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TESTING FOR LEAD IN SCHOOL DRINKING WATER: A SUMMARY OF SAMPLING PROTOCOLS

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INTRODUCTION

Low level lead exposure has been linked to neurobehavioral and cognitive effects in children.[1] No "safe" level of lead exposure exists and efforts should be made to reduce exposures to as low as possible.[1] The phasing out of lead in gasoline, residential paints, and solder in food cans has substantially decreased blood lead levels among the general population, but residual sources still exist.[1] Exposures can occur through lead in dust, water, air, soil, food, and consumer products. The relative contribution of water to total exposures increases with increasing lead levels in water and with increasing consumption of water with elevated lead levels.[1]

Water leaving a treatment plant generally has low lead concentrations, but lead can enter drinking water through leaching from lead service lines and lead-containing building plumbing components, such as fittings, solder, and galvanized pipes. The degree of leaching is influenced by water chemistry, smoothness of flow, and water use patterns. Characteristics such as pH, alkalinity, the presence/absence of corrosion inhibitors, stagnation time, and water temperature all influence the corrosiveness of water. Stagnant water will generally have higher water lead levels since the longer water is in contact with lead-containing components, the greater potential there is for leaching. In schools, intermittent water use throughout the day promotes stagnation, lack of laminar flow and leaching if lead-containing components are present.

Testing for lead in school water can help to ensure that lead levels are below an acceptable level, assess the potential for lead exposure, as well as identify the source(s) of contamination where elevated lead levels are found. The sampling protocol used to test for lead influences how results are interpreted. Understanding key aspects of sampling procedures can allow for more appropriate testing of lead in school water. Here we summarize four Canadian protocols for sampling lead in school water, including those from Ontario and Québec, which require annual testing of lead in school water, and two from Health Canada. Two guidance documents from the United States Environmental Protection Agency (EPA) and the California EPA are also discussed. This document is intended for public health practitioners and policy makers who are interested in understanding and potentially developing sampling protocols for lead in school drinking water.

SAMPLING PROTOCOLS

Sampling protocols outline key aspects important to assessing lead levels in school water. These aspects include: time of year and time of day (i.e. before, during, or after school) to sample, frequency of sampling, which outlets to sample, and the specific procedures used to collect samples. The objective of the sampling program will largely influence how sampling protocols are chosen or developed. Programs may be aimed at conducting initial screening to identify elevated levels, conducting routine sampling to ensure that levels are below an acceptable value, assessing the source of lead contamination where elevated levels have been found, or ensuring that mitigation actions have successfully lowered elevated lead levels. Regardless of the objective, some key considerations should be incorporated into any protocol:

- **Timing:** Sampling should be conducted during months when schools are in session, as well as during the school week versus on a weekend.
- **Location:** All outlets in a building that provide water intended for consumption or food preparation should be considered for testing, including those located in kitchens, staff rooms, and gymnasiums.
- **Efforts should be made to keep lead levels as low as possible,** even when they are below the Canadian maximum acceptable concentration (MAC) since there is evidence that low-level lead exposure can adversely affect health.
- **Sampling after changes to plumbing:** Sampling should always be conducted after renovations or repairs are made to a plumbing system. Any disruptions to the system can dislodge lead particles, increasing water lead levels in the short term.

In Canada, testing of lead in school drinking water generally occurs due to legislative requirements, as a voluntary measure, or for investigative purposes. No federal requirement exists for schools to test for lead in water, but Ontario, Quebec, and British Columbia require that testing be done in their respective provinces. In Ontario and Quebec, specific sampling protocols to be used in schools are provided.[2,3]

