Putting children first: Tackling lead in water at child care facilities

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Putting children first: Tackling lead in water at child care facilities

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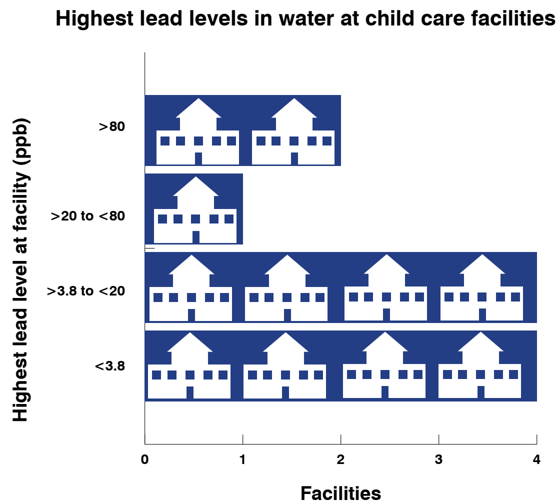
Table of contents

Executive summary

There is no safe level of lead exposure. Lead exposure is likely to impair children's normal brain development, contributing to learning and behavioral problems as well as lower IQs. Despite decades of progress in reducing children's exposure, America continues to have a toxic legacy of lead. The crisis in Flint, Michigan, has drawn renewed attention to the widespread health risks posed by lead in water.



Graphic illustrates the highest lead level detected at each of 11 child care facilities, excluding samples from non-drinking sources such as utility sinks and hose bibs. Our pilot used a health-based action level of 3.8 ppb to trigger remediation.

Children under the age of six are most vulnerable to harm from lead because of their developing brains, and infants who rely on formula mixed with drinking water are most exposed. While reducing all exposure to lead is important, priority should be given to child care facilities, where many young children spend a large portion of their days.

However, few states require child care facilities to test for lead in their water, and the Environmental Protection Agency's (EPA) voluntary "3Ts for Reducing Lead in Drinking Water"[1] guidance has significant gaps in the child care setting—including an outdated action level of 20 parts per billion (ppb). Given the critical need for more investigation in this area, Environmental Defense Fund (EDF) conducted a pilot project to evaluate new approaches to testing and remediating lead in water at child care facilities. This report provides a summary of this work and recommendations for best practices.

Collaborating with local partners, we identified sources of lead in drinking water—including lead service lines and brass fixtures—and removed sources that posed a significant risk of exposure in 11 child care facilities (nine facilities in commercial buildings and two in converted homes). These facilities:

- Serve a total of over 1,000 children.
- Care primarily for children from low-income families.
- Are located in four states: Illinois, Michigan, Mississippi, and Ohio.

[1] In October 2018, three months after this report was released, EPA updated its 3Ts guidance: www.epa.gov/safewater/3ts. Also see EDF's blog on the updated guidance: http://blogs.edf.org/health/2018/10/16/epa-updates-3ts-guidance-lead-drinking-water/.

Key results

- Flushing fixtures such as faucets and drinking fountains for just five seconds reduces lead levels. Flushing for 30 seconds is even more effective.
- Cleaning the aerator at the end of the faucet is important, but may increase lead levels. More investigation is needed.
- Replacing fixtures is effective when initial lead levels are high. However, it is not always sufficient to meet lead levels below 3.8 ppb. This is most likely because NSF International's current standards allow new brass fixtures to have added lead and leach up to 5 ppb into water. More investigation is needed.
- Portable lead meters that provide results in the field tend to underestimate lead levels compared to laboratory results.
- Water heaters may function as "lead traps" for upstream sources of lead, but more investigation is needed to identify the source of this lead and whether it could result in elevated levels at the hot water tap.

Lead testing:

- Collection of over 1,500 water samples (including 172 hot water samples) at 294 fixtures and 14 water heaters. Samples were collected before and after remediation to evaluate the impact of such measures.
- Analysis of all samples at a certified laboratory and 65% of samples with a portable meter.

Permanent removal of lead sources:

- Identification and replacement of two lead service lines—lead pipes connecting the water main under the street to the building. One replacement took place in Chicago, the other in a Cincinnati suburb.
- Replacement of 26 fixtures, including kitchen, classroom, and bathroom sinks, which had lead concentrations above our action level of of 3.8 ppb (or >2 ppb in Chicago).

Routine practices to reduce exposure:

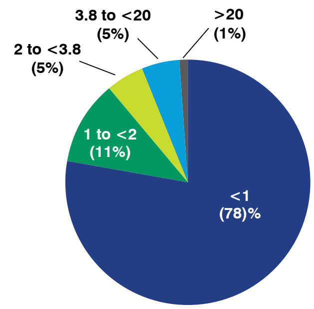
- Flushing fixtures by allowing the water to run for five or 30 seconds.
- Removing and rinsing aerator screens at the end of faucets.
- Draining and flushing 10 water heaters to remove lead particulate that may have accumulated in the tank.

Our partners

- Elevate Energy (Chicago)
- Greater Cincinnati Water Works (Cincinnati)
- Healthy Homes Coalition of West Michigan (Grand Rapids)
- Mississippi State University Extension (Starkville and Tunica)
- People Working Cooperatively (Cincinnati)

While more than three out of four samples collected had non-detectible lead levels (<1 ppb), seven of 11 child care facilities had at least one drinking water sample above our action level of 3.8 ppb. Fixture replacement was often effective, but we could not consistently reduce lead levels below 3.8 ppb, likely due to an inadequate NSF International standard (required almost everywhere in the U.S.) that allows new brass fixtures to leach up to 5 ppb of lead.

Lead level in baseline first draw water samples (ppb)



Addressing lead in water in child care facilities presents a significant opportunity to reduce lead exposure for many vulnerable children in a single location, with reasonable effort. To succeed in testing and remediating lead in water, child care facility operators, state licensing agencies, and health departments will need support from EPA, water utilities, and NSF International, as well as the families they serve. This report provides recommendations for each of these critical audiences.

Key recommendations

- Replace lead service lines in child care facilities when found through review of historical records and visual inspection.
- Require testing for lead in water in child care facilities for interior sources of lead.
- Set an interim action level of 5 ppb to investigate and remediate lead sources.
- Strengthen the NSF International 5 ppb leachability standard to reduce lead in new brass fixtures.

Introduction

There is no safe level of lead exposure. Even at low levels, lead exposure is likely to impair children's normal brain development, contributing to learning and behavioral problems as well as lower IQ. Despite decades of progress in reducing children's exposure, America continues to have a toxic legacy of lead.

Children under the age of six are most vulnerable to harm from lead, and formula-fed infants are most at risk of harm from lead in drinking water. While reducing lead in water everywhere is important, child care facilities should be prioritized over schools given that they serve children at a more vulnerable life stage, have less public accountability, and are more likely to have lead service lines (LSLs).

Water testing—in addition to inspection for LSLs and review of building age and plumbing materials—can help identify sources of lead in water for remediation and enable strategic interventions to reduce lead levels.

A critical opportunity to reduce lead exposure from water

Children spend a large portion of their days either in schools or child care facilities, the majority of which are not required to test their drinking water for lead under federal requirements because they obtain their water from a public water system. Much of the recent attention has focused on lead in schools—despite the fact that children under the age of six are most vulnerable to the detrimental impacts of lead. A recent EPA analysis demonstrates that for children less than six months of age, water is a major source of exposure. In fact, because infants consume more liquid per body weight than any other age group, formula-fed infants can receive up to 60 percent of their lead exposure from the tap water used to mix powered formula.

Other sources of lead

Child care facilities may have other sources of lead, primarily lead-based paint. EPA's Lead-Safe Renovation, Repair, and Painting (RRP) rule, which requires renovations of buildings to be carried out by certified renovators trained in lead-safe work practices, applies to child care facilities that are built before 1978.

Over 4 million children under the age of five are served annually by center- or home-based child care providers. Because child care facilities are often small and privately-owned, they may lack the facility support and public accountability found at public schools (e.g., through a school board)—and therefore are less likely to tackle the problem of lead in water on their own. See the box below for definitions of types of child care settings.

Definitions vary among states. For this report, we use:

- **Child care facility:** A building or structure used for educational, supervision or personal care services of children under six years of age.
- **Center-based:** Child care facility based in a commercial space.
- **Home-based:** Child care facility run out of a residential space.

How lead can get into water at child care facilities

Lead contamination rarely occurs naturally in water sources. It ends up in tap water due to corrosion of lead—containing pipes, solder, or brass fixtures—such as faucets and drinking fountains. The corrosion leaches (or dissolves) the lead from the metal into the water. The longer the water is in contact with the metal, the more lead leaches into the water until it reaches equilibrium. Temperature impacts leaching as well, such that more lead leaches into hot water.

Most water utilities treat water to reduce its corrosivity and limit leaching of lead from LSLs or interior plumbing. Over time, corrosion control treatments build up a protective coating on the inside of the plumbing. However, even with corrosion control, LSLs can unpredictably release lead into the water. When the pipe is disturbed, small pieces of lead ("lead particulate") can be released from the coating and end up in the water people drink or be caught in screens or other connections to be released later. Further, the on-off water use pattern of child care facilities (e.g., no water use at night) may promote leaching of lead plumbing material into water.

Lead pipes were banned by Congress in 1986 through the Safe Drinking Water Act. Yet there are still an estimated 6-10 million LSLs in use in the U.S. today, largely in the Midwest and Northeast. When present, LSLs contribute an estimated 50-75% of the lead in drinking water.

Congress also limited the use of lead in interior plumbing in 1986 to 0.2% lead (weighted average) in solder and 8% lead in brass fixtures. It wasn't until 2011 that Congress passed the Reduction of Lead in Drinking Water Act, which went into effect in 2014 and strengthened limits for lead in brass fixtures and fittings to 0.25%.

All facilities may have some lead in their drinking water. The older the building the more likely there will be leaded plumbing. In addition, smaller child care facilities (often home-based) built before 1986 are more likely to have an LSL than larger center-based facilities (or schools) because they are serviced by smaller pipes; lead pipes above 2 inches in diameter are rare. But these larger facilities may still have leaded brass fixtures.

