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*Features*

# FAILING OUR CHILDREN: LEAD IN U.S. SCHOOL DRINKING WATER

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**ABSTRACT**

Lead is the most prevalent toxicant in U.S. school drinking water. Yet for the vast majority of schools, federal regulation for testing taps and remediating contamination is voluntary. Using school case studies, this article discusses the regulatory vacuum that leaves children unprotected from potential exposure to very high lead doses through consumption of school water. Controlling lead hazards from water fountains, coolers, and other drinking water outlets in schools requires improved sampling protocols that can capture the inherent variability of lead release from plumbing and measure both the particulate and dissolved lead present in water. There is a need to reevaluate the potential public health implications of lead-contaminated drinking water in schools. Accounting for this misunderstood and largely overlooked exposure source is necessary in order to better understand and address childhood lead poisoning in the U.S.

## A PARADIGM CASE: LOS ANGELES UNIFIED SCHOOL DISTRICT

In September 2007, children at Woodlake Avenue Elementary School in the Los Angeles suburb of Woodland Hills told their parents that teachers had advised them against drinking the water from the school's fountains. Alarmed by the warning, the father of a first grader requested that the Los Angeles Unified




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School District (LAUSD) test the school's water outlets immediately for hazardous contaminants. After several weeks of inaction, LAUSD sampled Woodlake's taps and returned in November to announce the results. One fountain dispensed over five times the amount of lead considered acceptable for school drinking water by Environmental Protection Agency (EPA) standards and was shut off [1]. LAUSD promised school-wide replacement of drinking water fountains and lead-bearing plumbing materials at Woodlake but, several weeks later, had not begun the work.

Troubled by the inertia, in January 2008 the concerned father contacted a local television news station, which launched a district-wide investigation of lead in drinking water at LAUSD. In March, undercover reporters collected samples from 30 schools and found that nine had at least one drinking water outlet that tested high for lead. Among those outlets was the very fountain at Woodlake that had been found to dispense elevated levels in the fall and was shut off. Four months after its initial sampling, the reporters found this fountain back in service, without evidence that it had undergone repairs [2].

In its exchanges with parents, LAUSD consistently asserted that the problem at Woodlake was a new discovery. When pressed by the news station, however, district officials admitted that tests eight years earlier had revealed lead-in-water elevations at several district schools, including Woodlake. In fact, according to an internal district report, widespread problems with lead in LAUSD's drinking water had first been detected in 1988. To address the contamination, in 1990 LAUSD established a flushing policy, which required running the water for 30 seconds at every fountain in every school at the beginning of each school day [3, 4]. LAUSD's flushing program was based on a 1989 EPA guidance that listed flushing as an "interim measure" for reducing lead in water that can accumulate in outlets when not in use [5].

To assess how LAUSD's policy was implemented at Woodlake and other district schools, the undercover reporters expanded their investigation to the daily routines of school custodians. They noted persistent failures to flush drinking water outlets as well as falsification of "flushing logs," indicating that flushing had occurred when it had not. In April 2008, the news station informed LAUSD about its findings. Days later, the district's superintendent held a little-announced press conference in which he attributed the contamination to possible employee non-compliance with the flushing policy. He declared that although negligent staff would be held accountable, failure of LAUSD to flush taps "did not put any students in jeopardy" [6]. When asked why the district had not addressed the contamination sooner, the superintendent replied that in a democracy school officials depended on the public to raise problems of this nature [7].

The press conference, held seven months after the Woodlake father's original plea for action, was the district's first official acknowledgment of persistent lead-in-water problems at LAUSD [8]. LAUSD assured the public that it had begun sampling randomly selected drinking water fountains and was planning to remediate all those that exceeded the EPA's standard. It stressed that the district did not have the $300 million needed to replace all lead-bearing plumbing at the schools, but that it was committed to fixing the worst problems. Based on the limited number of test results available at the time, the superintendent asserted that the district's school water was "safe." "There is no reason for hysteria here," he stated [9]. The Woodlake father felt differently. "I am very concerned about [the contamination]," he said in a televised news interview, "because we don't even know really the long-term effects of this, or even the short-term effects, and we don't know how long the kids have been exposed to this" [10].

In May 2008, LAUSD began a multi-media and multi-language outreach effort to allay parent fears. As part of this campaign, it sent Woodlake a pediatric toxicologist from the Los Angeles County Department of Public Health to educate parents about the potential health impact of the contamination. The County official declared that unless students had been chewing on lead paint chips there was little to worry about, and that in fact ordinary foods and drinks contained more lead than the school's water. "If you eat one Brussels sprout, you are going to get far more lead from that one Brussels sprout than you will get from weeks of drinking water here," he said. "I guarantee you, that if you tested the milk, the soda, the juice, the water that your child gets in your own home, it dwarfs the lead that your child is getting exposed to here" [11]. Taking up the toxicologist's challenge, the news station commissioned testing of all the cited food and beverage items and revealed undetectable levels of lead in every case [12].

