COMMENTARY

Lead in School Drinking Water: Canada Can and Should Address This Important Ongoing Exposure Source

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ABSTRACT

Reducing all preventable lead exposures in children should be a public health priority given that blood lead levels in children that were once considered "safe" have since been associated with important neuro-developmental deficits. Limited Canadian data indicate that school drinking water can be an important component of children's overall exposure to lead. Outside of Ontario, however, Canadian schools are not required to test for lead in water; in most of Canada, school testing is case by case, typically initiated by parental concerns. Provinces and territories are encouraged to follow Ontario's example by instituting a routine school water lead testing program in order to identify facilities where action can result in a decrease in students' exposure to lead. Testing and remediation frameworks developed by the US Environmental Protection Agency, Health Canada, and the province of Ontario provide direction to school boards and local and provincial/territorial health authorities.

Key words: Lead; drinking water; schools

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The control of major historic sources of lead exposure, including leaded gasoline and residential paints, has lowered lead levels in children. US data indicate that the prevalence of blood lead levels (BLLs) ≥10 μg/dL among children 1-5 years of age decreased from 8.6% in 1998-1991 to 1.4% in 1999-2004,[1] while 2007-2009 Canadian data show that the geometric mean BLL of children aged 6-11 years was 0.90 μg/dL.[2] Still, BLLs <10 μg/dL have been linked to persistent deficits in intelligence as well as to neuropsychiatric disorders including antisocial behaviour.[3] A pooled analysis of seven prospective studies investigating the relationship between childhood lead exposure (from birth or infancy to 5-10 years of age) and full-scale IQ tests showed a log-normal dose-response relationship; a rise in BLLs from 20 to 30 μg/dL was associated with a drop in mean IQ of 1.1 points (95% CI, 0.7-1.5), a BLL rise from 10 to 20 μg/dL was associated with an IQ deficit of 1.9 points (95% CI, 1.2-2.6), and a BLL rise from 2.4 to 10 μg/dL was associated with the greatest deficit of 3.9 IQ points (95% CI, 2.4-5.3).[4] The observation of health impacts at lower levels of blood lead, and the demonstration that even small reductions in BLL can have important population-level health gains, stresses the need to address continuing residual exposure sources. It has been argued that the mitigation of ongoing lead sources is strongly cost-beneficial. In the US, researchers estimated that a mean decline of 15 μg/dL in children aged 1-5 years between 1976 to 1999 resulted in a gain of 2.2-4.7 IQ points per child; this gain was in turn estimated to result in economic benefits of $110-$319 billion, through increased productivity and higher lifetime earnings.[5] Although no cost-benefit analysis for drinking water could be identified, it is reasonable to assume that economic benefits would likewise accrue with the reduction of lead in school drinking water.

Children are exposed to lead through school drinking water

Elevated water lead levels exist in Canadian schools. Testing of Ontario schools in 2007 showed that 28% of 3,669 "first draw" 1L samples were above the Canadian drinking water guideline of 10 μg/L,[6] as were 9% of the 3,479 1L samples taken after 30 seconds of flushing.[7] School water systems can contain high lead levels for several reasons, the most common being leaching. Lead can enter treated water systems through leaching from plumbing, including tin-lead solder and brass fittings, within the municipal water distribution system or inside the school building.

Two factors, stagnation and outlet design, are especially important for school water systems. Stagnation plays a key role in lead leaching where lead plumbing, solder or fixtures exist. Water delivered after overnight stagnation and even after shorter periods of non-use, such as between morning and midday, can contain elevated lead levels through the progressive release of lead from plumbing.[8] The design of outlets in schools can further promote

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Table 1. Factors Associated With a High Degree of Lead Leaching Within a Plumbing System*

Factor	Comments
Long contact time	Drinking fountains and stand-alone water coolers are associated with intermittent use and longer stagnation periods.
Older plumbing systems	Older plumbing systems may have lead-based components.
Lead pipe length	Longer pipes increase contact time between water and plumbing and may increase leaching.
Smaller diameter pipes	Pipes of smaller diameter, such as those used in water fountains, increase contact time between water and plumbing.
Low pH	The pH is a measure of the hydrogen ions in water. Water with higher pH is associated with less leaching, especially if water is not well buffered. A higher pH can also increase the effectiveness of corrosion inhibitors.
Low alkalinity (as differentiated from pH)	Alkalinity is a measure of bicarbonate, carbonate or hydroxide compounds in water. Higher alkalinity will buffer the pH of water and help to form a protective scale lining along pipes.
Absence of corrosion inhibitors	Corrosion inhibitors, which are introduced to water systems at the municipal treatment level, form a protective scale lining along pipes.

* Assuming lead-containing plumbing is present.

leaching; drinking fountains typically contain more soldered joints and narrower piping than traditional taps, and if lead components are present, a high degree of leaching can occur. Beyond stagnation and outlet design, the roles of other factors in influencing lead concentrations in water are summarized in Table 1.