Existing requirements and guidelines

Child care facilities tend to our most vulnerable kids, yet they present a critical gap for regulation and well-established guidance regarding lead in drinking water. Currently, only seven states (Connecticut, Illinois, New Hampshire, New Jersey, Oregon, Rhode Island, and Washington) and one city (New York City) require licensed child care facilities served by community water systems to test their drinking water for lead.[2,3] Importantly, none of these requirements reaches child care facilities that do not have a license from the state or community.

The existing requirements vary widely in terms of testing protocol, lead standard, corrective action, and communication to parents and staff. The requirements often call for action when lead levels in water samples are over 15 ppb (EPA's Lead and Copper Rule action level) or 20 ppb (EPA's recommended trigger for action at schools and child care facilities). Neither of these levels are sufficient to protect children, and a lower limit is needed. We used a health-based benchmark action level of 3.8 ppb based on an increased probability that a child will have a blood lead level (BLL) greater than 3.5 micrograms per deciliter of blood (see page 28 for detail). Illinois recently set an action level of 2 ppb, based on the lowest level at which the state expects all approved laboratories to be able to quantify lead in a sample.

EPA has developed voluntary guidance—the 3Ts for Reducing Lead in Drinking Water—to help schools reduce lead in drinking water. EPA also has a shorter version for child care facilities. The 3Ts of this guidance are:

- Training officials about the risks of lead and potential sources of exposure.
- Testing drinking water for identification of issues and remediation if necessary.
- Telling staff and the larger community about the program and results.

The guidance for child care facilities references the guidance for schools, which provides various methods for reducing lead, including routine control measures, short-term measures, and permanent remedies. While the guidance provides a helpful framework, it was last updated in 2006 and uses 20 ppb to trigger remediation. This level was not selected based on health risks, nor has it been updated based on the latest science showing adverse health effects from low levels of lead exposure. The guidance was also originally designed for schools, which are less likely to have LSLs than smaller child care facilities. It therefore places little emphasis on identifying and replacing LSLs.

[2] There are additional federal requirements and some state requirements for child care facilities that operate their own public water system. Some states also have school testing requirements that apply to child care facilities on school property.
[3] Since this report was published, additional states have established child care testing requirements. For the most updated information on current state requirements, go to: https://www.edf.org/health/child-care-lead-water-requirements.

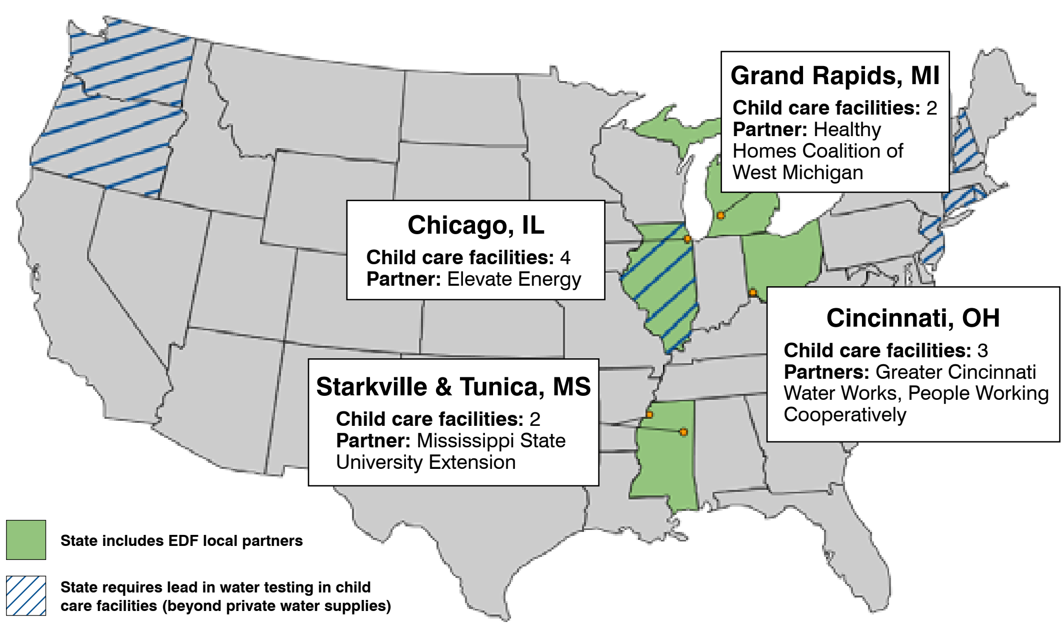
About EDF's pilot

To investigate new approaches and provide concrete recommendations for action, EDF developed and piloted a protocol to test for and remediate sources of lead in drinking water in child care facilities.

We worked in four states with a mix of local partners, including: Elevate Energy, an energy efficiency and healthy housing non-profit based in Chicago; Greater Cincinnati Water Works, a water utility; Healthy Homes Coalition of West Michigan, a lead poisoning prevention program; Mississippi State University Extension, a university extension offering external research, programs, and technology services; and People Working Cooperatively, a home repairs non-profit in Cincinnati. This diversity of partners allowed us to explore opportunities and challenges of implementing lead in water testing and remediation through a variety of institutions.

FIGURE 1

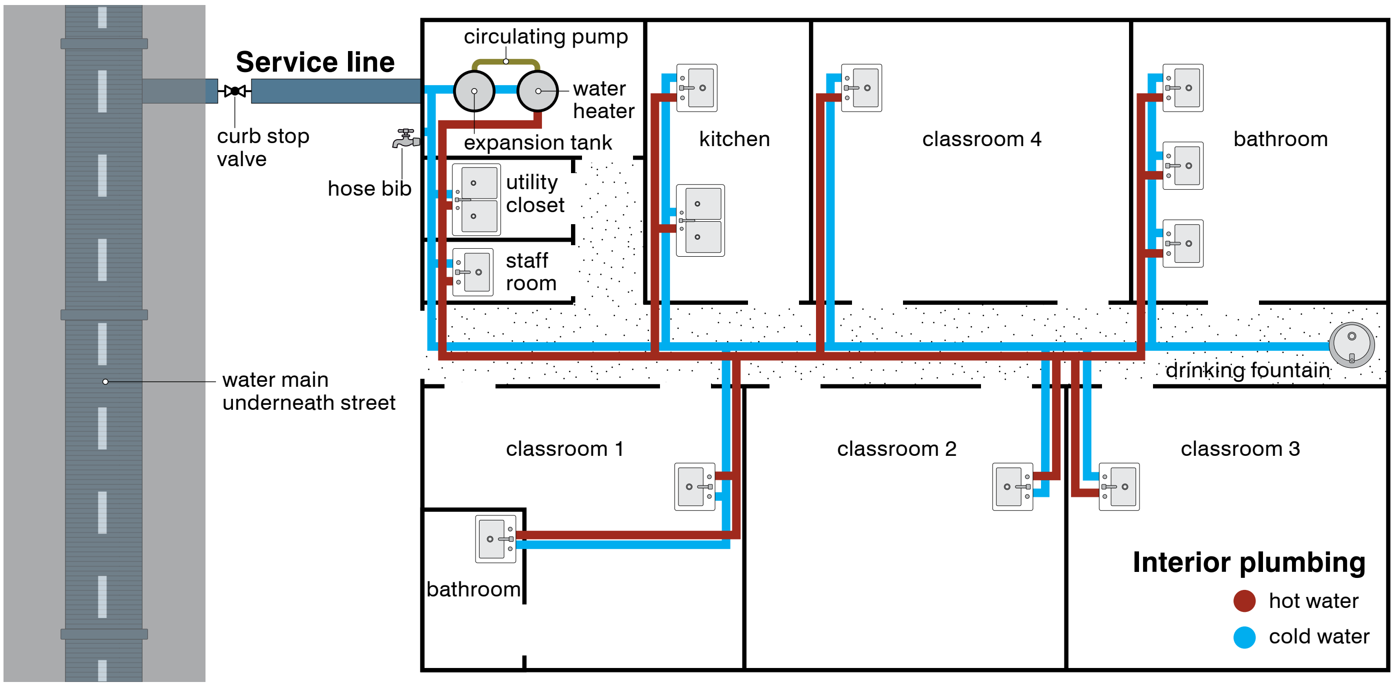
Lead in water at child care facilities: Existing requirements and EDF partners



EDF offered to pay for lead testing and remediation, which was conducted at 11 child care facilities serving over 1,000 children from primarily low-income families (see Figure 1 above). Our criterion for selecting child care facilities were that they serve as many children under six years of age from low-income families as possible in order to provide support to facilities that may not have the resources to tackle the issue on their own. Our local partners used their own networks and processes to recruit child care facilities into the pilot. They found it difficult to recruit both when they lacked a prior relationship with the child care facility and, for all but Chicago, when the facility did not anticipate a testing mandate in the future.
The layout of the water distribution system in a typical center-based child care facility is

FIGURE 2

Water distribution system at a typical center-based child care facility

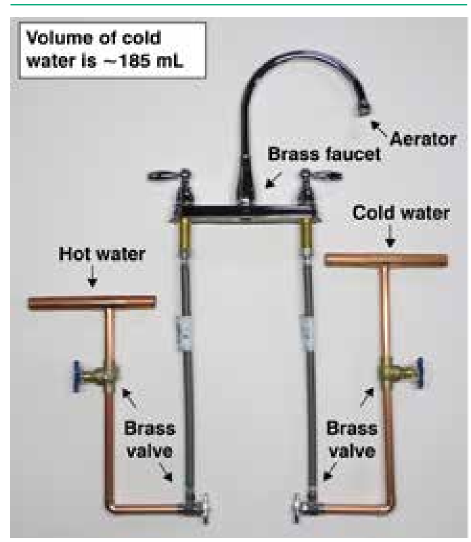


illustrated in Figure 2. Water enters the building through the service line and is connected through interior plumbing. The service line usually enters the building near the water heater, which produces hot water for the facility (red). Large centers may have an expansion tank connected to the water heater, which manages pressure changes due to temperature fluctuations. Classrooms often have sinks and bathrooms, and most center-based facilities also have at least one kitchen, staff room, and utility closet.

A typical brass faucet and associated plumbing is shown in Figure 3. In this example, the cold water volume—including the faucet through the plumbing shown—is about 185 mL. Therefore, a

FIGURE 3

Typical fixture and associated plumbing



250 mL sample (as recommended by EPA's 3Ts guidance) would include the faucet and associated plumbing beyond that pictured here.