As it promised, LAUSD installed copper pipes and new water fountains at Woodlake. It also invested extensive resources to determine the extent of the contamination district-wide. In November 2008, it initiated comprehensive sampling of all drinking water outlets in all 735 schools at a cost of $1.5 million. Five months and more than 66,000 tests later, LAUSD announced plans to turn off indefinitely and replace more than 2,000 fountains and faucets due to high levels of lead [13]. An internal presentation for the district's Human Relations Committee and the School Safety, Student Health and Human Services Committee specified that these outlets exceeded the EPA standard for school taps on *both* first- and second-draw samples [14]. Some samples were tens and hundreds of times the EPA standard. At least one of the samples measured at a level sufficient to classify the drinking water as "hazardous waste" [15]. Another approximately 7,000 outlets tested high for lead only on first-draw samples. LAUSD kept these outlets in service and committed to remediating them through daily flushing. Contaminated taps were identified in 92 percent of the district's schools [16].

## THE NATIONAL SCOPE OF THE PROBLEM

The LAUSD story typifies how some K-12 schools around the nation manage lead-in-water problems and highlights a systemic neglect of an environmental health hazard. School case studies reveal a pattern of incomplete understanding about how lead-bearing plumbing materials can release lead into water and what health risks such water can pose. This pattern often leads to: 1) inertia vis-à-vis the identification and remediation of contamination; 2) reactive and suboptimal water testing programs in response to pressure from parents, teachers, and individuals outside the school community; 3) resistance to information-sharing concerning testing protocols, analytical methods, test results, and solutions; 4) delays in announcing contamination problems and avoidance of discussions about their potential health effects; 5) adoption of remedial measures that are logistically and/or financially burdensome, rooted in outdated scientific understandings of lead corrosion, or implemented inappropriately, incompletely, and without proof of effectiveness; 6) delivery of reassuring public health messages prematurely and/or without firm grounding in scientific facts; and 7) a sense of confidence and certainty when unknowns abound. As a result, the unnecessary exposure of children to lead in school drinking water is often prolonged before concrete action is taken—if ever.

In September 2009, the *Associated Press* (AP) released a nationwide investigation showing that lead-contaminated drinking water affects schools in at least 27 states [17]. AP's analysis was based on data from the EPA, which are limited to the 8-11 percent of the country's 132,500 schools that are required by law to sample their taps for hazardous contaminants and report results to state authorities. Because these schools regularly provide water to at least 25 individuals a day and use their own water source (e.g., private well) or treat or sell their water, they are regulated as "public water systems" [18]. The rest of the nation's schools, which receive their water from local utilities, are not subject to federal regulation, and the EPA has no direct oversight responsibility for the quality of the drinking water they provide. Some of these schools have tested their water voluntarily and, in some cases, they have discovered serious lead contamination. Our research shows that when this category of schools is taken into account, the number of documented states affected by lead-contaminated school drinking water increases to at least 39 (including the District of Columbia). There is no scientific or practical reason to believe that the problem does not extend to schools in all 50 states.

A 2006 analysis by the U.S. Government Accountability Office (GAO) revealed that few states have developed comprehensive testing and remediation programs for lead in school drinking water, and about half the states have developed no programs at all [19]. Because many schools do not test for lead in drinking water, national data on the problem are limited. As a result, the true extent to which children across the nation are exposed to lead at school taps is unknown. What is evident, however, is that few schools have adopted measures to prevent such exposures. State and local officials correctly attribute this omission to the regulatory vacuum that leaves the vast majority of schools with no mandatory requirements for testing, unclear guidance on remediation, and little to no information about the potential health risks of lead at the tap.

Although the conventional wisdom is that lead in school drinking water poses little health risk, substantive gaps in our understanding of a) lead corrosion, b) proper water testing methods, and c) the research on childhood lead poisoning from contaminated water may have caused the impact of exposure to be underestimated.

## WHO REGULATES LEAD IN U.S. SCHOOL DRINKING WATER?

For the approximately 90 percent of U.S. schools that receive their water from local utilities, no local, state, or federal entity is required to ensure that water lead levels are acceptably low (Table 1). Although some states and regional EPA offices have, at their discretion, encouraged and even facilitated sampling at school taps, water lead levels at the majority of the nation's schools are not monitored or remediated routinely, if ever. Thus, responsibility for addressing potential problems is effectively delegated to parents, teachers, and individuals outside the school community who are usually unsuspecting of lead-in-water contamination, unaware of the health risks it might pose, unable to implement testing and remediation programs, and trusting that if there were a significant environmental hazard at school it would be controlled effectively and expediently by experts.

