded that "[e]xtensive and compelling evidence now indicates that lead-associated cognitive deficits and behavioral problems can occur at blood lead concentrations below 5 µg/dL"(micrograms per cubic deciliter).[12]

One stunning fact underscores the danger at hand: more than 24 million children in America will lose IQ points due to low levels of lead. See Figure 2.

Figure 2: More Than *24 Million Children* Will Lose IQ Points Due to Low Levels of Lead[13]



Moreover, because lead flows from blood into the organs and bones within several weeks, its damage to a child's health will not always show up in blood tests. Lead is a persistent toxin, so once absorbed, the lead remains in the body.[14] So, a child who drinks water from a fountain at school that episodically contains a slug of lead might not show elevated blood-lead levels a month or two later. But the harm persists in her body.

In light of this alarming data, the conclusion of public health experts and agencies is now unanimous: *there is no safe level of lead for our children.*[15]

Lead is Contaminating Water at Our Schools

It's a scary thing. Nobody expects to have this in their schools. Who knows how big the problem actually is?"

— Nicole Rich, mother in Ithaca, N.Y.

Seven-year old Jamison Rich goes to Caroline Elementary School in Ithaca, New York. Like many kids his age, he often drinks from a water fountain at the school after running around in gym or at recess. Unfortunately, the water at Caroline Elementary was contaminated with lead, with tests showing lead concentrations at 100 parts per billion (ppb). As reported by USA Today, a blood test revealed that Jamison has twice the average level of lead in his blood.[17]

Unfortunately, Jamison is not alone. Even the limited available data shows drinking water laced with lead at thousands of faucets and fountains in schools and early childhood programs across the country, as seen in the map at Figure 3.

The threat of lead in schools' water affects not only big cites but also suburban and rural communities. Jamison Rich lives in Ithaca, New York. Elsewhere, tests have documented lead tainted water in schools in Cherry Hill, New Jersey[19], Yarmouth, Maine[20], several other school districts in upstate New York[21] and suburban communities in Illinois.[22]

Moreover, some tests are showing exceedingly high levels of lead. For example, one drinking water fountain at a Montessori school in Cleveland had 1,560 parts per billion.[23] A school in the Chicago suburbs had lead at 212 times the federal standard.[24] Leicester Memorial Elementary in Massachusetts had a tap that tested at 22,400 ppb.[25]

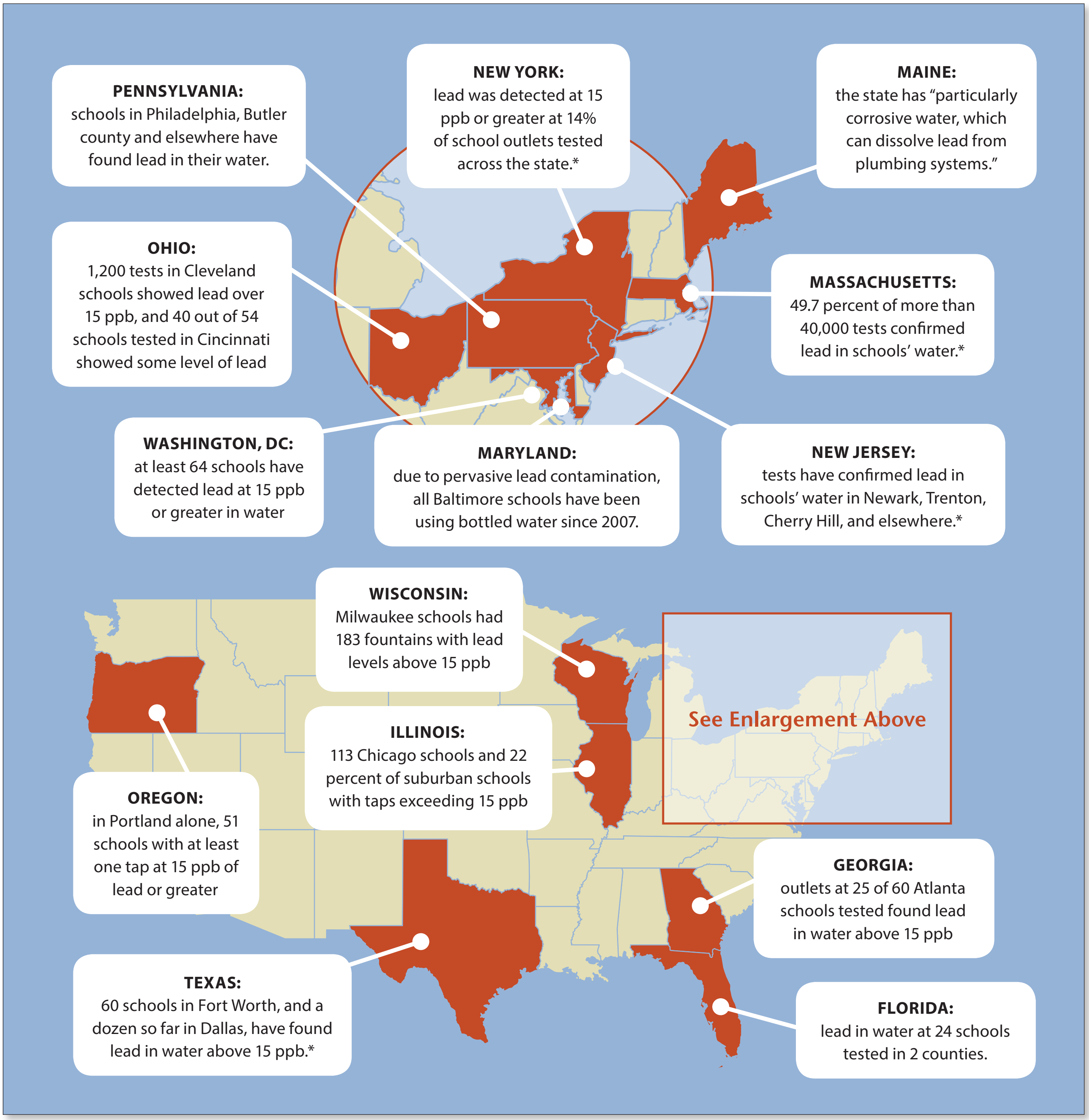
A More Pervasive Threat Than Confirmed by Testing

In all likelihood, these confirmed cases of lead in schools' water are just the tip of the iceberg. Most schools are not testing for lead at all. And even in those states and school districts that are testing, much of the available data is limited to test results showing concentrations in excess of 15 ppb (or a 20 ppb equivalent for schools, using a different sampling method). Yet we know that lead is toxic at very low levels.

Massachusetts is one of the few states to include test results confirming lead in concentrations below the 15 ppb level. Moreover, the data is extensive, with more than 40,000 test results reported by schools as of January 2017.

It is also shocking: *nearly half of the tests* (49.7 percent) conducted at Bay State schools so far have found some level of lead in the water, according to data published by the state as of January 6, 2017. The vast

Figure 3: Lead in Schools' Water Across the Country[18]



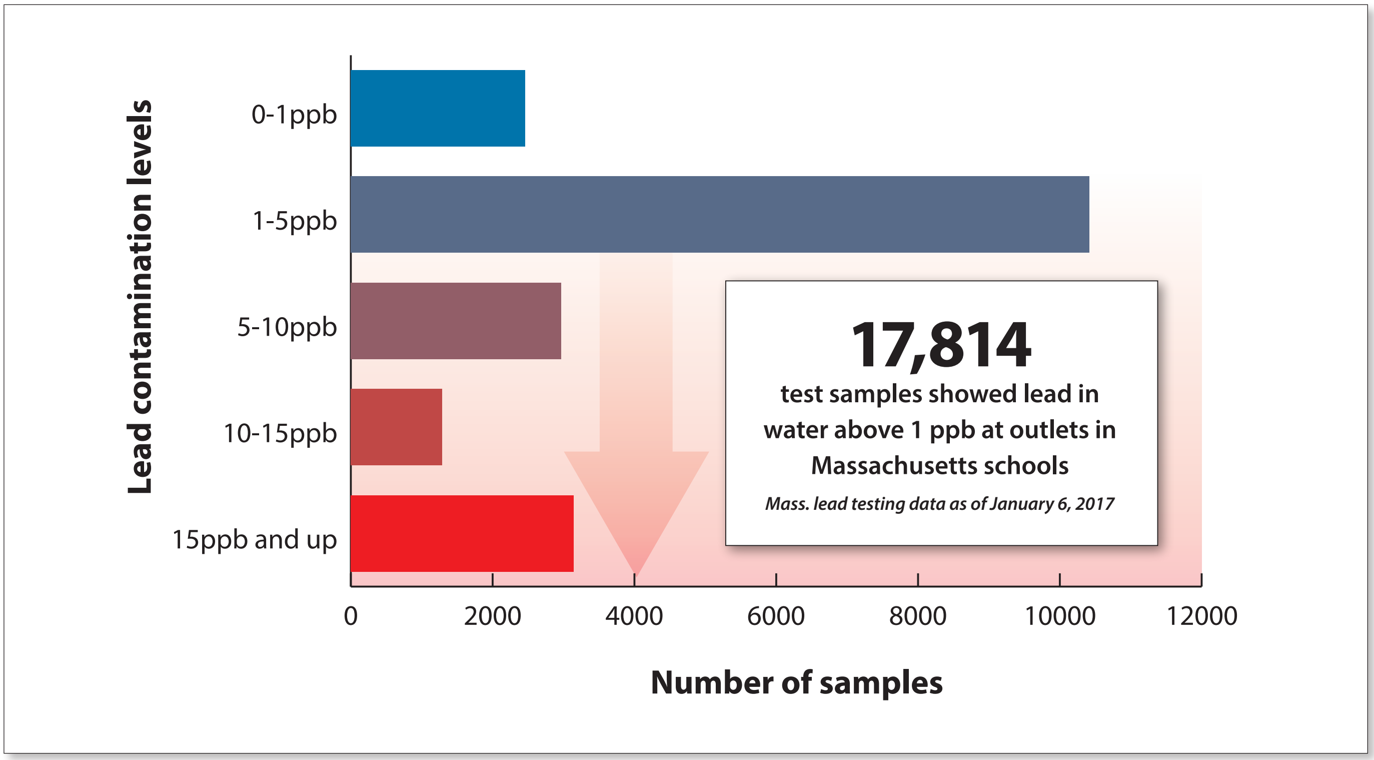
**more extensive test results are expected in these states in 2017.*

+ this map documents only where tests have confirmed lead in schools' drinking water; due to variability in conditions and test procedures, tests can fail to detect lead in schools' water systems.

++ for several of these states, data is only available from tests exceeding 15 ppb, though lead is hazardous at any level.

+++this map does not reflect where, whether, or how effectively some schools have sought to remediate lead contamination. But remediation is voluntary for most schools.

Figure 4: Massachusetts data shows lead in schools' water is pervasive threat[26]



majority of test results with some measurable level of lead were in concentrations greater than 1 part per billion. See Figure 4.

As demonstrated by the breakdown of Massachusetts' testing results in Figure 4, test results above 15 ppb only reveal a fraction of a much more pervasive lead contamination problem at our children's schools.

Finally, tests — even when properly done — can fail to capture lead exposure. Part of this conundrum is that corrosion and breaking off of lead particles from pipes is highly variable. Multiple water tests from one tap can result in highly variable lead levels between samples.[27] In a lead sampling study conducted in 2013, researchers concluded that a single sample from a water tap could not accurately reflect the level of lead flowing through the tap. In their test of 32 homes with lead service lines, samples from the same tap varied from below the lead action level to well above it. Not only that, but this level of variation was also true for most samples in the study.[28]

"This is like Russian roulette." Marc Edwards, on testing for lead in drinking water.[29]

In addition to the inherent variability in testing, some testing techniques mask lead risks even further. Chief among these is a practice known as pre-stagnation flushing, where taps are run for a certain number of minutes or even hours before test samples are drawn. This practice can artificially lower lead levels in test samples because it removes the water which was sitting stagnant in lead service lines or other lead-laden plumbing, and this extended period of time is when lead typically leaches into the water. With these considerations in mind, EPA is now recommending against the use of pre-stagnation flushing in testing water for lead.[30]

The recent experience of New York City provides a dramatic example of how pre-stagation flushing can fail to capture lead in schools' drinking water. In the summer of 2016, the city flushed the water in every school for two hours before sampling the water for lead. According to Dr. Yanna Lambrinidou from Virginia Tech, who has done extensive research on leaded drinking water, "Unless N.Y.C. schools flush every drinking water tap every evening for 2 hours routinely, their sampling technique is both unreliable and scientifically and morally indefensible." Dr. Marc Edwards, another nationally recognized lead expert at Virginia Tech, agrees. "The results should be thrown into the garbage, and the city should start over."[31] The city is now retesting taps at all its schools without the two-hour flushing step. With one third of the retesting complete as of early February, 2017, the results so far show *nine times* as many outlets with levels of lead above 15 ppb.[32]

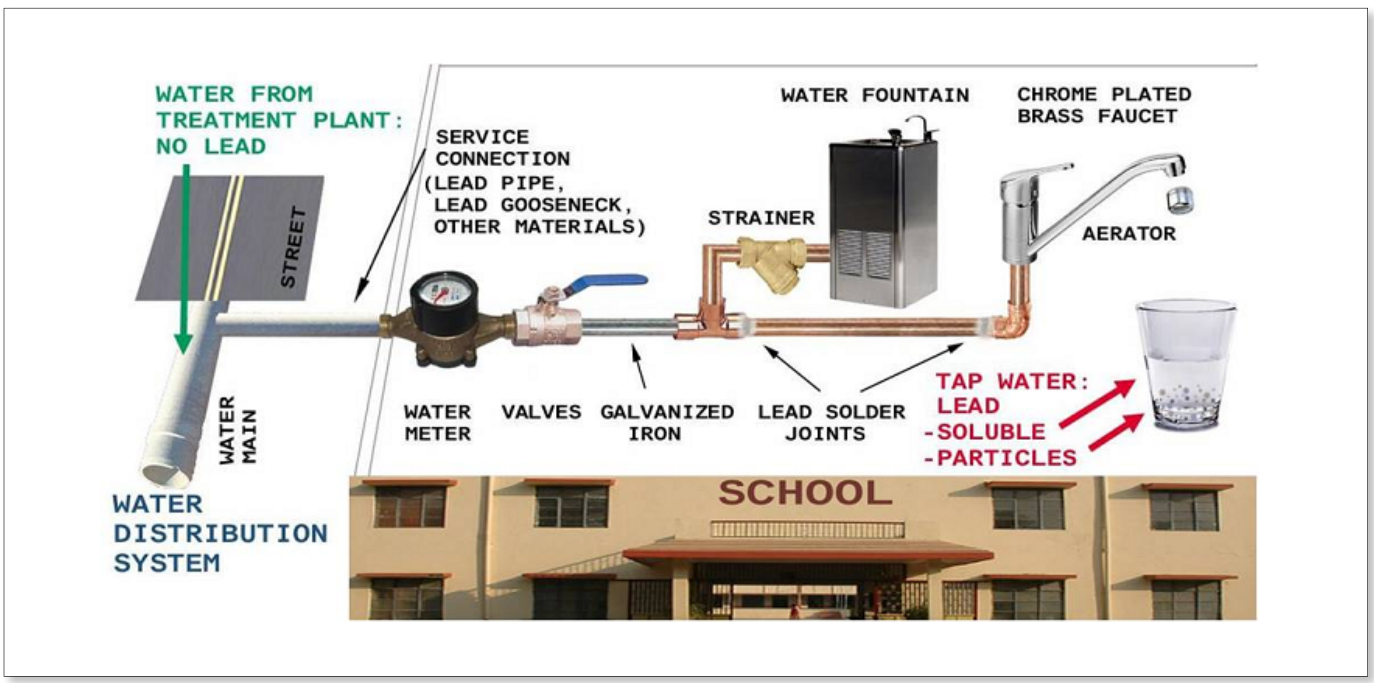
To be sure, the limited available test results are alarming enough, as they confirm the presence of a potent neurotoxin in thousands of faucets and fountains in schools across the country. But in truth, the scope of this lead-laden threat to our children's health is even wider.

How Lead Gets into Schools' Drinking Water

Most schools have at least some lead in their pipes, plumbing, or fixtures. And where there is lead, there is risk of contamination.

As with lead contamination elsewhere in our communities, the problem often starts with the pipe that brings water into a school or early childhood program — called the service line (or service connection). Where this service line is made of lead, it is a major source of water contamination.

In fact, *experts calculate that lead service lines account for 50-75 percent of lead found at the tap.*[33] In part, this is a function of the unparalleled surface area inside the service line where water is in direct contact with lead. In addition, the service lines are in closer proximity to disturbances from construction — especially repair work on water mains — which can dislodge lead particles into the water.[34] The role of lead service lines



Reproduced from Lead in School Water Delivery Systems. W.K. Kellogg Foundation, Managing Lead in Drinking Water at Schools and Early Childhood Education Facilities (February 2016), reproduced from Edwards, Marc and Simoni Triantafyllidou, Lead (Pb) in U.S. Drinking Water: School Case Studies (2009).

in water contamination is so strong that the Center for Disease Control was actually able to correlate them with elevated blood lead levels in Washington, D.C.[35]

While installing new lead service lines was halted decades ago, their toxic legacy is pervasive. According to a recent estimate by the American Water Works Association, over 6 million lead service lines remain in use across the nation. Though estimates vary, a conservative estimate is that the drinking water of 15 to 22 million people still passes through lead service lines.[36]

But if lead service lines are the beginning of the problem, they are not the end. Until 1988, many drinking water fountains or bubblers were manufactured with lead liners.[37] And until 2014, significant amounts of lead were allowed in new pipes, pipe fittings, plumbing fittings, and fixtures.[38] In other words, all but the most recently constructed schools and early childhood education programs are likely to have had lead in their water delivery systems.

A Lead Service Line[39] *Credit: EPA*

Data from several school districts underscores the danger from this source. For example, after brass fixtures were installed at 131 schools in Los Angeles, the school district found elevated lead levels.[40] And in Milwaukee, even after the school district stated that all lead service lines had been removed, tests showed 183 samples with lead in drinking water at levels greater than 15 parts per billion.[41]

Current Policies Do Not Ensure Lead-Free Drinking Water

Common sense suggests that the best way to keep drinking water free of lead is to stop using it in water delivery systems. Over time, national policies have embraced this preventative approach, at least with respect to new products. In 1986, new lead service lines were banned. In 1988, Congress passed the Lead Contamination and Control Act, which dramatically reduced the lead content of *new* pipes and plumbing to 8 percent. And then, as recently as 2014, the definition of "lead free" plumbing was ratcheted down to "not more than a weighted average of 0.25 percent lead when used with respect to the wetted surfaces of pipes, pipe fittings, plumbing fittings, and fixtures."[42] Moreover, some experts are concerned that even this relatively small amount of lead can still cause some contamination.[43]

Unfortunately, because these critical prevention policies were only adopted recently, we are still left with an extensive legacy of lead in the pipes and fixtures that bring water to the faucets in our homes and the fountains our children use at school. And with thousands of test samples now confirming the presence of lead in water, it is self-evident that our existing laws and rules are doing a poor job of protecting our children from this dangerous legacy.

The problem is not a failure to acknowledge the serious threat lead poses to children. Every relevant federal agency — including EPA — agrees that there is no safe level of lead for children, and that the *goal* should be to have zero lead in drinking water. So why is national policy falling so far short of this critical health goal?

Since 1974, the Safe Drinking Water Act (SDWA) has provided an important framework for ensuring that the water public utilities send to their customers and communities is clean and safe. As such, the primary focus of regulations promulgated by EPA pursuant to the Act — such as the Lead and Copper Rule — is on establishing and enforcing system-wide responsibilities of water utilities.

Unfortunately, this narrow regulatory focus leaves our drinking water vulnerable to contamination both before and after it is in possession of public water utilities. On the front end, it does little to prevent pollution of the rivers, lakes and streams that serve as sources of our drinking water; recently, we have seen cases where toxic threats — including nitrates, cyanotoxins, and chemical spills — have entered the drinking water supply.[44] And on the back end, it leaves water susceptible to contamination as it travels through plumbing in our homes and schools, all the way to the faucet where we actually drink it.

And yet it is on this "back end" where most lead contamination of drinking water occurs. This is particularly true with large buildings like schools, which have extensive pipes and plumbing before water reaches the tap. In this context, one can begin to understand why federal policy has been formulated in ways which fail to ensure the water coming out of the faucet is safe to drink.

Corroded water main with lead fittings. Photo by Mike Thomas via Flickr, CC BY NC ND 2.0

In 1991, EPA promulgated the Lead and Copper Rule, pursuant to SDWA. The rule is primarily designed to get utilities to identify problems that require system-wide action, such as adjusting corrosion control at the treatment plant. At least to some degree, the Lead and Copper Rule (LCR) has reduced lead concentrations in drinking water in large water systems that it requires to use corrosion control.

Yet the rule has four key shortcomings. First, ***the rule relies heavily on testing*** (rather than proactively removing lead-bearing parts). As discussed above, testing for lead can often lead to false negatives due to the "Russian Roulette" factor in corrosion and water sampling. In the wake of Flint, EPA has sternly warned water utilities of their obligations to implement this system faithfully — insisting on representative test samples and barring testing practices that mask lead levels (such as pre-stagnation flushing, per above).[45] There is much more that EPA can and must do to ensure its directives are enforced. But even if utilities scrupulously followed proper testing protocols, they are all but certain to miss significant amounts of lead in the water.

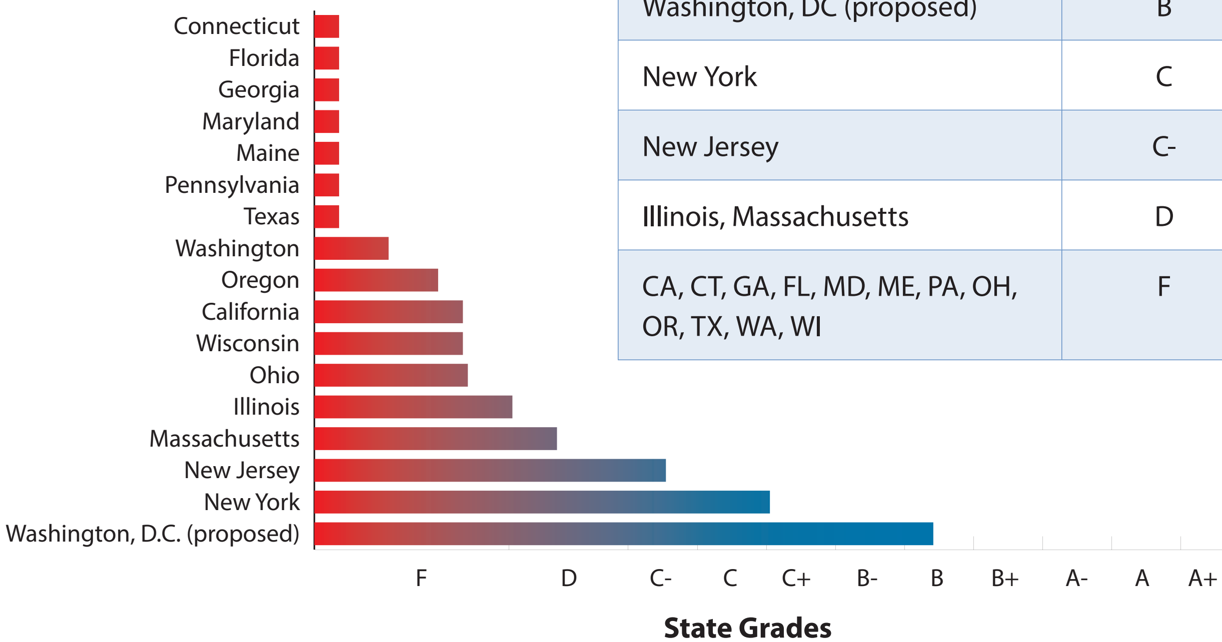
Second, ***the rule only mandates remediation when tests show lead concentrations in water greater than 15 parts per billion*** *(or 20 parts per billion in a sampling method for schools)*, even though there is no safe level of lead in drinking water. Third, even though we should be concerned with the health of any one household where there is lead in the water, ***the rule only requires utilities to take action when more than 10 percent of test samples exceed this 15 ppb "action level."***[46]

Fourth and finally, as the LCR only applies to water utilities, ***roughly 90 percent of schools and daycares across the country are exempt*** from even its limited requirements.[47]

In summary, federal requirements to protect our children from lead-laced water at schools and early childhood programs are weak to non-existent. Much stronger action by state and local officials will be critical for our children's health.