Our protocol, largely based on EPA's 3Ts guidance (see page 23 for important differences), was designed to identify and remove sources of lead in drinking water through stepwise assessment of records, visual inspection, and water testing, as well as to demonstrate the reduction in lead levels following remediation, including fixture replacement, aerator cleaning, and flushing.

Our general sampling and remediation protocol is outlined in Figure 4. Our local partners conducted all lead sampling and coordinated remediation methods with the facilities. We adapted our protocol to local circumstances.

At each facility, our local partner(s) first investigated whether there was an LSL by reviewing historical records, contacting the local water utility, and conducting a visual inspection. LSLs can unpredictably release particulate lead that either passes into the water immediately or gets caught in the aerators, connections, or pipe scales to be released later. As recommended by the Lead Service Line Replacement Collaborative, the best long-term solution to addressing LSLs is to remove them. Therefore, if an LSL was found, without regard to lead levels detected in the water, we worked with partners to arrange for its removal and to ensure appropriate flushing was completed before conducting regular fixture sampling, described below.

Image of a lead service line. Source: Associated Press.

FIGURE 4

Lead in water testing protocol for EDF's pilot

LSL Investigation

Invesitgate for LSL using historical records and visual inspection.

Replace LSL if found.

→ *Stagnate water*

Baseline Testing

Collect 2 samples at each fixture:

- First draw
- 30-second flush

Samples analyzed by lab

Collect 2 samples from the hot water heater drain.

Samples analyzed by lab & portable meter

Clean aerators

→ *Stagnate water*

Post-Aerator Cleaning Testing

Collect 4 samples at drinking water fixtures:

- First draw
- 5-second flush
- 30-second flush
- Hot water sample

Collect 1 first draw sample at other fixtures.

Samples analyzed by lab & portable meter

Replace fixture if EDF action level triggered

→ *Stagnate water*

Flush hot water heater

Post-Fixture Replacement Testing

Collect 1 or more samples at replaced fixtures:

Collect 2 samples from the flushed hot water heater.

Samples analyzed by lab & portable meter

See here for the full protocol.

Based on EPA's 3Ts guidance, our partners collected 250 mL water samples after allowing the water to sit in the pipes overnight (8-18 hour stagnation) at all water fixtures, including kitchen, classroom, bathroom, staff room, and utility closet sinks; drinking water fountains; and outdoor hose bibs (see Figure 2 above).

Water stagnation allows lead, if present, to leach from the pipes, fixtures, or other sources. Sampling stagnated water is expected to yield dissolved lead levels that are higher than those children are likely to be exposed to over the course of a day. Samples collected after flushing enable measurement of potential sources of lead upstream of the fixture and evaluation of the effectiveness of flushing as a remediation method.

On the first day of sampling ("baseline"), our partners collected two samples sequentially at each fixture:

- First draw sample: Water collected immediately after stagnation.
- 30-second flush sample: Water collected after 30 seconds of letting the water run.

FIGURE 5

Diagram of faucet aerator

Image courtesy of Philadelphia Water Department.

Where present, we cleaned the aerator—a screen often found at the end of a faucet—between the first and second day of sampling to remove lead particulates potentially caught in the screen. We removed the screens and washed them thoroughly in the tap water. See Figure 5.

On the second day of sampling ("post-aerator cleaning"), our partners collected four samples sequentially at all fixtures that could be reasonably used for drinking:

- First draw: Water collected immediately after stagnation.
- 5-second flush: Water collected after five seconds of letting the water run.
- 30-second flush: Water collected after total of 30 seconds of letting the water run.
- Hot water sample: Water collected with cold water faucet turned off and hot water turned on (represents first draw of water sitting in hot water pipes).

At fixtures not used for drinking (e.g., utility closet sink), we collected a single first draw sample on the second day of sampling.

We collected two 250 mL samples directly from the drain of the hot water heater (Figure 6) on either the first or second day of sampling.

When we replaced an LSL, we supplemented our testing protocol with additional baseline and post-remediation sampling, including 10 consecutive 1-liter samples collected from a single fixture before and after the replacement to provide a profile of the lead levels in the water.

FIGURE 6

Water heater with drain valve

We sent all samples to EHS Laboratory for inductive coupled plasma mass spectrometry (ICP-MS) analysis. ICP-MS is the gold standard analytical technique to detect lead in water and is an approved method under the Safe Drinking Water Act. Two-thirds of the samples were also analyzed using a portable lead meter.[4]

Based on lead testing results, we replaced fixtures where samples exceeded our 3.8 ppb health-based benchmark on the second day of sampling (after aerator cleaning). In Chicago, our action level was >2 ppb in an effort to conform to an anticipated state standard. See discussion of health-based benchmarks on page 28 for more detail. Where possible we also flushed water heater tanks to remove lead-contaminated water. Following such remediation, we collected follow-up samples both at fixtures and water heaters.

Our partners communicated the results back to the child care facilities' management and staff through a letter, detailed report, and verbal conversations. The child care facility staff communicated the results to parents.

Types of lead remediation used and evaluated

- **Lead service line replacement:** Replacing the lead pipe connecting the water main under the street to the child care facility followed by a robust flushing protocol to reduce lead levels. Without replacing the LSL, testing at fixtures may miss the unpredictable releases of lead particulate from LSLs and give a false sense of security.
- **Flushing fixtures:** Allowing water to run for a given amount of time before using a fixture.
- **Aerator cleaning:** Removing and rinsing the aerator screen at the end of a faucet.
- **Fixture replacement:** Removing an existing fixture and replacing it with a new, NSF/ANSI 61 certified fixture.
- **Flushing water heater tanks:** Draining the water heater tank and running cold water through for 10 minutes.
- **Filtering:** Installing an NSF/ANSI 53 certified point-of-use filter on a fixture.

[4] The limit of quantification of our laboratory analysis was 1 ppb. The limit of quantification of the two portable lead meters used was 2 ppb.

Results

Overall, we collected nearly 1,500 water samples at 294 fixtures, including 172 hot water samples. We also sampled from the drain of 14 water heaters. We sent all samples to a certified laboratory for ICP-MS analysis and analyzed 65% of the samples with a portable meter.

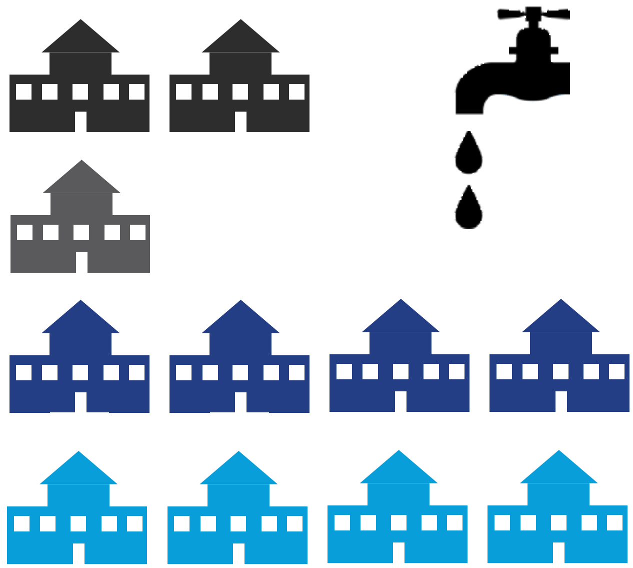
Table 1 provides a description of the 11 child care facilities and the results for each. The 11 facilities served a total of 1,096 children, with the majority from low-income families. The size of the facilities ranged from the two smallest, both in Mississippi, serving 25 and 27 children, to the two largest, both in Chicago, serving 178 and 213 children. Nine of the facilities were in commercial buildings while the other two were converted homes. The number of fixtures tested at each facility ranged from a low of eight at two facilities (Mississippi and Ohio) to a high of 66 in Cincinnati, but was not closely associated with the number of children served or the age of the building.

Based on historical records and visual inspections, we identified two child care facilities with LSLs—a center in Chicago and a converted home in the suburbs of Cincinnati—and removed them both prior to baseline fixture testing.

We found that four of the 11 child care facilities had no drinking water fixtures exceeding our action level of 3.8 ppb while seven had at least one drinking water fixture that triggered our action level on either day one or two of sampling—and therefore could be source of lead exposure to children in the facility. Of these, three were above the EPA 3Ts action level of 20 ppb with two facilities, in Chicago and Cincinnati, with highs greater than 80 ppb. The highest drinking water samples at the remaining four facilities were between our action level and EPA's current 3Ts action level. See Figure 7.

FIGURE 7

Highest lead levels in drinking water at 11 child care facilities



At least 1 tap water sample at:

2 facilities
Above 80 ppb
16x the lead level allowed in bottled water

1 facility
Above EPA's 3Ts level, but below 80 ppb
EPA's 3Ts level: 20 ppb

4 facilities
Above our action level, but below EPA's
EDF's action level: 3.8 ppb
EPA's 3Ts level: 20 ppb

4 facilities
All samples below EDF's action level
EDF's action level: 3.8 ppb

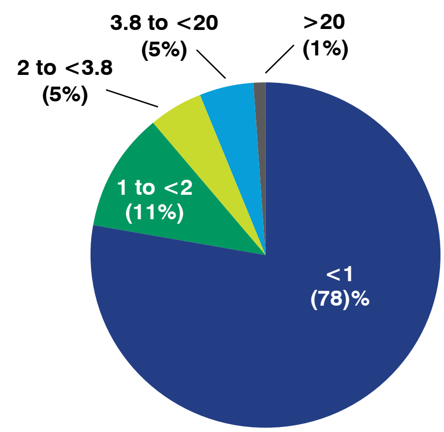
Results of water testing (excluding samples from utility sinks and hose bibs) at 11 child care facilities: two facilities had at least one tap water sample above 80 ppb level of lead; one facility had at least one sample above EPA's 3Ts action level of 20 ppb, but below 80 ppb; four facilities had at least one sample above our health-based action level of 3.8 ppb, but below 20 ppb; and 4 facilities had all samples below EDF's action level of 3.8 ppb.