Comprehensive federal regulation of drinking water safety in the United States was introduced in 1974. It was spurred by several influential studies that reported widespread problems with the safety of the nation's drinking water [20, 21]. To "assure that water supply systems serving the public [met] minimum national standards for protection of public health" [22], Congress passed the "Safe Drinking Water Act" (SDWA) of 1974. The SDWA authorized the EPA to establish enforceable "Maximum Contaminant Levels" (MCLs) for all substances in drinking water with known or suspected adverse effects on human health. These minimum water quality requirements would apply to every public water system in the country, including schools and child care facilities regulated as public water systems. Federal and state agencies as well as local water supply systems were to take a central role in implementing the new law.

The EPA's National Interim Primary Drinking Water Regulations of 1975 kept 50 parts per billion (ppb), the standard set by the U.S. Public Health Service (PHS) in 1962, as the maximum allowable concentration of lead in drinking water [23]. The EPA's requirement, like that of the PHS, applied at the point where the water enters the distribution system rather than at the consumer's tap. It

Table 1. U.S. School Lead-in-Water Testing and Remediation Requirements

| | Schools regulated as "Public Water Systems" | Schools not regulated as "Public Water Systems" |
|---|---|---|
| **Characteristics** | Regularly provide water to an average of at least 25 individuals a day and have their own water source, or treat their water, or sell their water. | Receive drinking water from a public water system that is owned by a city, town, or other entity and neither treat nor sell this water. |
| **Prevalence** | 8-11% of schools | 89-92% of schools |
| **Pertinent regulation** | **Federally mandated LCR**: Under the SDWA's LCR, schools are ***required*** to sample water for lead regularly, remediate, and report results to the public as well as to state/federal authorities. | **Voluntary LCCA**: No federal law requires sampling for lead in water, although a small number of public water utilities include very limited school sampling in their LCR compliance monitoring. The implementation and enforcement of the SDWA's LCCA is at each state's discretion. Under the LCCA, EPA provides schools with guidance for a ***voluntary*** lead-in-water reduction program. Several states (and regional EPA offices) have taken an active role in ensuring some school sampling and remediation as well as educating school communities about lead at the tap. |
| **Testing requirements** | Testing ***must*** occur at a fixed number of taps (5-60, depending on the size of the population served) every 6 months, unless the school qualifies for reduced monitoring. | Under the LCCA, EPA ***recommends*** that, at a minimum, every school water outlet regularly used for drinking and cooking is sampled for lead. There are no requirements for frequency of sampling. |
| **"Failure criterion" triggering remediation** | When over 10% of 1-L samples exceed 15 ppb lead (federally mandated LCR action level) | When over 20 ppb lead is detected in any 250 mL first-draw water sample (LCCA recommendation) |
| **Remediation requirements** | Under the LCR, remediation ***requirements*** include corrosion control optimization, public education, and lead service line replacement. | Under the LCCA, EPA ***recommends*** that any water outlet that fails the 20 ppb criterion be taken out of service and/or remediated. |
| **Reporting requirements to state or federal agency with primacy over enforcement of the SDWA** | Schools serving fewer than 3,300 individuals are **required** to report a 90th percentile lead value only when over 10% of 1-L samples exceed 15 ppb lead. Larger school communities are **required** to report a 90th percentile lead value at every sampling round. | Under the LCCA, EPA ***recommends*** that schools make all test results available to the public, but it does not specifically require reporting to state or federal agencies. |

was, therefore, guaranteed to miss the main source of the problem, namely, leaching of lead from lead service lines, lead solder, and indoor plumbing materials [24]. Hence, the original SDWA made it easy for public water systems to meet the 50 ppb MCL, even if the water provided by those systems dispensed hazardous levels of lead at drinking water outlets [25]. In 1977, the National Academy of Sciences acknowledged that, "the present limit of 50 μg/liter may not, in view of other sources of environmental exposure, provide a sufficient margin of safety, particularly for fetuses and young growing children" and recommended that the allowable concentration of lead in drinking water be lowered [26].

Increasing recognition that lead can leach from plumbing materials after the water has left the treatment plant, and an EPA estimate that "as many as 250,000 children [had] suffered measurable IQ losses as the result of drinking lead-contaminated water" [27], led to the passage of three important federal statutes, which expanded the SDWA's regulatory reach to the tap [28].

### The Lead Ban of 1986

This provision outlawed the new installation of solder and flux containing more than 0.2 percent lead and the use of pipes and pipe fittings containing more than 8 percent lead in all public water systems and in all buildings supplying drinking water for human consumption. Plumbing materials meeting these specifications were considered "lead-free" [29].