Figure 5: States not making the grade in keeping lead out of schools' drinking water

State	Grade
Washington, DC (proposed)	B
New York	C
New Jersey	C-
Illinois, Massachusetts	D
CA, CT, GA, FL, MD, ME, PA, OH, OR, TX, WA, WI	F



State Policies: Not Making the Grade

For this report, we evaluated laws and policies in 16 states - and proposed ordinance in the District of Columbia - on how well they protect children from lead in drinking water at school. The states were graded on five main criteria:

- *Getting the lead out: Are schools required to proactively remove lead from water delivery systems, or only required to take action in response to testing if at all? Are required steps sufficient to eliminate the threat of lead contamination?*
- *The "lead standard:" What level of lead triggers mandatory remedial action?*
- *Testing: Is testing required, and if so, how are tests conducted, and how often?*
- *Public disclosure and transparency: How much information is being shared with parents and the public?*
- *Applicability: Do the state laws apply to both schools and early childhood programs?*

The relative strength/weakness of these states' policies is shown in Figure 5. Nearly half of the states reviewed have failed to establish any meaningful law or policy for schools to reduce risks of lead in drinking water. Of the few states with laws on the books, some only require testing. (Washington state's board of health adopted a testing program in 2009, but it is unenforceable without funding from the legislature.[48])

Only two states — New York and New Jersey — require both testing and remediation, but their policies replicate some of the key limitations of the federal Lead & Copper Rule, such as only requiring action when lead levels exceed 15 ppb.

While mandatory rules to protect children's health received higher scores in our assessment, states did receive partial credit for well-funded voluntary measures with demonstrated results.

Heralding a more preventative approach, last year California became the first state in the nation to pass a law to eliminate lead service lines — not just for schools but across the entire state.

Signed into law by Governor Jerry Brown in September of 2016, SB 1398 requires public water systems to compile an inventory of known lead service lines by July 2018, after which they are required to provide the state with a timeline for the replacement of these lines. Erring on the side of public health, public water systems must either affirmatively determine whether service lines are made of lead, or have a plan for replacing them where the lead content cannot be determined by 2020.[49] One key caveat is that the state has yet to establish an enforceable timeline for this ambitious and preventative measure.

Wisconsin is also beginning to tackle lead service line removal. While the Badger State's program is not mandatory or comprehensive, it has already provided $14.5 million for a voluntary program that is beginning to remove lead service lines in Milwaukee and 17 other communities.[50]

As noted earlier, however, service lines are only one source of lead in schools' water. Neither California nor Wisconsin require schools to take specific measures to "get the lead out" of their fixtures or plumbing, or to shut off taps with elevated lead levels.

For purposes of comparison, we have included an ordinance currently under consideration by the District of Columbia. This proposed policy is far and away more protective of children's health than any state statute already on the books. If adopted, the ordinance would make Washington, D.C. the first jurisdiction in the country with the following protections: 1) requiring NSF filters at every tap in school used for drinking; 2) setting the "action level" at 1 part per billion, as recommended by the American Academy of Pediatrics; 4) requiring annual tests of all outlets; 5) publishing all testing and remediation data online; 6) placing bar codes with access to filter maintenance data on fountains at school; and 7) the law will apply to schools, early childhood programs, and even public parks.[51]

It is perhaps no accident that such a far-reaching measure should emerge in Washington, D.C., as the District has experienced a major crisis with lead in its drinking water back as far as 2003. Many of the policy ideas in the proposed ordinance came from parents and long-time lead-in-water activists, who have been spearheading the push for this potentially precedent-setting measure. The proposed ordinance is sponsored by nine District council members, including committee chairs Mary Cheh and David Grosso, as well as council member Charles Allen.

Finally, while our analysis focused on laws applicable to schools, we did give additional credit where those same policies also applied to early childhood programs. As per a previous study by the Environmental Law Institute, some states — such as Washington and Wisconsin - have requirements that apply *solely* to child care facilities.[52] We did not include such policies in our analysis.

Solutions to Ensure Safe Drinking Water at School

All of our children deserve safe drinking water — especially at the places they go each day to learn and play. Yet we have constructed systems that deliver water to their fountains and faucets laced with lead. And wherever there is lead, there is an ever-present risk of corrosion and contamination. Given this reality, the following solutions are imperative to ensure safe water at our schools and early childhood programs:

1) Get the Lead Out. The most effective way to ensure lead-free water for our children is, quite simply, to ***get the lead out.*** As documented above, lead service lines (LSLs) are a major source of water contamination. Last year, the National Drinking Water Advisory Council — comprised of experts, advocates, and affected communities advising EPA - made the clear case for LSL removal:

> The Council considers that the driving proactive principle to improve public health protection is removing full lead service lines from contact with drinking water to the greatest degree possible and minimizing the risks of exposure to the remaining sources of lead in the meantime.[53]

Marc Edwards, the Virginia Tech engineer who helped Flint residents confirm their water contamination, has called for the "complete removal of all lead service lines" across the country."[54]

Yet prevention cannot stop at the service line. As the data from Milwaukee to Los Angeles shows, schools and early childhood programs must take action to ensure that every part of their water delivery systems — from plumbing to fixtures to faucets — is lead-free.

2) Install and maintain NSF Certified Filters. Getting the lead out will take time. In the interim, every outlet used for drinking or cooking should be fitted with filters certified by the National Sanitation Foundation (NSF) to remove lead from water. Even with high levels of contamination in Flint, an EPA analysis documented that NSF filters proved effective at removing lead.[55]

3) Proactively prevent lead contamination. Rather than waiting for tests to confirm that the water our children drink is laced with lead, schools should be removing lead-bearing parts and installing filters certified to remove lead proactively. This preventative approach is critical because tests — even when properly done — can fail to capture lead exposure.

Photo by Jeff Turner via Flickr, CC BY 2.0

Moreover, a proactive prevention approach is consistent with other national policies aimed at protecting children's health from lead. To address lead from auto emissions, our nation has banned leaded gasoline. Belatedly, we also banned lead in paint. For a home to be certified as lead-safe, policies require rigorous remediation to "get the lead out."

4) Require action at 1 part per billion. Medical experts agree that there is no safe level of lead, and standards that trigger mandatory remediation — often called an "action level" — should reflect this health assessment. For this reason, the *American Academy of Pediatrics* is calling on officials "to ensure that water fountains in schools do not exceed water lead concentrations of 1 ppb."[56] At a minimum, *outlets with water exceeding this concentration should immediately be removed from service until permanent remediation — not mere flushing — ensures safe drinking water on an ongoing basis.*

5) Proper Testing. While schools must "get the lead out" proactively over time, testing in the interim can at least confirm some immediate threats to children's health and ensure that remediation steps are working properly. Schools and early childhood programs should test at *all* water outlets used for drinking and cooking annually, and use protocols designed to capture worst-case lead exposure for children. For example, U.S. EPA put out a clarification on sampling procedures in 2016 that recommends against prestagnation flushing.[57] And given the inherent variability in lead concentrations, officials must be careful to avoid suggesting that a failure to detect lead is the same as a permanent assurance of safe water.

6) Provide full disclosure and accountability. Parents have a right to know whether their children's water at school is safe. Moreover, as securing lead-free water at school will require several steps over time, transparency and accountability are critical to ensure that those steps are implemented and effective. Schools and early childhood programs should provide the public with information about lead-bearing parts in their water infrastructure, test results, and remediation plans and progress. Such information should be available both onsite and online, with community-appropriate language access. In Washington DC, citizen activists have urged local officials to require a bar code on each tap at school, so that parents can verify that filters are being maintained properly wherever their child fills her water bottle. Finally, all such information should be made accessible online on a statewide basis as Massachusetts has done. This provides the public with a clear picture of the scope of the lead-in-water problem, which facilitates informed statewide policy responses.

Finally, it is critical that all of these lead prevention measures apply to outlets used for *cooking* as well as drinking. As Edwards explains, "If you're cooking pasta in the tap water, you're using a huge volume of water and a high flow rate. Then you pour the water away and the lead sticks to the food. The net result is almost the same as drinking that entire volume of water."[58]

Communities Rising to the Head of the Class

“People walk up to me in the streets now and say, ‘Thanks.’”

—Susan Bauman, former mayor of Madison, WI as the city replaced lead service lines

A small number of cities are beginning to embrace the precautionary principle and have already been working either on getting the lead out of their water systems completely or providing a safe alternative. These trailblazers include Seattle, Baltimore, New York City, Milwaukee, Madison, and Lansing.

Seattle began testing the water at every one of its schools in 2004, a procedure that is repeated every three years. The Seattle School District has also set a lead action level that is lower than the national standard — 10 ppb — and any test that does not meet this threshold is investigated.[59] More importantly, Seattle has taken concrete action to “get the lead out.” In 2006, the city’s voters approved capital funding that allowed replacement of drinking water lines at nearly a third of its schools.[60] The district’s most recent school tests, conducted between 2013 and 2016, show that 97% of all tests passed district requirements.[61] Furthermore, all school test results going back to 2004 are published on the district website.

In ***Baltimore***, elevated levels of lead had plagued schools’ drinking water again and again over the course of 15 years. In 2007, the city shut off all drinking water outlets at schools and began providing bottled water instead. According to the city’s commissioner of health at the time, “Since our goal is 100 percent confidence, the best approach is to switch to bottled drinking water.”[62] Baltimore’s wholesale move to bottled water was clearly more protective of children’s health than continuing to react to piecemeal and uncertain test results. However, the bottled water approach is not without drawbacks. One issue is cost over time: The city now spends approximately $450,000 per year making bottled water available at all but a few of its 180 schools.[63] Moreover, bottled water is not guaranteed to be lead-free; in fact, FDA regulations allow up to 5 ppb of lead in bottled water.[64] This is five times as much lead as the AAP’s recommended 1 ppb standard.

New York City replaced all the lead service lines at its schools. In addition, when water tests show high lead levels, fixtures are removed and replaced as well. The upshot of these precautionary measures has been a substantial reduction in lead detected in almost 90,000 tests conducted since 2002.[65] Dr. Philip Landrigan, an expert on lead and a professor of preventive medicine and pediatrics at the Icahn School of Medicine at Mount Sinai, called New York City’s efforts “a model for the nation.”[66] Yet there is still work to be done. As noted earlier, the city only recently stopped flushing schools' pipes for two hours before testing. And with one-third of the retesting complete as of early February, 2017, the results so far show *nine times* as many outlets with levels of lead above 15 ppb.[67]

More broadly, a trio of Midwestern cities is at the forefront of efforts to fully replace lead service lines — not just at schools but across their communities.

Madison, Wisconsin, is already ahead of the pack. Faced with test results confirming lead in its water, the city dug out approximately 8,000 lead pipes between 2001 and 2010. Since then, the highest lead level in the city's water has been 3.5 ppb.[68] Moreover, in opting to "get the lead out" instead of adding phosphates to its water for corrosion control, Madison helped protect its beloved lakes. Phosphates contribute to algal blooms, which can harm wildlife and human health as well. And in the wake of Flint, Susan Bauman, who was Mayor of Madison during the pipe replacements can see the impact it has had on the city. "People walk up to me in the streets now and say, 'Thanks.'"[69]

Just 60 miles from Flint is ***Lansing,*** another city that has successfully removed lead from its water infrastructure. Last year, Lansing completed the removal of 14,500 lead pipes underneath the city.[70] And lastly, after identifying about 70,000 properties with lead pipes or lead service lines, ***Milwaukee*** is now planning to borrow $2.6 million from the federal-state loan fund for lead pipe replacement. The city is prioritizing lead pipe replacement at 385 day care centers.[71]

Other cities moving forward with lead service line replacement include Galesburg, Illinois, which is using a $4 million federal loan to remove half of the 10,000 lead service lines there.[72] Denver is also working to replace lead service lines as it finds them during construction projects.[73]

Policy Recommendations

"When it comes to schools, there often is an ideological divide…but potable water should know no ideological or political constraint."

—Bob Casey, Senator from Pennsylvania[74]

The science now makes clear that there is no safe level of lead exposure for our children. And in the wake of Flint, there is unprecedented interest from state decisionmakers to take action; according to the National Conference of State Legislatures, 40 bills to address the issue were introduced in 13 states last year.[75]

However, to ensure safe drinking water for our children, we need policies that are strong enough to "get the lead out" at school and pre-school.

States and communities should:

- Proactively "get the lead out" of schools and early childhood programs by removing lead service lines, lead-bearing plumbing, fixtures, etc.
- Install and maintain filters certified to remove lead on taps and fountains used for cooking and drinking
- Adopt a 1 ppb standard for lead in schools' drinking water, consistent with recommendations of the American Academy of Pediatrics
- Require testing at all water outlets used for drinking or cooking at all schools annually, using protocols designed to capture worst-case lead exposure for children
- Immediately remove from service any faucet or fountain used for drinking or cooking where testing indicates lead in the water
- Disclose all available information about lead in water infrastructure, test results, and remediation plans/progress both onsite and online
- Provide funding to remove lead in schools' water infrastructure

The federal government should:

- Enforce and strengthen federal rules to protect drinking water from lead — e.g. the Lead and Copper Rule
- Propose major funding to help states and communities remove lead in water infrastructure — including lead service lines and plumbing/fixtures in schools
- Marshal the authority of all relevant federal agencies to protect public health from contamination of drinking water

And of course, we should fully protect all sources of drinking water from pollution.

Methodology

For presentation of Massachusetts testing data in Figure 4:

Figure 4 presents data from Massachusetts' voluntary program for testing lead in schools' drinking water, as of January 6, 2017. Since mid-2016, the Massachusetts Department of Environmental Protection (MassDEP) has provided funding for Massachusetts schools to participate in a voluntary water testing program to test for the presence of lead and copper. More than 40,000 tests of fountains and faucets have been completed so far. The state compiles and publishes all the test results — and reported remediation — online in a single spreadsheet. *Significantly, the published results include those tests detecting levels of lead in water at concentrations below 15 parts per billion.* As of early January 2017, Massachusetts is one of the few states that provides such a comprehensive statewide picture of lead in schools' water.

MassDEP periodically provides updated information on test results from the school taps that have been tested, including tap identifying information and the lead and copper test results, in an excel sheet on the department's website.[76] The results are reported in mg/L (milligrams per liter), but can be converted to parts per billion (ppb) using a metric conversion calculator.

To examine the Massachusetts results, the excel spreadsheet was downloaded from the state's website and the results were custom sorted, first by "analyte name" (to sort out the lead results from the copper results) and then by "result" (or lead/copper level found). The "results" were ordered highest to smallest so that the highest lead levels would appear first. Then the results were grouped into the following categories:

- tap samples that had lead results higher than .015 mg/l (15 ppb)
- samples that had a lead level higher than .01 mg/l (10 ppb), up to and including .015 mg/l
- samples with a lead level higher than .005 mg/l (5 ppb), up to and including .01 mg/l
- samples with a lead level higher than .001 mg/l (1 ppb), up to and including .005 mg/l
- samples that had any determinable lead level below .001 mg/l (1 ppb) but above 0 mg/l
- samples where no lead was detected (identified by MassDEP as "ND" results)

For assessing state policies:

In scoring states' laws and policies related to lead in schools' drinking water, we assigned the following values for specific measures based on our assessment of their relative importance in ensuring lead-free water at school:

Criteria	Score
Lead Standard In Water	
uses EPA action level of 15 ppb (1 liter sample) or 20 ppb (250 mL sample)	5
uses more protective state standard but greater than 1 ppb	10
uses 1 ppb or zero	20
law does not specify	0
Get the Lead Out	
requires pro-active replacement of lead service lines	35
requires pro-active install of NSF-certified filters at every tap/fountain used for drinking or cooking	35
requires immediate shut off of water outlets used for drinking or cooking that exceed testing standard for lead	20
requires replacing lead plumbing and/or fixtures	20
requires some remediation (broad discretion, could allow flushing only)	10
no action required (at schools)	0
Public Disclosure/Transparency	
disclosure of lead infrastructure — service lines, fixtures	5
disclosure of all specific test results	5
disclosure information available online	5
disclosure information available at the outlet — e.g., bar code on the fountain	5
disclosure of remediation plan and implementation	5
no notification required (specific to schools)	0

Criteria	Score
Testing Protocols	
test for worst-case results — several samples per tap, not just a first-draw sample and prohibit sampling protocols known to hide lead — e.g., pre-test stagnation flushing	15
prohibits sampling protocols known to hide lead — e.g., pre-test stagnation flushing	10
test all faucets and fountains used for drinking or cooking	15
test at least some outlets at every school	5
test every year (at schools)	5
test every 2-5 years (at schools)	2
no testing required (at schools)	0
Applicability	
law applies to schools and early childhood programs	15
TOTAL SCORE	**185**

Score	Grade
175-185	A+
162-175	A
148-161	A-
134-147	B+
120-133	B
106-119	B-
92-105	C+
78-91	C
64-77	C-
40-63	D
0-39	F

For some criteria, states could earn points towards their grade for multiple, applicable policies: for example, we credited New York with a total of 30 points for "Get the Lead Out" because its law requires both 1) immediate shut off of outlets (20); and 2) some form of remediation (10). Where appropriate, we gave states partial credit for credible voluntary measures that, as best we could verify, were actually being implemented.

Finally, while our analysis focused on laws applicable to schools, we did give additional credit where those same policies also applied to early childhood programs. As per a previous study by the Environmental Law Institute, some states — such as Washington and Wisconsin - have requirements that apply *solely* to child care facilities. We did not include these policies in our analysis.

To a large degree, the successful implementation of lead prevention policies will depend on funding and enforcement. Yet funding comes from so many different sources — including the federal drinking water state revolving fund — that we could not establish a reliable way to assess sufficient funding for any given state's efforts. Similarly, absent uniform data, we had no meaningful way to compare the effectiveness of state enforcement or compliance efforts.

Sources of information on state laws and policies relating to lead in schools' drinking water include the following:

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Appendix

History of Federal Policy on Lead in Drinking Water

National Policy/Guidance	What it does
Safe Drinking Water Act, 1974	Authorized EPA to establish Maximum Contaminant Levels for all substances known or suspected to be hazardous to humans. These requirements applied to every Public Water System in the U.S.
EPA Interim Drinking Water Regulations, 1975	Kept the standard maximum allowable concentration of lead at 50 parts per billion (ppb) where water enters the distribution system.
Lead Ban, 1986	Among other bans, pipes and pipe fittings with more than 8% lead were banned. Any pipe or fitting under 8% lead was considered "lead free".
Lead Contamination and Control Act, 1988	Banned the manufacture and sale of water fountains that did not meet the "lead free" definition. The LCCA defined "lead-free" as: "not more than 8 percent lead, except that no drinking water cooler which contains any solder, flux, or storage tank interior surface which may come in contact with drinking water shall be considered lead-free if the solder, flux, or storage tank interior surface contains more than 0.2 percent lead." In addition, the EPA was mandated to issue guidance to schools on how to identify and remediate lead-contaminated drinking water. States were required to distribute this guidance and required to help develop testing and remediation programs for schools. However, school testing was not mandatory.
EPA Guidance, 1989	The first federal guidance to schools on assessing and remediating leaded drinking water. EPA also recommended that "action be taken to limit exposure" whenever lead levels exceeded 20 ppb.
Lead and Copper Rule, 1991	Public Water Systems are required to provide corrosion control and routine water monitoring. If over 10% of samples collected from a water system exceeded lead levels of 15 ppb, the system was to intensify water quality monitoring, optimize corrosion control, issue public notification and other education materials, and in some cases, monitor and/or replace lead service lines.
ACORN v. Edwards, 81 F.3d 1387 (5th Cir. 1996)	The State of Louisiana was sued for failing to implement several provisions of the SDWA that required the establishment of water testing programs. The Court's decision held the Act's provisions were unconstitutional and compelled the state to enact federal programs which the state had no option to decline. The decision does not restrict states from creating their own school drinking water programs.
EPA Guidance, 2006	EPA issues its latest guideline for monitoring lead in school drinking water, focused on three aspects: training of school officials on the hazards of lead, proper lead testing, and proper telling to school communities about test results. The EPA guidance is stated to be "only suggestions... not requirements".

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Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control

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Background: This study is a cost–benefit analysis that quantifies the social and economic benefits to household lead paint hazard control compared with the investments needed to minimize exposure to these hazards.

Objectives: This research updates estimates of elevated blood lead levels among a cohort of children ≤ 6 years of age and compiles recent research to determine a range of the costs of lead paint hazard control ($1–$11 billion) and the benefits of reduction attributed to each cohort for health care ($11–$53 billion), lifetime earnings ($165–$233 billion), tax revenue ($25–$35 billion), special education ($30–$146 million), attention deficit–hyperactivity disorder ($267 million), and the direct costs of crime ($1.7 billion).

Results: Each dollar invested in lead paint hazard control results in a return of $17–$221 or a net savings of $181–269 billion.

Conclusions: There are substantial returns to investing in lead hazard control, particularly targeted at early intervention in communities most likely at risk. Given the high societal costs of inaction, lead hazard control appears to be well worth the price.

Key words: cost–benefit, economics, housing, lead poisoning. *Environ Health Perspect* 117:1162–1167 (2009). doi:10.1289/ehp.0800408 available via *http://dx.doi.org/* [Online 31 March 2009]

Lead poisoning is a serious hazard for children and causes significant biological and neurologic damage linked to cognitive and behavioral impairment (Bellinger 2008a, 2008b). The level of lead exposure has fallen dramatically over the past 30 years because the lead content has been reduced in gasoline, household paint, food canning, industrial emissions, water lead, and other sources, and because public health and housing initiatives have targeted the problem. According to the National Health and Nutritional Examination Survey (NHANES), a population survey administered by the Centers for Disease Control and Prevention (CDC), the geometric mean for blood lead levels (BLLs) for children 1–5 years of age fell from 14.9 μg/dL in 1976 to 1.7 μg/dL in 2006 (CDC 2007b). The number of children 1–5 years of age with BLLs at least 10 μg/dL has fallen from an estimated 13.5 million to 174,000 over the same period (NHANES 2003–2006). Although the 1- to 5-year age grouping is useful for comparison over time, I focus on a cohort of children ≤ 6 years of age in which there are an estimated 194,000 children with BLLs at least 10 μg/dL.

Recent research has indicated that significant neurologic damage to children occurs even at very low levels of exposure (Bellinger 2008a, 2008b; Chen et al. 2007; Lanphear et al. 2005). Preventing these levels of exposure in young children will require controlling a significant and persistent cause of lead poisoning: lead paint used in housing before its ban in 1978. Although pre-1950 house paint has the largest concentration of lead-based paint hazards, house paint produced in 1950–1978 also contains substantial lead content. Poor, urban minorities disproportionately reside in housing units containing lead-based paint hazards, creating significant inequity in health and neurologic outcomes by ethnicity and socioeconomic status (CDC 2004). Because the costs of lead paint abatement are nontrivial and the removal must be done on a unit-by-unit basis (rather than imposed at an industry level), there must be substantial commitment to further reduce lead poisoning among vulnerable children.

A growing body of literature has detailed the economic costs and risks of lead poisoning, including several analyses summarizing these costs and setting them against the estimated costs of lead paint hazard control. However, recent research has broadened still the scope of our understanding of the societal costs of lead poisoning. For example, new studies have begun to analyze the correlation of lead poisoning with crime rates and their associated costs, as well as linking early lead exposure to adult-onset health problems. In this article I aim to comprehensively address the costs and benefits of household lead hazard control vis-à-vis new discoveries in the medical, psychological, and economic literature. I focus on children ≤ 6 years of age, because lead exposure is the highest for this age group, and this is the period when lead exposure produces the most significant damage.

In this analysis, I constructed an upper and lower bound on the cost-effectiveness of strategies to reduce lead exposure. The reasoning behind this methodology is that there is no single estimate that accurately reflects either the costs or benefits of lead hazard control. On the costs side, the actual expense of reducing lead paint hazards in affected homes varies with the extent of interventions required. On the benefits side, the number of children with lead exposure ranges from those reported in state child blood lead surveillance data to those determined from weighted estimates of national surveys. Although several factors could make one extreme or another more credible, it is likely that the truth lies within this interval.

Incidence of Low-Level Childhood Lead Poisoning

Although the attention on lead and children historically has focused on BLLs of ≥ 10 μg/dL, recent evidence suggests that lower levels incur high individual and societal costs. Although community, medical, and environmental interventions have generally been initiated at a BLL of 10 μg/dL, the government has found no level of exposure to lead below which adverse health effect do not occur (CDC 2004). BLLs between 2 and 10 μg/dL have been found to cause persistent cognitive damage (Bellinger 2008a, 2008b; Binns et al. 2007; Lanphear et al. 2005), and children with BLLs in this range are likely to benefit from aggressive intervention. Table 1 compares the composition of children with BLLs between 2 and 10 μg/dL with the demographic patterns of the entire cohort of children ≤ 6 years of age in 2006. Given limited sample sizes in the data, it is inadvisable to independently measure the characteristics of the population with levels > 10 μg/dL.

Of the 27.97 million children ≤ 6 years of age in the United States in 2006 (U.S. Census Bureau 2008), 24.7%, or 6.9 million, have BLLs between 2 and 10 μg/dL (NHANES 2003–2006). Males, Hispanics, African Americans, and children in households below 200% of the federal poverty line

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I am grateful to A. Hertel-Fernandez, D. Ratner, and M. Walters for excellent research assistance, and to J. Bivens, D. Jacobs, C. Emig, and three anonymous reviewers for constructive comments.