Figure 8 provides the results for the first draw baseline samples—samples modeled after EPA's 3Ts guidance—for the 291 fixtures we tested.[5] More than three out of four of the baseline first draw samples had levels below 1 ppb. Seventeen of 291 (6%) exceeded our action level of 3.8 ppb and only two (1%) exceeded EPA's 3Ts trigger of 20 ppb. On average, lead levels were higher on the second day of testing, following aerator cleaning (see page 21).

We conducted remediation at all seven facilities pictured above, including fixture replacements at six facilities and LSL replacements at two. Using >2 ppb as our action level in Chicago and 3.8 ppb elsewhere, we replaced 26 kitchen, classroom, and bathroom fixtures in six facilities.

FIGURE 8

Lead levels in baseline first draw samples (ppb)



[5] While we tested a total of 294 fixtures, three baseline first draw samples were lost before laboratory analysis.

TABLE 1

Summary results for all 11 child care facilities

Location	Building age	Child care type	# children enrolled	Low-income children	Presence of LSL?	All fixtures: # tested	All fixtures: Lead levels † (ppb)	Replaced fixtures: # fixtures replaced	Replaced fixtures: Lead levels ‡ (ppb)
Chicago, IL	1956	Center	145	95%	No	29	3.6 (<1-91)	11	<1 (<1-1)
Chicago, IL	1950-60s	Center	87	95%	Yes (replaced)	18	1.3 (<1-4)°	2	3.8 (1-10)
Chicago, IL	1995	Center	213	95%	No	49	<1	0	N/A
Chicago, IL	1995	Center	178	85-90%	No	50	0.6 (<1-4*)	0	N/A
Grand Rapids, MI	1951	Center	60	66%	No	16	1 (<1-18.9)	3	1.8 (<1-3.8)
Grand Rapids, MI	1952	Center	65	Variable	No	17	<1 (<1-1.1)	0	N/A
Starkville, MS	1957	Center (converted home)	27	100%	No	8	2.4 (<1-23.6)	3	2.9 (0.5-5.8)
Tunica, MS	1993	Center	25	100%	No	12	0.7 (<1-6.1*)	0	N/A
Cincinnati suburb, OH	1910	Center (converted home)	65	100%	Yes (replaced)	8	2 (<1-8.1*)°	0	N/A
Cincinnati, OH	1956	Center	84	82%	No	21	1.2 (<1-35.6*)	1	<1
Cincinnati, OH	1990	Center	147	17%	No	66	1.2 (<1-88.4)	6	3.0 (<1-18.2)
			1,096 children		**2 LSLs replaced**	**294 fixtures tested**		**26 fixtures replaced**	

† Mean and range of lead levels detected from all samples collected at a facility before any fixture replacements and after LSL replacement (where relevant). When levels were below the limit of quantification (<1 ppb), we used 0.5 ppb to calculate the mean.

‡ Mean and range of lead levels detected from samples collected only from replaced fixtures. When levels were below the limit of quantification (<1 ppb), we used 0.5 ppb to calculate the mean.

* These ranges each include at least one fixture that tested above our action level but we did not replace because it was not a likely drinking water source (e.g., utility sink, outside hose bib).

° Fixture sampling post-LSL replacement. Two fixtures at Cincinnati suburb facility had pre-LSL replacement levels above our action level but they were below after LSL replacement.

Two facilities, one in Chicago serving 145 children and one in Cincinnati serving 147, accounted for nearly two-thirds of the replaced fixtures. The Chicago facility required 11 fixture replacements, with lead at one fixture as high as 91 ppb.

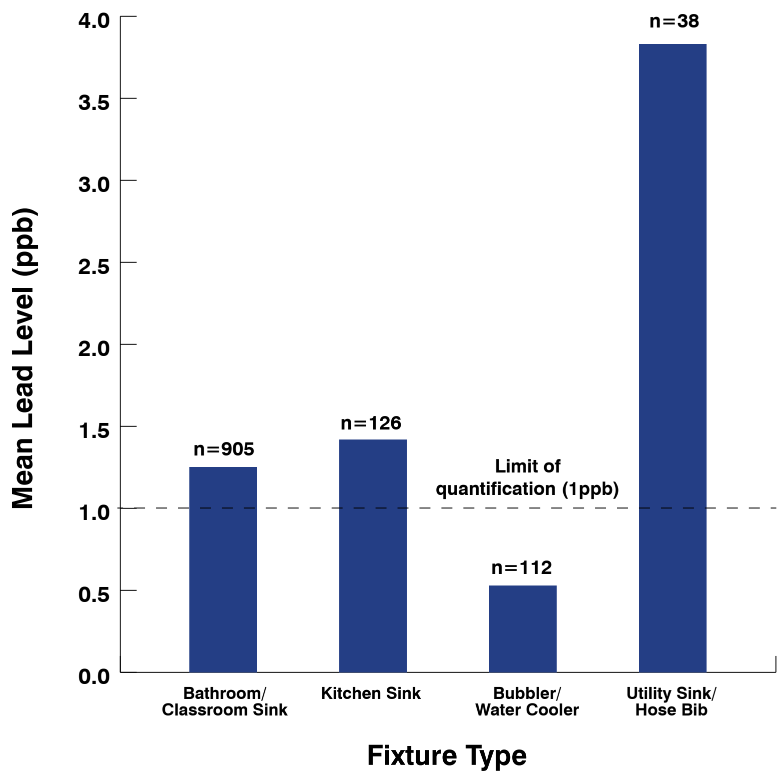
Five facilities had no fixtures replaced. Two of these facilities had at least one sample above 3.8 ppb at a utility sink or hose bib, but because these water sources were not likely to be used by children for drinking, we did not replace these fixtures.

We installed filters at select locations where fixture replacement did not reduce levels below our action level. We also drained and flushed 10 water heaters to remove lead-contaminated water.

Samples also varied by fixture type. Figure 9 illustrates the mean lead level by fixture type. Drinking water fountains (bubblers and water coolers) had the lowest lead levels, with nearly all non-detectible lead levels (non-detects reported as 0.5 ppb in Figure 9). Kitchen sinks had an average lead level of 1.4 ppb (range <1-27 ppb). Though we had a limited sample size, non-drinking water faucets, like utility sinks and outside hose bibs, had the highest lead levels (average 3.8 ppb, range <1-35.6 ppb).

FIGURE 9

Mean lead level by fixture type



This chart illustrates the mean lead levels by fixture type for all samples (excluding those collected before LSL replacement or after fixture replacement as well as hot water samples). When levels were below the limit of quantification (1 ppb), we used 0.5 ppb.

Hot water samples at the taps were not notably different than cold water samples. At the hot water tap, only four of 172 (2%) samples were above our action level of 3.8 ppb. However, we found high lead levels from the samples collected from the drains of hot water heaters. Half (seven of 14) of water heater tanks tested in child care facilities had levels over 50 ppb, with one sample at 2,680 ppb. See page 32 for additional detail.

What interventions were effective?

Flushing

We evaluated the impact of flushing fixtures and found that flushing for 30 seconds—and even as short as five seconds—reduced lead levels. When excluding results below the limit of quantification, flushing fixtures for 30 seconds reduced levels on average by 3.7 ppb. Flushing for just five seconds, which may be a more practical, everyday solution, reduced lead levels on average by 3 ppb. Flushing for five seconds decreased the percentage of samples with lead levels above 3.8 ppb from 6% to 1% and increased the percentage of samples below 1 ppb (our limit of quantification) from 76% to 88%. However, if an LSL is present, then a longer flush will be needed to ensure that the water sitting in the service line is flushed out of the system. The time would need to be sufficient to replace the amount of water in the interior plumbing and the LSL, accounting for the flow rate.

Flushing is a cost effective solution to reduce lead in drinking water at the tap. We did not use flushing of fixtures as a primary remediation strategy, as it relies on consistency and patience from all users, including child care staff and children. It also raises concerns in areas with water shortages. However, given that most of the water children consume at child care facilities is unlikely to be the first water collected following an overnight stagnation, 3.8 ppb may be an achievable benchmark when accounting for the water that children are actually drinking.

We found that flushing water heater tanks was generally effective in reducing lead levels, but difficult to carry out in some settings (e.g., where there is no floor drain). For all but one of the water heaters, flushing through the tank drain significantly reduced the lead levels. See page 32 for additional detail.

Aerator cleaning

Routine aerator cleaning is commonly recommended as an important practice to reduce lead in water. However, our results indicate that under certain situations it may increase lead levels.

While lead levels decreased at some fixtures following aerator cleaning, overall, aerator cleaning did not have a strong effect on the percentage of water samples with lead concentrations above 3.8 ppb or above detection levels. Furthermore, when lead was detected, aerator cleaning increased lead levels by 4.5 ppb, on average. This was driven largely by results from two of the 11 facilities, where lead levels jumped dramatically following aerator cleaning. For example, at one facility in Chicago, lead levels at 15 fixtures were non-detect (<1 ppb) on the first day of sampling but increased (range: 1-91 ppb) following aerator cleaning.

Partner with Healthy Homes Coalition of West Michigan cleans a faucet aerator.

We think that aerator cleaning may increase lead levels by disturbing particulates stuck in the aerator screen without fully flushing them out. If true, one option to minimize such an effect is to soak aerators in vinegar for a few minutes, allowing the lead particulate to dissolve and easily be washed away. Some existing aerator cleaning protocols already include soaking in vinegar (e.g., Philadelphia Water Department, Michigan Department of Health and Human Services).

Another possibility is that the process of removing the aerator screen may disrupt the protective scale inside the fixture developed through corrosion control, thus releasing lead. The act of removing and reinstalling the aerator could also have resulted in minute pieces of brass getting into the water sample. At a facility in Cincinnati, samples from a sink in an infant room increased from 37 ppb to 88 ppb lead following aerator cleaning. In this case, the aerator broke during cleaning and was not put back on the faucet; therefore, the increased lead level could not have come from particulate dislodged from the screen during cleaning.

Additional research is needed to confirm our findings and develop an evidence-based protocol for routine cleaning of aerators.