### The Lead Contamination and Control Act (LCCA) of 1988

New tests by the EPA, which showed that drinking water coolers often contained lead solder or lead-lined tanks, prompted Congress to add a new provision to the SDWA. Based on concerns that water coolers were commonplace in schools, the LCCA characterized all refrigerated water fountains that did not meet the EPA's definition of "lead-free" as "imminently hazardous consumer products" [30]. It banned their manufacture for, and sale in, interstate commerce and required their manufacturers and importers to repair, replace, or recall them. The LCCA also mandated that the EPA issue guidance instructing all schools on how to identify and remediate lead-contaminated drinking water. It required states to disseminate this guidance and develop programs that would help school officials implement testing and remediation procedures and inform parents, teachers, and other employees about test results [31]. The LCCA did not make testing or remediation in schools mandatory.

In January 1989, the EPA issued the first federal guidance on assessing and remediating lead in school drinking water. With this guidance, the agency announced a new lead-in-water standard for schools and urged the immediate disuse and remediation of taps that did not meet it. "In light of recent studies which reveal that even low levels of lead in drinking water can have subtle adverse effects on children," stated the guidance, "EPA recommends that action be taken to limit exposure or reduce lead in water whenever lead levels exceed 20 ppb" [32]. This standard, applied to a 250 milliliter (mL) sample taken immediately after overnight stagnation and prior to any flushing, was based neither on health risk nor on expected health outcomes. It was merely a trigger for remedial action. The sampling protocol prescribed was designed to identify water outlets dispensing high lead and pinpoint the sources of any contamination.

The passage of the LCCA, together with the dissemination of the EPA's guidance, prompted many schools to test for lead in drinking water. However, an EPA audit in 1990 revealed that state adoption and enforcement of the regulation was often weak and even nonexistent [33]. Many schools had not repaired or removed lead-tainted coolers, used sampling protocols other than the one recommended by the EPA, carried out very limited or inappropriate sampling, or failed to conduct water testing at all. This overall anemic response to the LCCA on the state level mirrored the EPA's own stance toward the new provision. In 1990, upon receipt of an EPA questionnaire about how states were addressing the LCCA, one state official characteristically wrote:

> Quite frankly, I'm disappointed at EPA's inconsistency and lack of leadership or direction with regard to this Act. On June 15, 1989, I received from EPA a letter which states "EPA has no official expectations of States in implementing the LCCA." If the Agency has "no expectations," then what is the purpose of the questionnaire?. . . Why must the state be placed in a position of defending our lack of attention to a non-funded federal program with no official expectations? [34]

The EPA auditors reported that harmful concentrations of lead continued to flow out of school water outlets, and that both the EPA and the states needed to be more aggressive in protecting children from unnecessary exposure to lead at the tap [35].

Six years later, a court ruling in the case of ACORN v. Edwards, 81 F.3d 1387 (5th Cir. 1996) held that provisions in the section of the LCCA compelling states to enact and enforce a federal regulatory program without having the option to decline were unconstitutional. This decision did not prohibit states from developing lead-in-water initiatives, but it also did not encourage a "more aggressive" approach to lead contamination at school taps. According to the GAO, state efforts in this regard were limited [36]. Moreover, they were never funded.

The EPA's most recent revision of its guidance to schools was published in 2006. Titled "3Ts for Reducing Lead in Drinking Water in Schools," it is based on the principle that controlling lead in school drinking water requires: a) proper "training" of school officials on the nature of lead at the tap, appropriate testing methods, and health risks of exposure; b) proper "testing" of drinking water; and c) proper "telling" to school communities about sampling programs, test results, remedial actions, and potential health effects. The comprehensive, if not daunting, 100-page document opens with a prominently featured disclaimer: “This manual contains recommendations on how to address lead in school drinking water systems; these are suggestions only and are not requirements” [37].

### The Lead and Copper Rule (LCR) of 1991

With the goal of reducing exposures to lead-tainted drinking water nationwide, in 1991 the EPA promulgated the first federal law regulating lead at the tap in communities served by public water systems through corrosion control and routine water monitoring. The LCR replaced the 1962 PHS lead-in-water standard of 50 ppb at the distribution system entry point with an at-the-tap maximum contaminant level *goal* (MCLG) of zero. As a MCLG, this standard was not enforceable, but represented the optimal lead-in-water level below which there was “no known or expected risk to health” [38]. The LCR also introduced a “lead action level” of 15 ppb in a 1-liter (L) sample for the purpose of assessing corrosion control on a community-wide scale (the LCCA guideline of 20 ppb in a 250 mL sample corresponds to approximately 12 ppb in a 1-L sample) [39]. Similarly to the school water standard, the LCR’s lead action level was not health-based. It was derived from an estimation of lead concentrations considered at the time economically and technologically feasible to assess.

Under the LCR, every public water system was required to evaluate regularly the presence and severity of lead contamination in the communities it served by identifying worst-case lead-in-water levels at drinking water taps in high-risk homes (e.g., with lead service lines or lead solder). If more than 10 percent of samples exceeded 15 ppb, public water systems were to intensify water quality monitoring, optimize corrosion control, issue public notification and education materials, and in some cases monitor and replace lead service lines [40]. Schools regulated as public water systems were also required to comply with the LCR.