This report was made possible by generous support from the Partnership for America's Economic Success, the California Endowment, and the William Penn Foundation.

The author declares she has no competing financial interests.

Received 19 November 2008; accepted 31 March 2009.

are disproportionately more likely to have higher-than-average lead exposures.

Sources of Lead and Costs of Lead Hazard Control

Although bans on leaded gasoline and paint have greatly reduced the incidence of dangerous lead levels in children, many children are still at risk for damaging lead exposure. Lead paint and the related dust and chips are the leading cause of high lead levels in U.S. children (Levin et al. 2008). Nontrivial sources of lead poisoning are contributed by lead-contaminated water, soil, and dust, although the condition of lead-based paint is a strong predictor of lead in house dust (Lanphear et al. 1998).

Other incidental sources of household lead exposure include the manufacture of stained glass and glazed pottery, remodeling of homes, toys or pottery containing lead-based paints (Mid-Atlantic Center for Children's Health and the Environment 2003), certain calcium supplements including antacids and infant formula (Scelfo and Flegal 2000), and secondhand smoke (Mannino et al. 2003). Levin et al. (2008) document additional sources of lead exposure in eating utensils, breast milk, chocolate, candy, and other imported foods and related packaging.

Unfortunately, assessing the costs of removal of all lead hazards is difficult, so this analysis is restricted to the most common source of dangerous lead in children's environments: lead-based paint. Although I posit an adjustment for this assumption in the final sections of this article, this restriction downwardly biases the costs estimates, inflating the return on investment.

Lead paint in housing. Lead paint was used frequently in housing units until its ban in 1978; occupants of pre-ban houses are at a significantly greater risk for lead exposure. For these older housing units, the U.S. Department of Housing and Urban Development's (2002) lead guidelines list several methods of safely controlling the lead hazard possibilities, including paint stripping, replacement, encapsulation, and enclosure. Jacobs et al. (2003) present a case study in which the costs of improper removal of lead-based paint were examined. They found the cost of decontamination after uncontrolled use of power sanders to be $218,320 for a single house, greatly exceeding the incremental costs of incorporating lead-safe work practices into repainting, a cost they estimated to be $1,200 for the individual homeowner [in 2006 U.S. dollars (USD)].

The President's Task Force on Environmental Health Risks and Safety Risks to Children (2000) estimates the costs for two methods of controlling lead-based paint hazards. The first is lead hazard screening and interim controls, estimated to cost $1,200 per housing unit. The second method is inspection, risk assessment, and full abatement of lead paint, estimated to cost $10,800 per housing unit. Because of the variation in abatement requirements, regional differences in costs, condition of housing stock, and variation in the costs of adequate supervision and regulation of such work, the costs of lead hazard control can best be identified by a range rather than a precise estimate. Using the lower and upper bound values found in the President's Task Force (2000), it is likely that the true cost lies in the range of $1,200–$10,800 per housing unit. This is line with the finding of Korfmacher (2003) that the national average cost of making housing lead-safe is $7,000 per unit.

According to the U.S. Department of Housing and Urban Development (2002), 38 million U.S. homes have lead paint, of which 24 million housing units were deemed to have lead hazards in 2000 (Jacobs et al. 2002). Four million of these homes have young children, and 1.2 million houses are at significant risk, with low-income families and children ≤ 6 years of age. Linearly extrapolating predicted reductions in units at risk of lead paint hazards from the President's Task Force (2000), 1.02 million homes are at significant risk in 2006. Targeting these 1.02 million homes most in need and using the bounds on costs of $1,200–$10,800 per housing unit, the estimated cost lies between $1.2 billion and $11.0 billion.

Benefits to Reduction

Health care costs. High lead levels can cause multiple and irreversible health problems, which include learning disabilities, attention deficit–hyperactivity disorder (ADHD), mental retardation, growth stunting, seizures, coma, or, at high levels, death. Previous studies have identified damaging effects of lead on the nervous, hematopoietic, endocrine, and renal systems (Bernard 2003).

Treatment for low lead levels entails continuous monitoring of blood levels and prevention of further exposure, whereas higher lead levels require chemical chelation to leach lead from the body, an expensive, time-consuming, painful, and sometimes dangerous procedure. Kemper et al. (1998) have provided the most comprehensive assessment of health care costs. They estimate the cost for CDC's prescribed medical interventions at each blood lead range.

Kemper et al. (1998) estimated costs of screening and treatment as follows: venipuncture ($8.57), capillary blood sampling ($4.29), lead assay ($23), risk assessment questionnaire ($2), nurse-only visit ($42), physician visit ($105), environmental investigation and hazard removal ($440), oral chelation ($332), and intravenous chelation ($2,418). These costs have been inflated to 2006 USD using the overall Consumer Price Index, an arguably conservative estimate of medical inflation because medical costs have increased at rates significantly higher than general inflation over the past decade. As children's BLLs increase, so do their medical costs. Based on the assumptions of Kemper et al. (1998) and the CDC (2004) recommendations, it is possible to estimate the health costs per child given the levels of lead found in the population.

Although there is no BLL below which adverse health effects have not been observed (Bernard 2003; Binns et al. 2007; Brown 2007), the costs of medical diagnostics, prevention, and treatment for those with BLLs < 10 μg/dL are not included in this analysis because the medical costs of treating those below this CDC intervention level have not been fully assessed in the literature. To the extent that this omission is substantial, the medical benefits to lead hazard control are underestimated. This analysis also assumes that children who need treatment receive treatment immediately. If immediate treatment delays future health problems, and thus costs, then the medical benefits are again underestimated.

For children with levels ranging from 10 to 20 μg/dL, further diagnostic testing is required, necessitating venipuncture and a lead assay, followed by an additional nurse-only visit, for a total cost of $74 per child. For children with levels ranging from 20 to 45 μg/dL, the CDC (2004) recommends eight visits for diagnostic testing, including a nurse follow-up, and environmental investigation of the home in question, for a total cost of $1,027 per child. For children with BLLs of 45–70 μg/dL, the recommended regime includes all of the above, accompanied by oral chelation, for a total cost per child in the range of $1,335. For

Table 1. Demographics of childhood lead poisoning (%).

Characteristic	BLL 2–10 μg/dL	Share of total population ≤ 6 years of age[a]
Children ≤ 6 years of age	24.7	100.0
Sex		
Male	53.6	51.1
Female	46.4	48.9
Race		
White, non-Hispanic	47.4	57.9
Black, non-Hispanic	23.6	13.7
Hispanic	24.6	21.1
Other	4.6	7.3
Income (% federal poverty line)		
Up to 200%	60.2	46.4
200–400%	22.8	29.2
≥ 400%	17.1	24.4

Author's analysis of NHANES (2003–2006).
[a]Shares of population ≤ 6 years of age by race do not match ratios in other data because of differences in sampling and definitions.

children with levels ≥ 70 μg/dL, oral chelation is replaced with intravenous chelation, for a total cost of $3,444 per child.

The estimated number of children affected in each group is a combination of two sets of data: pooled NHANES (2003–2006) and state child blood lead surveillance data from the National Center for Environmental Health (CDC 2007a). Given the relatively low level and nonrepresentative nature of state-level testing, the 39,526 children with BLLs > 10 μg/dL (as reported by the states) represent an absolute lower bound of prevalence. According to analysis of NHANES 2003–2006, 194,227 children have BLLs > 10 μg/dL. Because small sample sizes prevent accurate categorizing of children into each subgrouping of BLL, the upper bound is extrapolated by applying the ratio of confirmed cases in the CDC state-level surveillance data (CDC 2007a) to the numbers found in the NHANES and applying it to each subgroup. For example, because 39,526 is 20.35% of 194,227, the upper bound of children affected in the 10- to 15-μg/dL group is 24,554 confirmed cases divided by 20.35%, or 120,656 children. Table 2 reports the health care costs and incidence by BLL groupings. Summing across groups, the total cost of treatment is between $10.8 and $53.1 million.

The estimated range includes only the direct lead treatment costs for children ≤ 6 years of age. Lead poisoning causes negative health effects later in life, such as neurologic disorders, adult hypertension, heart disease, stroke, kidney malfunction, elevated blood pressure, and osteoporosis (Korrick et al. 2003; Latorre et al. 2003; Muntner et al. 2005). Many of these conditions are chronic illnesses that must be managed throughout an individual's life course with either expensive pharmaceuticals or continual medical interventions. The biological effects of lead poisoning do not appear to affect all populations equally. Mexican-American and African-American populations possess a disproportionately strong relationship between elevated lead levels and hypertension, among other arterial diseases (Muntner et al. 2005).

Social and behavioral costs. The most well-established area of research on the effects of BLLs on children and society centers around the relationship between high BLLs and cognitive and behavioral impairment. Even low levels of exposure appear to lower children's IQ, which increases the need for enrollment in special education services, reduces the likelihood of high school and college graduation, lowers lifetime earnings (both through educational and IQ pathways), and greatly increases their propensity to engage in violent criminal activity. In this section I examine each of these factors in turn, assessing the evidence and determining the costs of lead exposure to the individual and society.

IQ and lifetime earnings. A variety of studies analyze the effects of high BLLs on intellectual function, most frequently quantified by IQ. Lanphear et al. (2005) have established a clear nonlinear, negative relationship between IQ and BLL based on pooled international data. The rate of IQ loss is greatest per unit blood lead < 10 μg/dL.

Data from NHANES (2003–2006) and state-level surveillance of lead poisoning (CDC 2007a) determine the number of children ≤ 6 years of age affected at each BLL ≥ 2 μg/dL (Table 3). The average BLL for the 2- to 10-μg/dL group is based on the NHANES (2003–2006), the average BLL for the 10- to 20-μg/dL group is taken at the midpoint, assuming a uniform distribution of lead levels within the group, and the average BLL for the ≥ 20-μg/dL group is taken at 20 μg/dL. The small sample size does not allow for accurate estimates of average levels > 10 μg/dL; however, the assumption of the minimum is most conservative. Average IQ loss per 1 μg/dL is derived from the findings of Lanphear et al. (2005), assuming an even distribution of IQ loss within each BLL group.

Total IQ loss is computed for each BLL group, summed, and then multiplied by the estimated number of children affected. IQ loss from elevated BLLs falls between 9.3 and 13.1 million points. Although these losses have severe social and behavioral consequences, they also carry a significant financial burden of lost lifetime earnings.

Drawing from Salkever (1995), Schwartz (1994), and Nevin et al. (2008), I suggest that each IQ point loss represents a loss of $17,815 in present discounted value of lifetime earnings (in 2006 USD). Using the previously computed total IQ loss of 9.3–13.1 million points, net lifetime earnings loss is calculated to fall between $165 and $233 billion for all children ≤ 6 years of age in the 2006 cohort. This estimate includes the indirect effects of lower educational achievement and workforce participation in addition to the direct effect of lower hourly wages.

With every loss in lifetime earnings comes an associated loss in potential tax revenue for the government. Korfmacher (2003), using the methodology of Grosse et al. (2002), estimates that the state of New York is losing nearly $78 million in tax dollars each year because of lowered earnings from lead poisoning. If we perform the same exercise with a 15% marginal tax, lost tax revenue from lead poisoning is estimated to be $25–$35 billion for each cohort of lead-poisoned children.

Special education. Children with high lead levels are in need of special education because of their slower development, lower educational success, and related behavioral problems. Schwartz (1994) found that 20% of children with BLL > 25 μg/dL needed special education. He suggests that the needs of these children span an average of 3 years, requiring assistance from a reading teacher, psychologist, or other specialist. Korfmacher (2003) estimated that the average annual cost of special education is $14,317 per child (inflated to 2006 USD).

Based on the findings of Schwartz (1994), the 20% of children with BLLs > 25 μg/dL

Table 2. Health care costs (2006 USD).[a]

Blood lead level (μg/dL)	Cost of recommended medical action ($)	Lower bound of affected children (no.)	Upper bound of affected children (no.)[b]	Lower bound cost ($)	Upper bound cost ($)
10–15	74	24,554	120,656	1,816,996	8,928,552
15–20	74	8,185	40,220	605,690	2,976,305
20–45	1,207	6,347	31,189	7,660,829	37,644,611
45–70	1,335	376	1,848	501,960	2,466,585
> 70	3,444	64	314	220,416	1,083,104
All levels		39,526	194,227	10,805,891	53,099,158

[a]Kemper et al. (1998) provided estimates for the costs of recommended action (inflated to 2006 USD). [b]The upper bound values are calculated assuming that CDC state-level surveillance confirmed cases represent 20.35% of estimates > 10 μg/dL derived from NHANES (2003–2006): 39,536 confirmed cases to 194,227 cases as estimated from NHANES (2003–2006).

Table 3. Lead and IQ.[a]

BLL (μg/dL)	Lower bound of affected children (no.)	Upper bound of affected children (no.)	Average BLL per BLL group (μg/dL)[b]	Average IQ point loss per μg/dL[c]	Lower bound IQ loss	Upper bound IQ loss
2–10	5,632,147	7,400,920	3.13	0.513	9,043,482	11,883,583
10–20	32,739	160,876[d]	~ 15	0.19	199,053	978,129
≥ 20	6,678	32,815[d]	~ 20	0.11	46,946	230,690
Totals					9,289,482	13,092,402

[a]Data for children with BLLs < 10 μg/dL are estimated from CDC NHANES 2003–2006. Data for children > 10 μg/dL are from state-level surveillance and assume uniform distribution of cases within each BLL group. Lower and upper bound for 2- to 10-μg/dL group represents 95% CIs for NHANES estimate. [b]Average BLL calculated for 2–10 μg/dL using CDC NHANES 2003–2006, average BLL for 10–20 μg/dL taken as the midpoint, and average BLL for ≥ 20 μg/dL group uses the most conservative lower bound (the floor) for the mean. [c]Data from Lanphear et al. (2005); assume uniform decreases within BLL groups. [d]Values calculated assuming that CDC confirmed cases represent 20.35% of all cases, given that CDC confirmed cases represent 20.35% of NHANES estimates for those > 10 μg/dL.

is estimated to fall between 693 and 3,404 children (using the same bounds analysis as described previously). Multiplying out these factors with the average cost per child for 3 years of special education, it costs an estimated $30–$146 million for each cohort of lead-poisoned children.

In addition to the relationship of reduced IQ on lifetime earnings and the additional investments required in special education, research indicates adverse effects of lead exposure directly on educational achievement and children's readiness for school (Rothstein 2004). In addition, studies have found significant and negative effects of early and minimal lead blood exposure on statewide exam scores, in the same order of magnitude as the effect of poverty (Miranda et al. 2007).

Elevated BLLs are associated with an increased risk of not completing high school (Needleman 2004). Cohen et al. (1998) quantified the effects of dropping out of high school on lowered lifetime earnings and increased criminal activity. Although there may be a direct link between elevated lead levels and high school completion, this analysis chooses to avoid any potential double-counting and assumes that these effects are included indirectly in the earnings and criminal activity discussions. Excluding the nonmarket benefits of education (Haveman and Wolfe 1984) leads to an underestimate of the benefits of lead hazard control.

Research by Braun et al. (2006) has quantified the long-observed association between childhood lead exposure and development of ADHD. ADHD is a highly prevalent, lifelong psychiatric disorder that places children at an increased risk for conduct disorder, antisocial behavior, criminal activity, and drug abuse (Costello et al. 2003). Prevalence is estimated at 3–8% of children ≤ 15 years of age (CDC 2005). ADHD is managed through a combination of prescription drug therapy and counseling sessions for children and more severe adult cases. In addition to high lifelong treatment costs, ADHD also extracts significant productivity costs for parents of ADHD children. Work by Birnbaum (2005) finds that the parents of a child with ADHD collectively incur approximately $5 billion in work and productivity losses.

The total cost of lead-linked ADHD cases in the United States is found by computing the number of ADHD cases annually linked to early lead exposure, extracted from the study of Braun et al. (2006). Of the 1.8 million ADHD cases in children 4–15 years of age, 21.1%, or 290,000, are linked to BLLs > 2 μg/dL (Braun et al. 2006). Assuming average medical treatment costs per child of $565 for drug and counseling therapy and average parental work loss costs of $119 per child, lead exposure costs $267 million annually to individual families and society. Because the costs of medical treatment and work losses are likely to increase greatly with the severity of the condition, these estimates represent a conservative lower bound for the total costs of lead-linked ADHD cases.

Behavior and crime. Medical and economic research has established a connection between early childhood lead exposure and future criminal activity, especially of a violent nature. Bellinger et al. (1994) found that increased lead exposure correlates strongly with social and emotional dysfunction. Needleman et al. (1996) examined schoolchildren between the ages of 7 and 11 years who had a clinical diagnosis of lead poisoning at an early age and found worsening of behavior patterns as children with high BLLs aged. Needleman et al. (2002) indicated that adjudicated delinquents are four times more likely to have blood lead concentrations > 25 ppm than nondelinquent adolescents.

Recent work by Wright et al. (2008) examined a cohort of young adults from childhood and found a considerably higher and significant rate of arrest, particularly for violent crimes, among young adults who had elevated lead exposures at an early age. These clinical findings confirm broader research that links lead exposure to antisocial and destructive behavior, both in humans and animal subjects (Canfield et al. 2004; Denno 1990; Froehlich et al. 2007; Surkan and Zhang 2007).

Nevin (2000) finds that the variation in childhood gasoline lead exposure from 1941 to 1986 explains nearly 90% of the variation in violent crime rates from 1960 to 1998, and that lead paint explains 70% of the variation in murder rates from 1900 to 1960. Reyes (2002) takes the evidence of a relationship between lead poisoning and criminal behavior and estimates that the Clean Air Act (U.S. Environmental Protection Agency 2009) in the 1970s and 1980s accounts for one-third of the drop in crime throughout the 1990s.

Both clinical and econometric evidence suggest that lowered lead levels will lead to lower crime rates. The Federal Bureau of Investigation (2006) lists numbers of crimes per 100,000 residents, and the U.S. Bureau of Justice Statistics (2004) estimates their associated direct costs. Using Nevin's (2006) estimate of the annual number of crimes that could have been averted with a 1-μg/dL reduction in the average preschool blood lead, the total direct costs of lead-linked crime can be computed.

A 1-μg/dL reduction in the average preschool BLL results in 116,541 fewer burglaries, 2,499 fewer robberies, 53,905 fewer aggravated assaults, 4,186 fewer rapes, and 717 fewer murders (Table 4). The total direct cost of lead-linked crimes is approximately $1.8 billion, including direct victim costs, costs related to the criminal justice system through legal proceedings and incarceration, and lost earnings to both criminal and victim. An additional $11.6 billion is lost in indirect costs, which include psychological and physical damage necessitating medical treatment and preventive measures resulting from the criminal action. For this conservative analysis, I considered only the direct costs of each crime. Although these effects are for only a 1-μg/dL decrease, complete removal of lead hazards would have even larger effects.

The consequences of an antisocial and destructive pathology among lead-poisoned children are not isolated to criminal activity alone. Recent research has indicated that moderate levels of childhood lead exposure can greatly increase an individual's propensity for risk-taking activities. For instance, Lane et al. (2008) found that BLLs > 20 μg/dL are strongly linked to repeat teenage pregnancies and cigarette smoking among low-income youth, both of which incur sizeable costs to individuals, families, and society.

Discussion

To demonstrate the cost-effectiveness of lead hazard control, I summed and compared the total benefits and costs of childhood lead level reduction. The costs of lead hazard control range from $1.2 to $11.0 billion. The benefits to lead hazard control is the sum of the costs for medical treatment ($11–$53 billion), lost earnings ($165–$233 billion), tax revenue ($25–$35 billion), special education ($30–$146 million), lead-linked ADHD cases ($267 million), and criminal activity ($1.7 billion), for a total of $192–$270 billion. The net benefit of lead hazard control ranges from

Table 4. Lead and crime.

Crime	All crimes per 100,000 residents (no.)[a]	Lead-linked crimes per 100,000 residents (no.)[b]	Total lead linked crimes (no.)	Direct costs per crime ($)[c]	Total direct costs ($)[c]
Burglaries	1335.7	38.7	116,541	4,010	467,329,410
Robberies	213.7	0.83	2,499	22,871	57,154,379
Aggravated assaults	352.9	17.9	53,904	20,363	1,097,628,286
Rape	37.6	1.39	4,186	28,415	118,945,567
Murder	8.3	0.238	717	31,110	22,305,512
Totals			177,847		1,763,363,153

[a]Calculated using crime incidence data from the Federal Bureau of Investigation (2006). [b]Data from Nevin (2006). [c]Data from the Bureau of Justice Statistics (2004); inflated to 2006 USD.

$181 to $269 billion, resulting in a return of $17–$221 for each dollar invested in lead hazard control (Table 5).

The estimate of the benefits of controlling lead hazards presented in this paper is still quite conservative. The absolute lower bound of lead prevalence > 10 μg/dL uses state-level confirmed cases and excludes many important and potentially substantial costs. These include health care later in life, neonatal mortality, benefits of lead hazard control on property value and energy savings, community improvement, lead paint litigation, indirect costs to criminal activity, and other intangible benefits. Similarly, this analysis calculates the benefit for one cohort of U.S. children, whereas the duration of lead hazard controls are likely to endure for ≥ 6 years (Wilson et al. 2006). Including future cohorts and assessing a full lifetime of costs would vastly increase the benefit to lead hazard control.

That said, the major source, lead-based paint, is by no means the only source of dangerous lead exposures among children. If a similar distribution of lead exposures or high and low BLLs are found from both lead-based paint and other types of lead hazards, a rough adjustment for other major sources of lead exposures on these benefits decreases the final benefit range by 30%, because lead-based paint represents about 70% of childhood exposure to lead (Levin et al. 2008). This leads to a net benefit ranging from $124 to $188 billion, resulting in a return of $12–$155 for each dollar invested in lead paint hazard control.

Conclusions

Public health and housing policy has been slow to address these remaining lead poisoning risks, moving incrementally with targeted, more reactive policies. If the cost of proactive and universal lead hazard control is seen as prohibitive, the costs of inaction have proven to be significantly greater. For every dollar spent on controlling lead hazards, $17–$221 would be returned in health benefits, increased IQ, higher lifetime earnings, tax revenue, reduced spending on special education, and reduced criminal activity.

To put these results in perspective, it is useful to compare these net benefits to an intervention commonly understood as tremendously cost effective—that of vaccinations. Cost–benefit analyses show that vaccination against the most common childhood diseases delivers large returns on investment, saving between $5.30 and $16.50 in costs for every dollar spent on immunizations (Zhou et al. 2005). Given the high societal costs of inaction, lead hazard control appears to be well worth the expense as well.

Table 5. Total costs and benefits of lead control.

	Conservative estimate	Optimistic estimate
Total benefit from lead reduction	$192.38	$270.45
Total cost of lead control	$11.02	$1.22
Total net benefit	$181.37	$269.23
Cost–benefit	1–17	1–221

All costs and benefits are in billions of 1996 dollars.

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Preventing Toxic Lead Exposure Through Drinking Water Using Point-of-Use Filtration

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Summary

Lead exposure through drinking water is an acute and persistent problem in the United States. The Flint, Michigan, water crisis brought national attention to this problem, but every city is at risk where lead-containing materials are present in water infrastructure and building plumbing. Preventing childhood exposure to lead is the consensus policy in the medical community and exposure costs the U.S. tens of billions of dollars annually, but the federal Lead and Copper Rule requires remediation only after lead is present at levels considered medically unsafe, and relies on an inherently unreliable testing program. Recent federal and state efforts to reduce exposure focus resources on lead pipe replacement and testing to identify lead risk; neither course adequately protects the public. This Article recommends promoting point-of-use filtration to remove lead, an approach that has received little attention despite the fact that filtration technology is inexpensive and very effective. It specifically recommends that Congress provide a refundable tax credit for individuals to acquire a filtration system and replacement filters, and require all non-residential buildings to use best available technology for filtration in drinking fountains. Promoting filtration is consistent with primary prevention, will provide individuals a means to protect themselves, and will effectively and efficiently remove toxic lead currently present at the tap.

If you were going to put something in a population to keep them down for generations to come, it would be lead.

—Dr. Mona Hanna-Attisha[1]

One of the recent lessons of Flint, Chicago, Pittsburg[h], and other cities is that we should never again consider water that passes through a lead pipe safe.

—Dr. Marc Edwards[2]

If they get a good test, it doesn't prove water is safe relative to lead . . .

What proves water is safe is if the filter is there and installed properly.