While food, consumer products and leaded dust are also important continuing sources of childhood lead exposure, drinking water intake constitutes approximately 10% of total lead exposure in 2-year-old children (11% in adults).[9] This estimate is based on a water lead concentration of 4.8 µg/L and a consumption rate of 0.6 L/day; the contribution of water to total lead exposure increases with more frequent consumption and where water contains higher lead levels. Although no data on water consumption patterns in Canadian schoolchildren could be identified, the 2004 Canadian Community Health Survey suggests that 70% of children consume water on a daily basis.[10] Considering that children can spend up to 8 hours a day at school, it is reasonable to assume that some of this water consumption occurs during the school day. Additionally, initiatives to restrict soft drink sales[11] and ban bottled water sales[12] in schools may increase the importance of school sinks, fountains and coolers as sources of hydration. Consequently, some children may be exposed to lead on a daily basis through their school's drinking water, and in areas where municipal lead service pipes are the cause, residential water levels may also be elevated, further contributing to children's exposure.

The Canadian response

Ontario is the only jurisdiction in Canada to establish a regulatory framework to assess lead levels in school drinking water. All Ontario schools must test their facility's water annually; if any sample exceeds an action level of 10 µg/L, schools are required to implement mitigation measures.[13] Recently, Ontario instituted a reduced testing frequency, based on risk level, thus allowing allocation of efforts towards "priority" schools. Changes to the testing requirements allow testing every three years for schools that show lead results below 10 µg/L for all samples over the previous 2 years.[14]

Outside of Ontario, testing for lead in school drinking water occurs case by case, typically initiated by parental concerns[15,16] or as part of testing of residences and institutions in neighbourhoods where lead is shown to be leaching from the distribution system.[17] Health Canada (HC) provides some guidance for lead testing in schools to specifically locate the source of lead in drinking water within a building and to identify how best to proceed with remedial actions. Their technical document outlines a screening phase, which requires testing of water from each outlet, and a program phase, which requires monitoring of "high priority" outlets, following development of a school-specific corrosion control program.[18] Health Canada's sampling plan is adapted from the US Environmental Protection Agency's (EPA) guidelines, which also include diagnostic sampling techniques to determine sources of lead contamination in samples taken from different locations in the school facility and a list of refrigerated water cooler models identified as containing lead-based plumbing.[19]

Although the resources described above are valuable in developing a school-based screening and monitoring program, each has important limitations. Ontario only requires samples to be collected from a single outlet within a facility. As lead levels can vary between outlets, samples taken from a single outlet may not be representative of the building's water supply. Several reasons exist for this variability, including differences in tap and fountain fittings and differences in frequency of outlet use throughout the facility. Additionally, testing of refrigerated water coolers is excluded; this is an important oversight as refrigerated units in schools can be an important source if leaded components are present. Both HC and EPA guidelines encourage thorough sampling of outlets within the facility. The EPA guidelines, in particular, describe in-depth diagnostic sampling to determine the source of contamination; such sampling programs can be time-consuming and expensive. Schools would benefit from further direction on how to identify "priority" outlets, as well as a simplified approach to sampling "priority" schools. Differences between sampling frameworks developed by Ontario Ministry of the Environment, Health Canada and EPA are summarized in Table 2.

In order for any lead monitoring program to be effective, the roles and responsibilities of provinces, municipalities and schools must be clear and practical. Programs should consider the resources involved in monitoring and mitigation; this is particularly important considering that school districts may have limited discretionary budgets. Testing needs to be prioritized to identify schools in which elevated lead levels may exist and in which risk is highest in order to ensure optimal use of resources. Testing programs should emphasize elementary schools (which in many cases house day-care centres or pre-kindergarten programs) as lead exposure is a greater concern among younger children,[20] although it is not clear at what age children no longer represent a susceptible population. Older schools, in which lead plumbing is more likely, and neighbourhoods known to have lead service pipes, as well as schools located in areas where previous residential sampling has found elevated levels or where municipal water is "soft" or of low pH, need to be tested. Following Ontario's example, testing frequency can be

Table 2. Differences Between Monitoring Frameworks for Lead Levels in School Drinking Water Developed by the Ontario Ministry of the Environment, the US Environmental Protection Agency (EPA), and Health Canada

Organization	Action Level(s)	Stagnation Period	Sample Volume	No. of Samples	Sampling Method
Ontario Ministry of the Environment[13]	10 μg/L	≥6 hours	1 L	Two	Samples collected from single outlet. A "first draw" sample is collected. A second flushed (30 seconds) sample is collected approximately 35 minutes after the first sample.
Health Canada[18]	1st: 20 μg/L 2nd: 10 μg/L	≥8 hours	250 mL	Screening phase: All outlets Program phase: High-priority outlets	"First draw" samples collected from all outlets. Follow-up sampling is conducted for outlets exceeding the first action level (AL). For follow-up sampling, outlets are flushed for only 30 seconds* prior to sample collection. Samples must not exceed the second AL.
EPA[19]	20 μg/L	≥8 hours	250 mL	All priority outlets (number not specified)	Initial sampling is conducted of all priority outlets. Follow-up sampling is conducted for outlets exceeding the AL. For follow-up sampling, outlets are flushed for 30 seconds prior to sample collection.