Since 1991, significant progress has been made in monitoring lead-in-water levels in cities and towns across the country and at 8 to 11 percent of U.S. schools. The LCR, however, allows up to 10 percent of sampled taps to dispense any amount of lead without triggering remediation and public notification requirements. This means, that unless the contamination in a community or school is extensive, it can legally be left unaddressed.

In May 2004, former U.S. Senators Jim Jeffords (I-VT) and Paul Sarbanes (D-MD) as well as U.S. Delegate Eleanor Holmes Norton (D-D.C.) and U.S. Representative Henry Waxman (D-CA) introduced the “Lead-Free Drinking Water Act of 2004” [41, 42]. As a proposed amendment to the SDWA, this bill directed the EPA to promulgate regulations requiring every state to develop a program under which schools licensed by the state would conduct annual testing for lead in drinking water and remediate identified problems. The bill authorized the EPA to provide funding to each state in order to assist schools with the costs of the program. The bill did not succeed. It was reintroduced in 2005 and again in 2007, but it never became law [43-45].

## WHY LEAD IN SCHOOL DRINKING WATER IS A HEALTH CONCERN

Lead is widely recognized as one of the most pervasive and serious environmental health threats in the United States, especially for children. In the last few decades, dramatic progress has been made to reduce lead exposure from gasoline, paint, dust, food/drink cans and drinking water [46-48]. Despite these improvements, however, clinical evidence has recently demonstrated adverse health impacts at blood lead levels (BLLs) below the 10 micrograms per deciliter (ug/dL) Centers for Disease Control and Prevention (CDC) "level of concern" [49-52]. Decreased IQ and cognition have been linked to BLLs as low as 3 ug/dL, reinforcing the notion that there is no safe level of lead exposure [53-56]. BLLs above 10 ug/dL are termed "elevated blood lead levels" (EBLLs) or "lead poisoning" in some jurisdictions, and the federal government has had a national health objective of eliminating EBLLs in children by 2010 (possibly now to be extended to 2020) [57]. There is near universal acknowledgment from public health experts that this goal will not be met for many more years.

The harmful health effects from lead exposure through drinking water have been formally recognized since the 1850s when they were linked to high infant mortality, spontaneous abortion, neurological diseases, and digestive problems. Historian Werner Troesken suggested that use of lead pipes in major cities produced one of the most serious environmental health disasters in U.S. history [58]. Millions of lead pipes are still present in service lines in front of buildings throughout the U.S., and lead-bearing plumbing materials can still cause very serious lead contamination of water (above 100 ppb lead), even in new construction [59]. Although health effects and exposure pathways vary dramatically from person to person, in part due to differences in individual water and food consumption patterns, lifestyles, and genetic risk factors [60, 61], lead exposure from drinking water is currently believed to account for only 10-20 percent of total lead exposure on average in the general population, and for 40-60 percent of total lead exposure on average in infants dependent on reconstituted formula [62].

Our recent research has demonstrated that the potential contribution of lead in water to blood lead of children may have been underestimated. First, we discovered that the standard EPA methods used to assess the concentration of lead in drinking water can sometimes "miss" up to 99 percent of the lead that is actually present [63, 64]. Second, we demonstrated that in several recent cases of childhood lead poisoning from water, the affected children were not directly drinking the contaminated water. Rather, they were exposed from pasta and other food that had been cooked in that water [65, 66]. Prior research did not consider the likelihood that lead in water could concentrate in food, or that food preparation could serve as a major pathway of lead exposure due to the large volume of water used for cooking [67, 68]. Finally, we determined that from 2000-2007 in Washington D.C. the incidence of blood lead poisoning for children less than 1.3 years of age was directly correlated to the levels of lead in their drinking water [69].

Children in many major cities are routinely screened for EBLLs typically around age 1 and 2 years, if at all. In two recent cases of severe lead poisoning in school-age children through accidental ingestion of lead-containing particles in jewelry, the affected children were initially misdiagnosed at the emergency room with symptoms of a viral infection and sent home [70, 71]. In one case, medical personnel finally noted via x-ray that lead was present in the child's stomach, but by that point the child went into respiratory arrest and died [72]. As a result of this incident, and because health problems resulting from consumption of lead in children's playthings often go undetected, decisive action was taken to protect school-age children nationally from acute lead hazards (i.e., lead concentrations that if ingested even once can cause sudden and severe elevations in a child's BLL). In 2004, the U.S. Consumer Product Safety Commission (CPSC) recalled more than 150 million children's jewelry pieces, and the following year, after announcing that it was "aware of several cases in which children developed high blood lead levels after swallowing or repeatedly sucking on jewelry items," it established 175 micrograms (ug) of lead as a dose triggering acute health concerns [73]. This lead dose (175 ug is equivalent to 700 ppb in a 250 mL glass of water) was exceeded in drinking water samples collected at 10.3 percent of schools in Washington D.C. based on sampling conducted in 2007, even after 45 minutes of remedial flushing the night before.