—Dr. Marc Edwards[3]

For more than one year, reports of lead contamination in drinking water dominated the news cycle in a city where 4,075 of 6,118 residences exceeded the U.S. Environmental Protection Agency (EPA) action level for lead in drinking water of 15 parts per billion (ppb).[4] Testing found lead levels of 50 ppb in 2,287 residences and 300 ppb in 157 residences.[5] The raw water supply quickly corroded lead-containing materials in the drinking water distribution infrastructure, and allowed lead to leach into the drinking water supply.[6] The Water and Sewer Authority (WASA) for the city was aware of lead contamination for more than one year but did not timely inform the public, which learned

Author's Note: The original manuscript for this Article was submitted in partial satisfaction of the author's LL.M. degree in Environmental Law at The George Washington University (GWU) Law School. The views expressed are solely those of the author and do not reflect the official policy or position of the U.S. Air Force, U.S. Department of Defense, or U.S. government. I would like to thank my wife, Jennifer Mitchell, for her thoughtful insight, valued input, and constant support; GWU Law School Associate Dean LeRoy Paddock, Visiting Associate Professor Eun Hee Han, and Head Reference Librarian Germaine Leahy for their assistance and input throughout the writing process; and my parents, Monica Domagala and Stanley Mitchell. This Article is dedicated to Aria and Ian Mitchell.

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about the lead contamination from newspaper reporting.[7] Up to 42,000 children were exposed to alarming levels of lead through drinking water and are now at serious risk of reduced intelligence, behavior problems, and other adverse health effects.[8] During the lead crisis, late-term miscarriages and spontaneous abortions occurred at an unusually high rate.[9] The lead crisis resulted in congressional hearings and an independent four-month investigation producing a 143-page report finding fault from the WASA to the Department of Public Health to EPA.[10]

This lead crisis occurred in Washington, D.C., from 2001-2004. A similar water crisis occurred in Flint, Michigan, from 2014-2016. Dangerous lead persists in drinking water across the United States today.[11] And another crisis could occur in any city that has lead-containing material in its drinking water infrastructure and privately owned plumbing materials.

Exposure to lead through drinking water is a persistent problem in the United States that poses a serious health risk anywhere lead is present in drinking water infrastructure or privately owned plumbing. The threat that lead in drinking water poses to entire communities is the product of a legacy of lead-containing materials in drinking water infrastructure and private buildings; the significant, permanent, and irreversible health effects of low-level lead exposure; the inherent difficulty of regulating lead; the specific failings of the federal Lead and Copper Rule (LCR)[12] to protect public health; and government incompetence and misconduct. Lead infrastructure, including up to 6.1 million lead service lines (LSLs) in drinking water infrastructure and 81 million housing units in the United States constructed prior to 1986, poses a risk of releasing lead and contaminating drinking water at any time.

Lead causes significant, permanent, and irreversible neurological damage in children at very low levels of exposure. Once ingested, low-level lead exposure in children is associated with significant adverse neurological health effects, such as lower IQ, behavioral problems, and attention-deficit disorders; and adverse effects in the immune, cardiovascular, and reproductive systems. Public health experts agree that there is no safe level of lead exposure in children. They also agree that a primary prevention program is the only scientifically defensible policy and the only policy that will protect children from dangerous lead exposure. Preventing childhood exposure to lead rather than reacting when children have measurable blood lead levels (BLLs) therefore is now the primary medical policy for lead exposure in children. Significant economic, societal, and personal costs result from low levels of lead exposure, costs that disproportionately fall on low-income and minority communities.

The current regulatory approach of the federal LCR is insufficient to protect the public from lead in drinking water because the inherent difficulty of regulating lead and specific limitations of the LCR allow lead to be present at the tap. Lead is difficult to regulate because it enters drinking water after the water leaves the treatment plant primarily through corrosion of lead-containing materials, and cannot be effectively removed by the public water system (PWS) before consumption. The LCR thus addresses lead in water by requiring PWSs to control corrosion, monitor corrosion control efficacy through testing lead levels in water at representative taps, and take remedial measures like LSL replacement based on an action level of 15 ppb. This regulatory structure does not effectively protect the public from lead in drinking water because lead can leach into drinking water at any time, even with corrosion control treatment, and testing for lead in drinking water is inherently unreliable.

Beyond the inherent difficultly of regulating lead in drinking water, the LCR imposes requirements that further threaten public health, like testing for lead in water with first-draw samples and using an action level not based on health effects. Regulatory gaps allow PWSs and states to show compliance with the LCR even when lead contamination is widespread. And perhaps most problematic, government incompetence and misconduct has dramatically increased the risk of lead exposure in drinking water and caused dangerous lead exposure across entire cities like the crisis in Flint.

Recent legislative efforts to reduce lead in drinking water have focused on funding lead pipe replacement programs and testing drinking water for lead. These programs are inadequate to protect public health. Lead pipe replacement is a massive infrastructure project that will take several decades to complete even under the best-case scenario. Lead will continue to be present at the tap in the interim,

7. *Id*.
8. Carol D. Leonnig, *High Lead Levels Found in D.C. Kids; Numbers Rose During Water Crisis*, Wash. Post, Jan. 27, 2009, at A1.
9. Carol D. Leonnig, *Increase in Miscarriages Coincided With High Levels of Lead in D.C. Water, Study Finds*, Wash. Post, Dec. 9, 2013, https://www.washingtonpost.com/politics/increase-in-miscarriages-coincided-with-high-levels-of-lead-in-dc-water-study-finds/2013/12/09/22b4fe72-60f9-11e3-8beb-3f9a9942850f_story.html?utm_term=.be6175cebfec.
10. David Nakamura, *4-Month Probe Cites Disarray Within WASA; Communication Failures Hurt Response to High Lead Levels*, Wash. Post, July 16, 2004, at A1; James W. Moeller, *Legal Issues Associated With Safe Drinking Water in Washington, D.C.*, 31 Wm. & Mary Envtl. L. & Pol'y Rev. 661, 706-08 (2007).
11. *See*, *e.g.*, Kris Maher, *Schools Across the U.S. Find Elevated Lead Levels in Drinking Water*, Wall St. J., Sept. 5, 2018, https://www.wsj.com/articles/schools-across-the-u-s-find-elevated-lead-levels-in-drinking-water-1536153522?mod=searchresults&page=1&pos=2&ns=prod/accounts-wsj; *see also* Michael Hawthorne & Cecilia Reyes, *Brain-Damaging Lead Found in Tap Water in Hundreds of Homes Tested Across Chicago, Results Show*, Chi. Trib., Apr. 12, 2018, http://www.chicagotribune.com/news/watchdog/ct-chicago-water-lead-contamination-20180411-htmlstory.html.
12. 40 C.F.R. §§141.80 et seq.

exposing another generation of children. Federal and state policies that react to the confirmed presence of lead in drinking water through testing are inconsistent with a primary prevention approach and conflict with current scientific research on the adverse health effects of childhood lead exposure at very low levels. Resources would be better used on programs that actually reduce the risk of lead exposure rather than funding water testing programs that are inherently unreliable and can justify inaction when significant risk of lead exposure exists.

Any serious policy to limit lead in drinking water must implement a primary prevention strategy that includes efforts to reduce lead present at the tap using point-of-use (POU) filtration. POU filtration has received little attention as a national policy solution despite the fact that it is inexpensive and highly effective at removing lead. Health experts and governments already recommend filtration as the first line of defense when there is a known lead risk in drinking water. Recognizing that lead can leach into drinking water at any time if drinking water is exposed to lead-containing materials and testing does not adequately quantify the risk of lead exposure, a primary prevention policy applied to drinking water should assume that lead is present at the tap.

Consistent with primary prevention, in order to mitigate the widespread risk of lead exposure through drinking water across the United States, the U.S. Congress should enact a refundable tax credit for individuals to acquire a filtration system and replacement filters certified for lead reduction under National Sanitation Foundation (NSF) International/American National Standards Institute (ANSI) Standard 53, and require all nonresidential buildings to include the best available technology (BAT) for water filtration in drinking fountains. A federal refundable tax credit would fill the gap in government efforts to reduce lead exposure through drinking water and provide individuals the opportunity to protect themselves and their families from significant lead exposure. Requiring BAT for filtering water from drinking fountains in nonresidential buildings will efficiently protect the public from lead in water outside the home.

Part I of this Article addresses how lead enters drinking water, the health effects and costs of lead exposure, and current medical policy of preventing lead exposure in children. Part II provides a comprehensive discussion of relevant sections of the Safe Drinking Water Act (SDWA)[13] and specific requirements of the LCR to address the threat of lead in drinking water. Part III discusses how the LCR is inadequate to protect public health, including the inherent difficulty of regulating and testing for lead, and the specific shortcomings of the LCR. Part IV discusses government incompetence and misconduct when implementing the LCR, and presents the Flint water crisis as an illustration of how that can exponentially increase and lengthen the already significant risk of lead exposure through drinking water. Part V recommends a robust POU filtration program to reduce the risk of lead exposure through drinking water, financed with a refundable tax credit for individuals and requiring nonresidential buildings to install BAT for filtration. Part VI concludes.

I. Lead in Water, Health Effects, and Primary Prevention

This part will discuss how lead enters drinking water, the adverse health effects of lead and attendant costs, and the medical consensus that preventing exposure to lead is the primary policy for children based on its significant, permanent, and irreversible adverse health effects. This part will provide context for why removing lead from water is critical and why current regulatory efforts that allow lead to be present at the tap pose a serious health risk. Understanding how lead enters drinking water and the attendant health risks will also provide support for funding a robust private filtration program and requiring filtration in nonresidential buildings.

A. *How Lead Enters Drinking Water*

Lead is a heavy metal constituting 0.002% of the earth's crust, to which humans had little exposure prior to extracting it for use.[14] Humans have used lead pipes in drinking water infrastructure for millennia.[15] Lead pipes were so common in ancient Rome that the word "plumbing" comes from the Latin word for lead, "plumbum."[16] Using lead pipes for service lines was a common practice in the United States until the 1950s because of lead's natural flexibility and resistance to subsidence and frost.[17]

The Reduction of Lead in Water Act banned the use of lead plumbing materials in large part,[18] but the United States has a legacy of lead-containing materials in drinking water infrastructure and the use of lead in plumbing and fixtures in buildings.[19] There are at least 6.1 million LSLs in drinking water infrastructure serving 15-22 mil-

13. 42 U.S.C. §§300f-300j-26, ELR Stat. SDWA §§1401-1465.

14. World Health Organization (WHO), Childhood Lead Poisoning 15-16 (2010).

15. Dartmouth Toxic Metals Superfund Research Project, *Lead: A Versatile Metal, Long Legacy*, https://www.dartmouth.edu/~toxmetal/toxic-metals/more-metals/lead-history.html (last visited Sept. 28, 2018) [hereinafter Dartmouth Research].

16. Jack Lewis, *Lead Poisoning: A Historical Perspective*, EPA J., May 1985, https://archive.epa.gov/epa/aboutepa/lead-poisoning-historical-perspective.html.

17. Simoni Triantafyllidou & Marc Edwards, *Lead (Pb) in Tap Water and in Blood: Implications for Lead Exposure in the United States*, 42 Critical Revs. Envtl. Sci. & Tech. 1297, 1300 (2012).

18. The Reduction of Lead in Water Act (RLWA) prohibits the use of "any pipe, any pipe or plumbing fitting or fixture, any solder, or any flux . . . in the installation or repair of (1) any public water system or (2) any plumbing in a residential or non nonresidential facility providing water for human consumption that is not lead free." 42 U.S.C. §300g-6(a)(1)(A). The RLWA defines "lead free" as "not containing more than .2 percent when used with respect to solder and flux, and not more than a weighted average of 0.25 percent lead when used with respect to the wetted surfaces of pipes, pipe fittings, plumbing fittings, and fixtures." *Id.* §300g-6(d)(1).

19. Triantafyllidou & Edwards, *supra* note 17, at 1302-03.

lion people.[20] The 81 million housing units in the United States constructed prior to 1986 are certain to have lead solder.[21] Housing units constructed after 1986 are likely to have brass plumbing materials, 1.5%-8% lead by weight.[22] The total number of lead pipes and solder in the United States drinking water infrastructure is unknown, as is the amount of lead-containing materials in privately owned buildings.[23]

Lead exposure through ingestion is a significant risk when drinking water infrastructure and private plumbing materials contain lead. Lead enters drinking water primarily through corrosion and all water is corrosive to varying degrees.[24] Lead leaches into water as dissolved lead or detaches into water as particulate lead.[25] Lead can leach or detach into drinking water from any lead-containing material: pipes in the water distribution system, building plumbing systems, solder connecting pipes, and even brass and bronze (copper alloys that contain lead) faucets and fixtures.[26] Once lead-containing materials have corroded, lead can leach into water indefinitely.[27]

Exposure to lead in drinking water contributes to elevated BLLs.[28] Children, especially infants fed formula, and pregnant women are at particular risk of exposure to lead from drinking water.[29] Recent studies suggest that the risk of lead exposure through drinking water can be significant and greater than previously thought.[30]

The specific public health crisis in Flint, Michigan, has shown a national spotlight on the problem of lead in drinking water, but the risk of exposure to dangerous levels of lead in drinking water is a national problem. In 2004, the *Washington Post* reported that 274 utilities serving 11.5 million people found dangerous levels of lead in the water.[31] Since then, little has changed as residents in city after city are exposed to lead through drinking water. In 2005, lead contamination in drinking water was found in Columbia, South Carolina.[32] In 2006, testing in Durham and Greenville, North Carolina, found lead contamination.[33] In 2015, the Natural Resources Defense Council (NRDC) reported that 1,100 community water systems serving 3.9 million people reported lead contamination.[34] A USA Today Network investigation found that from 2012-2015, approximately 2,000 water systems servicing six million people across all 50 states had lead-contaminated water.[35]

Communities threatened by lead-contaminated water continue to accumulate. In January 2016, schools in Sebring, Ohio, were temporarily closed, and the city manager warned children and pregnant women not to drink tap water because of lead contamination.[36] In the five years prior to 2017, lead contamination has been found in more than two dozen South Carolina communities.[37] In 2016, lead was still contaminating the water in the Calumet neighborhood of East Chicago, Illinois, seven years after EPA identified the neighborhood as a lead Superfund site.[38] And schools across the United States have drinking fountains providing lead-contaminated water.[39] The reported cases of lead contamination and high-profile crises are almost certainly just the tip of the iceberg of lead-contaminated water.[40] And the national problem of lead exposure through drinking water is especially acute because of the significant, permanent, and irreversible adverse health effects of lead exposure.

20. David A. Cronwell et al., *National Survey of Lead Service Line Occurrence*, 108 J. Am. Water Works Ass'n 182, 182 (2016).
21. Triantafyllidou & Edwards, *supra* note 17, at 1302-03.
22. *Id.*
23. U.S. Government Accountability Office (GAO), Drinking Water: Additional Data and Statistical Analysis May Enhance EPA's Oversight of the Lead and Copper Rule 1 (2017); Triantafyllidou & Edwards, *supra* note 17, at 1302.
24. Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper, 56 Fed. Reg. 26460, 26466 (June 7, 1991).
25. Triantafyllidou & Edwards, *supra* note 17, at 1302-03.
26. 56 Fed. Reg. at 26466.
27. *Id.*
28. *See* Mona Hanna-Attisha et al., *Elevated Blood Lead Levels in Children Associated With the Flint Drinking Water Crisis: A Special Analysis of Risk and Public Health Response*, 106 AJPH Res. 283, 285-87 (2016); Simoni Triantafyllidou et al., *Reduced Risk Estimation After Remediation for Lead (Pb) in Drinking Water at Two US School Districts*, 466 Sci. Total Env't 1011, 1020-21 (2014); Triantafyllidou & Edwards, *supra* note 17, at 1328-35; Marc Edwards et al., *Elevated Blood Lead in Young Children Due to Lead-Contaminated Drinking Water: Washington D.C. 2001-2004*, 43 Envtl. Sci. & Tech. 1618, 1621-22 (2009); Rebecca Renner, *Out of Plumb: When Water Treatment Causes Lead Contamination*, 117 Envtl. Health Persp. 542, 544 (2009).
29. U.S. Department of Health & Human Services, Toxicological Profile for Lead 220-24 (2007) [hereinafter HHS Toxicological Profile]; Simoni Triantafyllidou et al., *Assessing Risk With Increasingly Stringent Public Health Goals: The Case of Water and Blood Lead in Children*, 12 J. Water & Health 57, 67 (2014).
30. Triantafyllidou et al., *supra* note 29, at 67.
31. Carol D. Leonnig, *Lead Levels in Water Misrepresented Across U.S.*, Wash. Post, Oct. 5, 2004, at A1.
32. Michael Wines & John Schwartz, *Unsafe Lead Levels in Tap Water Not Limited to Flint*, N.Y. Times, Feb. 8, 2016, https://www.nytimes.com/2016/02/09/us/regulatory-gaps-leave-unsafe-lead-levels-in-water-nationwide.html.
33. *Id.*
34. Erik Olson & Kristi P. Fedinick, What's in Your Water? Flint and Beyond 4 (2016).
35. Alison Young & Mark Nichols, *Beyond Flint: Excessive Lead Levels Found in Almost 2,000 Water Systems Across All 50 States*, USA Today, Mar. 11, 2016, https://www.usatoday.com/story/news/2016/03/11/nearly-2000-water-systems-fail-lead-tests/81220466/.
36. Jessica Mendoza, *Flint, Part Two? Ohio Town's Pipes May Be Contaminated With Lead*, Christian Sci. Monitor, Jan. 25, 2016, https://www.csmonitor.com/USA/2016/0125/Flint-part-two-Ohio-town-s-pipes-may-be-contaminated-with-lead.
37. Sammy Fretwell, *Lead Tainted Water in SC Communities*, State, Mar. 17, 2016, http://www.thestate.com/news/local/article61283287.html.
38. Craig Lyons, *"It's a Disaster": East Chicago Still Reeling From Lead Crisis, and EPA Can't Say If Water Is Safe*, Chi. Trib., July 21, 2017, http://www.chicagotribune.com/suburbs/post-tribune/news/ct-ptb-east-chicago-one-year-later-st-0723-20170721-story.html.
39. *See, e.g.*, Maher, *supra* note 11; *see also* Christopher Heimerman, *Water in DeKalb, Sycamore Schools Tests Positive for Lead Contamination*, Daily Chron., Jan. 12, 2018, http://www.daily-chronicle.com/2018/01/12/water-in-dekalb-sycamore-schools-tests-positive-for-lead-contamination/an9bdl0/; Malini Ramaiyer, *6 Berkeley Schools Shut Off Water Source Because of Lead Contamination*, Daily Californian, Jan. 26, 2018, http://www.dailycal.org/2018/01/24/lead-contamination-water-sources-six-schools-berkeley-unified-school-district/; Matt Rocheleau, *High Lead Levels Found in Water at Hundreds of Schools*, Boston Globe, May 2, 2017, https://www.bostonglobe.com/metro/2017/05/01/high-lead-levels-found-hundreds-massachusetts-schools/bflx2ZXaLYLSl10r0Hvj7L/story.html; Sara Roth, *99% of Portland Schools Have High Lead Levels*, KGW8, Sept. 6, 2016, https://www.kgw.com/article/news/health/99-of-portland-schools-have-high-lead-levels/283-268102018.
40. *See* discussion *infra* Sections III.B, III.H.

B. Health Effects of Lead

Lead is extraordinarily toxic to humans.[41] BLLs[42] greater than 100 micrograms per deciliter (μg/dL) (1,000 ppb) can cause protracted vomiting, encephalopathy, and even death.[43] Children are particularly vulnerable to the harmful effects of lead even at very low levels.[44] Children are exposed to lead in greater quantities from age-appropriate hand-to-mouth behavior and they adsorb lead more efficiently than adults.[45] Lead is significantly more toxic to a child's developing brain than an adult's.[46] BLLs of less than 5 μg/dL (50 ppb) are associated with significant adverse neurological effects: decreased intelligence, lower academic performance, attention-deficit disorders, and behavioral problems.[47]

Women exposed to lead as children can expose a fetus from lead stored in bone.[48] Lead exposure in utero is correlated with increased instances of fetal death, lower birth weight, and cognitive impairment.[49] It is now well-established that there is no known safe level of lead exposure in children.[50] Making matters worse, the substantial adverse neurological health effects of lead exposure in children are permanent, irreversible, and most significant at BLLs less than 10 μg/dL (100 ppb).[51]

C. Economic and Social Costs of Lead Exposure

The adverse health effects of lead, particularly the neurological effect of reduced intelligence and behavioral problems, have significant economic, social, and personal costs in the United States. By conservative estimates, each point of lost IQ "represents a loss of $17,815 in the present discounted value of lifetime earnings."[52] When controlled for inflation, children in the United States who turned two years old in 2000 are expected to earn $110-$318 billion more in present value of future earnings than children who turned two in the mid-1970s based on the significant reduction of average BLLs over time.[53] The economic cost in lost earnings remains massive today. For children under six years old from 2003-2006 with BLLs 2-10 μg/dL, the total loss in lifetime earnings is estimated to be $165-$233 billion.[54] The estimated present value of economic losses for children who were five years old in 1997 is estimated to be $43.4 billion.[55] With hundreds of thousands of children identified with BLLs greater than 5 μg/dL every year,[56] massive economic losses accrue annually.[57]

Medical studies identifying reduced intelligence, attention-deficit disorders, and behavioral disorders as adverse health effects of lead exposure prompted research into the relationship between lead exposure and crime rates. Cross-sectional studies have identified a strong correlation between childhood lead exposure and increased adult crime rates.[58] There is a particularly strong correlation between childhood lead exposure and murder rates.[59] Confirming cross-sectional study findings, prospective longitudinal studies have found prenatal and childhood lead exposure associated with adolescent delinquent behavior,[60] and a significant predictor of later adult criminal behavior.[61]

Researchers estimate that every 1 μg/dL reduction in BLLs in preschool-age children "results in 116,541 fewer burglaries, 2,499 fewer robberies, 53,905 fewer aggravated assaults, 4,186 fewer rapes, and 717 fewer murders."[62] Some researchers now believe that the reduction of lead exposure in children in the late 1970s and early 1980s contributed significantly to the precipitous drop in crime rates in the 1990s.[63] In addition to the obvious personal and social

41. *See generally* U.S. EPA, Air Quality Criteria for Lead Vol. I ch. 6 (2006) [hereinafter Air Criteria].
42. The half-life of lead in blood is approximately 35 days. Theodore Lidsky & Jay Schneider, *Lead Neurotoxicity in Children: Basic Mechanics and Clinical Correlates*, 126 Brain 5, 10 (2003). BLLs, the most common measure of exposure, therefore reflect relatively recent exposure. *Id*. The half-life of lead in the brain is approximately two years and, when stored in bone, decades. *Id*.
43. HHS Toxicological Profile, *supra* note 29, at 22-23. Recent research suggests that the number of deaths attributable to lead exposure is significantly higher than previously thought at levels much lower than 100 ppb. *See* Bruce P. Lanphear et al., *Low-Level Lead Exposure and Mortality in US Adults: A Population-Based Cohort Study*, 3 Lancet Pub. Health e177 (2018).
44. *See* Air Criteria, *supra* note 41, at 6-1, 7-8; HHS Toxicological Profile, *supra* note 29, at 220-24.
45. HHS Toxicological Profile, *supra* note 29, at 220-21; WHO, *supra* note 14, at 18.
46. HHS Toxicological Profile, *supra* note 29, at 220-24.
47. National Toxicology Program, HHS, NTP Monograph: Health Effects of Low-Level Lead xviii-xxi (2012).
48. Lidsky & Schneider, *supra* note 42, at 9.
49. *See generally* Marc Edwards, *Fetal Death and Reduced Birth Weights Associated With Exposure to Lead Contaminated Drinking Water*, 48 Envtl. Sci. & Tech. 739 (2014); Lidsky & Schneider, *supra* note 42, at 9-10.
50. *See*, *e.g.*, American Academy of Pediatrics Council on Environmental Health, *Prevention of Childhood Lead Toxicity*, 138 Pediatrics 1, 1-2 (2016) [hereinafter CEH]; HHS Toxicological Profile, *supra* note 29, at 31.
51. Bruce P. Lanphear et al., *Low-Level Environmental Lead Exposure and Children's Intellectual Function: An International Pooled Analysis*, 113 Envtl. Health Persp. 894, 895-96 (2005).
52. Elise Gould, *Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control*, 117 Envtl. Health Persp. 1162, 1164 (2009).
53. Scott D. Grosse et al., *Economic Gains Resulting From the Reduction in Children's Exposure to Lead in the United States*, 110 Envtl. Health Persp. 563, 567 (2002).
54. Gould, *supra* note 52, at 1164.
55. Phillip J. Landrigan et al., *Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental Disabilities*, 110 Envtl. Health Persp. 721, 724 (2002).
56. *See* Centers for Disease Control and Prevention (CDC), *Lead—CDC's National Surveillance Data (2012-2016)*, https://www.cdc.gov/nceh/lead/data/national.htm (last updated June 29, 2018).
57. Landrigan et al., *supra* note 55, at 726.
58. *See*, *e.g.*, Rick Nevin, *Understanding International Crime Trends: The Legacy of Preschool Lead Exposure*, 104 Envtl. Res. 315, 330 (2007); *see also* Jessica Reyes, *Environmental Policy as Social Policy? The Impact of Childhood Lead Exposure on Crime*, 7 B.E. J. Econ. Analysis & Pol'y 1, 33 (2007).
59. *See* Nevin, *supra* note 58, at 330; Paul B. Stretesky & Michael J. Lynch, *The Relationship Between Lead Exposure and Homicide*, 155 Pediatric Adolescent Med. 579, 580-82 (2001).
60. Kim N. Dietrich et al., *Early Exposure to Lead and Juvenile Delinquency*, 23 Neurotoxicology & Teratology 511, 514-17 (2001).
61. *See* Brian B. Boutwell et al., *The Intersection of Aggregate-Level Lead Exposure and Crime*, 148 Envtl. Res. 79, 81-84 (2016); John Wright et al., *Association of Prenatal and Childhood Blood Lead Concentrations With Criminal Arrests in Early Adulthood*, 5 PLoS Med. 732, 735-37 (2008).
62. Gould, *supra* note 52, at 1165.
63. *See*, *e.g.*, Reyes, *supra* note 58, at 36.

costs of crime, the estimated direct economic cost of crime attributable to childhood lead exposure is $1.8 billion for every 1 μg/dL increase in the average preschool BLL.[64]

The economic and social costs of lead follow from the personal tragedies individuals and families suffer from lead poisoning. The case of Freddie Gray is a poignant example of the personal and familial cost of childhood lead exposure. Freddie was born in August 1989 into a home with peeling and flaking lead paint.[65] In June 1991, at only 22 months old, Freddie's BLL tested at an astonishing 37 μg/dL.[66] Freddie developed attention-deficit disorder, was in special education classes his entire academic career, and failed to graduate from high school.[67] Freddie's struggles with self-regulation and aggression were clear with frequent school suspensions and more than a dozen arrests.[68]

In 2010, the Gray family received a structured settlement from a lead poisoning lawsuit filed in 2008, but the settlement money was insufficient to put Freddie's life back on track.[69] On April 19, 2015, Freddie died in police custody after sustaining injuries while being transported in the back of a police van without a seat belt.[70] Freddie Gray's death while in police custody caused severe anger and mass protests in Baltimore.[71] Freddie's tragic death received significant news coverage, but it is Freddie's troubled life after severe childhood lead poisoning that is the silent tragedy that children and families face across the United States every day.