In BC, guidance has been developed to support testing, including recommendations on specific protocols to be used based on the objective(s) of sampling. This guidance references protocols from Ontario and Health Canada, and also from other jurisdictions, such as US and United Kingdom.[4] Health Canada provides guidance on two sampling protocols based on whether the objective of sampling is to assess "typical" exposures or to investigate potential sources of lead contamination within a building.[5,6] Outside of Canada, agencies also provide guidance for testing lead in school water. Similar to Canada, the US has no federal requirement to test for water lead levels in schools, unless schools own/operate their own public water supply in which case these schools would fall under the Lead and Copper Rule requirements.[7] Some state and local jurisdictions have developed their own requirements. The US EPA and California EPA both offer comprehensive guidance on how to test for lead in school water.[7,8]

Table 1 provides a summary of key aspects of protocols developed by Health Canada, Ontario Ministry of the Environment and Climate Change, Québec Ministère de l'Environnement et de la Lutte contre les changements climatiques , as well as the US (federal) and California EPAs.

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TABLE 1. SUMMARY OF SAMPLING PROTOCOLS FOR TESTING LEAD IN SCHOOL DRINKING WATER DEVELOPED IN CANADA AND THE US

Agency	Health Canada[5] (Lead in Drinking Water document)	Health Canada[6] (Guidance on Controlling Corrosion in Drinking Water Systems document)	Ontario Ministry of the Environment and Climate Change[2]	Québec Ministère de l'Environnement et de la Lutte contre les changements climatiques	US Environmental Protection Agency[7]	California Environmental Protection Agency[8]
Objective	To assess typical exposures	To investigate potential sources of contamination	To conduct routine required monitoring	To conduct routine required monitoring	To investigate potential sources of contamination	To conduct routine required monitoring
When?	In either June or October for schools, and between June and October for multi-dwelling and large buildings (i.e., when fully occupied and functional)	As needed to investigate exceedances and to determine if corrosion control is required	Between May 1 and October 31	Between July 1 and October 1	Not specified	During months when schools are in session
Which outlets?	All drinking water fountains and cold water taps where water is used for drinking or food preparation. Outlets that are used for consumption should be prioritized over infrequently used outlets	Drinking water fountains and outlets used for drinking and cooking should be prioritized	All drinking water fountains and outlets used for drinking or food preparation. Outlets in change rooms, bathrooms, and any outlets in classrooms that are not used for consumption can be excluded.	An outlet that has been confirmed or suspected to contain lead parts, including lead solder. The outlet should be accessible to consumers, frequently used, and should not be connected to a treatment device (e.g. point of use filter)	Any outlets used for drinking, including fountains, home economic room sinks, teachers' lounge sinks, nurse's office sinks, sinks in special education classrooms, and other sinks known to be used for consumption	Up to 5 of the busiest outlets in the school should be selected. Selection should be made after observing use of all outlets by students and staff during morning, break and lunch periods. Large industrial sinks providing water not intended for consumption can be excluded
How often?	At least once per year	At least once per year when corrosion control is implemented (i.e., to assess its effectiveness)	Annually, unless the facility is eligible for reduced sampling every 3 years[a]	Depends on the size of the water system supplying the facility. In general, schools should be tested no less than once every 5 years	Not specified	Not specified, but all schools should be tested at least once before November 1, 2019

[a] Schools are eligible for reduced sampling if they meet the following criteria: two of the most recent years of test results from both standing and flushed samples do not exceed the current Maximum Acceptable Concentration (MAC); all drinking water outlets have been sampled in the facility at least once since June 7, 2007; and a notice of reduced lead sampling has been submitted to the Ministry of the Environment and Climate Change.

SAMPLING PROCEDURES

Key components to consider include:

Type of sample: First draw samples can help to assess potential leaching within the outlet, while flushed samples can identify contamination further down the plumbing system. First draw samples collected after a period of stagnation (e.g. 6 hours, 8 hours, overnight) provide an idea of the highest water lead levels within the system and provide a good reference point when determining if mitigation measures have been successful.

Volume of water, flow rate, and temperature: A small volume (e.g. 125 mL) generally represents water collected from a smaller section of the plumbing system, such as at the outlet, while a larger volume (e.g. 1 L) represents water collected further down the plumbing system. Higher flow rates can result in higher lead levels as lead particles may be dislodged with fast flowing water. Colder water generally has lower lead levels than hot water.