If we, as a society, are concerned about a potential dose of 175 ug lead from products such as toys and trinkets that are not intended for human consumption, we most certainly should be concerned about a similar dose of lead in drinking water. No prior studies of lead-in-school-water hazards have explicitly considered acute health risks from ingestion of single glasses of water with worst-case levels of lead. Preliminary bio-kinetic modeling predicts that if a child consumed a single 250 mL drink of water at the higher lead doses measured in schools (i.e., around 20,000 ppb lead), the child's blood lead would spike from 0 to over 50 ug/dL [74]. Levels of lead in the child's blood would remain over the 10 ug/dL CDC level of concern for a period of weeks from a single exposure [75]. This acute elevation in BLLs can cause a variety of immediate common maladies, including abdominal discomfort, nausea, headaches, and gastrointestinal upset.

Supporting our concern about the serious health risk posed by lead-contaminated water in schools, we uncovered a case of high BLLs in a Washington D.C. child attending an elementary school with lead-in-water problems during the city's historic 2001-2004 lead-in-water crisis. The highest lead-in-water measurement at this child's school was 7,300 ppb lead (i.e., 365 times the EPA lead standard for school taps). No other lead hazard was found in the child's home environment. We suspect that this case represents the tip of an iceberg of lead exposure risk. The vast majority of environmental risk assessments in Washington D.C. and nationally, whether conducted in 2001-2004 or at other times, do not include school water testing for lead, even when no lead hazards are identified in the home. Yet the intermittent water consumption in schools—with periods of little or no water use on weekends, holidays and over summer break—regularly produces very long stagnation periods of water inside the piping. This water use pattern is considered "worst case" for causing release of hazardous levels of lead from the plumbing and contamination of the water supply [76-78]. School children, especially those attending elementary school or daycare centers, are much more vulnerable to adverse health effects from lead exposure than adults [79]. The combination of "worst-case" levels of lead in water and the presence of a vulnerable age group, makes this issue of vital public health concern.

## SOURCES OF LEAD IN SCHOOL WATER AND THE CHALLENGE OF ASSESSING CONTAMINATION

School buildings have intricate plumbing systems, sometimes very old, containing multiple potential sources of water lead contamination. These include lead pipe, galvanized iron pipe, lead-containing solder joints, and system components made of lead-containing brass. In order to assess the public health risk from elevated lead in school drinking water, it is obviously necessary to first determine the extent and severity of any contamination. This task can be challenging for several reasons. First, many schools and school districts are unaware that identifying and remediating lead in drinking water is solely their responsibility. Second, some schools and public water utilities sample school taps in a manner that hides lead problems. Third, even well-intentioned sampling efforts using standard protocols can inadvertently miss lead hazards. This is because of failure to capture lead particles in samples, inadequate detection of lead particles when captured, and inherent variability in lead release from sample to sample.

It has only recently been recognized that particulate lead can be the dominant form of lead in drinking water [80], and it is believed that these particles are responsible for much of the lead in samples testing above 100 ppb lead in schools. Our own studies demonstrate that following the standard EPA protocol can miss much of the particulate lead present in the water for the following reasons:

- Under some circumstances, the likelihood that lead particles will be released into the water increases with flow rate. Yet the EPA's school sampling instructions, which correctly promote replicating "typical water use patterns," recommend that bottles be filled with a "small," "pencil-sized" flow from the outlet [81]. This type of sampling procedure can artificially prevent the normally occurring release of lead particles and does not provide reliable information about lead levels in water consumed by children who use moderate or high flow rates to fill water bottles from cafeteria, bathroom, and other school sinks.

- Particulate lead can settle or adhere to the plastic sampling containers, remaining undissolved even after acidification to pH < 2, as specified in the EPA standard procedures. This lead can be left behind in the bottle when the water is introduced to the analytical detector [82, 83]. As a result, the lead associated with lead particles can be "missed." For example, a Washington D.C. water sample actually containing 508 ppb lead, only measured as 102 ppb using the standard EPA analytical protocol [84]. More recently, another sample, which actually contained more than 1,500 ppb lead, only measured as 3 ppb using procedures that are listed as acceptable by the EPA. This latter sample would have provided false assurance that the water was "safe" based on EPA guidelines, when it was not. The presence of the higher concentrations of lead was only revealed after stronger acid and heating steps were added to the protocol.
- Unlike with soluble lead in water, the mobilization of particulate lead from plumbing occurs sporadically. This means that repeated testing of some taps can produce multiple samples with low lead levels and a few samples with excessively high lead levels due to the release of lead particles. Current guidance, however, will "clear" a school tap as safe based on collection of a single sample below 20 ppb in a 250 mL sample, even if this tap periodically dispenses high levels of lead in particulate form.