Lead poisoning from exposure to lead-contaminated water can similarly ruin lives and terrify communities for years. In Flint, the entire city was traumatized as a result of the water crisis. Residents felt deep fear from drinking the water, profound guilt from providing lead-contaminated water to children, physical pain as manifestations of stress, and profound anxiety that the damage and disability from lead exposure will never end.[72] Some parents of children exposed to lead have suffered nervous breakdowns and contemplated suicide as a result of the crisis.[73] The lead-contaminated water in Flint not only was a direct public health crisis, but also a mental health emergency.[74] The personal, familial, and community cost of a contaminated water system only begins with drinking the water.[75]

The tragic life of Freddie Gray and drinking water catastrophe in Flint highlight the inequitable reality that the significant adverse health effects, social and economic costs, and personal and community burden of lead exposure are not evenly distributed. Poor communities and minority children have the most lead exposure.[76] Freddie Gray was African American and grew up in one of the poorest neighborhoods of Baltimore.[77] Flint's current population is approximately 57% African American and has struggled with poverty for decades.[78] During the water crisis, Flint was one of the poorest cities in America, with a median household income of $25,650 and per capita income of $14,923 from 2012-2016.[79] In 2015, Flint had the highest poverty rate for a city of its size.[80]

National data confirm anecdotal evidence of lead's disproportionate effect on poor and minority communities. The most recent National Health and Nutrition Examination Survey (NHANES) found BLLs remain high in children from poor communities and non-Hispanic black children despite steadily declining BLLs generally.[81] The recent NHANES documented disparity in lead poisoning is consistent with historic data.[82] Racial disparities in lead exposure are the result of racism and discriminatory policy and practice.[83] Toxic lead exposure is an almost insurmountable impediment to economic advancement perpetuating poverty.[84] In short, lead exposure is a clear and present public health danger, particularly for children, leading to significant social and economic costs and perpetuates economic inequality and the legacy of racism in the United States.

D. Preventing Childhood Lead Exposure as Primary National Policy

The medical and scientific community agree that, based on the significant, permanent, and irreversible adverse health

64. Gould, *supra* note 52, at 1165.
65. Terrence McCoy, *Freddie Gray's Life a Study on the Effects of Lead Paint on Poor Blacks*, Wash. Post, Apr. 29, 2015, https://www.washingtonpost.com/local/freddie-grays-life-a-study-in-the-sad-effects-of-lead-paint-on-poor-blacks/2015/04/29/0be898e6-eea8-11e4-8abc-d6aa3bad79dd_story.html?utm_term=.c1a3bcda4c2a.
66. *Id*.
67. *Id*.
68. *Id*.
69. *See id*.; Mark Puente & Doug Donovan, *The Truth About Freddie Gray's "Pre-Existing Injury From Car Accident*," Balt. Sun, Apr. 29, 2015, http://www.baltimoresun.com/news/maryland/bs-md-gray-settlement-20150429-story.html.
70. John W. Cox et al., *Who Was Freddie Gray? How Did He Die? And What Led to the Mistrial in Baltimore*, Wash. Post, Dec. 16, 2015, https://www.washingtonpost.com/local/who-was-freddie-gray-and-how-did-his-death-lead-to-a-mistrial-in-baltimore/2015/12/16/b08df7ce-a433-11e5-9c4e-be37f66848bb_story.html?utm_term=.a49fd29b73de.
71. *Id*.
72. *See* Abby Goodnough & Scott Atkinson, *A Potent Side Effect to the Flint Water Crisis: Mental Health Problems*, N.Y. Times, Apr. 30, 2016, https://mobile.nytimes.com/2016/05/01/us/flint-michigan-water-crisis-mental-health.html.
73. *Id*.
74. *See id*.
75. *See NOVA: Poisoned Water* (PBS television broadcast, May 31, 2017).
76. *See* Emily A. Benfer, *Contaminated Childhood: How the United States Failed to Prevent the Chronic Lead Poisoning of Low-Income Children and Communities of Color*, 41 Harv. Envtl. L. Rev. 493, 504 (2017).
77. McCoy, *supra* note 65.
78. Flint Water Advisory Task Force, Final Report 15 (2016) [hereinafter FWATF Final Report].
79. U.S. Census Bureau, *Quick Facts: Flint City, Michigan*, https://www.census.gov/quickfacts/fact/table/flintcitymichigan/PST045216 (last visited Sept. 28, 2018).
80. Press Release, Michigan League for Public Policy, Census Data Shows Flint and Detroit Poverty Worst in Nation, People of Color Still Struggling Statewide (Sept. 15, 2016), http://www.mlpp.org/census-data-shows-flint-and-detroit-poverty-worst-in-nation-people-of-color-still-struggling-statewide.
81. Advisory Committee on Childhood Lead Poisoning Prevention, CDC, Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention 15 (2012) [hereinafter Advisory Committee].
82. *See* Benfer, *supra* note 76, at 504.
83. *See id*. at 505-13.
84. *See id*. at 504-05; Hanna-Attisha, *supra* note 1 ("If you were going to put something in a population to keep them down for generations to come it would be lead.").

effects of low-level lead exposure, preventing childhood exposure must be the primary policy to protect children (primary prevention).[85] "Once an elevated blood lead concentration has been detected, it is too late to prevent lead's deleterious effects on the developing brain."[86] The Centers for Disease Control and Prevention (CDC) used to recommend individual intervention for childhood lead exposure based on a specified blood lead "level of concern," which lowered over time from 60 µg/dL to 15 µg/dL.[87] In 2012, the CDC's Advisory Committee on Childhood Lead Poisoning Prevention recommended eliminating use of the term "level of concern," and adopting a primary prevention policy based on overwhelming scientific and medical evidence that there is no known safe level of lead exposure in children and that the adverse health effects of lead exposure are permanent and irreversible.[88] The Advisory Committee noted that "setting a 'level of concern' for lead has always failed to include consideration of uncertainty or the inclusion of a margin of safety."[89]

The CDC has adopted the primary prevention approach to childhood lead exposure and has eliminated the use of blood lead "levels of concern" in children.[90] The CDC now uses a reference level of 97.5th percentile of the NHANES' blood lead distribution to determine which children have BLLs that are much higher than the average child.[91] The reference level is not a health-based standard but rather an identifier updated every four years to determine where primary prevention programs and direct intervention resources are most needed.[92] Primary prevention is now the policy of the CDC, American Academy of Pediatrics, and World Health Organization, and widely recognized as the most important policy to protect children from lead.[93]

It is no surprise that lead is extraordinarily toxic to humans and requires primary prevention for children. Humans evolved in an environment with only trace amounts of lead.[94] The lead burden of humans today is 500-1,000 times greater than pre-industrial humans.[95] Taking into account lead's widespread use for several millennia, efforts to reduce human exposure to this toxic metal are fairly recent.[96] The primary regulatory effort in the United States to reduce lead exposure at the tap, and subject of the next part, is the LCR that was promulgated pursuant to the SDWA.

II. Regulation of Lead in Drinking Water

This part discusses how the LCR, which implements the SDWA, regulates lead in drinking water. The statutory structure of the SDWA and the specific requirements of the LCR are necessary context for understanding how the LCR is insufficient to protect public health from lead in drinking water. This part discusses first the SDWA generally and next the relevant provisions of the LCR.

A. The SDWA

The SDWA requires EPA to establish maximum contaminant level goals (MCLGs) and promulgate primary drinking water regulations for contaminants[97] if EPA determines that

> (i) the contaminant may have an adverse effect on the health of persons,
>
> (ii) the contaminant is known to occur or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern, and
>
> (iii) in the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems.[98]

National primary drinking water regulations (NPDWRs) promulgated under the SDWA apply only to PWSs.[99] The SDWA defines a PWS as "a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals."[100] EPA is required to review and revise NPDWRs every six years.[101]

An MCLG is the maximum contaminant level (MCL) "at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety."[102] MCLGs are aspirational goals to protect public health, not federally enforceable standards.[103]

NPDWRs are implemented as an MCL or a treatment technique.[104] When an MCLG is established for a con-

85. CEH, *supra* note 50, at 5; Lidsky & Schneider, *supra* note 42, at 15.
86. Lidsky & Schneider, *supra* note 42, at 15.
87. Advisory Committee, *supra* note 81, at 3.
88. *Id.* at 3-5.
89. *Id.* at 4.
90. CDC, CDC Response to Advisory Committee on Childhood Lead Poisoning Prevention Recommendations 5-6, 8 (2012) [hereinafter CDC Response]; CDC, *Lead—What Do Parents Need to Know to Protect Their Children?*, https://www.cdc.gov/nceh/lead/acclpp/blood_lead_levels.htm (last updated May 17, 2017).
91. CDC Response, *supra* note 90.
92. *Id.* at 7; Advisory Committee, *supra* note 81, at 6.
93. CDC Response, *supra* note 90; CEH, *supra* note 50, at 5; WHO, *supra* note 14, at 54.
94. WHO, *supra* note 14, at 16.
95. *Id.*
96. *See* Dartmouth Research, *supra* note 15.
97. "Contaminant" is defined under the SDWA as "any physical, chemical, biological, or radiological substance or matter in water." 42 U.S.C. §300f.
98. *Id.* §300g-1(b)(1)(A), (E).
99. *Id.* §§300f(1)(A), 300g. The SDWA also provides in 42 U.S.C. §300g for a narrow, limited exception for certain PWSs.
100. *Id.* §300f(4)(A). Regulatory requirements applicable under the SDWA vary based on the size and type of a PWS. The SDWA divides PWSs into community water systems, which serve users year-round, *id.* §300f(15), and water systems, which is any PWS that is not a community water system, *id.* For NPDWRs, EPA has further defined non-community water systems into transient non-community water systems, systems that do not regularly serve at least 25 of the same persons over six months per year, and non-transient non-community water systems, systems that regularly serve at least 25 of the same persons over six months per year. 40 C.F.R. §141.2 (2017).
101. 42 U.S.C. §300g-1(b)(9).
102. *Id.* §300g-1(b)(4)(A).
103. *Id.* §§300(f)(1), 300g, 300g-1(b)(4)(A); 40 C.F.R. §141.2.
104. 42 U.S.C. §300g-1(b)(3)(C)(i)-(ii), (4)(B), (7).

taminant, the MCL must be as close to the MCLG as is "feasible" under the SDWA.[105] "Feasible" means the use of the best technology, treatment technique, or other means available that EPA finds after examination for efficacy under field conditions and considering costs.[106] EPA must conduct a comprehensive cost-benefit analysis for each proposed MCL.[107] When EPA sets an MCL as an NPDWR, a PWS may not provide water that exceeds the MCL.[108] EPA has promulgated numerous MCLs.[109]

EPA may use a treatment technique rather than an MCL for an NPDWR if "it is not economically or technologically feasible to ascertain the level of the contaminant."[110] When using a treatment technique, EPA must identify treatment techniques that "would prevent known or anticipated adverse effects on the health of persons to the extent feasible," and must conduct the same cost-benefit analysis required for an MCL.[111]

EPA is required to identify technologies that will meet MCLs.[112] For small PWSs, EPA must identify technologies that comply with MCLs and treatment techniques.[113] Like other major environmental legislation, however, PWSs are not required to use a specific technology to meet the contaminant levels required under an MCL.[114]

The SDWA utilizes cooperative federalism to enforce the SDWA. States have primary enforcement authority of the SDWA when a proper application is made to EPA.[115] States must adopt drinking water regulations at least as stringent as NPDWRs and provide for adequate enforcement of state regulations, among other requirements, in order to assume enforcement responsibility.[116] The SDWA does not prohibit states from further regulating drinking water or PWSs.[117] All states have assumed primary enforcement authority except Wyoming and the District of Columbia.[118]

B. The LCR

EPA's LCR was first promulgated in 1991 and remains largely unchanged in its substantive requirements.[119] The LCR established a health-based MCLG of zero for lead[120] and a treatment technique relying primarily on corrosion control but also includes source water treatment, LSL replacement, and public education.[121] PWSs are generally required to "install and operate optimal corrosion control treatment."[122] The LCR requires source water treatment and public education about lead risks and mitigation when a PWS exceeds the "action level" for lead.[123] The LCR requires LSL replacement when a PWS exceeds the lead "action level" after applying required corrosion control and source water treatment.

The "action level" for lead is 0.015 milligrams per liter (mg/L) (15 ppb), which is met when the 90th percentile[124] from sampling required under the LCR is greater than 0.015 mg/L (15 ppb).[125] The action level for lead is *not* a health-based standard, but rather reflects "a level that is generally representative of effective corrosion control treatment."[126] Selecting a lead "action level" based on the efficacy of corrosion control is the natural result of using a treatment technique relying primarily on corrosion control.[127]

Large PWSs (serving greater than 50,000 people) are required to install and operate optimal corrosion control treatment while small (serving at most 3,300 people) and medium (serving between 3,300 and 50,000 people) PWSs are required to do so only when sampling exceeds the lead action level.[128] When testing exceeds the lead action level despite optimal corrosion control treatment, the PWS must replace per year at least 7% of the LSLs under PWS control.[129] The PWS is not required to replace any LSL from which water samples test under the lead action level and may stop replacing LSLs when required testing is under the lead action level for two consecutive six-month monitoring periods.[130] As part of an LSL replacement program, the PWS must offer to replace privately owned LSLs but is not required to pay replacement costs.[131] When an owner of a privately owned LSL declines the PWS offer to replace the LSL or the PWS is prohibited to do so by state or local law, the PWS must do a partial LSL replacement.[132]

105. *Id.* §300g-1(b)(4)(B). EPA may establish an MCL at a level other than "feasible" if the technology or process used to determine the feasible level would increase the concentration of other contaminants or interfere with complying with other NPDWRs, or if the benefits of the MCL would not justify the costs. *Id.* §300g-1(b)(5), (6).
106. *Id.* §300g-1(b)(4)(D).
107. *Id.* §300g-1(b)(3)(C).
108. *Id.* §300g-3(a), (b), (g).
109. 40 C.F.R. §§141.60-.66 (2017).
110. 42 U.S.C. §300g-1(b)(7).
111. *Id.* §§300g-1(b)(3)(C)(ii), (7).
112. *Id.* §300g-1(b)(4)(E)(i).
113. *Id.* §300g-1(b)(4)(E)(ii)-(iii).
114. *Id.* §300g-1(b)(4)(E)(i).
115. *Id.* §300g-2.
116. *Id.* §300g-2(a).
117. *Id.* §300g-3(e).
118. Mary Tiemann, Congressional Research Service, Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements 17 (2017).
119. 40 C.F.R. §§141.80-.91 (2017); Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper, 56 Fed. Reg. 26460 (June 7, 1991).
120. 40 C.F.R. §141.51(b). Optimal corrosion control treatment is defined at *id.* §141.2. Further requirements for optimal corrosion control under the LCR are contained in *id.* §§141.81-.82, with a primary focus on alkalinity and pH adjustment, calcium hardness adjustment, and the addition of phosphate or a silicate-based corrosion inhibitor.
121. *Id.* §141.80(b).
122. *Id.* §141.80(d).
123. *Id.* §141.80(e)-(g).
124. The 90th percentile sample is the product of the total number of samples and 0.9 when samples are arranged and numbered in ascending order from least to greatest mass concentration. *See id.* §141.80(c)(3). For 30 samples (30 × 0.9 = 27), sample number 27 is the 90th percentile sample. If the 27th sample of 30 samples is greater than .015 mg/L (15 ppb), the sample batch exceeds the lead action level.
125. *Id.* §141.80(c)(1).
126. 56 Fed. Reg. at 26490.
127. *Id.*; EPA Office of Water, Lead and Copper Rule Revisions White Paper 6 (2016) [hereinafter EPA White Paper].
128. 40 C.F.R. §141.81(b).
129. *Id.* §141.84(b).
130. *Id.* §141.84(c), (f).
131. *Id.* §141.84(d).
132. *Id.*

The LCR relies on testing to determine whether a PWS exceeds the lead action level, and for medium and small PWSs, whether corrosion control is required. All PWSs are required to identify sources of lead in the water distribution system as well as water quality information "indicating locations particularly susceptible to high quantities of lead concentrations."[133] Community water systems are required to identify whether lead materials are present in the water distribution system and home plumbing.[134] PWSs are generally required to collect testing samples from buildings that contain lead materials in privately owned plumbing or use an LSL unless no qualifying sources are available.[135] For community water systems, the PWS must use water samples from single-family structures when available.[136] Taken together, these testing requirements attempt to require testing from sources of drinking water most likely to leach lead.[137]

Sample collection techniques are proscriptive and specific.[138] Testing samples must generally be one-liter first-draw samples after water stands motionless in the plumbing system for six hours.[139] PWSs may allow residents to collect samples after providing proper instruction, which can be written.[140] The number of samples a PWS must collect varies based on the number of people served, ranging from five samples for PWSs serving at most 100 people to 100 samples for PWSs serving greater than 100,000 people.[141] Samples collected in addition to required samples must be included in the sample set for determining the 90th percentile sample.[142] States may, but are not required to, invalidate samples only for (1) improper laboratory analysis causing inaccurate results, (2) draws from sites that do not meet the selection criteria, (3) container damage in transit, and (4) substantial evidence of tampering.[143] States may not invalidate a sample solely because a subsequent sample tested at a different level.[144] States also are not allowed to invalidate a resident-collected sample because of collection errors.[145]

PWSs must collect and test the required number of samples from the required sources every six months.[146] Any PWS that has two consecutive monitoring periods meeting the lead action level and within the permissible water quality control range may reduce testing to once per year and reduce the number of required samples generally by half.[147] Small and medium PWSs meeting the action level for lead and copper for three consecutive years may reduce testing from annually to once every three years.[148] PWSs that meet 0.005 mg/L (5 ppb) for lead and .65 mg/L for copper for two consecutive six-month monitoring periods based on the 90th percentile test may reduce testing to once every three years.[149] The LCR provides for specific months when PWSs must draw samples for reduced monitoring.[150] Small PWSs may test once every nine years if the system can show that there are no plastic pipes or service lines with lead plasticizers; pipes, service lines, solder joints, and fixtures are lead-free unless they meet any standard under 42 U.S.C. §300g-6(e), and the 90th percentile of lead does not exceed 0.005 mg/L (5 ppb).[151]

The LCR is inconsistent with current medical and scientific knowledge about the health effects of lead exposure. Noting that the goal of the original LCR was to limit lead exposure in sensitive populations, specifically young children, EPA justified the 0.015 mg/L (15 ppb) action level based on models predicting the number of children with BLLs greater than 10 µg/dL (100 ppb) would drop from 3.5% to 1.6% when excluding lead paint and contaminated soil risks.[152] EPA's use of children with BLLs greater than 10 µg/dL (100 ppb) to measure benefits is fundamentally flawed given the medical and scientific consensus that significant and irreversible adverse health effects occur when BLLs in children are less than 10 µg/dL (100 ppb).[153] Moreover, the LCR's primary reliance on reducing lead content in water through controlling corrosion measured by testing is inconsistent with a primary prevention approach to lead exposure.[154] Requiring corrosion control and possibly LSL replacement at a specified action level is precisely the kind of reactive policy of years past now rejected in the medical community.[155] Regulating lead at the tap based on a health standard, however, poses special challenges not present for other contaminants, a problem addressed in the next part.

III. The Inadequacy of the LCR

This part discusses why the LCR is inadequate to protect public health from lead in drinking water. The LCR's inability to protect public health is necessary to understand why Congress should promote POU filtration with a refundable tax credit for individuals and require filtration in drinking fountains in nonresidential buildings. Lead poses a unique regulatory problem based on how and when

133. *Id.* §141.86(a)(2).
134. *Id.* §141.42(d).
135. *Id.* §141.86(a).
136. *Id.* §141.86(a)(3).
137. U.S. EPA, Lead and Copper Rule—Clarification Requirement for Collecting Samples and Calculating Compliance 2 (2004) [hereinafter EPA Clarification].
138. *See* 40 C.F.R. §141.86(b).
139. *Id.* §141.86(b)(3).
140. *Id.* §141.86(b)(2); EPA Clarification, *supra* note 137, at 2; *see* Michigan Department of Environmental Quality (MDEQ), Drinking Water Lead and Copper Sampling Instructions (2016).
141. *See* 40 C.F.R. §141.86(c).
142. *Id.* §141.86(e).
143. *Id.* §141.86(f)(1).
144. *Id.* §141.86(f)(3).
145. *Id.* §141.86(b)(2); EPA Clarification, *supra* note 137, at 6.
146. 40 C.F.R. §141.86(d)(1).
147. *Id.* §141.86(d)(4)(ii). Small and medium PWSs must meet only the lead and copper action level to qualify initially for annual testing. *Id.* §141.86(d)(4)(i).
148. *Id.* §141.86(d)(4)(iii).
149. *Id.* §141.86(d)(4)(v).
150. *Id.* §141.86(d)(4)(iv) (states can approve different draw times).
151. *Id.* §141.86(g).
152. 56 Fed. Reg. at 26491.
153. *See* discussion *supra* Section I.B.
154. *See* discussion *supra* Section I.D.
155. *See id.*

lead enters drinking water and because testing for lead is inherently unreliable.

Additionally, the LCR has specific provisions and gaps that exacerbate the inadequacy of the LCR: (1) the LCR action level is not a health-based standard, (2) reduced monitoring allows lead contamination to go undetected for years, (3) allowing residents to collect samples increases the risk of inaccurate samples, (4) requiring partial LSL replacement increases lead exposure, (5) required first-draw samples significantly underestimate the amount of lead in drinking water most of the time, and (6) PWSs can game the LCR testing requirements to reduce the amount of lead to show compliance. The inherent limitations of the LCR and specific inadequacies are discussed in turn below.

A. The Unique Nature of Lead as a Drinking Water Contaminant

Most contaminants are removed from source water at the water treatment plant prior to distribution to the tap.[156] Lead is rarely in source water, however, and the vast majority of lead that enters drinking water occurs from corrosion of lead-containing materials after treated water leaves the water treatment plant.[157] Lead can leach into drinking water from any lead-containing material from treatment to the tap.[158] Once lead-containing materials have corroded, lead can leach into water indefinitely.[159]

The amount of lead that leaches into drinking water is highly variable and depends on the amount and age of lead materials; the surface area of the lead-containing materials; the duration that water is in contact with lead-containing materials; nitrification; biofilm formation and microbial growth; and, most significantly, the corrosivity of the distributed water.[160] Total alkalinity, pH, dissolved inorganic carbonate, calcium, hardness, temperature, free chlorine, total dissolved solids, and dissolved oxygen all contribute to the corrosivity of water.[161] It is difficult to identify the extent to which any particular factor contributes to corrosion and, in turn, lead leaching; in fact, lead leaching can vary even when water quality is constant.[162] All water is corrosive to some degree and will corrode lead-containing materials over time.[163]

EPA recognized the difficulty inherent in regulating lead with an MCL.[164] An MCL measured at the tap would hold PWSs responsible for lead entering drinking water from privately owned plumbing material, which are beyond the reach of the SDWA.[165] An MCL measured when drinking water leaves the water treatment plant would remove little to no lead in drinking water.[166] An MCL measured when drinking water leaves the control of the PWS would fail to protect consumers from lead entering drinking water from privately owned plumbing materials.[167] And the variability of lead at the tap and source water quality across PWSs make applying a single MCL applicable to all PWSs infeasible.[168] The U.S. Court of Appeals for the District of Columbia (D.C.) Circuit thus found in a challenge from the NRDC that EPA's use of a treatment technique for the LCR was reasonable and that "[a] single national standard (i.e. an MCL) is not suitable for every public water system."[169]

EPA cannot regulate lead to a level consistent with a health-based standard using corrosion control. Instead, the EPA action level attempts to regulate as low as possible given the technological limits of corrosion control with LSL replacement required only when corrosion control fails based on testing samples drawn from locations most at risk for lead exposure. Testing for lead, however, is complicated, inherently unreliable, and can be used to justify inaction when lead poses a serious risk to children.