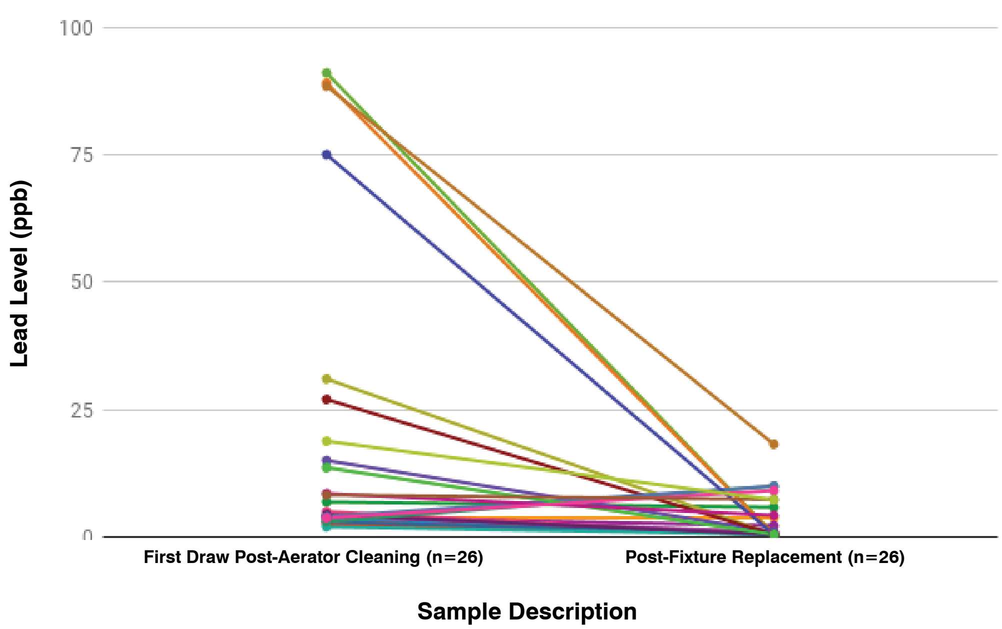
Fixture replacement

We replaced 26 of 294 fixtures (9%) based on our 3.8 ppb action level (>2 ppb in Chicago) on the second day of sampling (post-aerator cleaning). Three of these fixtures were replaced based on our lower action level of >2 ppb in Chicago. We conducted follow-up testing at all replaced fixtures.

Figure 10 illustrates lead levels before and after fixture replacement. We found that fixture replacement was effective when initial lead levels were high. When levels post-aerator cleaning were >5 ppb, fixture replacement led to an average reduction of 19.9 ppb (± 6.3 ppb) in lead levels.

FIGURE 10

Lead levels before and after fixture replacement (all samples)

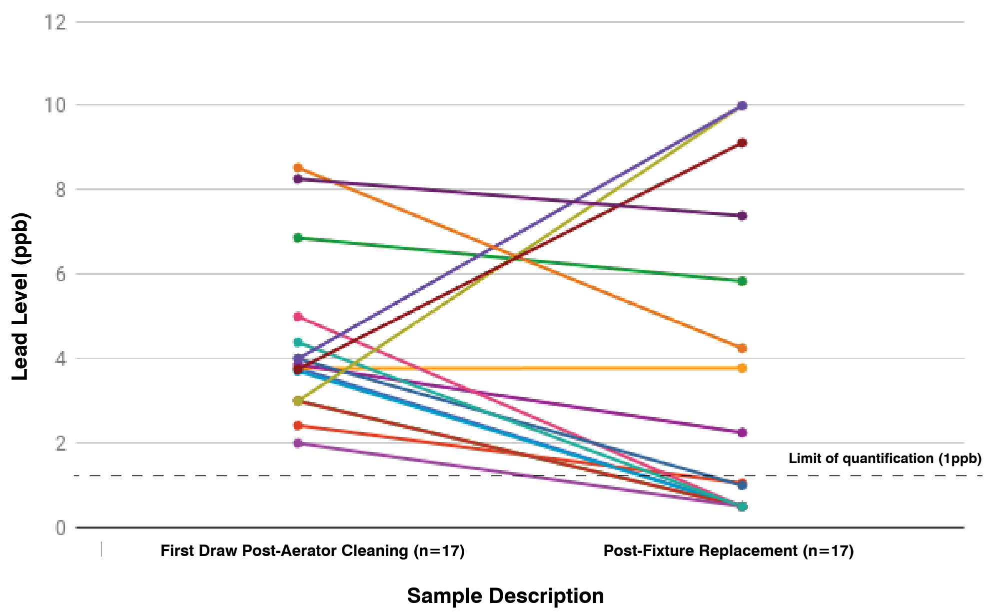


This chart illustrates lead levels at fixtures for first draw post-aerator cleaning and post-fixture replacement. Lines connect data for a single fixture.

However, where lead levels were initially close to our action level, replacement was not consistently effective (see Figure 11). In fact, when levels post-aerator cleaning were <5 ppb, fixture replacement on average resulted in a 2.0 ppb (± 1.0 ppb) increase in lead levels. While most initial follow-up testing results were under our action level (71%), a handful of fixtures (29%) tested above our action level following replacement. At two facilities, we conducted follow-up testing within 1-2 days after replacement. Three of these fixtures temporarily had higher lead levels following fixture replacement than prior to replacement, but decreased over time (data on decrease over time not shown).

FIGURE 11

Lead level before and after fixture replacement when baseline samples ≤10 ppb



This chart illustrates lead levels at fixtures for first draw post-aerator cleaning and post-fixture replacement when the initial sample was 10 ppb or lower. Lines connect data for a single fixture. The limit of quantification for ICP-MS (1 ppb) is indicated with a dashed line; samples below the limit of quantification are plotted at 0.5 ppb.

We found that fixture replacement did not consistently reduce lead levels to below our action level. This is likely because the current NSF International standards (NSF/ANSI 61) allows lead to be added to brass fixtures at up to 0.25% by weight and up to 5 ppb of lead to be leached from such fixtures following overnight stagnation under its evaluation protocol. A recent study analyzed three types of recently manufactured NSF/ANSI 61 "lead-free" faucets and found that leaching continued after 19 days (range: 1.5-3.0 ppb).

If the observed levels were due to lead from new fixtures, we would expect to see the lead levels reduce over time as lead exposed due to machining (i.e., cutting or grinding the surface during during the manufacturing process) leached into water and the coating from corrosion control built up. While we did not control for the time lapse between replacement and sampling in this pilot, we have some evidence to suggest this occurred at two centers. At a child care facility in

Cincinnati, follow-up first draw samples collected two days after replacement of six fixtures still showed elevated lead levels—one as high as 18 ppb.[6] However, when additional follow-up samples were taken three weeks later, the first draw levels were <1-2.6 ppb at each of these fixtures. We found a similar effect at one facility in Chicago, where immediate resampling post-fixture replacement resulted in lead levels of 10 ppb at two fixtures, which reduced down to 2 ppb after 5 weeks. Until the NSF International leachability standard is lowered to make it more protective, we think that consistently achieving levels below 5 ppb for at least a few weeks after fixture replacement may be difficult.

It is also possible that we continued to detect lead following fixture replacement because the act of replacing the fixture could have dislodged scale or particulates, leading to a release of lead. Alternatively, the lead levels we detected might have been due to upstream sources of lead or random fluctuations in lead levels from day to day.

More investigation is needed to evaluate overall risk from fixture replacement and weigh options to tighten the NSF International standard.

[6] After we received these results, we installed NSF 53 certified filters as an interim measure.

Case studies on lead service line replacement

We replaced LSLs at two child care facilities: one in a commercial building in Chicago and one in a converted home in the suburbs of Cincinnati in the City of Mount Healthy. As described in the case studies, each provides insights into the challenges of replacement and the benefits provided when the water utility supports the effort.

Cincinnati suburb

Greater Cincinnati Water Works (GCWW) has a proactive LSL replacement program, with a plan to replace the remaining 27,000 LSLs within the City of Cincinnati's limits over a 15 year period. As part of this program, customers in the city are required to replace LSLs within the next 15 years.

In December 2017, GCWW established a cost sharing grant, where any customers can receive 40-50% off, up to $1,500, of the cost of replacement on private property. Along with the cost sharing grant, customers can elect to have the remaining balance added to their property taxes as an assessment, interest free, to pay off within 10 years. However, the property tax assessment only applies to customers within the city limits. For communities outside of the city, within GCWW's service area, local or state legislation needs to be established for these communities to participate in property assessments. While there is interest from community leaders, GWCC is actively collaborating to develop ways to offer property assessments to all of its custumers.

Under city ordinances, GCWW, has the flexibility to prioritize LSL replacement based on the public health risk and economic consideration. The utility anticipates making any school, child care provider, or other business frequented by children a high priority for replacement.

We worked with GCWW and People Working Cooperatively, a community non-profit helping residents of the Cincinnati metro area with critical home repairs, to remove an LSL in a child care facility based in a converted home. GCWW relied on their internal records to determine that the facility likely had an LSL, and confirmed it by conducting a visual inspection. Due to complications restricting the city from working on private property, we coordinated a full LSL replacement by hiring an independent contractor to remove the portion of the LSL from the property line to the child care facility on the same day that GCWW replaced the portion from the property line to the water main.

The full line replacement was seamlessly coordinated between both parties, replacing the lead line with copper piping. The City of Mount Healthy did not charge any street opening permitting fees.

Following replacement, GCWW flushed the line immediately to remove any lead particulates from the system. GCWW provided the child care facility management with additional instructions to flush interior plumbing based on the American Water Works Association's (AWWA) C810-17 Replacement and Flushing of Lead Service Lines standard ("AWWA's flushing standard"), as well as a pitcher filter, replacement filter, and other educational literature.

City of Chicago

The City of Chicago mandated the use of LSLs up to 2 inches in diameter until 1986—when Congress banned them and other lead components in plumbing. Because of this, Chicago has a large number of LSLs with an estimated 78% of water accounts in the city serviced by an LSL. Unlike many communities across the country, Chicago does not have a proactive replacement program.

One of the child care facilities in Chicago was in a building constructed in the 1950s-1960s and adjoined to two other buildings. Elevate Energy, a Chicago based non-profit that partners with child care centers to cut utility and maintenance costs, determined that the service line material was likely lead based on reviewing the age and size of the piping through the City of Chicago's Sewer and Water Atlas. A licensed plumber confirmed the presence of an LSL through visual inspection. Because the City of Chicago's Department of Water Management does not have a program to assist property owners with replacement, we hired a licensed plumbing contractor to conduct all of the work.