As a result, even schools that strictly follow the EPA's lead-in-water testing guidance are potentially missing significant lead hazards present in the water children routinely drink.

We have also demonstrated that in the more aggressive environment inside the human stomach (pH as low as 1.0, warm temperature, hydrochloric acid instead of nitric acid, mild agitation via churning) a large fraction of lead particles from brass, solder, lead pipe, and lead rust can dissolve and become bioavailable. Hence, lead in water that is "missed" by standard lab testing procedures can be absorbed once ingested [85, 86]. Our recent research on cases of childhood lead poisoning in Greenville NC [87, 88], Washington D.C. [89, 90], and Durham NC [91], demonstrated that a key source of lead exposure was lead solder particles of about 1 to 100 micrometer diameter. It is our belief that the "worst case" lead levels detected in school water are often due to particulate lead, and that the reported lead concentrations in school samples are often lower than those to which children are actually exposed.

## CASE STUDIES

The passage of the LCCA in 1988 heightened public awareness about potential health risks from lead-tainted water coolers and prompted many schools to test their drinking water for lead. Since then, numerous stories have appeared in the news media about problems with elevated lead in U.S. school drinking water. Although the EPA has generally taken a back seat on the issue, two regional offices have assumed a more active role in helping schools protect children from hazardous levels of lead at school taps [92]. EPA Region I helped the Massachusetts Department of Environmental Protection communicate with all schools in the state about lead in drinking water and supported efforts by Boston Public Schools to ensure that the water used to prepare school meals was not contaminated with lead. Similarly, EPA Region II developed a program that funds and provides technical support for lead-in-water sampling to schools in New York State and New Jersey. Early exemplary work was also done by EPA Region III, which aggressively pursued lead in water problems at Philadelphia public schools [93].

Unfortunately, case studies across the country illustrate that most school communities remain unsupported in addressing lead-at-the-tap contamination problems. The burden for complying with EPA guidance too frequently falls on concerned parents, teachers, and individuals outside the school community who sacrifice their personal time and resources to push school districts toward implementation of proactive testing and remediation programs. In case after case this burden is shouldered only after a prolonged exposure of children to high levels of lead in water, delayed parental notification, and questionable remedial measures that can be expected to continue in the absence of a protective regulatory framework. Here are some examples.

### LAUSD

LAUSD first learned about problems with lead in school water in 1988 [94]. It adopted flushing as a permanent solution and failed to ensure that it was implemented properly. It formally informed parents about the persistence of the contamination 20 years later, in response to pressure from a concerned parent and an undercover investigation, but it coupled the news with false claims that downplayed health risks. Currently it is controlling lead levels at approximately 9,000 taps via a single morning flush, which is not always carried out and despite evidence that this measure can be unsuccessful at keeping lead levels low for the duration of the school day [95].

### Washington D.C. Public Schools (DCPS)

DCPS was first made aware of lead-in-water problems in 1987. Initial tests showed some taps dispensing lead levels over 80 ppb. The school system declared that although this was "a matter of concern," it was "not a health hazard" [96]. Seven years later, following a new round of testing, a television news station exposed that the district had failed to shut off several problem fountains, including one that had measured 1,520 ppb lead [97]. Following the January 2004 *Washington Post* story informing residents that excessive levels of lead had been flowing out of the city's taps for 2½ years, school samples were collected after first running the water for 10 minutes. This flushing step is a well-known remedial measure used to reduce lead when there are known contamination problems. Outcry about the invalid and misleading methodology led to limited retesting, which revealed problems in 29 of 145 schools [98]. It was later discovered that, at the recommendation of the local water utility and EPA Region III, DCPS had conducted the second sampling round with the use of still another protocol that misses lead hazards. Water outlets were flushed for 10 minutes the night before sampling and aerators, which can trap lead particles and release them slowly into the water, were removed. Despite the faulty methodology, some taps tested as high as 7,300 ppb. DCPS testified under oath that every problem tap would be remediated, but when questioned years later school officials revealed that no corrective action had been taken.

In 2006, lead-in-water elevations revealed in a new sampling round were not shared with the public until we obtained the results through a Freedom of Information Act request and forwarded them to the D.C. City Council [99]. That testing round showed contamination in 12 of the 16 schools sampled. In one elementary school, 77 percent of the taps sampled measured above 20 ppb. Subsequent sampling at all schools in 2007 included 45-plus minutes of running the water the night before sampling. The instruction was recommended by the local water utility and agreed upon by EPA Region III, but when questioned by the press neither agency admitted responsibility for it [100]. Despite use of this unconventional protocol, results revealed contamination in 75 percent of schools. Fourteen schools had at least one tap dispensing water with lead levels above 700 ppb, the lead dose that CPSC classified as an acute health concern for toys, trinkets, and consumer products. The highest measurement was 20,000 ppb. To address the contamination, DCPS installed lead filters at all drinking water fountains. In 2009, the district began a new testing round using the same 45-plus minute flushing practice. Following complaints from the public, DCPS finally promised to abandon the flawed instruction. It also agreed to allow parallel sampling by a team of independent scientists and community members. Testing thus far has indicated that the filters are controlling lead-in-water levels effectively.