B. The Unreliability of Testing for Lead in Drinking Water

The LCR uses monitoring through testing lead in drinking water from representative taps drawn from high-risk locations to determine whether corrosion control treatments are effective and, for small PWSs, required.[170] Relying on testing for lead at the tap, however, is insufficient to measure the individual and systemic risk of lead exposure. Testing for lead is inherently unreliable and the circumstances under which samples are drawn can significantly affect the lead content of the sample. Particulate lead is a particular problem because testing cannot predict the risk of particulate lead at the tap. Finally, a lack of inventory of the lead-containing materials in PWSs further undermines the utility of testing for lead.

Testing for lead at the tap to measure the risk of future lead exposure is inherently unreliable because lead can enter drinking water at any time even with corrosion control treatment.[171] A single test for lead provides reliable information about the lead content of water at the tap only for the specific sample.[172] Subsequent tests could yield sig-

156. *See* 56 Fed. Reg. at 26471.
157. Sheldon Masters et al., *Inherent Variability in Lead and Copper Collected During Standardized Sampling*, Envtl. Monitoring & Assessment, Feb. 20, 2016, at 1; Miguel A. Del Toral et al., *Detection and Evaluation of Elevated Lead Release From Service Lines: A Field Study*, 47 Envtl. Sci. & Tech. 9300, 9300 (2013); 56 Fed. Reg. at 26463.
158. 56 Fed. Reg. at 26466; *see* discussion *supra* Section I.A.
159. *Id*.
160. Masters et al., *supra* note 157, at 2; 56 Fed. Reg. at 26463, 26466.
161. 56 Fed. Reg. at 26466.
162. *Id*. at 26473.
163. *Id*. at 26466.
164. *Id*. at 26471.
165. American Water Works Ass'n v. Environmental Prot. Agency, 40 F.3d 1266, 1269, 25 ELR 20335 (D.C. Cir. 1994); 56 Fed. Reg. at 26476.
166. 56 Fed. Reg. at 26475.
167. *Id*. at 26472-73.
168. *See id*. at 26472-77, 26487.
169. *American Water Works Ass'n*, 40 F.3d at 1271.
170. *See* discussion *supra* Section II.B.; Del Toral et al., *supra* note 157, at 9304.
171. Masters et al., *supra* note 157, at 2; Yanna Lambrinidou & Marc Edwards, Opinion, *Five Myths About Lead in Water*, Wash. Post, Feb. 26, 2016, https://www.washingtonpost.com/opinions/five-myths-about-lead-in-water/2016/02/26/a3279d26-d686-11e5-9823-02b905009f99_story.html?utm_term=.54c4e2f1404c.
172. *See* Masters et al., *supra* note 157, at 2; Del Toral et al., *supra* note 157, at 9304.

nificantly different results even when water quality does not change.[173] Multiple field studies have found highly variable lead concentrations in sequential drinking water samples from the same tap and across taps in a PWS using different corrosion control techniques.[174]

One controlled study concluded that the variability of lead concentration attributed to sampling error is probably "dominated by the *inherent variability* in lead released from the plumbing materials themselves."[175] To reliably measure the risk of systemwide lead exposure in a PWS, thousands more tests would be necessary than required under the LCR and at greater frequency.[176] Even then, reliability would be far from assured.[177] What can be assured, however, is that one-time testing from multiple taps in a system is insufficient to determine whether water is safe.[178]

Testing is also unreliable because collection techniques, system conditions, and timing can have significant effects on the lead concentration of the sample. Variables that can affect lead concentrations include stagnation time, draw time, flow rate, flushing, the distance water travels in an LSL, physical disturbance of LSLs, water usage, and the time of year samples are drawn.[179] Some variables increase the lead concentration in water at the tap. For example, LSLs that have been disturbed—including partial replacement, lead repair, meter installation, shut-off valve replacement, and significant street excavation—can significantly increase the lead concentration of drinking water.[180] Some variables artificially reduce the amount of lead delivered at the tap. For example, pre-flushing—running the tap prior to the stagnation period—can remove lead already present in the water and result in lower lead concentrations.[181]

Individual sample collection generally underestimates significantly the peak lead level in water. One study of five sampling techniques designed to determine the best collection procedure[182] found that none of the techniques were proficient.[183] The best method came within 70% of the peak lead concentration only 48% of the time but was less than 30% of peak lead concentration 30% of the time.[184] For example, a lead test measuring .010 mg/L (10 ppb) or less would miss a peak lead level of .033 mg/L (33 ppb) on 30% of lead tests. First-draw samples—samples collected immediately after a stagnation period without first running the tap—were within 70% of peak lead only 30% of the time.[185] The unreliability of the first-draw method is consistent with prior studies.[186]

Lead testing cannot determine risks posed by particulate lead in water because current lead sampling, testing, and exposure models often assume that dissolved lead predominates in drinking water.[187] Making matters worse, particulate lead release is particularly erratic, and it is close to impossible to identify particulate release risk through testing.[188] The inability of testing to identify lead risks from particulate lead are particularly concerning because current corrosion control techniques do not address the problem of particulate lead.[189] The process that causes lead to flake off into water is different than leaching and lacks sufficient research to prevent particulate lead release.[190] Even under the best-case application of the LCR, particulate lead poses a substantial and unknown risk to children.

Even if there were an implemented testing procedure that reliably identifies peak lead in drinking water at the tap, local testing would fail to predict the risk of lead exposure because many states have no idea who is at risk of lead exposure. The LCR monitoring program relies on samples drawn from sources at the highest risk of lead exposure.[191] Low-risk sources are not expected to leach lead and thus do not provide useful data on whether corrosion control is working or necessary across a PWS.

Many PWSs have failed to perform the materials evaluation for lead required under the LCR.[192] This is no surprise with respect to community PWSs required to identify lead materials in private plumbing because it is difficult to comprehend how a PWS could possibly satisfy this requirement. But even the location of LSLs is woefully incomplete. Many states have identified challenges in locating LSLs and nine explicitly rejected an EPA request to make LSL locations public information based on these difficulties.[193]

Flint had not completed a materials evaluation prior to its water crisis.[194] As a result, Flint did not know which homes were at risk for lead exposure or even how many homes were affected.[195] As the governor of Michigan stated in the aftermath of the lead crisis in Flint: "A lot of work is being done to even understand where the lead services [sic] lines fully are, so I would say any numbers you're hearing at this point are still speculation."[196] Even if states do have a full materials evaluation, the LCR does not require states report this information to EPA, and 13 states have refused to provide this information even if it were avail-

173. *See* Masters et al., *supra* note 157, at 2; Brandi Clark et al., *Profile Sampling to Characterize Particulate Lead Risks in Potable Water*, 48 Envtl. Sci. & Tech. 6836, 6837 (2014); Del Toral et al., *supra* note 157, at 9304.
174. *See* Del Toral et al., *supra* note 157, at 9304 (finding high variability in lead concentrations in sequential samples from the same tap and across the PWS in a field study of the Chicago Department of Water Management and citing studies with similar results from other PWSs).
175. Masters et al., *supra* note 157, at 12 (emphasis added).
176. *Id*.
177. *See id*.
178. *See id*.; Del Toral et al., *supra* note 157, at 9304.
179. *See generally* Del Toral et al., *supra* note 157.
180. *Id*. at 9304-05.
181. *Id*. at 9303.
182. Peak lead levels were determined by using a sequential-draw procedure testing at least 12 one-liter sequentially collected samples. Water Research Foundation, Evaluation of Lead Sampling Strategies xv (2015).
183. *Id*. at 48-49.
184. *Id*.
185. *Id*. at 48-49, 51.
186. Del Toral et al., *supra* note 157, at 9302-03.
187. Triantafyllidou & Edwards, *supra* note 17, at 1316-18.
188. *Id*. at 1317.
189. *Id*. at 1318.
190. *Id*.
191. *See* 40 C.F.R. §141.86(a).
192. *See* GAO, *supra* note 23, at 26-27.
193. *Id*. at 27.
194. FWATF Final Report, *supra* note 78, at 44.
195. *See id*.; Arthur Delaney, *Lots of Cities Have the Same Lead Pipes That Poisoned Flint*, Huffington Post, Feb. 22, 2016, https://www.huffingtonpost.com/entry/lead-pipes-everywhere_us_56a8e916e4b0f71799288f54.
196. *Id*.

able.[197] Where high-risk taps are unknown, testing cannot serve as a proxy for the efficacy of corrosion control even if testing were reliable.

The unreliability of testing for lead in drinking water to determine the risk of lead exposure is not a new insight; it has been known for decades. In fact, it is one of the reasons that EPA promulgated an NPDWR as a treatment technique instead of using an MCL.[198] EPA found that "data indicate that the variability in tap [lead] levels can persist even in cases where water quality conditions are kept relatively constant."[199] It therefore is "technologically infeasible to ascertain whether the lead [ ] level at a tap at a single point in time represents effective application of the best available treatment technology."[200]

The unreliability of testing is one of the many ways the LCR does not adequately protect public health. The next six sections address specific deficiencies of the LCR.

C. The LCR Action Level Is Not a Health-Based Standard

The most significant shortcoming of the LCR is that the lead action level of 0.015 mg/L (15 ppb) is not a health-based standard. A PWS testing under 15 ppb at the 90th percentile does not mean that the PWS is delivering water safe to drink, it means only that additional corrosion control, LSL replacement, and public education requirements, as applicable, under the LCR are not required at that time.[201] All of these regulatory protections are tied to the capability of corrosion control technology, not rooted in scientific and medical understanding that there is no safe level of lead exposure in children.[202]

Many states, municipalities, and school districts advertise the lead action level as a health-based standard. For example, almost every PWS in Arkansas in the most recent lead monitoring period had lead present in the water for the 90th percentile test.[203] Eight PWS 90th percentile tests were above 15 ppb and one PWS tested at 110 ppb.[204] Another 16 PWS 90th percentile tests were 10 ppb or greater.[205] Arkansas nevertheless advertises the safety of the state's drinking water and compliance with the SDWA without qualification and even recommends that Arkansas residents not use water filters.[206] The city of Philadelphia, Pennsylvania, also advertises the EPA action level as a safety standard.[207] Philadelphia touts its record of testing below the EPA lead action level and safety of drinking water delivered to homes in meeting water quality standards for lead.[208]

Providing a false sense of security by advertising the EPA action level as a safety standard is particularly misleading for lead exposure risks at individual taps because the LCR monitoring requirements are not meant to identify lead exposure risks at individual taps.[209] Setting the action level at the 90th percentile allows individual taps to test above the action level with no limit. Table 1 is a chart of hypothetical monitoring results at and above the 90th percentile from a community water system that would not trigger additional corrosion control, LSL replacement, or public education requirements.

Table 1. Hypothetical Lead Monitoring Results

Sample Percentile	Lead Concentration (ppb)
100	100,000
99	75,000
98	25,000
97	15,000
96	7,000
95	4,000
94	3,000
93	1,500
92	1,000
91	500
90	14

Although LCR-compliant, this hypothetical example would be a clear and present health danger to the 10 highest testing samples. Considering the unreliability of testing and the number of samples taken during a monitoring period being a small fraction of the total taps,[210] the risk of lead exposure throughout a PWS based on this hypothetical sample could be a crisis to which the LCR does not require a response.

D. Reduced Monitoring

The LCR allows PWSs to test for lead under monitoring requirements once every three years after initial compliance, which is a significant regulatory gap that allows dangerous lead levels in drinking water for years.[211] Reduced monitoring has resulted in delayed responses to toxic lead

197. GAO, *supra* note 23, at 26.
198. 56 Fed. Reg. at 26473.
199. *Id.*
200. *Id.*
201. 40 C.F.R. §141.80(d)-(g).
202. *See* discussion *infra* Section II.B.
203. Arkansas Department of Health, Lead Test Results, http://www.healthy.arkansas.gov/images/uploads/pdf/drinking-water-LeadMonitoringResults.pdf.
204. *Id.*
205. *Id.*
206. Arkansas Department of Health, *Public Water System FAQS*, http://www.healthy.arkansas.gov/programs-services/topics/drinking-water-public-water-system-faqs (last visited Sept. 28, 2018).
207. City of Philadelphia, *Lead in Drinking Water*, http://www.phila.gov/water/wu/drinkingwater/pages/leadinfo.aspx (last visited Sept. 28, 2018).
208. *Id.*
209. U.S. EPA, 3Ts for Reducing Lead in Drinking Water in Schools, Revised Technical Guidance 12 (2006) [hereinafter EPA 3T Revised Technical Guidance].
210. *See* 40 C.F.R. §141.86(c).
211. Del Toral et al., *supra* note 157, at 9305.

exposure in drinking water. In 2011, two homes in Brick Township, New Jersey, which qualified for triennial testing, tested over 15 ppb.[212] Three years later at the next monitoring period, a shocking 16 of 34 homes exceeded 15 ppb, with one home testing over 12 times the EPA action level.[213] Brick Township is a striking example of how pipes can corrode quickly and with little warning, exposing the danger of triennial monitoring. Brick Township's pipes corroded quickly because of the city's increased use of salt treatment on roads in the winter.[214] Treating roads with salt increased chloride in Brick Township's source water, which in turn caused pipes to corrode.[215] Corrosion went undetected because of reduced monitoring and caused the alarming amounts of lead to leach into Brick Township's drinking water.[216]

The water crisis in Washington, D.C., also highlights the potential danger of triennial monitoring. Lead pipes corroded quickly after changes in the quality of the source water. In November 2000, Washington, D.C., changed the disinfectant for the drinking water supply from chlorine to chloramine.[217] Using chloramine to disinfect had the unintended consequence of corroding the water distribution system and caused lead to leach into the drinking water. Within eight months, the 90th percentile sample in Washington, D.C., exceeded 15 ppb.[218] By December 2001, the 90th percentile sample was almost 80 ppb,[219] with some homes testing at 20 times the EPA action level.[220]

Lead-contaminated water persisted in Washington, D.C., for three years, during which fetal death rates rose and BLLs rose above 10 µg/dL in approximately 859 tested children in Washington, D.C., and likely thousands more due to lack of blood lead testing in vulnerable populations.[221] In total, 42,000 children in Washington, D.C., from 2001-2004 are at risk of lifelong health consequences from lead exposure through drinking water.[222] The Washington, D.C., water crisis, which was 20-30 times worse than Flint,[223] shows directly the disastrous consequences of not acting on lead contamination for three years. Every PWS on triennial testing is at risk of a Washington, D.C.-type crisis.

E. Resident Collection

The LCR allows PWSs to rely on residents to collect samples for LCR compliance, and PWSs almost exclusively do so.[224] PWSs satisfy this requirement with an instruction sheet accompanying testing materials,[225] which materially differ between PWSs.[226] Using residents to collect water samples with little more than an instruction sheet as a guide decreases the likelihood that samples are collected correctly using current sampling protocol required under the LCR.[227] Many PWSs face challenges getting properly collected samples from residents and lack the resources necessary to ensure proper sampling.[228] Compounding this problem, studies show that in order to capture peak lead levels, more sophisticated procedures are necessary,[229] which will increase the likelihood of collection errors from resident sampling.[230] If researchers with expertise in corrosion and water sampling have difficulty capturing peak lead concentration from water samples,[231] using residents to collect samples further undermines the reliability of testing.

The LCR compounds resident collection error by prohibiting PWSs from excluding a sample based on collection error.[232] This part of the rule was intended to prevent PWSs from excluding samples with high lead concentrations to lower the 90th percentile.[233] EPA interprets this rule strictly and does not let PWSs exclude samples even if it is likely that sampling error would result in underreporting lead concentration.[234] A sampling procedure designed to capture peak lead would leave little room for error and result in underreporting lead content in most cases.[235] Even under the current testing protocols, errors like collecting samples after flushing the tap would result in underreporting lead concentration of the water.[236] Including incorrectly collected samples that underreport lead concentration will lower the 90th percentile sample and potentially not trigger remedial action under the LCR otherwise required.

F. LSL Replacement

The LCR's LSL replacement provision has two critical deficiencies. The LCR allows PWSs to stop a required LSL replacement program as soon as the 90th percentile test for two consecutive monitoring periods is under the lead

212. Wines & Schwartz, *supra* note 32.
213. *Id.*
214. *Id.*
215. *Id.*
216. *Id.*
217. Edwards et al., *supra* note 28, at 1618.
218. *Id.* at 1619.
219. *Id.*
220. Wines & Schwartz, *supra* note 32.
221. Edwards et al., *supra* note 28, at 1618, 1621; Edwards, *supra* note 49, at 741-42.
222. Leonnig, *supra* note 8.
223. Katherine Shaver & Dana Hedgpeth, *D.C.'s Decade-Old Problem of Lead in Water Gets New Attention During Flint Crisis*, Wash. Post, Mar. 17, 2016, https://www.washingtonpost.com/local/dcs-decade-old-problem-of-lead-in-water-gets-new-attention-during-flint-crisis/2016/03/17/79f8d476-ec64-11e5-b0fd-073d5930a7b7_story.html?utm_term=.66b85d1b135e.
224. Del Toral et al., *supra* note 157, at 9301.
225. *See*, *e.g.*, MDEQ, *supra* note 140; Illinois Environmental Protection Agency, Lead/Copper Sample Collection Instructions (2016).
226. Del Toral et al., *supra* note 157, at 9301.
227. Water Research Foundation, *supra* note 182, at xv.
228. *Id.*
229. *Id.*; *see generally* Del Toral et al., *supra* note 157.
230. Water Research Foundation, *supra* note 182, at xv.
231. *See generally* Water Research Foundation, *supra* note 182.
232. 40 C.F.R. §141.86(b)(2).
233. EPA Clarification, *supra* note 137, at 2.
234. *Id.* at 6.
235. *See* Water Research Foundation, *supra* note 182, at xv.
236. EPA Clarification, *supra* note 137, at 2.

action level.[237] Allowing a PWS to pause an LSL replacement program based on unreliable testing is an unacceptable risk to public health when lead has leached into water despite corrosion control efforts in the past.

The LCR's partial LSL replacement mandate presents a known risk of increased lead exposure to individual homeowners. The LCR LSL replacement program requires the PWS to replace the PWS-owned portion of an LSL even if a homeowner elects not to replace the privately owned portion of the LSL.[238] Disturbance of LSLs causes a sharp increase in lead leaching into drinking water and can persist for years.[239] A PWS is required to offer to replace at homeowner expense the privately owned portion of an LSL when replacing the publically owned portion.[240] Homeowners are unlikely to pay for an expensive LSL replacement project if unaware of the full extent of increased lead exposure because of partial replacement. Partial LSL replacement therefore is likely not to mitigate lead exposure but rather increase lead exposure.[241]

G. *First-Draw Samples*

EPA requires one-liter, first-draw tap samples under the LCR monitoring program and recommends that schools and day-care centers collect first-draw samples.[242] First-draw samples usually are not effective in determining the risk of lead exposure at the tap.[243] First-draw samples significantly underestimate peak lead levels in drinking water about 70% of the time.[244] Even after the first one-liter draw, any particular one-liter sample significantly underestimates peak lead concentration most of the time when compared to 12 one-liter sequential samples from the same tap.[245]

Sequential sampling and testing multiple liters of water after stagnation is the only way to measure peak lead with any reliable accuracy.[246] The LCR essentially requires that PWSs collect samples that significantly underestimate peak lead most of the time and recommends schools and day-care centers serving the most vulnerable populations do the same. First-draw samples therefore can justify inaction for and provide a false sense of security to an entire PWS when an underestimate of peak lead from first-draw samples lowers the 90th percentile sample below the lead action level.

H. *Gaming the LCR Monitoring Program*

The LCR's monitoring program has significant gaps allowing testing techniques to lower lead concentration below the actual risk of exposure. Collection procedures that will artificially reduce lead concentration include pre-flushing water lines prior to stagnation, limiting stagnation time to a minimum number of hours, instructing homeowners to remove aerators prior to sampling, and providing narrow bottles for sampling with instructions to open taps slowly.[247] The Washington, D.C., WASA employed all of these techniques at some point since 2002.[248] Philadelphia, a city where 10% of children still have BLLs greater than 5 µg/dL (50 ppb), has instructed residents to pre-flush the tap prior to the stagnation period, remove aerators prior to sampling, and use a low water flow during sampling.[249]

In Flint, pre-flushing and small-mouth bottles contributed state lead testing results (90th percentile at 11 ppb) markedly below the levels of private testing conducted at Virginia Tech (25 ppb).[250] In Durham, North Carolina, in 2006, a child was lead-poisoned from drinking water despite tests showing compliance with the LCR.[251] Durham was removing aerators prior to sampling.[252] In 2016, when New York City stopped pre-flushing, taps exceeding the EPA action level increased by nine times.[253] One school in Staten Island where pre-flush tests found six outlets over the EPA action level and a high concentration of 49 ppb, now found 53 taps over 15 ppb, 14 over 1,000 ppb, a drinking fountain over 3,680 ppb, and a classroom faucet over 32,500 ppb.[254] These are only a few examples of practices that persist across the United States undermining already unreliable lead testing programs.[255]

These collection techniques that reduce lead concentration are legal. EPA issued guidance in 2016 recommending that PWSs conduct sampling with wide-mouth bottles and that sampling instruction not include directions to remove

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237. 40 C.F.R. §141.84(f).
238. *Id*. §141.84(d).
239. *See* Del Toral et al., *supra* note 157, at 9304-05.
240. 40 C.F.R. §141.84(d).
241. *See id*.
242. *Id*. §141.86(b)(1); EPA 3T Revised Technical Guidance, *supra* note 209, at 12; U.S. EPA, 3Ts for Reducing Lead in Drinking Water in Child Care Facilities: Revised Guidance 10 (2005).
243. Water Research Foundation, *supra* note 182, at 48-49; *see* Del Toral et al., *supra* note 157, at 9302-03 (collecting studies finding first-draw samples unreliable to measure peak lead concentration).
244. Water Research Foundation, *supra* note 182, at 48-49, 51.
245. *Id*.
246. *See id*.; Clark et al., *supra* note 173, at 6837.
247. Marc Edwards et al., Gaps in the EPA Lead and Copper Rule That Can Allow for Gaming Compliance: DC WASA 2003-2009, at 2-4 (2009).
248. *Id*.
249. Oliver Milman & Jessica Glenza, *Philadelphia's Water-Testing Procedures Are "Worse Than Flint"—Expert*, Guardian, Jan. 28, 2016, https://www.theguardian.com/environment/2016/jan/28/philadelphia-water-testing-crisis-flint-health-risk.
250. FWATF Final Report, *supra* note 78, at 8, 18, 29, 20-21, 44; Marc Edwards et al., *Our Sampling of 252 Homes Demonstrates a High Lead in Water Risk: Flint Should Be Failing to Meet the EPA Lead and Copper Rule*, Flint Water Study, Sept. 8, 2015, http://flintwaterstudy.org/2015/09/our-sampling-of-252-homes-demonstrates-a-high-lead-in-water-risk-flint-should-be-failing-to-meet-the-epa-lead-and-copper-rule/.
251. Renner, *supra* note 28, at 544, 547.
252. *Id*. at 547.
253. Kate Taylor, *New York Changes How It Tests for Lead in Schools' Water, and Finds More Metal*, N.Y. Times, Feb. 3, 2017, https://www.nytimes.com/2017/02/03/nyregion/new-york-dept-education-lead-water.html.
254. *Id*.
255. *See* Oliver Milman, *US Authorities Distorting Tests to Downplay Lead Content of Water*, Guardian, Jan. 22, 2016, https://www.theguardian.com/environment/2016/jan/22/water-lead-content-tests-us-authorities-distorting-flint-crisis; Oliver Milman & Jessica Glenza, *At Least 33 US Cities Used Water Testing "Cheats" Over Lead Concerns*, Guardian, June 2, 2016, https://www.theguardian.com/environment/2016/jun/02/lead-water-testing-cheats-chicago-boston-philadelphia.

aerators or pre-flush.[256] These recommendations, however, are guidance, not a regulatory requirement. In response to a 2016 *Guardian* investigation on lead testing procedures, many water departments from 81 major cities east of the Mississippi River said EPA had not issued clear guidance on testing, they never received a memo from EPA, or that the sampling techniques are not illegal.[257]

The only real accountability to prevent PWSs from employing legal collection practices designed to lower the 90th percentile sample is political. Political pressure often encounters government resistance and forces change only after tragic lead exposure to entire communities.[258] And given the history of government incompetence and misconduct in administering the LCR discussed in the next part, relying on political pressure to protect people from lead exposure will result in dangerous lead exposure across the United States.