Number of samples: Sampling procedures should aim to collect a representative number of samples. A single sample collected from a single outlet may not accurately reflect water lead levels within a building or for a specific fitting since lead levels can be highly variable. A plumbing profile of the building should be developed and regularly updated to identify all potential outlets for sampling. If all the outlets are not sampled, the highest use outlets should be prioritized.

Who conducts sampling: Samples should be collected by qualified individuals with an adequate understanding of where, when, and how to collect samples, as well as how to record, store, and transport samples.

Laboratory analysis: Samples should be sent to an accredited laboratory experienced in analyzing lead in water, and that provide information on the analytical method used and the detection and/or reporting limits of the method. It is important to contact a laboratory prior to sampling since laboratories will provide specific information on how to collect, record, store, and transport samples, as well as provide containers for sample collection. The sample preparation steps are essential to ensuring an accurate result reflecting the total lead concentration.

The specific procedures used to collect water samples will largely be influenced by the objective of a sampling program. Typically, programs aimed at identifying the source and extent of lead contamination within a facility will be more comprehensive in terms of the number of outlets sampled and the number and type of samples collected (e.g. first draw and flushed samples versus only one of these types), compared with programs aimed at assessing “typical” exposures. Table 2 outlines the sampling procedures, including recommendations/steps to follow for when to test and how much to draw, from the agencies referenced in Table 1.

TABLE 2. SAMPLING PROCEDURES OUTLINED IN SAMPLING PROTOCOLS DEVELOPED IN CANADA AND THE US TO ASSESS WATER LEAD LEVELS IN SCHOOLS

Health Canada[5] (Lead in Drinking Water document[a])	Health Canada[6] (Guidance on Controlling Corrosion in Drinking Water Systems document)	Ontario Ministry of the Environment and Climate Change[2]	Québec Ministère de l'Environnement et de la Lutte contre les changements climatiques[3]	US Environmental Protection Agency[7]	California Environmental Protection Agency[8]
Random Day Time (RDT) sampling. Collect two 125 mL samples per outlet. Samples should be collected randomly during the day without prior flushing: no stagnation period is prescribed, to better reflect consumer use. Water should flow at a medium or high flow rate and aerators should not be removed. The lead concentration at each outlet is determined by averaging the results of the two samples.	Two-tier sampling. Collect samples after plumbing has not been in use for a minimum of 8 hours, but not more than 24 hours. Do not remove aerator. Sampling is conducted in two steps (Tier 1 and Tier 2). Tier 1 sampling is to be conducted at all outlets selected for sampling. Tier 2 sampling is to be conducted only at outlets where elevated levels were found in Step 1. Tier 1 and 2 sampling can be conducted at the same time, with Tier 2 samples only being analyzed if exceedances are found for Tier 1 samples. **Tier 1 sampling:** 1. Collect a 250 mL first draw (i.e. no prior flushing) sample from each outlet. 2. Collect a 250 mL 5-minute flushed sample from an outlet closest to the service connection **Tier 2 sampling:** Collect a 250 mL 30-second flushed sample.	Develop an inventory of all outlets. Collect samples after plumbing has not been in use for a minimum of 6 hours. Do not remove aerator, and if applicable, do not remove point of use filter. Collect two 1 L samples per outlet. 1. Collect a first draw sample (i.e. no flushing prior to sample collection). Water should flow at a normal rate. 2. Flush the outlet for 5 minutes by turning on the cold water and letting it flow at full volume. Wait 30 minutes and collect a second 1 L sample; do not use the outlet during this 30-minute period.	Collect at minimum 1 sample per facility. The outlet should be flushed for 5 minutes prior to collecting a sample. For outlets with both hot and cold water values, the hot water should be run for 2 minutes, followed by the cold water for 3 minutes. Do not remove aerator prior to sampling.	Develop a plumbing profile for the facility (guidance provided). Collect samples before the facility opens and before any water is used. Water should ideally sit in pipes for 8 to 18 hours. Collect one 250 mL sample per outlet. Sampling is conducted in two steps (Step 1 and 2). Step 1 sampling is to be conducted at all outlets selected for sampling. Step 2 sampling is to be conducted only at outlets where elevated levels were found in Step 1. **Step 1:** Collect a first draw (i.e. no prior flushing) sample from each outlet. **Step 2:** 1. If applicable, remove aerator/screen and clean the debris. Collect a first draw sample. 2. If the outlet does not have an aerator or screen, flush the outlet for 30 seconds and collect a sample.	Collect samples on a Tuesday, Wednesday, Thursday or Friday morning, after plumbing has not been in use for a minimum of 6 hours. Do not remove any filters, aerators, or screens prior to sampling. Collect one 1 L sample per outlet. Initial sampling is required at all outlets selected for sampling. Repeat, second repeat, and corrective action sampling is required at all outlets where initial sample exceeds the action level. **Initial sampling:** Collect first draw samples from all selected outlets. **Repeat sampling:** Collect a 1 L sample, using procedures used for initial sampling, at all outlets where the initial sample exceeds the action level. Sampling should be conducted within 10 days of receiving results from initial sampling. **Second repeat sampling:** Collect a 1 L sample, using procedures used for initial sampling, at all outlets where the repeat sample exceeds the action level. Sampling should be conducted within 10 days of receiving results from repeat sampling. Corrective actions should be taken at outlets where the second repeat sample exceeds the action level. **Corrective action sampling:** Collect a 1 L sample, using procedures used for initial sampling, at all outlets where corrective actions were undertaken.