One of the buildings adjoined to the child care facility had a newer, ductile iron service line on the property. As the pipe was up to code and could handle the flow, we only needed to disconnect the LSL at the facility and connect the internal water distribution system with 8 feet of interior copper piping to the ductile iron line in the adjacent building. It was a straightforward, relatively low-cost solution. However, the city required that the LSL be disconnected from the main under the street at the property owner's cost. As part of our arrangement with the child care facility, EDF paid for the work.

The City of Chicago charged $1,728 in permits and fees to cover costs such as street closure and lost parking meter revenue. Furthermore, city records had inaccurately identified the location of the water main under the street, leading to additional complications and work hours. After digging and having no success locating the main, the contractors reached back out to the city—but the city was unable to provide any additional help. The contractor returned on a second day along with companies using ground radar and sonar detection technologies, and, together, they were ultimately able to locate the water main (which was 10 feet below grade) to disconnect the LSL.

We developed flushing protocols for the contractor and for the child care facility's maintenance staff, based on AWWA's flushing standard. The contractor flushed from an outside connection at full velocity, followed by an initial full-facility flush. Elevate Energy provided facility staff with instructions to flush interior plumbing.

Water sampling pre-and post-LSL replacement

In both locations, we collected a water profile (i.e., 10 sequential 1 liter samples from the fixture closest to the service line entry point) before and after replacement to provide a snapshot of water samples from further upstream of the fixture. At the Chicago facility, the sampling profile before replacement showed lead levels fairly consistently at 2 ppb for each liter sample; after replacement we saw similar results. At the Mount Healthy facility, we observed a peak at liter two (5.6 ppb), followed by levels hovering at 2-3 ppb in the 10 liter profile. After replacement, the levels went down: all liters were <1 ppb except for liters 2-4, which ranged from 1.3-1.5 ppb.

Comparing costs for LSL replacements in two facilities

In general, the cost of replacing an LSL at a child care facility, due to their size and water flow requirements, may be greater than at a home.

The replacement cost was lower overall for the facility in the suburbs of Cincinnati (City of Mount Healthy), primarily because of Chicago's permitting fees. Additionally, it is likely that the replacement in Chicago would have been significantly higher had the entire service line been replaced rather than connected to an existing ductile line and disconnected at the main and the building.

Cost breakdown of LSL replacement at Mount Healthy converted home child care facility:
Total cost: **$8,680** ($4,980 by GCWW and $3,700 by EDF)

- Public side replacement: $4,980
  - Public LSL replacement: $3,380
  - Restoration on private property: $1,601
  - Permitting: $0
- Private side replacement: $3,700
- GCWW cost sharing grant: $0 (not available at the time of replacement)
- GCWW property tax assessment: $0 (Mount Healthy is outside the Cincinnati city limits)

Cost breakdown of LSL replacement at Chicago facility:
Total cost: **$10,058** (all EDF's cost; no support or grants available from the City of Chicago)

- Connect to existing ductile iron service line: $1,810
- Street opening and backfill (two visits): $5,705
- Find and disconnect existing lead service under street (two visits): $815
- Permitting and fees: $1,728
  - Public way opening to disconnect service line: $500
  - Connect water service pipe: $250
  - Public way opening to cut and seal disconnected LSL: $500
  - Lost parking meter revenue and miscellaneous fee: $478

Novel aspects of our protocol: Lessons learned

Our pilot project built on EPA's voluntary 3Ts guidance for schools and child care facilities, and used new approaches not considered in the guidance. We expanded on EPA's current guidance in four main ways:

1. Investigated and, if found, removed lead service lines.
2. Used a health-based benchmark to trigger remediation.
3. Used portable lead meters to screen lead levels at the tap.
4. Tested hot water at tap and at water heaters.

See below for details on lessons learned from each of these four approaches.

Investigated and, if found, removed lead service lines

Attempting to reduce lead levels by replacing fixtures is unlikely to be of much value when there is an LSL that can unpredictably release large amounts of lead. Thus, before initial testing to identify sources of lead in internal plumbing, we think it is essential to investigate for the presence of LSLs through review of city, water utility, and child care records and conduct a visual inspection to confirm the LSL's presence. If an LSL is found, it should be replaced, as it represents the largest source of lead in the building. Factors such as cost and logistics of replacement differ by locality. See the case studies from Cincinnati and Chicago (page 25) for details.

Used a health-based benchmark to trigger remediation

Instead of EPA's 3Ts action level of 20 ppb, we used a health-based benchmark of 3.8 ppb to trigger lead remediation. While there is no safe level of lead, this benchmark is based on the increased probability that a child will have a blood lead level (BLL) greater than 3.5 micrograms per deciliter of blood (µg/dL). We derived 3.8 ppb from a 2017 EPA report, "Proposed Modeling Approaches for Health-Based Benchmark for Lead in Drinking Water," which provided a range of potential values. We conducted an analysis of the EPA report and concluded that a conservative health-based benchmark for individual action on lead in drinking water should be 3.8 ppb—reflecting a 1% increase in the probability of a formula-fed infant living in pre-1950 housing of having a BLL of 3.5 µg/dL.

We used an action level of >2 ppb in Chicago in an effort to conform to new lead in water testing requirements under Illinois Public Act 099-0922, enacted in January 2017. Illinois recently set an action level of 2 ppb, based on the lowest level at which the state expects all approved laboratories to be able to quantify lead in a sample. Our pilot began well before Illinois established its action level.

We replaced 15 fixtures where sampled water tested between 3.8 ppb (or >2ppb in Chicago) and 20 ppb, six fixtures that sampled above 20 ppb, and an additional five fixtures below our action level out of caution. Under 3Ts trigger of 20 ppb, only six of these fixtures would have been replaced. While 3.8 ppb may be difficult to achieve (see page 23), clearly EPA's 3Ts action level of 20 ppb is insufficient. We recommend an interim action level of 5 ppb, until NSF International's leachability standard is strengthened.

Used portable lead meters to screen lead levels at the tap

We piloted two portable lead meters—Palintest and ANDalyze—to investigate whether such tools could be reliably used in lieu of laboratory testing with ICP-MS, the gold-standard, to identify problematic fixtures. We analyzed 758 samples with the Palintest meter and 242 samples with the ANDalyze meter.

The Palintest is an EPA-approved meter to detect low levels of lead in drinking water. ANDalyze is a newer tool that relies on DNA-based fluorescence technology; it has not been approved by EPA for drinking water use. Both tools are handheld and provide lead results within minutes. We evaluated whether these portable meters could be used as reliable and accurate screening tools to identify problematic fixtures. We compared results from the portable lead meters to the ICP-MS laboratory analysis. If the portable meter proved to be a reliable screening tool, it would allow for immediate replacement and remediation of lead-reducing delays in replacement and, potentially, overall costs.

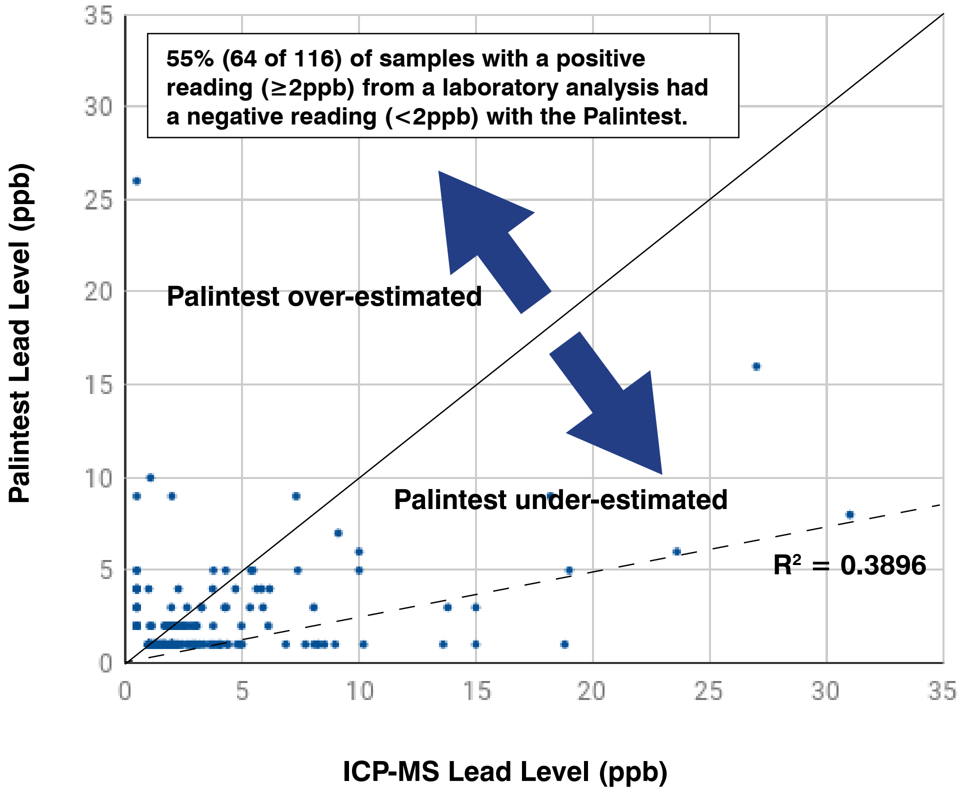
Palintest

Palintest portable lead meter tended to underestimate lead in water levels compared to the laboratory analysis (Figure 12), likely because the Palintest protocol does not include a full acid digestion to solubilize any particulate lead. Of 116 samples, 55% (64) with a positive reading (≥2 ppb) from laboratory analysis had a negative reading (<2 ppb) with the Palintest. In 18 instances (11% of the samples), the Palintest had a positive reading (≥ 2 ppb) while the laboratory results were below the limit of quantification (<1 ppb); however, 14 of these samples came from the same meter and we suspect there may have been a technical issue resulting in false readings.

Palintest meter. Photo credit: Danielle Scruggs.

FIGURE 12

Comparing Palintest and ICP-MS lab results



This chart compares sample results from the Palintest meter to the ICP-MS laboratory analysis. When the reading was below the limit of quantification (2 ppb for Palintest and 1 ppb for ICP-MS), we plotted the value at half the limit of quantification. The dotted line represents the observed correlation between the ICP-MS and Palintest measurements, while the solid line represents what the trendline would be if the two tests were perfectly correlated.