* The 1-minute flushing value found in the 2007 document should read 30 seconds flushing (Personal communication, France Lemieux, Water, Air and Climate Change Bureau, Health Canada, August 27, 2009).

Table 3. Summary of Different Approaches to Dealing With Drinking Water Found to Be Above the Sampling Strategy Action Level

Approach	Result	Comments
Replacing lead-containing plumbing with certified fittings*	↓ Lead levels & exposure	Represents the ideal approach to dealing with lead contamination, but due to high costs, is not typically implemented. Extensive flushing is required after partial replacement of lead pipes or service lines due to the release of lead particles.[21]
Altering water chemistry	↓ Lead levels & exposure	At the municipal treatment level, pH can be increased, alkalinity adjusted, and/or corrosion inhibitors can be added.
Regular flushing of plumbing system	↓ Exposure	Flushing should only be used for temporary mitigation; can be time consuming and is associated with use of large volumes of water. Flushing must be conducted systematically in the mornings and after weekends and holidays. Given the lack of experimental data, it is not clear how long flushing must occur for lead levels to be significantly reduced, as well as how factors such as plumbing characteristics, locations of lead contamination, and water chemistry influence required flushing times. Recommended flushing times are 1-5 minutes for individual fountains,[22-24] 10 minutes for entire systems within a building[23,24] and 15 minutes for refrigerated units.[24]
Use of only cold- water taps	↓ Exposure	Cold water is associated with less leaching than hot water.
Alternative drinking water sources	↓ Exposure	Alternatives may come with additional concerns, such as generation of plastic waste with bottled water.
Water filtration	↓ Lead levels & exposure	Point-of-use filters are installed at individual fountains. Filters should contain activated carbon to remove dissolved lead in water. Appropriate, certified filters must be used in order to effectively remove lead from water. Proper installation and filter maintenance is also required, including daily flushing to remove trapped bacteria.

* Health Canada recommends the use of NSF International (NSF)/American National Standards Institute (ANSI) health-based performance standard (NSF/ANSI Standard 61) certified fittings.

based on the level of risk, to avoid burdening local health units and school boards with lower-yield testing.

Mitigation

Several options are available to decrease lead exposures through drinking water (Table 3). Flushing is often considered an effective mitigation action, but it can be time consuming, wastes water and is not effective for all school water systems. Source removal through the replacement of lead plumbing components, although associated with higher initial costs, offers a long-term, permanent solution to elevated drinking water lead levels. The advantages and disadvantages of each action should be evaluated before implementation as no one method may be feasible or appropriate for every school.

Practical research is needed

The exploration and reporting of best practices on monitoring and remediation, including the establishment of criteria to prioritize areas in which high water lead levels are likely to exist, are needed to better guide school-based lead monitoring and remediation programs. Recommendations for remediation need to be evaluated, particularly for flushing; while flushing can decrease lead levels in water over the short term, the frequency and length of flushing required to maintain low lead levels in various school environments are not well understood. In order to better estimate current risks and the potential gains that mitigation could bring, the distribution of exposure to facility water by Canadian schoolchildren should be monitored prospectively. An assessment should be conducted to apportion the various sources (including school water) in contributing to blood lead levels for both younger and older children. Finally, the effectiveness of monitoring programs needs to be evaluated at the school and provincial levels; cost-benefit evaluations should consider the costs of remediation versus the direct and indirect cost of unmitigated lead exposure.

Where do we go from here?

School drinking water can be an important source of lead exposure to a susceptible population, but at present, outside of Ontario, no mandated monitoring framework exists.

Monitoring in Ontario has shown that schools with elevated water lead levels are not uncommon, supporting the argument that all provinces and territories should consider implementing policies to reduce children's lead exposure in schools.

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RÉSUMÉ

La réduction de toutes les expositions au plomb évitables chez les enfants doit être une priorité de santé publique. En effet, des plombémies chez l'enfant autrefois considérées comme sans danger ont depuis été associées à d'importants déficits neuro-développementaux. Des données canadiennes limitées indiquent que l'eau potable en milieu scolaire peut représenter une part importante de l'exposition globale des enfants au plomb. Toutefois, à l'exception de l'Ontario, les écoles canadiennes ne sont pas tenues d'analyser l'eau potable pour y déceler la présence de plomb. Dans la majeure partie du pays, l'eau en milieu scolaire est testée de manière ponctuelle, généralement à la suite d'inquiétudes exprimées par les parents. Les provinces et les territoires sont invités à suivre l'exemple de l'Ontario en instaurant un programme systématique de tests visant à déterminer la présence de plomb dans l'eau en milieu scolaire, afin de cibler les infrastructures où une intervention pourrait aboutir à la réduction de l'exposition des élèves au plomb. Les cadres relatifs aux tests et aux mesures d'atténuation mis au point par l'Agence de protection de l'environnement des États-Unis, par Santé Canada et par la province de l'Ontario peuvent guider les conseils scolaires et les autorités sanitaires provinciales et territoriales à cet égard.

Mots clés : plomb; eau potable; écoles