MITIGATION AND RECOMMENDED PRACTICES

Sampling programs should provide guidance on mitigation actions to be taken if elevated lead levels are found. Common mitigation actions that have been put in place in schools in response to elevated water lead levels include:

- removing the source of lead contamination by replacing lead-containing components and fittings with ones certified as meeting low-lead content requirements;
- altering water chemistry at the treatment plant level to reduce corrosiveness of water, and consequently, lead leaching, if water is found to be corrosive;
- installing filters certified for the removal of lead at outlets confirmed to have elevated lead levels;
- regular and frequent flushing of plumbing systems to remove stagnant water;
- using only cold water taps for drinking and food preparation, as there is generally more lead leaching from hot water taps;
- supplying/encouraging the use of alternative sources of water, such as bottled water.

These actions vary in cost, time investment, and effectiveness, and are associated with advantages and limitations. Unfortunately, no comprehensive cost-benefit analysis has been conducted to evaluate mitigation strategies to address elevated lead levels in schools or other buildings. In general, actions such as replacing leaded plumbing and altering water chemistry at the treatment plant are most effective at lowering exposures in the long term, but may have higher initial costs, compared with actions that rely on behavioral changes, such as daily flushing or use of alternative sources of water. However, flushing programs, which are routinely implemented in schools, can also be costly in the long term. Evidence suggests that lead levels can reach pre-flush levels within hours of flushing in schools and other buildings.[9,10] Consequently, flushing needs to be conducted consistently and frequently throughout the day to effectively reduce lead water levels, which can require substantial staff time, resources, and wastage of water. Additionally, supplying or encouraging use of bottled water can be costly and creates substantial plastic waste if implemented over the long term.

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SUMMARY

Low-level lead exposures are linked to cognitive and behavioral impacts in children. Reducing lead exposures from all potential sources, including school drinking water, is an important public health action to protect the health of children. The presence of lead service lines and lead-containing plumbing as well as water chemistry parameters influence water lead levels. In schools, intermittent water usage can promote stagnation which can result in greater leaching from lead-containing plumbing. The use of appropriate sampling protocols and procedures allows for accurate assessment of lead in drinking water. Here, we outlined key aspects of six available protocols to test for lead in school drinking water and some important considerations for sampling programs.

For more resources, please visit the National Collaborating Centre for Environment Health's topic page on lead in drinking water.

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