LEAD IN TAP WATER:
ASSESSING CONSUMER EXPOSURE AND IDENTIFYING CORRECTIVE ACTIONS

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Research conducted 2008 – 2012
WHY DID WE DO THIS RESEARCH?

The harmful health effects of lead have pushed regulatory agencies and health authorities to aggressively pursue lead reduction from environmental sources, including limiting the concentration of lead in tap water. Recent findings show that there is no safe level of exposure to lead, and that effects on IQ are measurable even at blood lead levels (BLLs) which were traditionally considered to be safe. As a result, regulations are becoming more stringent for tolerable BLL (reduced from 10 to 5 µg/dL) and for lead levels in drinking water (CDC 2012). In Canada, older municipalities face a legacy of lead service lines (LSLs). Over 60,000 households with LSLs are reported in large cities such as Montréal and Toronto. Water lead levels at the tap of these households are higher and often exceed regulated levels in drinking water. High lead levels are also found in large buildings, including schools, due to the presence of lead-bearing elements in plumbing and long periods of stagnation.

Full replacement of LSLs is considered the best option to eliminate lead at the source and prevent future events of lead release resulting from scale disruption. These replacements require substantial investments which could add up to billions of dollars in Canada. Because LSLs ownership is shared by both the homeowner and the municipality, most replacement efforts have resulted in partial lead service line replacements (PLSLR). Studies have shown that the connection of copper to lead pipe following a PLSLR can markedly increase lead levels at the tap.

Managing lead in tap water typically requires three steps:

1. Locate sites where lead is present and represents a significant source of exposure, especially for young children.
2. Evaluate whether immediate corrective actions are required, or prioritize future actions.
3. Select and implement appropriate corrective actions.

This research investigated the most effective method of managing lead in tap water, by:

→ Evaluating existing and new lead sampling protocols to determine the best approach for lead source detection, compliance monitoring or exposure estimation.
→ Evaluating whether water lead levels in households and schools represent a risk for elevated lead levels in Canadian children, including an investigation of both dissolved and particulate forms of lead.
→ Investigating the efficacy of corrosion control options, LSL replacement (full or partial), and point-of-use filtration as corrective actions in households and schools.
→ Investigating lead release from partial lead service line replacements (PLSLR).
WHAT DID WE DO?

DETERMINATION OF WATER LEAD LEVELS IN TARGET SITES OF EXPOSURE

Water lead levels were measured using nine different sampling protocols in 1240 residences with LSLs and at 521 taps in large buildings, including schools. Pilot- and bench-scale tests were also carried out with five different water chemistries to investigate the impact of potential interfering factors, such as iron pipes, coagulants, and chlorine on lead release in tap water. Finally, data mining was completed on more than 87,000 water lead samples to complete the analysis and draw further conclusions.

DETERMINATION OF THE HEALTH RISK

An epidemiological study was conducted in 306 households with or without an LSL in a distribution system. The BLL of children from one to five years old was measured, as were the lead levels from sources of exposure in the house (e.g. water, dust, paint). An analysis was carried out to estimate the contribution of each lead source to BLLs in children. In parallel, an in vitro assay was developed and applied to 65 samples to simulate the gastric digestion of lead particles from tap water. The impact of the water lead levels measured at households and schools on BLLs in children was evaluated using the Integrated Exposure Uptake and Biokinetic (IEUBK) model developed by the US Environmental Protection Agency.

EVALUATION OF REMEDIATION METHODS

The benefits of corrosion control options for lead reduction were measured at bench, pilot and/or full-scale, with five different water chemistries, over one to three years. Corrosion control options studied included orthophosphates (orthoP) or silicates dosing, pH adjustment, and adjustment of the chloride to sulphate mass ratio (CSMR). Interfering parameters such as chlorine, temperature, iron, and bacteria were investigated.

Of special focus was the study of the long-term lead release from PLSLRs. Corrosion control options tested at pilot-scale on field-collected LSL were also investigated after a PLSLR. Impact factors such as iron, chlorine, orthoP increase, and hydraulic regime were studied over three years with regular monitoring providing long-term information. PLSLRs are currently being investigated at full-scale and compared to pilot-scale results. For that purpose, specific sampling protocols were developed and applied in three distribution systems in three provinces. Monitoring was performed in 236 households with full or partial LSL. In 60 of these households, samplings were repeated over 6 to 20 months before and/or after PLSLR. Also, for one distribution system studied, innovative monitoring of particulate lead release using point-of-entry filtration was initiated. Finally, lead and copper-lead pipes are currently being analyzed (fall 2014/winter 2015) at full and pilot-scale to link the water lead levels released from the pipes to the scales formed into it.

Partial Lead Service Line Replacement
WHAT DID WE FIND?

WATER LEAD LEVELS AT TARGET SITES OF EXPOSURE

Within the same distribution system, water lead levels in households with an LSL vary with the piping characteristics (length and diameter), the season, the concentration of iron in water, a coagulant or disinfectant change (iron and aluminum release, chlorine, chloride-to-sulphate mass ratio (CSMR)), and the type of residence. Overall, lead concentrations are higher in summer and in single-family homes, and increase in the presence of iron in the distribution system. Lead particles originating mostly from solders and brass fixtures in the plumbing are detected in the first litres collected after stagnation. Prior extensive flushing eliminates most of these particles. Samples collected after stagnation can serve to detect a LSL, provided that an accurate estimation of the piping volume is performed and that the residence is a single-family detached home to control for stagnation. In one of the distribution systems studied the presence of an LSL is highly probable when water lead levels exceed 3 µg/L after 5 minutes of flushing in summer.