### Baltimore City Public Schools (BCPS)

BCPS first became aware of lead-in-water contamination in 1992. Problem fountains were shut off, but future school administrators who were unaware of the issue reactivated them. In 2003, an investigation by a concerned father revealed that many of the fountains that had tested high 11 years earlier were still in operation. "Parents need to be alerted to the fact that their children are being placed in danger," he warned [101]. School officials admitted that many of the water outlets that had been disconnected in 1992-1993, "were somehow reactivated" [102]. To address the problem, BCPS announced the temporary closing of all water fountains at all schools and began to distribute bottled water. In 2004, the district turned back on some fountains that tested below the EPA lead-in-water standard of 20 ppb and committed to flushing them daily. Three years later, however, sampling at ten randomly selected schools by the city's Health Department revealed that 10 of 84 fountains which had previously passed testing were again dispensing elevated levels of lead [103]. BCPS calculated that permanent use of bottled water would be cheaper than continued testing and ineffective remediation. "Since our goal is 100 percent confidence," said the city's Commissioner of Health in November 2007, "the best approach is to switch to bottled drinking water" [104]. In the past six years, the district has spent more than $2.5 million on bottled water [105].

## Seattle Public Schools (SPS)

SPS first became aware of lead-in-water elevations in 1990. Most problem fountains and faucets were replaced, but testing two years later revealed persistent contamination in more than 40 schools [106]. A 1993 report recommended routine flushing of taps, the replacement of lead-bearing fountains, new pipes in four schools, and periodic sampling. Some water fountains were replaced, but the district did not implement a consistent program to address the contamination [107]. It also failed to officially notify the school community.

In December 2003, two fathers of students at Wedgwood Elementary School obtained SPS's 1993 report and discovered that four fountains at Wedgwood had tested high for lead a decade earlier. Out of concern about the orange color of the school's drinking water, they took samples from the very same fountains. Results revealed elevated lead levels in all samples, with the highest measurement at 200 ppb. "I think most citizens operate under the delusion that the safety of their children is being scrutinized by regulatory agencies in the schools," said one of the fathers. "It's quite the contrary" [108]. The EPA and the city's Health Department both denied responsibility.

SPS responded to the revelations by authorizing district-wide sampling and the delivery of bottled water to all schools built before 1997. Testing began in April 2004. Results showed that more than 70 percent of SPS schools had at least one water fountain with excessive levels of lead. In one school, 22 of the 24 fountains tested high [109]. In another, the fountain in the kindergarten and first grade class measured 1,600 ppb lead. The average lead level for that school's 27 fountains was 175 ppb [110]. At 19 schools, over half of the fountains had lead problems [111]. Twenty-six schools had fountains dispensing contaminated water even after flushing [112].

Local authorities contended that the contamination did not pose significant health risks, and a toxicologist hired by SPS opined that everything could be toxic in high enough doses, including pure water itself. In response to official statements that were perceived as downplaying the dangers of lead-contaminated water, one of the two fathers leading the campaign for safe water organized a public health forum that featured a nationally renowned expert in childhood lead poisoning and a leading water quality researcher. The two speakers offered a more sobering view of the health effects of lead in water, which convinced some Seattle School Board members to support the creation of a district-wide policy requiring regular and aggressive testing and remediation [113, 114].

SPS addressed the contamination by repairing or replacing all problem fountains and conducting limited replacement of school plumbing. The school board adopted its first drinking water policy in December 2004, which lowered the allowable lead level for school taps to 10 ppb and established requirements for water quality testing, remediation, and public notification every three years [115].

## CONCLUSION

School case studies in Los Angeles, Washington D.C., Baltimore, and Seattle highlight the potential exposure of sensitive populations to very high lead doses through consumption of contaminated drinking water. Lead levels greater than the EPA guideline of 20 ppb were measured at as many as 92 percent of taps in some schools, and some drinking water outlets released concentrations of lead sufficient to classify the water as "hazardous waste." Controlling lead hazards from drinking water at schools requires improved sampling protocols that can capture the inherent variability of lead release from plumbing and that can quantify both the particulate and dissolved lead present in water. Depending on the type of lead-in-water problems encountered, practical and concise remediation guidance is needed for school communities. Most importantly, the potential public health implications need to be reevaluated. While the association between lead in water and lead in blood has been documented through decades of prior scientific research, the possible contribution of school drinking water lead to the body's total lead burden is not a current focus of public health agencies. Accounting for this misunderstood and largely overlooked exposure source is necessary in order to better understand and address childhood lead poisoning in the U.S.

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