Because it was apparent that the Palintest was unreliable for our purposes at low lead levels, we generally did not feel comfortable making decisions based on the Palintest results. Instead, we waited until we had laboratory results in hand to make remediation decisions. See case study from Chicago (page 31) for the one exception to this approach.

While the Palintest meter tended to underestimate lead levels, in every instance where laboratory results indicated levels above 20 ppb and we also had Palintest results (27 samples, data not shown[7]), the Palintest meter produced a positive reading—even if much lower than the lab result. This suggests that the Palintest may be effective in flagging levels over the EPA's current 3Ts action level of 20 ppb. Further, modifying the test procedure by allowing for a longer acidification period may increase the accuracy of the Palintest tool.

[7] These data include eight results from fixtures as well as 19 results from water heater drains.

Case study from Chicago

At one child care facility in Chicago, we used the Palintest meter and found it to be an effective way to screen for highly problematic fixtures—quickly flagging them for replacement.

We sampled at 29 fixtures, including 27 drinking water sources, using the Palintest meter the same day we collected the sample. Six drinking water fixtures were flagged by the Palintest—with readings of 8, 9, 12, 16, 25, and 27 ppb. Based on these results, our Chicago-based partner, Elevate Energy, contracted with a licensed plumber who replaced these six fixtures just five days after the samples were collected.

We received the laboratory results 18 days after fixture replacement. The lab results demonstrated that 10 drinking water fixtures had lead levels above the action level we used in Chicago (>2 ppb). The five with the highest ICP-MS levels (27-91 ppb) had been flagged by the Palintest meter and had already been replaced (Figure 13). The sixth fixture we had replaced based on the Palintest meter (#17 on Figure 13), had a lead level of just 2 ppb based on the ICP-MS analysis. We would not have replaced this fixture based on the ICP-MS results.

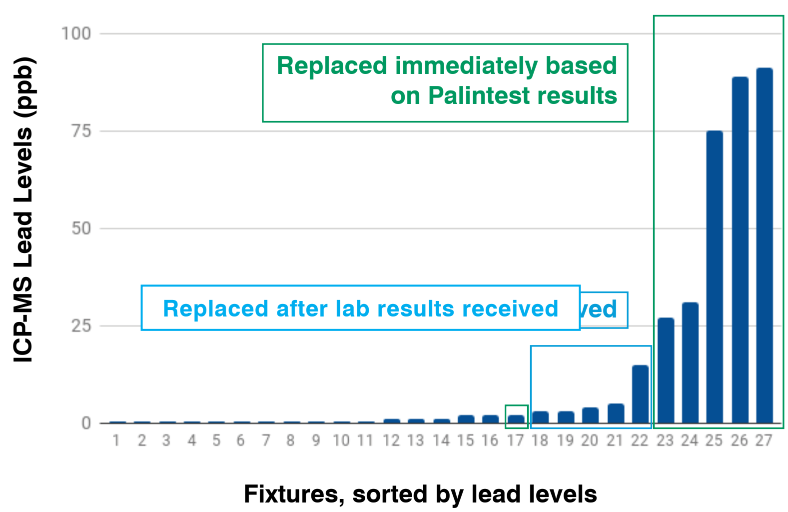
Partner at Elevate Energy collects water from a classroom sink. Photo credit: Danielle Scruggs.

We then conducted five additional fixture replacements (for a total of 11 replacements) to address the fixtures with lower lead levels but still above our action level (3-15 ppb).

Eight weeks after initial sampling, we resampled every fixture at the center. All follow-up samples demonstrated either non-detectible levels of lead or 1 ppb.

FIGURE 13

ICP-MS results for 27 drinking water fixtures



ANDalyze

We did not collect sufficient data with the ANDalyze meter to draw conclusions on its accuracy. The vast majority of samples analyzed with the ANDalyze meter resulted in a non-detect finding, and results were generally inconsistent with the laboratory analysis. Our experience was that it was less user friendly than the Palintest tool, potentially leading to user error and likely inaccurate results. While it may be used effectively by trained personnel, we do not anticipate that child care staff or a plumber could routinely use such a tool.

Image of partner using ANDalyze meter. Photo credit: Danielle Scruggs.

Conclusions on portable lead meters

For the reasons described above, our original goal of identifying problem fixtures with portable lead meters and immediately replacing the lead source was generally not successful. In addition to accuracy issues, conducting same day fixture replacement was impractical due to the need to coordinate with plumbers and locate the type of new fixture needed.

A cost-effective field meter that could provide immediate, accurate lead results would be helpful. While the opportunity for immediate results from portable screening tools such as Palintest and ANDalyze is appealing, our results suggest that they are not yet ready to be used in lieu of lab testing.

What did we pay?

Laboratory testing (ICP-MS): $8-10/sample. Samples came with pre-paid return envelopes for shipping.

Palintest: $7/sample; $1,581 for portable meter.

ANDalyze: $6/sample; we received and returned two portable units on loan (normal cost is $1,995 each).

There may, however, be other important uses of such tools. For example, Chicago Public Schools is using portable meters to allow for field evaluation of automatic flushing techniques where there is a fixture with previously identified high lead levels. In other words, Chicago is using these tools not to identify a high level but rather to determine how much automatic flushing is needed to get levels below 2 ppb. More work is needed in this area.

Tested hot water at tap and water heaters

Hot water is more likely to leach lead from plumbing than cold water. Despite this risk, current testing protocols do not include sampling hot water. Rather, EPA recommends drinking only cold water. However, we are concerned that child care facilities may use hot water for drinking purposes, such as when mixing infant formula or other powdered drinks with water.

In addition, we anecdotally learned of concerns that lead particulate from an LSL or other lead sources could settle and accumulate at the bottom of the hot water tank where high temperatures from the flame or electric heater coil may dissolve the lead into the water. Theoretically, settled particulate could also be re-suspended when the hot water flow is high.

To explore these two issues, we incorporated sampling of hot water at the tap, as well as directly from the water heater drain, into our protocol.

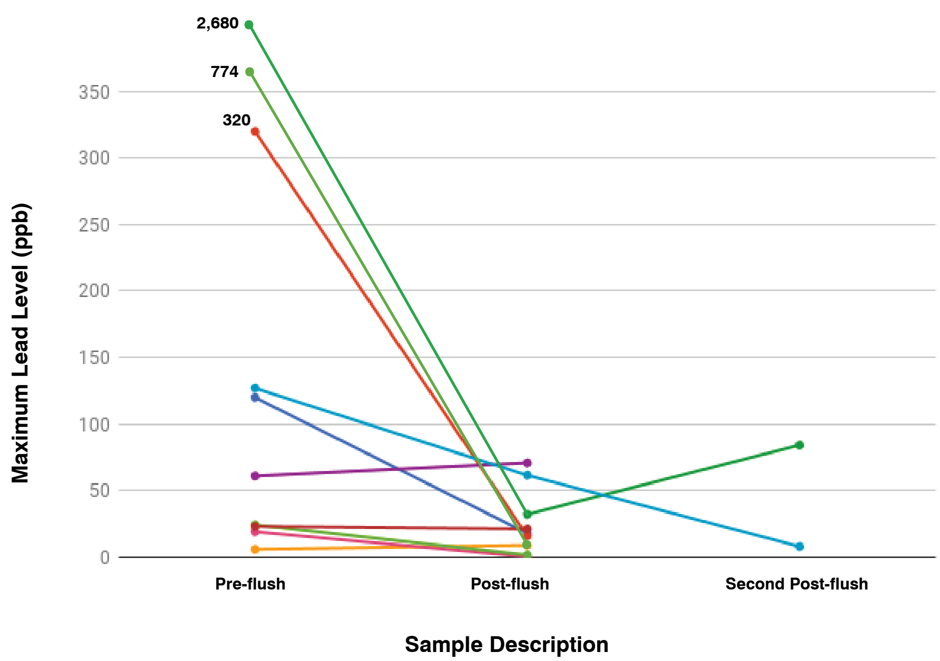
We found alarmingly high lead levels from the samples collected from the drains of hot water heaters, which we think likely accumulated over time from upstream sources of lead. Half (seven of 14) of water heater tanks tested in child care facilities had levels over 50 ppb, with one as high as 2,680 ppb. The initial samples from the water heater often were discolored—some even like a sludge.

Water samples collected directly from water heater drain. Initial draw pictured on the left.

Our partners performed sustained flushes through the drain on 10 water heater tanks to remove accumulated sludge and particulate (Figure 14). The flushing helped significantly in all but one case. Among water heaters where initial samples tested above 50 ppb, flushing dropped the lead levels on average from 456 ppb to 20 ppb. When initial water heater samples tested below 50 ppb, the drop was less evident (from 17 ppb pre-flush to 13 ppb post-flush, on average). In two cases, our partners performed second flushes in an attempt to further reduce the lead levels (with mixed results). Flushing the water heater can be challenging, however, if there is not a floor drain nearby. Some facilities may need a plumber's assistance to perform a sustained flush of the water heater.

FIGURE 14

Lead results for 10 water heaters: Before and after flushing



Measured lead levels in 250 mL of water collected from 10 hot water heaters in 9 child care facilities. Pictured: Highest lead level detected during each sampling phase—the initial sampling (pre-flush), following a full flush of the water heater (post-flush), and following a second flush of the water heater (second post-flush). Lines connect data for a single water heater.

Hot water samples at the taps, fortunately, did not have considerably different lead levels than cold water samples. At the hot water tap, only 4 of 172 (2%) samples were above our action level of 3.8 ppb. The vast majority of hot water samples (83%) had non-detectible lead concentrations.

However, our first draw samples of hot water may not adequately reflect actual exposure. For example, using large amounts of hot water prior to sampling could change the pressure in the tank and allow lead particulates to be suspended into the distribution system. Additional research is needed to determine the exposure impact of high lead levels in water heaters. Despite these unknowns, it is clear that hot water heaters can act as a large reservoir for lead. See our blog for more details.