High water lead levels in large buildings are explained by the stagnation time, the water chemistry, and the presence of lead-bearing elements. The extreme water lead levels measured in some large buildings are caused by the release of lead particles from the piping. Flushing reduces water lead levels in large buildings and households with a LSL. However, these levels increase rapidly (within 30 min) after flushing, and increase markedly with hydraulic disturbances such as a high flow rate, or opening the tap abruptly.

DETERMINATION OF THE HEALTH RISK

The BLL of young Canadian children is generally low, and varies seasonally. However, tap water is a significant contributor, and for single-family homes with long LSL (20-40 m), BLLs of children may exceed the recently revised Center for Disease Control (CDC) threshold of 5 µg/dL.

Extreme lead levels and lead particles were measured at the tap of large buildings with aggressive water or problematic plumbing. Because lead particles are absorbed through the blood system, children exposed to water in these buildings could experience BLLs largely over the threshold.

EVALUATION OF REMEDIATION METHODS

Optimal corrosion treatment varies with water quality, especially alkalinity, pH, iron and aluminum content. OrthoP dosing was effective in reducing water lead levels in problematic large buildings and in households with full LSLs. Adjustment of pH and CSMR was less efficient in reducing lead levels resulting from full LSLs. Increasing orthoP or chlorine dosing reduced lead release. OrthoP and silicates dosing performance for total and soluble lead reduction varied with water quality, especially alkalinity.

Adverse effects of PLSLR on water lead levels were measured at pilot-scale without corrosion control, and after orthoP dosing and with pH adjustment. The worst-case scenario was observed with orthoP dosing, even when increased dosages are tested (0.5-2 mg/L as PO4). In the presence of a PLSLR, lead release increased with iron in water, and more lead particles were generated compared to full LSL configurations. It was also demonstrated that specific scales develop at the lead-copper junction of a PLSLR.

One of the most important findings of this study is the general observation that adverse effects of PLSLRs are less pronounced in the full-scale systems studied than would be predicted by the numerous and extensive pilot-scale investigations. In general, lead levels are reduced by PLSLRs; however this improvement does not occur immediately and is more evident six months after the PLSLR work is completed. More importantly, in the absence of corrosion control, water lead levels still remain high...
and close to regulated levels. We now believe that the adverse effects observed at pilot-scale can occur at full-scale, but at a lesser degree and not systematically. Full-scale monitoring will end in May 2015, and final conclusions and recommendations will be issued specifically on PLSLRs. Considering the limited reduction of water lead concentrations observed in full-scale systems, the potential adverse effects observed at pilot-scale, and stringent water standards, PLSLRs do not appear to be cost-effective and should be avoided.

Carbon block point-of-use devices (NSF/ANSI 53 certified for lead removal) are efficient in removing dissolved and particulate lead from tap water in single family homes and large buildings, and the anticipated degradation of the microbiological quality of tap water is not observed for the models tested.

WHAT DO THESE FINDINGS MEAN FOR MUNICIPALITIES AND REGULATORS?

Public health advisories should be mailed to households with an LSL before the critical period of summer, especially in single-family detached homes.

Investigation should be carried out in schools and daycares in order to detect problematic sites and/or taps, and to implement corrective actions.

When changes are made to water treatment processes and associated chemistry (coagulant, disinfectant, etc.), care should be taken to fully evaluate potential adverse effects of these modifications on lead release in the system.

Corrosion control and especially orthoP dosing efficiently reduces lead release from LSLs and the plumbing in large buildings. However, orthoP treatment has its limitations, especially when PLSLRs are in place. OrthoP treatment will not prevent galvanic corrosion and is not the optimal solution for utilities with a large number of PLSLRs in place.

Industry-certified point-of-use filtration is an efficient temporary measure to reduce water lead levels. The microbiological quality of the filtered water does not change, provided that adequate maintenance is performed.

Sampling after stagnation is not a protocol capable of LSL detection except in single-family detached homes. However, it does provide important information on the consumers’ exposure. Sampling after flushing can detect the presence of an LSL with reliability, provided that investigation has already been made on the lead levels in residences with an LSL in that utility.

Single-family homes should be prioritized for full LSL replacements, considering the higher frequency of high lead levels in the tap water of these houses.

PLSLR should be avoided, considering:

1. the potential adverse effect of PLSLRs observed at pilot-scale in presence or absence of corrosion control
2. the modest reduction of lead levels after PLSLR observed to date at full-scale, and
3. the more stringent water quality regulations.

Incentives supported by utilities and regulators should be put in place to actively promote and facilitate full LSL replacements. These incentives should include proven measures, such as:

- replacement of the homeowner section of an LSL through direct, partial or total funding
- deferred reimbursement through taxation
- extending homeowner access to hire the utility’s contractor
- registration of LSL on property records
“The City of Toronto embarked on a very aggressive program to remove all the lead pipes within its system. We estimated replacing 65,000 lead service connections in a 9 year period at a cost of $250 million dollars. Dr. Prévost’s work...really forced us to revisit the entire program.”

- Michael D’Andrea, Executive Director, Engineering and Construction Services, City of Toronto

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