IV. Government Incompetence and Misconduct

This part discusses the threat to the public health of entire communities because of violations of the LCR through incompetence, malfeasance, and, in some cases, alleged criminal misconduct on the part of government officials. The fact of government incompetence and misconduct strongly supports funding private filtration so individuals can protect themselves from lead in the home and requiring filtration in drinking fountains in nonresidential buildings. This part will first discuss how LCR violations throughout the nation exacerbate the threat of lead exposure, and then explore the Flint water crisis as an example of how government incompetence and alleged official misconduct resulted in widespread toxic lead exposure.

A. LCR Violations

Failing to collect samples for testing from high-risk taps is a particular problem in administration of the LCR. Washington, D.C., intentionally employed this technique in 2003 and refused to make public the sampling pool in order to avoid LSL replacement requirements.[259] PWSs that have not completed the required materials evaluation are probably not testing from high-risk locations. As a practical matter, selecting locations for testing without information about lead materials is little more than a guessing game.

Violations of the LCR extend far beyond materials evaluations and testing locations. According to a June 2016 NRDC report, in 2015, "over 18 million people were served by 5,363 community water systems that violated the [LCR]."[260] PWS violations ranged from failing to test properly for lead and water conditions, to failing to report violations to state officials, to failing to implement corrosion control.[261] This number only includes detected violations and likely is a significant underestimate, considering underreporting has been a problem since the LCR's inception and Flint's rampant violations were known and unreported at that time.[262] Making matters worse, EPA and state authorities with primary enforcement authority took no formal enforcement action for nearly 90% of violations and only 3% resulted in penalties.[263] This anemic enforcement rate likely contributed to a culture of noncompliance that tolerated incompetence, misconduct, and cover-up resulting in the Flint water crisis.

B. The Flint Water Crisis

The water crisis in Flint is a tragic example of government incompetence, malfeasance, and alleged criminal misconduct at all levels of government. The seeds of Flint's water crisis began in 2011 when Gov. Rick Snyder stripped Flint's city council of power and appointed an emergency manager to fix Flint's fiscal problems.[264] In June 2013, using his power as emergency manager, Edward Kurtz unilaterally decided to switch Flint's water source to the Flint River rather than Lake Huron-treated water from Detroit.[265] On April 25, 2014, Flint officially switched its water source to the Flint River.[266] Nine days prior, Michael Glasgow of the Flint Utilities Department e-mailed the Michigan Department of Environmental Quality (MDEQ) warning that the Flint water treatment plant was not prepared to handle the switch.[267] Flint's water treatment system had not been used in 50 years and river water is very difficult to treat with water chemistry changing sometimes by the hour.[268]

The disastrous health and safety consequences to the people of Flint began almost immediately. Within the first six months, brown water began coming out of taps, *E. coli* contamination required boil notices, and more than 70 cases of legionellosis were reported in Flint resulting in 12 deaths.[269] In October 2014, General Motors switched its water source back to Lake Huron because water was corroding engine parts.[270] Corrosion was occurring because Flint increased chloride treatment to kill bacteria but did not treat the water with corrosion control as required under the LCR.[271] Emergency Manager Darnell Earley, replacing Kurtz, rejected a proposal from Valerie Brader, the state deputy legal counsel and senior policy advisor, and Michael Gadola, the governor's legal counsel, to switch back to Lake Huron water provided through Detroit.[272]

256. U.S. EPA, Clarification of Recommended Tap Sampling Procedures for Purposes of the Lead and Copper Rule (2016).
257. Milman & Glenza, *supra* note 255.
258. *See NOVA: Poisoned Water*, *supra* note 75.
259. Edwards et al., *supra* note 250, at 2.
260. Olson & Fedinick, *supra* note 34, at 5.
261. *Id.*
262. *Id.*
263. *Id.* at 6.
264. FWATF Final Report, *supra* note 78, at 39; *NOVA: Poisoned Water*, *supra* note 75.
265. FWATF Final Report, *supra* note 78, at 17, 40.
266. *NOVA: Poisoned Water*, *supra* note 75.
267. FWATF Final Report, *supra* note 78, at 17.
268. *NOVA: Poisoned Water*, *supra* note 75.
269. *Id.*; FWATF Final Report, *supra* note 78, at 17.
270. *NOVA: Poisoned Water*, *supra* note 75.
271. *Id.*
272. FWATF Final Report, *supra* note 78, at 17-18.

Residents alarmed at the quality of the water protested at town meetings with city officials dismissing their concerns and insisting that Flint's water was safe to drink.[273]

Shortly after Flint switched its water source, LeeAnne Walters, who like many Flint residents was experiencing hair loss and whose children were suffering painful skin rashes while bathing, requested documents from Flint about water treatment and requested that Flint test her water for lead.[274] Walters' water tested at 104 and 397 ppb for lead.[275] Flint officials insisted that Walters' water was an isolated problem, not systemic.[276] Walters contacted Miguel Del Toral at EPA and shared the results of her lead test.[277] In February 2015, Del Toral contacted the MDEQ to determine whether Flint was using corrosion control and informed the MDEQ that corrosion control was required.[278] The MDEQ told Del Toral that Flint was using corrosion control.[279] Walters then found through her document requests a water monthly operational report showing that Flint was not treating water with corrosion control.[280] Walters shared the report with Del Toral who again contacted the MDEQ about the use of corrosion control in Flint's water system.[281] In April 2015, the MDEQ informed Del Toral that Flint was not using corrosion control.[282] Del Toral again informed the MDEQ that the LCR requires corrosion control for Flint.[283]

As lead continued to leach into Flint's drinking water, public protests escalated in Flint with no government response.[284] In June 2015, Del Toral, frustrated with EPA's lack of response and alarmed at Flint's failure to implement corrosion control, wrote an interim report warning of serious risks of lead exposure to Flint residents from failing to use corrosion control.[285] Del Toral provided a copy to Walters, who sent the report to the press.[286] The disclosure did not trigger government action to protect the residents of Flint.[287] Instead, the MDEQ dismissed Del Toral's report; MDEQ spokesman Brad Wurfel commented, "the residents of Flint do not need to worry about lead in the water supply . . . anyone who is concerned about lead in the drinking water in Flint can relax."[288] EPA did not take any action or even require that MDEQ force Flint to implement corrosion control.[289] Instead, EPA Region 5 Administrator Susan Hedman apologized to Flint's mayor for the release of Del Toral's report and the mayor went on television telling residents that Flint water was safe to drink.[290] The MDEQ described Del Toral as a "rogue employee" and said that Del Toral had been "handled."[291]

In summer 2015, Walters contacted Dr. Marc Edwards at Virginia Tech to perform lead tests on her water.[292] Walters took 30 samples, with some testing as high as 13,280 ppb.[293] Flint and the MDEQ refused to take action, insisting that the water was safe to drink because LCR monitoring from July-December 2014 showed the 90th percentile at 6 ppb and at 11 ppb for the next six-month monitoring period.[294] Official tests were artificially low because Flint was not sampling from high-risk sources and was using collection techniques that reduce lead levels, including pre-flushing for five minutes and using narrow collection bottles.[295] Flint specifically excluded samples from Walters' home from the sampling pool.[296]

Walters and Dr. Edwards then organized a private lead testing program collecting 300 representative samples throughout Flint.[297] On September 8, 2015, Virginia Tech completed testing on 252 samples and found the 90th percentile of lead at 25 ppb.[298] Several samples tested over 100 ppb and one sample tested over 1,000 ppb.[299] Researchers at Virginia Tech concluded that "even if the remaining samples did not detect lead, Flint had a very serious lead problem in the drinking water" and released the results to the public.[300] Dr. Edwards estimated that 40% of homes in Flint had lead contamination above 15 ppb.[301] Instead of acting to protect the residents of Flint, the MDEQ disputed Virginia Tech's findings.[302]

Shortly after Dr. Edwards released the results of the water testing, Dr. Mona Hanna-Attisha, director of the pediatric residency program at Hurley Medical Center, conducted a study of BLLs in children after Flint switched water sources.[303] Dr. Hanna-Attisha compared BLLs from 2013 with BLLs in 2015 and found that the number of children with BLLs above 5 µg/dL doubled and in some neighborhoods almost tripled.[304] Instead of recognizing Dr. Hanna-Attisha's study as consistent with and supporting Dr. Edwards water test results, the state of Michigan disputed Dr. Hannah-Attisha's study.[305] It was not until later in September when Dr. Eden Wells, chief medical officer of the Michigan Department of Health and Human Services (MDHHS), concluded that Dr. Hannah-Attisha's

273. *NOVA: Poisoned Water*, *supra* note 75.
274. *Id*.
275. *Id*.
276. *Id*.
277. *Id*.
278. *Id*.; FWATF Final Report, *supra* note 78, at 18.
279. FWATF Final Report, *supra* note 78, at 19; *NOVA: Poisoned Water*, *supra* note 75.
280. *NOVA: Poisoned Water*, *supra* note 75.
281. *Id*.
282. *Id*.
283. FWATF Final Report, *supra* note 78, at 19.
284. *NOVA: Poisoned Water*, *supra* note 75.
285. *Id*.; FWATF Final Report, *supra* note 78, at 20.
286. *NOVA: Poisoned Water*, *supra* note 75.
287. *Id*.
288. *Id*.; FWATF Final Report, *supra* note 78, at 20.
289. FWATF Final Report, *supra* note 78, at 51.
290. *NOVA: Poisoned Water*, *supra* note 75.
291. *Id*.
292. *Id*.
293. *Id*.
294. *Id*.; FWATF Final Report, *supra* note 78, at 19, 21.
295. FWATF Final Report, *supra* note 78, at 44, 51; *NOVA: Poisoned Water*, *supra note* 75.
296. FWATF Final Report, *supra* note 78, at 29; *NOVA: Poisoned Water*, *supra* note 75.
297. *NOVA: Poisoned Water*, *supra* note 75.
298. FWATF Final Report, *supra* note 78, at 21.
299. *Id*.
300. *Id*.; *NOVA: Poisoned Water*, *supra* note 75.
301. *NOVA: Poisoned Water*, *supra* note 78.
302. *Id*.
303. *Id*.
304. Hanna-Attisha et al., *supra* note 28, at 283.
305. *NOVA: Poisoned Water*, *supra* note 75.

research was sound that Flint, the state of Michigan, and EPA began to take Flint's water crisis seriously.[306] On October 1, 2015, the MDHHS publically confirmed Dr. Hanna-Attisha's findings. On October 16, Flint switched its water source back to Lake Huron.[307]

The Flint water crisis represents government malfeasance and incompetence at its worst. At every level of government from Flint to EPA, incompetence, denial, and cover-up failed the people of Flint and exposed approximately 8,000 children to lead contamination. The state appointed emergency managers who put money over community health in making a risky switch in water source to the Flint River and then ignored clear evidence of dangerous and contaminated water.[308] The Flint water crisis could have been significantly mitigated if emergency managers had switched Flint's water source back to Lake Huron in October 2014 as the people demanded and the state legal counsel recommended.[309]

The Flint Utilities Department was not prepared to handle the complicated task of treating river water for public consumption.[310] As a result, the people of Flint were in significant danger the minute that water began to flow from the Flint River to the tap. A dangerous decision at its inception was made exponentially more so because Flint illegally failed to treat the water with corrosion control. And Flint's illegal practice of not selecting high-risk homes for testing and using collection techniques that reduce lead concentration hid the obvious threat.

The MDEQ failed to execute its mission and protect the people of Flint. The MDEQ advised Flint water treatment plant staff not to use corrosion control and then lied to EPA about its application, failed to correct and even condoned improper water sampling techniques, insisted on the accuracy of incorrect data, and ignored Flint residents, elected officials, and EPA.[311] The MDEQ waited months before accepting EPA's offer to provide expert assistance to address lead contamination, actively worked to discredit the work of outside experts, and ignored the people of Flint.[312] For 18 months, the MDEQ advertised Flint's water as safe to drink and insisted on the safety of Flint's water even after compelling evidence of elevated BLLs in Flint's children.[313] MDEQ's illegal acts, incompetence, and sustained dissemination of false information directly caused the Flint water crisis.[314]

The MDHHS failed to identify that BLLs in Flint were rising. An internal analysis concluding that BLLs were rising was questioned, and the MDHHS never resolved the conflict.[315] The MDHHS' internal failures and initial questioning of Dr. Hanna-Attisha's study likely extended the water crisis by three months.

EPA failed to protect the people of Flint after the MDEQ disclosed in April 2015 that corrosion control was not being used. EPA did not require Flint to use corrosion control until July 2015, deferring corrosion control pending a legal opinion that the MDEQ requested despite the clear and unambiguous requirement that community water systems use corrosion control.[316] EPA deferred to the MDEQ despite internal protests from Del Toral and clear evidence of egregious LCR violations.[317] EPA also did not use its enforcement authority until issuing a January 2016 emergency order after increasing public pressure and clear evidence of elevated BLLs in children.[318] EPA's apathy and failure to timely enforce the SDWA exacerbated and extended the Flint water crisis. It was the extraordinary efforts of Walters, protests of the Flint community, Dr. Edwards' team of researchers at Virginia Tech, and Dr. Hanna-Attisha's research that exposed the Flint water crisis.[319]

The fallout from the Flint water crisis resulted in a congressional investigation and detailed state investigation. The people of Flint voted Dayne Walling out of office and Susan Hedman resigned as administrator of EPA Region 5.[320] To date, 15 government officials have been indicted in connection with the Flint water crisis, including former emergency managers Darnell Earley and Gerald Ambrose for misconduct in office and willful neglect of duty; former Flint Public Works Administrator Howard Croft and former Flint Utilities Administrator Daugherty Johnson for conspiracy and false pretenses; Flint Laboratory Water Quality Supervisor Mike Glasgow for tampering with evidence and willful neglect; fired head of the MDEQ Liane Shekter-Smith for misconduct in office and willful neglect of duty; MDEQ Water Quality Analyst Adam Rosenthal for misconduct in office, tampering with evidence, and willful neglect of duty; MDEQ employee Mike Prysby for tampering with evidence, and treatment and monitoring violations of Michigan's SDWA; and several other MDEQ officials.[321] Several officials at the MDHHS face more serious charges in connection with the legionellosis outbreak, including involuntary manslaughter.[322] But the lifelong health consequences for as many as 8,000 chil-

306. *See* FWATF Final Report, *supra* note 78, at 21; *NOVA: Poisoned Water*, *supra* note 75.
307. FWATF Final Report, *supra* note 78, at 21.
308. *Id.* at 40.
309. *Id.* at 17-18.
310. *Id.* at 43-44.
311. *Id.* at 27-28.
312. *Id.* at 28-29; *NOVA: Poisoned Water*, *supra* note 75.
313. FWATF Final Report, *supra* note 78, at 29; *NOVA: Poisoned Water*, *supra* note 75.
314. FWATF Final Report, *supra* note 78, at 29.
315. *Id.* at 31-32.
316. *Id.* at 18, 51.
317. *NOVA: Poisoned Water*, *supra* note 75.
318. FWATF Final Report, *supra* note 78, at 51-52.
319. John McQuaid, *Without These Whistleblowers, We May Never Have Known the Full Extent of the Flint Water Crisis*, Smithsonian Mag., Dec. 2016, https://www.smithsonianmag.com/innovation/whistleblowers-marc-edwards-and-leeanne-walters-winner-smithsonians-social-progress-ingenuity-award-180961125/; *NOVA: Poisoned Water*, *supra* note 75.
320. Josh Sanburn, *Former EPA Official Grilled Over Flint Water Crisis*, Time Mag., Mar. 15, 2016, http://time.com/4259438/susan-hedman-flint-water-crisis-congress/.
321. Paul Egan, *These Are the 15 People Criminally Charged in the Flint Water Crisis*, Detroit Free Press, June 14, 2017, https://www.freep.com/story/news/local/michigan/flint-water-crisis/2017/06/14/flint-water-crisis-charges/397425001/.
322. *Id.*

dren in Flint exposed to toxic lead, a community living in fear and loss of trust in government, and the $1.5 billion price tag is the true legacy of this government-caused public health disaster.[323]

In a perfect world, the water crisis in Flint would produce lasting lessons learned that are implemented in every community across the United States and political action for robust enforcement and revision of the LCR. Instead, EPA Region 5 Administrator Hedman refused to take responsibility before Congress in March 2016, stating: "I don't think anyone in the EPA did anything wrong."[324] And the Flint crisis has not deterred government officials from resisting attempts to protect residents from lead in water. Just this year, the mayor of Denmark, South Carolina, refused to allow Dr. Edwards to collect testing samples from town wells for bacteria after finding lead in tap water in some Denmark homes.[325] The mayor claimed that additional testing is unnecessary because "the state Department of Health and Environmental Control has found [the water] to be safe."[326]

Because of government incompetence and misconduct and the inadequacy of the LCR to protect public health from lead exposure, children across the United States are at risk of suffering the significant and permanent adverse health effects of lead exposure. This continuing risk of lead present at the tap demands a policy approach that promotes removing the lead that is present at the tap consistent with primary prevention: a refundable tax credit for individuals to purchase a filtration system and replacement filters certified for lead reduction under NSF/ANSI Standard 53, and requiring nonresidential buildings install BAT for filtration in drinking fountains.

V. Preventing Lead Exposure With a Refundable Tax Credit and Requiring BAT

This part recommends that Congress provide a refundable tax credit for individuals to acquire a filtration system and replacement filters certified for lead reduction under NSF/ANSI Standard 53, and require best available filtration technology in drinking fountains in nonresidential buildings. The medical community has adopted primary prevention to address the significant, permanent, and irreversible health effects of lead in children at very low BLLs. The LCR is inconsistent with primary prevention because the inherent difficulty of regulating lead in water, the unreliability of testing, and specific shortcomings of the LCR allow lead to be present in drinking water at the tap. Lead will persist in drinking water as long as there are lead-containing materials in drinking water infrastructure and private plumbing.

Researchers studying corrosion and the efficacy of lead testing recommend that it usually is better to assume that lead is present in drinking water at unsafe levels and focus on preventing exposure than to rely on the results of testing to determine when intervention is necessary.[327] Government incompetence and misconduct in implementing the LCR exacerbate the inherent difficulty of regulating lead and the inadequacy of the LCR. Further, compliance with the LCR can create a false sense of security in the safety of drinking water, particularly at individual taps.

Public policy to address lead in drinking water must recognize that even with best regulatory efforts to prevent lead leaching into drinking water, the risk of lead in drinking water will persist across the country and testing cannot assure safety. Consistent with the medical consensus that primary prevention is necessary to protect children from lead exposure, public policy should promote efforts to remove lead that is actually present in water at the point of use. This part first discusses why POU filtration will fill the regulatory gap, and next recommends that Congress provide a refundable tax credit for POU filtration and require nonresidential buildings to filter water at drinking fountains.

A. POU Filtration Is Effective and Fills the Regulatory Gap

Promoting and funding POU filters effective at reducing lead is consistent with a primary prevention approach to childhood lead exposure and would fill the regulatory gap that necessarily results in dealing with lead at the tap. Filtration technology implements a primary prevention approach because removing lead from water at the tap prevents exposure to lead. Filtering water at the tap will also remove many other contaminants and protect against attacks to drinking water supplies by the intentional introduction of contaminants. Recent efforts to reduce lead in drinking water do not adequately protect public health, making promotion of POU filtration all the more necessary.

Water filtration technology is highly effective at removing lead from drinking water at the tap. NSF International[328] tests filtration technology to ensure that filters meet minimum standards of filtration for many contaminants.[329] Filters that meet NSF filtration standards for health effects receive certification under the NSF/ANSI

323. *See NOVA: Poisoned Water*, *supra* note 75.

324. Steve Carmody, *Flint Mayor Leaving Office After Defeat, but Not Politics*, Mich. Radio, Nov. 4, 2015, http://michiganradio.org/post/flint-mayor-leaving-office-after-defeat-not-politics; Sanburn, *supra* note 320.

325. Sammy Fretwell, *Small Town SC Mayor Won't Let Flint Water Crisis Researcher Test Wells for Pollution*, State, Jan. 27, 2018, http://www.thestate.com/news/local/article196354779.html.

326. *Id.*

327. Masters et al., *supra* note 157, at 12-13.

328. NSF International is an independent, accredited organization that develops health standards and certification programs to protect food, water, consumer products, and the environment. NSF International tests products advertised to perform a claimed function (e.g., filtration) and provides certification if the product is effective to the NSF-established standard. NSF International, *Certified Product Listings for Lead Reduction*, http://info.nsf.org/Certified/DWTU/listings_leadreduction.asp?ProductFunction=053|Lead+Reduction&ProductFunction=058|Lead+Reduction&ProductType;=&submit2=Search (last visited Sept. 28, 2018) [hereinafter *NSF Product Listings*].

329. *Id.*

Standard 53 for Drinking Water Treatment Units.[330] NSF/ANSI Standard 53 includes certification for lead reduction in drinking water for POU filtration systems, including pour-through pitchers, faucet mounts, countertop units connected to a sink faucet, under-the-counter plumbing-connected filters, and refrigerator filters.[331] To receive certification, filters must be able to filter lead below 10 ppb from a challenge level of 150 ppb.[332] After providing certification, NSF annually audits manufacturing facilities to confirm that the product sold to the public meets the standard confirmed in the laboratory.[333] There are hundreds of water filtration systems that meet the NSF/ANSI Standard 53, including convenient faucet mount options and pour-through pitchers.[334]

In practice, NSF/ANSI Standard 53 certified water filtration technology performs significantly better than the reduction level of 10 ppb required under Standard 53. In response to the water crisis in Flint, EPA performed a filter challenge assessment on the efficacy of Brita and Pur manufactured filters that are NSF Standard 53-certified to remove lead from drinking water.[335] EPA conducted this test to determine whether these POU filters would filter effectively when filtering water with lead levels greater than 150 ppb.[336]

Based on more than 200 samples, including samples with confirmed lead levels above 150 ppb and some over 4,000 ppb, the POU filters reduced average lead concentration to 0.3 ppb, the highest lead concentration after filtration was 2.9 ppb, and 80% of the filtered samples were below the detectable level for lead.[337] EPA then collected more than 50 additional samples from locations recommended by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR).[338] The filters again removed lead to less than 1 ppb on average.[339] The ATSDR reviewed EPA's study and confirmed the results: filtered water from POU filters certified for lead removal is safe for consumption and cooking for all people, including children and pregnant women.[340] NSF/ANSI Standard 53-certified POU filtration technology thus would effectively remove lead present in drinking water at the tap.

The SDWA recognizes the utility of POU filtration and even contemplates the use of POU filtration to comply with NPDWRs. For some contaminants, filtration is a treatment technique.[341] The SDWA also requires EPA to list POU treatment units as a compliance technology for small PWSs to meet SDWA standards.[342] EPA has listed POU filtration technologies as compliance technologies under the SDWA.[343] Reverse osmosis and cation exchange are compliance technologies for lead, but other filtration technologies also filter lead effectively.[344]

States have implemented POU treatment systems for compliance with NPDWRs. For example, Arizona allows qualifying PWSs to use POU treatment systems to comply with NPDWRs.[345] Under the Arizona program, a PWS authorized to use POU treatment must use a treatment system that complies with applicable NSF/ANSI standards, including Standard 53.[346] EPA advertises POU filtration as effective for individuals to reduce exposure to lead at the tap.[347] Some states also recommend that individuals use POU filters to protect from the risk of lead exposure through drinking water.[348] State implementation of POU filtration to comply with NPDWRs as well as EPA and state recommendations that individuals use POU filters to protect themselves from lead in drinking water reflect what NSF/ANSI standards and the Flint water filtration field test confirm: POU filtration is highly effective at reducing lead in drinking water.