Key results

- Flushing fixtures such as faucets and drinking fountains for just five seconds reduces lead levels. Flushing for 30 seconds is even more effective.
- Cleaning the aerator at the end of the faucet is important, but may increase lead levels. More investigation is needed.
- Replacing fixtures is effective when initial lead levels are high. However, it is not always sufficient to meet lead levels below 3.8 ppb. This is most likely because NSF International's current standards allow new brass fixtures to have added lead and leach up to 5 ppb into water. More investigation is needed.
- Portable lead meters that provide results in the field tend to underestimate lead levels compared to laboratory results.
- Water heaters may function as "lead traps" for upstream sources of lead, but more investigation is needed to identify the source of this lead and whether it could result in elevated levels at the hot water tap.

Recommendations

As a result of the legacy of lead, child care facility operators, state licensing agencies, and health departments need to evaluate all locations where many young children, especially infants, spend significant time. Therefore, child care facilities must address the issue even if they did not have a role in creating the problem. To succeed, they need support from EPA, local water utilities, and NSF International, as well as the families they serve. We make the following recommendations to address lead in water based on our experience from this pilot project.

Recommendations to child care facility operators

Child care facility operators should:

- Evaluate their drinking water for lead. This evaluation should include:
  - Determining if the facility has lead pipes, including an LSL, by evaluating the age of the building (built pre-1986 may have an LSL), contacting the utility, and having a licensed plumber conduct a physical inspection.
  - Testing each water fixture, with the samples analyzed by an approved laboratory method. There currently is no effective method to predict which fixtures will have significant levels of lead without testing the water.
- If an LSL is found, work with the drinking water provider (utility) both to remove the lead pipe and flush the system after replacement to minimize lead exposure. Follow AWWA's flushing standard.
- Add to the standard operating procedures for staff and children:
  - Avoid using hot water for cooking or drinking.
  - Avoid using hose bibs (outdoor or at utility sinks) for drinking.
  - Flush fixtures (minimum five seconds) before drinking to reduce lead levels. After long periods of non-use (e.g., vacations), a longer flush may be needed.
  - When cleaning aerators, soak in vinegar for several minutes to dissolve any lead present.
  - Follow the manufacturer's instructions for routine flushing of the hot water heater to reduce accumulated sediment (including lead), extend the life of the water heater, and improve its overall energy efficiency.
- Where lead levels from a fixture exceed 5 ppb, facilities managers should replace fixtures and, until replaced, consider taking the fixture out of service or using NSF 53 certified filters to remove lead.
- Resample fixtures after remediation steps are employed.
- Participate in the Eco-Healthy Child Care Program®, which includes addressing lead in water and other sources.

Recommendations to EPA

EPA's 3Ts guidance for child care facilities is a helpful framework, but there are several ways that it could be improved to better protect children at child care facilities. Because LSLs are more common in child care facilities than schools, we recommend that EPA's 3Ts guidance place a greater emphasis on LSL identification and replacement. Further, because lead releases from an LSL are unpredictable, we recommend starting any investigation by searching historical records, such as those from the local water utility, and conducting a physical inspection to identify if an LSL is present. If possible, it is always best to replace the LSL because it can significantly contribute to lead in the water throughout the entire distribution system.

Furthermore, we recommend that EPA lower its 3Ts action level from 20 ppb to 5 ppb as an interim measure—further lowering it once NSF International's leachability standard is updated. 20 ppb is not health-based nor is it based on corrosion control feasibility (such as the Lead and Copper Rule Action Level of 15 ppb). Compared to schools, a lower action level at child care facilities may be even more prudent because they serve children at a more vulnerable stage of their lives. Our results suggest that a lower action level is attainable.

Finally, the protocol detailed in EPA's 3Ts guidance for both child care facilities and schools should be updated to include a robust protocol for aerator cleaning and to address hot water and water heaters as potential sources of lead in child care facilities.

Recommendations to NSF International on its standards for new plumbing

NSF International's NSF/ANSI 61 standard is required in every state in the U.S. except for Hawaii. It should review its standard to reduce the leaching limit for brass fixtures from 5 ppb to 1 ppb, especially for fixtures in child care facilities and schools.

Recommendations to state child care facility regulatory agencies

More states and localities should require testing and remediation for lead in water at child care facilities. This should include developing a reasonable and protective protocol for testing water,

Key areas for additional research

- **Aerator cleaning:** Confirm finding that aerator cleaning can increase lead levels and develop an evidence-based protocol for routine cleaning of aerators.
- **Water heaters:** Identify the source(s) of high lead levels in water heaters. Conduct more rigorous sampling of the hot water distribution system to determine if high levels at water heaters may influence levels at the tap.
- **Fixture replacement:** Confirm the amount of time/flushing needed to remove lead from new fixtures that meet NSF/ANSI 61 standard. Research whether washing fixtures at the manufacturing facilities (e.g., vinegar wash) would result in reduced lead levels immediately after they are installed.

detailing locations that should be tested and how frequently testing should take place. We recommend that such mandatory testing specifically require:

- Replacing LSLs in child care facilities when found, regardless of testing results.
- Using an accredited lab for lead in water analysis until further research on portable meters confirms that they can be used reliably.
- Setting an action level of 5 ppb or below to investigate and remediate interior lead sources.
- Specifying practical and effective remediation options for lead at the tap—such as fixture replacement, flushing, aerator cleaning with vinegar, and filtration—but allowing the facility flexibility in developing their own remediation plan.
- Resampling fixtures after remediation steps are employed.

Recommendations to drinking water utilities

Utilities should:

- Develop a comprehensive program to eliminate LSLs in the community, including making it easier to identify locations with LSLs (e.g., public maps) and making replacement at child care facilities a priority.
- Assist child care facilities that seek to replace their LSLs.
- Provide technical assistance and no- or low-cost water testing services for water samples.

Recommendations to public health departments

Public health departments should:

- Assist local child care facilities with water sampling, as appropriate.
- Consider and address lead in water at child care facilities in cases of children with elevated blood lead (EBL):
    - When a child's treatment plan includes environmental investigation, encourage their child care facility to test for lead in water following EPA's 3Ts protocol with the amendments described above.
    - Provide facility with educational/awareness materials consistent with this report.
    - Identify locations of all child care facilities caring for EBL children so that patterns might be identified and investigated.

Recommendations to parents

Parents should ask their child care provider:

- Whether the facility has an LSL.
- Whether the facility has tested for lead, including in water, but also for other sources such as paint.
- What the results and remediation plans are (if testing results are available).

Funding LSL replacement

Communities and utilities across the country have taken various strategies to fund LSL replacement. In some locations, the water utility provides assistance in funding LSL replacement in low income and/or at risk locations, like child care facilities.

Find examples of various funding mechanisms and assistance programs in the following resources:

- EDF's website highlighting community, utility, and state programs
- Lead Service Line Replacement Collaborative: Community Access to Funding

Conclusion

Lead in drinking water is a legacy of past uses of the toxic metal in pipes, solder, and fixtures—which remain in our water distribution system today. Current laws and regulations limit the lead content in new brass used in plumbing materials. However, lead can still be added to brass as long as the overall amount is less than 0.25% and the lead leaching is below 5 ppb.

With millions of children spending much of their day in child care facilities, reducing lead in drinking water at these facilities is an important step in protecting children from lead. Identification and replacement of LSLs at child care facilities through review of historical records and visual inspection should be a priority. For all other sources of lead, testing is an essential step. However, such testing must be coupled with actions that address high lead levels. We suggest using 5 ppb as an interim action level to trigger remediation until the NSF International leachability standard for new brass fixtures is strengthened.

Though child care facilities are currently a major gap in the effort to reduce children's exposure to lead from drinking water, they also present a critical opportunity for renewed progress in the future.

Key resources

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Our Partners

Elevate Energy

Elevate Energy is a 501c3 nonprofit organization with a mission to design and implement energy and healthy housing programs that lower costs, protect the environment, and ensure the benefits of energy efficiency reach those who need them most. We are committed in working with others to ensure everyone has access to the benefits of the clean energy economy. Elevate Energy has over 15 years of experience addressing complicated healthy housing challenges in the Chicago region and throughout the United States. We also provide energy and water efficiency assistance to child care facilities and used this study to create a safer, healthier environment for children.

Greater Cincinnati Water Works

Greater Cincinnati Water Works is an innovative water utility providing essential drinking water services to more than 1.1 million residents in the Greater Cincinnati metropolitan area. The employees of GCWW strive to be the standard of excellence in water services and are committed to providing a plentiful supply of high quality water while supporting environmental sustainability and fiscal responsibility. With our mission as our guide, along with customer and community centered values, we enhanced our lead control strategies to include more targeted forms of education and outreach and a program to assist property owners with lead service line replacement. GCWW has also initiated a focus on children through intense sampling programs in schools and other buildings where children may congregate. Ultimately, GCWW is committed to doing the right thing for our customers and communities by working together to move towards a lead safe City now and in the future.

Healthy Homes Coalition of West Michigan

The Healthy Homes Coalition of West Michigan believes all children should have the opportunity to grow up in a healthy home that is free from environmental hazards. Our mission is to improve children's health and wellbeing by eliminating harmful housing conditions. We achieve that mission through policy and advocacy, outreach and education, direct services, and continuous collaboration. Child care centers are an extension of that home environment. It is with that in mind that the Healthy Homes Coalition was eager to participate in this study to learn more about commonsense opportunities for making all of children's environments safer.

Mississippi State University Extension Service

The Mississippi State University Extension Service provides research-based information, educational programs, and technology transfer focused on issues and needs of the people of Mississippi, enabling them to make informed decisions about their economic, social, and cultural well-being. Safe drinking water is very much a need of Mississippians. MSU Extension participated in this study because of the need for information related to mitigation of lead in drinking water and informing child care centers of best practices.

People Working Cooperatively

People Working Cooperatively exists to help low-income homeowners stay independent and healthier in their own homes by providing critical home repair, accessibility and energy conservation services. As a nonprofit construction company, PWC's licensed technicians provide important housing services directly to low-income seniors, people with disabilities and other families in need. PWC continues to pursue partnerships that can help reduce exposure to environmental contaminants in the built environment, particularly in underserved communities who are at the greatest risk. Collaborating with EDF and the Greater Cincinnati Water Works has been a tremendous opportunity to help maintain healthy environments in the places where we live, work, play and learn.

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