In addition to removing lead actually present at the tap, promoting POU filtration nationally would also remove other harmful contaminants present and support water security against the intentional introduction of contaminants into water distribution systems. Filtration systems meeting NSF/ANSI Standard 53 generally filter for many more contaminants than just lead.[349] For example, the readily accessible Brita faucet mount filtration system reduces 21 other contaminants, including harmful contaminants like asbestos, benzene, and toluene, and more than 40 volatile organic compounds.[350] Filtration systems also often reduce other compounds, including emerging contami-

330. *Id*.
331. *Id*.
332. *Id*.; NSF International/ANSI Standard 53, Drinking Water Treatment Units—Health Effects 3, 9 (2016).
333. *NSF Product Listings*, *supra* note 328.
334. *Id*.
335. U.S. EPA, Flint, MI Filter Challenge Assessment (2016).
336. *Id*. at 1.
337. *Id*. at 1, 3.
338. *Id*. at 1.
339. *Id*. at 4.
340. *See id*. at attachment.
341. *See* 40 C.F.R. §§141.70, 141.500 (establishing filtration as an NPDWR for PWSs where the source water is, or is directly influenced by, surface water for *Giardia lamblia*, viruses, heterotrophic plate count bacteria, *Legionella*, *Cryptosporidium*, and turbidity).
342. 42 U.S.C. §300g-1(b)(4)(E)(ii)-(iii).
343. *See generally* Announcement of Small System Compliance Technology Lists for Existing National Primary Drinking Water Regulations, 63 Fed. Reg. 42039 (Aug. 6, 1998); *see* U.S. EPA, Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems 3-1, 3-3 (2006).
344. U.S. EPA, *supra* note 343, at 3-3; U.S. EPA, *supra* note 335, at 3-4.
345. *See* Ariz. Admin. Code §R18-4-218.
346. *Id*. §R18-4-218B(3); Arizona Department of Environmental Quality, Arizona Point of Use Compliance Program Guidance 5 (2005).
347. U.S. EPA, Concerned About Lead in Your Drinking Water? 2 (2017).
348. *See*, *e.g.*, Minnesota Department of Health, Point-of-Use Water Treatment Units for Lead Reduction (2010); *see also* Florida Department of Environmental Protection, *Monitoring Lead and Copper in Florida Drinking Water*, https://floridadep.gov/water/source-drinking-water/content/monitoring-lead-and-copper-florida-drinking-water (last modified Apr. 11, 2018).
349. *See* NSF International, *NSF Product and Service Listings: NSF/ANSI 53 Drinking Water Treatment Units—Health Effects*, http://info.nsf.org/Certified/DWTU/Listings.asp?ProductFunction=053%7CLead+Reduction&ProductFunction=058%7CLead+Reduction&ProductType=&submit2=Search (last visited Sept. 28, 2018).
350. NSF International, *NSF Product and Service Listings: NSF/ANSI 53 Drinking Water Treatment Units—Health Effects, the Brita Company Products*, http://info.nsf.org/Certified/DWTU/Listings.asp?TradeName=SAFF-100&Standard=053&ProductType=&PlantState=&PlantCountry=CHINA&PlantRegion=&submit3=Search&hdModlStd=ModlStd (last visited Sept. 28, 2018).

nants. The Brita faucet system, for example, filters bisphenol-A, estrone (a hormone), and several over-the-counter and pharmaceutical drugs.[351] POU filtration's ability to remove a range of contaminants could be effective against attacks to drinking water supplies by the intentional introduction of contaminants.[352] A single filter does not reduce every potential contaminant,[353] but use of a POU filter will provide effective protection against many contaminants.

Filtration to remove lead actually present in drinking water also is important because recent regulatory, congressional, and state actions to reduce lead in water are inadequate to protect public health. EPA is considering substantially revising the LCR. Under consideration is a full LSL replacement program; requiring all systems to use and update corrosion control; incorporating a health-based "household action level"; requiring POU filters when there is a disturbance of an LSL or lead levels exceed a health-based standard; strengthening testing procedures and real-time monitoring of water quality; requiring PWSs to post all sampling results and shortened deadlines for public notice and education; making LSL locations public; more reporting requirements to EPA; and increased public education about lead risks for new customers of a PWS and those at risk of lead exposure.[354]

Even if EPA promulgated all of the proposed rule revisions, the LCR still would not sufficiently protect individuals from lead exposure. Completely removing all LSLs is absolutely necessary in the long term to protect people from lead exposure, but is a massive undertaking requiring local expenditures up to $80 billion.[355] The utility work required to remove all LSLs would take decades to complete, exposing another generation of Americans to dangerous levels of lead in the interim.[356] And major cities like Chicago have no intention of beginning a voluntary LSL replacement program.[357] If EPA were to allow partial LSL replacement, the lead problem would be worse for those served.[358] The proposed use of filtration is reactive to LSL disturbances and threshold levels reliant on unreliable testing. Filtration that is reactive does not implement primary prevention.

The other proposals would improve the LCR on paper but would not fix the inherent regulatory problem of lead leaching at any time and unreliable testing. Ironically, an improved LCR could provide an increased false sense of security, making lead exposure worse for some individuals. And there is no reason to believe that a strengthened LCR will sufficiently protect communities from lead exposure resulting from government incompetence and misconduct. A strengthened LCR would likely add further complexity to a complicated regulation that local governments already struggle to implement.

Recent congressional and state efforts to prevent lead exposure also are inadequate to reduce lead exposure at the tap. The Water Infrastructure Improvements for the Nation Act of 2016 (WIIN Act) required EPA to establish a grant program to assist voluntary lead testing programs at schools and day-care centers.[359] The testing grant program must provide funds to assist implementation of EPA's voluntary water testing program for schools and day-care centers named "3Ts for Reducing Lead in Drinking Water in Schools" (3T testing program) or a state program equivalent at least as stringent.[360] At least seven states and the District of Columbia now require that K-12 schools test for lead in drinking water and at least another 13 provide financial assistance to school districts to test for lead in drinking water.[361]

Testing for lead in school drinking water rather than first taking proactive measures to reduce the risk of lead exposure is the type of reactive approach to lead exposure inconsistent with primary prevention and could justify inaction when there is a significant risk of lead at the tap. Even worse, some school districts do not take remedial measures unless testing shows lead present above 20 ppb.[362] And school districts can spend millions of dollars on testing that is inherently unreliable.[363]

The WIIN Act also requires EPA to establish a grant program for local projects to reduce lead in drinking water.[364] The grant program authorized for appropriation $60 million per year for fiscal years 2017-2021 for qualifying lead reduction projects.[365] The grant program, while important, is very small compared to the $80 billion of funding necessary to eliminate just the risk posed by LSLs.[366] The grant program also likely does not authorize funds to remove lead actually present in drinking water.[367]

Where possible LCR revisions, WIIN Act provisions, and school testing programs fall short, a robust POU filtration program can succeed. Removing lead actually present at the tap through POU filtration implements the primary prevention policy for childhood lead exposure in drinking water. POU filtration is a highly effective last line of

351. NSF International, *NSF Product and Service Listings: NSF/ANSI 401 Drinking Water Treatment Units—Emerging Compounds/Incidental Contaminants*, http://info.nsf.org/Certified/DWTU/Listings.asp?TradeName=&Standard=401&ProductType=&PlantState=&PlantCountry=&PlantRegion=&submit3=Search&hdModlStd=ModlStd (last visited Sept. 28, 2018).
352. Irwin Silverstein, U.S. EPA, Investigation of the Capability of Point-of-Use/Point-of-Entry Treatment Devices as a Means of Providing Water Security 31-33 (2006).
353. *See id.*
354. EPA White Paper, *supra* note 127, at 8-16.
355. *Id.* at 9.
356. *See* Lead and Copper Working Group to the National Drinking Water Advisory Council, Final Report 13-17, 45 (2015); Emily Lawler, *DEQ Rules Propose Michigan Remove All Lead Service Lines in 20 Years*, MLive, Nov. 29, 2017, http://www.mlive.com/news/index.ssf/2017/11/deq_rules_propose_michigan_rem.html.
357. Hawthorne & Reyes, *supra* note 11.
358. *See* Del Toral et al., *supra* note 157, at 9304-05.
359. 42 U.S.C. §300j-24(d).
360. *Id.* §300j-24(d)(5).
361. GAO, K-12 Education: Lead Testing of School Drinking Water Would Benefit From Improved Federal Guidance 25-30 (2018)
362. *Id.* at 27.
363. *Id.* at 15-16.
364. 42 U.S.C. §300j-19b(b).
365. *Id.* §300j-19b(a)(2), (b)(6)(d).
366. EPA White Paper, *supra* note 127, at 9.
367. 42 U.S.C. §300j-19b(a)(2) (defining a lead reduction project as "(i) replacement of publically owned LSLs, (ii) . . . addressing conditions that contribute to increased concentration of lead in water, and (iii) providing assistance to low-income homeowners to replace LSLs. . . .").

defense against lead present at the tap. Because of the difficulty of regulating lead and history of government misconduct in implementing the LCR, a filtration strategy to reduce lead in drinking water should not rely primarily on government implementation.

B. Congress Should Provide a Refundable Tax Credit for Individuals and Require Nonresidential Buildings to Use BAT for Filtration

In order to promote POU filtration, Congress should provide a refundable tax credit for individuals to purchase a water filtration system and replacement filters certified to reduce lead under NSF/ANSI Standard 53, and require nonresidential buildings use BAT for filtration in drinking fountains. Providing a refundable tax credit for individuals to purchase a qualifying water filtration system and replacement filters will allow individuals to implement primary prevention without government assistance and fill the regulatory gap where government has been unable to adequately protect public health. Requiring nonresidential buildings to use BAT for filtration in drinking fountains will provide protection for individuals from lead in water outside the home and effectively enlist the private sector to address the problem of lead in drinking water.

1. Refundable Tax Credit for Individuals

Providing individuals a refundable tax credit to purchase a filtration system and replacement filters certified to reduce lead under NSF/ANSI Standard 53 is an effective and efficient mechanism to allow individuals to implement primary prevention for themselves and their families. There are faucet-mounted and water pitcher filters that are NSF/ANSI Standard 53-certified to reduce lead that are readily available to the public.[368] Congress has broad authority to reach consumer behavior through the tax code.[369] Tax credits provide the taxpayer a dollar-for-dollar reduction of their tax liability.[370] Refundable tax credits are paid to the taxpayer even if there is no offsetting tax liability.[371] Providing a refundable tax credit to individuals for the purchase of a qualifying filtration system will fund private purchase of filtration systems. Directly funding purchase of filtration systems avoids the expense of a government or nonprofit middleman, efficiently allocating resources to distribute filtration systems.[372]

Providing individuals with a means to protect themselves and their families from lead in drinking water is necessary where government has been unable to protect public health. Funding private purchase of filtration systems and replacement filters accomplishes this goal. It is difficult to ask communities to trust local government to protect the water supply from lead contamination given the inherent difficulty of regulating lead and widespread incompetence and misconduct of state and local government in implementing the LCR. If the public knew the inherent difficulty of regulating lead in drinking water, unreliability of testing, and limited knowledge of which taps are at risk of lead contamination, it is safe to conclude that the use of POU filtration would significantly increase. Removing financial barriers to acquiring a filtration system and replacement filters will also help low-income individuals protect themselves and help reduce the disproportionate effect lead exposure has on minority and low-income communities.[373]

The cost of a refundable tax credit for water filtration systems would be modest. The NSF/ANSI Standard 53-certified Brita Faucet Filtration System SAFF-100, which filters 100 gallons of water before filter replacement, currently costs approximately $19.[374] Replacement filters currently cost approximately $19.[375] The NSF/ANSI Standard 53 certified ZeroWater pitcher costs approximately $20.[376] An eight-pack of ZeroWater replacement filters with a 15-gallon capacity for each filter costs approximately $90.[377] A $100 refundable tax credit would purchase a filtration system and filters sufficient to filter 500 gallons of water in the case of the faucet mount and 120 gallons in the case of the ZeroWater pitcher.

If 100 million individuals took advantage of the tax credit, likely a significant overestimate with approximately 152 million filers in 2017,[378] the cost would be $10 billion. By contrast, the lost earnings for children under six years old with BLLs 2-10 μg/dL from 2003-2006 is estimated to be $165-$233 billion.[379] And costs from lead exposure extend well beyond lost earnings, including significant medical, education, social, and personal costs.[380] Moreover, Congress could easily fund a refundable tax credit through increasing revenues elsewhere in the tax code. A uniform credit would provide the most protection from lead in drinking water, but Congress could limit the cost given competing priorities by lowering the credit limit, means-testing the credit in full or in part, or limiting the number of years for which the credit is available.

Funding a federal refundable tax credit for filtration would allocate federal resources to a problem many state

368. *See, e.g.*, Brita, *Basic Faucet Filtration System*, https://www.brita.com/faucet-systems/basic/ (last visited Sept. 28, 2018); *see also* ZeroWater, *Pitcher/Dispenser 6-Cup*, https://www.zerowater.com/products-pitchers.php (last visited Sept. 28, 2018).
369. *See* National Fed. of Indep. Bus. v. Sebelius, 567 U.S. 519, 563-74 (2012) (upholding the shared responsibility payment of the Affordable Care Act as a proper exercise of Congress' power under the Taxing Clause).
370. *See, e.g.*, 26 U.S.C. §24(a).
371. *See id.*; Lily L. Batchelder et al., *Efficiency and Tax Incentives: The Case for Refundable Tax Credits*, 59 Stan. L. Rev. 23, 32-34 (2006).
372. *See generally* Batchelder et al., *supra* note 371.
373. *See* discussion *supra* Section I.C.
374. Brita, *supra* note 368.
375. Brita, *Faucet Mount Filter*, https://www.brita.com/replacement-filters/faucet-system/ (last visited Sept. 28, 2018).
376. ZeroWater, *supra* note 368.
377. ZeroWater, *Replacement Filters*, https://www.zerowater.com/products-filters.php (last visited Sept. 28, 2018).
378. Internal Revenue Service, *Filing Season Statistics for Week Ending December 29, 2017*, https://www.irs.gov/newsroom/filing-season-statistics-for-week-ending-december-29-2017 (last updated Jan. 12, 2018).
379. Gould, *supra* note 52, at 1164.
380. *See* discussion *supra* Section I.C.

and local governments would struggle to fund. State and local governments need upwards of $1 trillion by 2037 just to maintain current levels of water service.[381] Although the federal government provides some assistance through revolving loan funds and limited direct financing, local governments bear most of the cost of water infrastructure projects through bond issues.[382] Local governments face a shortfall of up to $530 billion between available funds and necessary funds for water infrastructure projects.[383] Allocating federal funds for POU water filtration would provide a stopgap measure for individuals to ensure safe drinking water as local governments face funding shortfalls for critical water infrastructure maintenance.

Investing in POU filtration is more important than additional direct congressional expenditures to replace lead-containing materials. POU filtration will ensure water without dangerous lead concentrations for hundreds of millions of Americans where the same sum would fund only a small fraction of the massive LSL replacement project,[384] which does not include lead-containing materials in approximately 81 million American homes. The potential reach of a tax credit-funded filtration program can quickly provide safe water to significantly more people than equal direct expenditures on replacing LSLs. Stated simply, funding POU filtration with a tax credit will efficiently allow individuals access to safe water while policymakers struggle with the difficult public health problem of how best to identify and remove lead-containing material in drinking water infrastructure and private plumbing.

A uniform refundable tax credit for all filers is preferable because there is no accurate accounting of at-risk homes. Given the massive number of people whose drinking water passes through lead-containing material, overcorrecting with a uniform credit is necessary for primary prevention because an accurate accounting of at-risk homes could take decades or possibly will never be complete given the obvious challenges of identifying lead material in private plumbing. Implementing a primary prevention policy to protect against the significant, permanent, and irreversible health effects of lead requires immediate action.

A uniform refundable tax credit is also preferred in order to establish POU filtration as a regular cultural practice. Encouraging filtration with a refundable tax credit is the first step to establishing POU filtration as a habit. The more homes that use POU filters, the more likely POU filtration will be seen as a regular and necessary practice. Just as devices to protect public health like smoke alarms are now common,[385] uniform promotion of POU filtration will encourage cultural adoption of filtration as a public health necessity. Excluding individuals based on income or location would necessarily reduce the number of people using POU filtration and frustrate its adoption as a common practice. The consequences of childhood lead exposure and primary prevention policy support promoting POU filtration with the goal of universal adoption in the home. A uniform refundable tax credit would best accomplish this goal.

2. BAT for Filtration in Nonresidential Building Drinking Fountains

Providing a refundable tax credit for individuals will ensure safe drinking water in the home but will not reduce lead in drinking water outside the home. Nonresidential buildings can be a significant source of lead exposure, especially for children in school and day-care.[386] And while some states and local school districts are implementing EPA's 3T testing program,[387] widespread adoption of filtration in schools consistent with primary prevention policy to reduce lead at the tap has not materialized. Requiring nonresidential buildings to install drinking fountains with BAT will fill a regulatory gap for lead in drinking water in public buildings and protect against lead exposure at taps outside the home consistent with primary prevention.

Under the BAT approach, owners and operators of nonresidential buildings would be required to use BAT for filtration when considering the cost of implementation. In practice, covered buildings could satisfy this requirement by installing one of the many drinking fountain stations on the market that filter for lead certified under NSF/ANSI Standard 53.[388] Buildings would have to replace the filters at the end of the useful life, which would be no different than having to replace heating, ventilating, and air-conditioning filters or other routine maintenance on a building. Monitoring and replacing filters fits comfortably in the responsibility of building managers and can be easily implemented.

Using BAT for filtration in drinking fountains in nonresidential buildings would significantly reduce lead and other contaminants at a reasonable cost. A drinking fountain bottle-filling station that includes an NSF/ANSI Standard 53-certified filter costs approximately $1,800 with a filter capacity of 3,000 gallons.[389] Replacement filters cost as little as $57 when purchased in a 12-pack.[390] A filtered drinking fountain without a bottle-filling station costs approximately $750 and has a filter capacity of 1,500 gal-

381. American Water Works Association (AWWA), Buried No Longer: Confronting Americas Water Infrastructure Challenge 3 (2012).
382. AWWA et al., A Cost Effective Approach to Increasing Investment in Water Infrastructure 1 (2011); American Society of Civil Engineers, 2017 Infrastructure Report Card: Drinking Water 2 (2017).
383. AWWA et al., *supra* note 382, at 1.
384. EPA White Paper, *supra* note 127, at 9.
385. *See* Marty Ahrens, Smoke Alarms in U.S. Home Fires 1 (2015).
386. *See, e.g.*, Taylor, *supra* note 253.
387. *See, e.g.*, Alabama Department of Environmental Quality, Determining Lead Levels in Drinking Water Alabama's PK Thru 12 Public Schools Master Plan 1-3 (2017).
388. *See, e.g.*, Elkay, *Elkay Enhanced EZH2O Bottle Filling Station & Single ADA Cooler, Filtered 8 GPH Light Gray*, http://www.elkay.com/drinking-solutions/lzs8wslp (last visited Sept. 28, 2018).
389. *Id.*
390. Amazon, *Elkay 51300C 12-Pack WaterSentry Plus Replacement Filters*, https://www.amazon.com/Elkay-51300C-WaterSentry-Replacement-Filters/dp/B005MEWL60/ref=sr_1_1?ie=UTF8&qid=1539270859&sr=8-1&keywords=Elkay%2B51300C&th=1 (last visited Sept. 28, 2018).

lons.[391] Replacement filters cost approximately $60.[392] After the initial investment in a drinking water station, replacing the filter would be the only recurring cost.

If requiring all drinking fountains to have BAT for filtration is too costly, Congress could limit the filtration requirement to a specified number of drinking fountains per floor or require application of BAT for filtration in buildings primarily serving children like schools and day-care centers. Requiring schools to install BAT for filtration would provide political cover for school districts to spend money on effective filtration rather than unreliable testing programs. Congress could also provide a waiver for owners of buildings that can show that there are no lead-containing materials in drinking water infrastructure and building plumbing. Requiring that waiver applicants show that no lead-containing materials exist may provide the incentive for policymakers to finally do the materials evaluation for lead in drinking water infrastructure that should have been completed decades ago.

Congress likely the authority under the Commerce Clause to require BAT for drinking fountain filtration in nonresidential buildings. Congress has the power to "regulate Commerce . . . among the several States."[393] All economic activity that substantially affects commerce falls under the scope of Congress' authority to regulate commerce.[394] The distribution of drinking water is an economic activity, and the collective effect on commerce of lead exposure through drinking water and benefit from requiring filtration in all nonresidential buildings would easily qualify as substantial.[395] Exposure to lead in drinking water costs the United States billions of dollars annually.[396] The adverse health effects of lead exposure affect many markets, including health care, education, and employment markets, to name a few.[397]

Using BAT to reduce contaminants in the environment is a familiar regulatory approach. The SDWA sets MCLs based on the performance of control technology.[398] Both the Clean Water Act (CWA) and the Clean Air Act (CAA) require technology controls to reduce contaminants in the environment.[399] The CWA requires direct dischargers of regulated pollutants from point sources into the waters of the United States and indirect dischargers into publicly owned treatment works to meet maximum permissible limits based on the performance control technology.[400] The CAA requires that emitters of hazardous air pollutants and new sources of covered pollutants meet emission limits based on the performance of control technology.[401] The CAA also specifically requires major modifications of major emitting sources to apply best available control technology to reduce the emission of covered pollutants.[402] The application of control technology under the CWA and CAA has realized significant reductions of discharges of pollutants into the environment.[403]

Requiring BAT for drinking fountain filtration in nonresidential buildings will effectively and efficiently fill the regulatory gap that allows lead in drinking water at the tap outside the home. Filtration in nonresidential buildings will reach schools and day-care centers where children consume a substantial portion of drinking water. Requiring filtration comes at a modest cost to ensure safe water outside the home for all Americans through a familiar and effective regulatory approach.

VI. Conclusion

The problem of lead in drinking water will persist as long as there are lead-containing materials in drinking water infrastructure and private plumbing. Regulatory efforts to control corrosion are inadequate to prevent lead from leaching into drinking water, and testing for lead in water is inherently unreliable. The LCR suffers from multiple regulatory gaps, and government incompetence and misconduct have exposed entire cities to lead-contaminated water. The problem of lead in drinking water is not limited to high-profile crises like those seen in Washington, D.C., and Flint; it is a problem across the United States. Most significantly, without an accurate accounting of lead-containing materials in drinking water infrastructure and private plumbing, it is impossible to determine which taps are at risk of lead contamination.

The significant, permanent, and irreversible adverse health effects of lead exposure in children at very low levels require a solution to remove lead actually present at the tap consistent with the medical consensus policy of primary prevention; POU filtration is an effective and inexpensive solution. Providing a refundable tax credit to individuals for a filtration system and replacement filters certified for lead reduction under NSF/ANSI Standard 53 will allow individuals to protect themselves from lead

391. Elkay, *Elkay Cooler Wall Mount ADA Filtered, Non-Refrigerated Light Granite*, http://www.elkay.com/lzsdl (last visited Sept. 28, 2018).
392. Home Depot, *WaterSentry VII Coolers and Fountains Replacement Filter for Elkay and Halsey Drinking Fountains*, https://www.homedepot.com/p/Elkay-WaterSentry-VII-Coolers-and-Fountains-Replacement-Filter-for-Elkay-and-Halsey-Drinking-Fountains-51299C/206925498 (last visited Sept. 28, 2018).
393. U.S. Const. art. I, §8, cl. 3.
394. *See, e.g.*, Gonzales v. Raich, 545 U.S. 1, 17 (2005).
395. *See, e.g.*, Wickard v. Filburn, 317 U.S. 111, 128-29 (1942) (finding Congress could regulate consumption of homegrown wheat because cumulative effects would affect the commodity price); *see also Gonzales*, 545 U.S. at 22 (finding Congress could prohibit purely intrastate cultivation and use of marijuana as part of comprehensive legislation to regulate interstate marijuana market).
396. *See* discussion *supra* Section I.C.
397. *Id.*
398. 42 U.S.C. §300g-1(b)(4)(B), (D).
399. 33 U.S.C. §§1251-1387, ELR Stat. FWPCA §§101-607; 42 U.S.C. §§7401-7671q, ELR Stat. CAA §§101-618.
400. 33 U.S.C. §§1311(a)-(b), 1314(b), (d), 1316, 1317.
401. 42 U.S.C. §§7411(a)-(b), 7412(d).
402. *Id.* §7475(a).
403. *See* William L. Andreen, *Water Quality Today—Has the Clean Water Act Been a Success?*, 55 Ala. L. Rev. 537, 569-73 (2004); David A. Keiser & Joseph S. Shapiro, National Bureau of Economic Research, NBER Working Paper No. 23070, Consequences of the Clean Water Act and the Demand for Water Quality 21-22 (2018); U.S. EPA, *Progress Cleaning the Air and Improving People's Health*, https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health (last updated Aug. 14, 2018).

in drinking water and promote POU filtration to protect public health and provide safe drinking water. Requiring nonresidential buildings to install BAT for filtration will provide the public protection from lead in drinking water from significant sources outside the home like schools, day-care centers, and workplaces. POU filtration will ensure safe drinking water while searching for a solution to the more difficult problem of identifying and removing lead-containing materials from drinking water infrastructure and private plumbing.

If a refundable tax credit were available to the residents of Washington, D.C., and Flint, and nonresidential buildings had filtered drinking fountains during the high-profile lead-contaminated water crises, the significant, permanent, and irreversible health consequences for thousands of children could have been avoided. Many families likely already would have owned and used POU filtration, and those who did not could have quickly purchased a POU filtration system to ensure water without dangerous lead. Parents could send their children to schools and day-care centers that have safe drinking water and adults could use drinking fountains at work without being exposed to toxic lead. A modest investment in POU filtration can prevent the devastating health effects of the next lead crisis and protect individual taps across the country that are delivering dangerous levels of lead today.