LEAD

Exposure Among Urban & Arctic Indigenous Populations, High-Risk Groups, Partial Lead Service Line Replacement & Other Remediation Protocols.

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Lead exposure of Canadians living in urban environments & Indigenous communities in the Canadian Arctic or sub-arctic.

The following provides a comparative analysis of predominate lead sources believed linked to lead exposure among Canada's urban and Indigenous Artic populations. As illustrated in research, geography, socio-cultural practices, socio-economics, and other demographic conditions play a determining role into the types of exposures different populations experience. Data also recognizes sub-population vulnerability, such as age, with lead exposure and risks (1).

The modality for predominate lead exposure varies according to geographical locations, with exposures being vastly different between Canada's Artic and urban populations. Although blood lead levels for both unban residents and Indigenous Artic communities are largely below US guideline levels set at 1-1.2µmol L^{-1} (1) for adults, exceptions exist. For developing fetuses and children it is argued that no safe blood lead levels (BLL) exists despite Health Canada safety guidelines set at 0.48 µmol L^{-1} for children (2,3).

For Indigenous Artic populations, socio-cultural practice linked to traditional food consumption is correlated with increased BLL (1). Lead in the tissue of traditional meats and fish (2) is passed through the food chain, adding to individual total lead body burdens (1,2). Contamination of waterfowl hunted with lead pellets is thought to be the primary contributor of BLL among Artic communities (1,4). In a report by Scheuhammer, 10% of birds hunted with lead bullets had breast meat lead levels exceeding 0.5µmol L^{-1}(5). Additionally, ingestion of lead pellets by grazing waterfowl is associated with elevated lead levels in bird tissue (6). The collective impacts are concerning given that 18% of Indigenous persons tested in Northern Ontario had BLL ≥100µg/L (7). Studies by Hanning et al., found that 5% of Artic adults exceed recommended lead concentration levels (2), while Dewailly et al., reported that Indigenous infants are disproportionately at greater risk for high blood cord lead levels (1). According to Hanning et al., Indigenous BLL were found to be as high as urban Ontario communities suffering from common forms of lead contamination such as lead base paint and water contamination (2).

Exposure for urban dwellers is predominantly linked to dust-borne lead from residential lead paint (1,8), direct contact with and/or dust associated with contaminated soil (9,10) and lead service lines in older communities (1,8-10). As reported by Lavallois (11), 306 older homes thought likely to be serviced by lead lines and/or with lead based paint were tested for lead contamination in both tap water and household dust. Results indicated that 1.6% of homes had lead water levels beyond the recommended limit of 10µg/L while 3.9% of homes exceeded floor or windowsill dust limits of 40µg/ft^2 and 250 µg/ft^2 respectively (12). In this same study, tap lead concentrations had an arithmetic mean of 1.6 µg/L while the geometric mean for floor and windowsill dust was 0.85 µg/ft^2 and 7.14 µg/ft^2 respectively (11). Despite these low levels of lead exposure, contaminated water and lead paint were found to produce detectable BLL in children aged 1-5, with contaminated water having the greatest impact on these levels (11). Soil in urban centers is increasingly recognized as a significant source of lead contamination with researchers noting a correlation between lead soil concentrations and BLL (9,13,14). Lead in soil is often high near building foundations contaminated by lead paint and former use of leaded fuels. It is readily tracked into homes, adding to lead dust levels (15,16).

Lead contamination of the traditional Indigenous food chain along with hunting practices appears significant in contributing to human BLL for Northern Artic communities (2,17). Additionally, persons residing in older urban communities who are subject to contaminated water, leaching of lead paint in the home, and contaminated soil are also at greater risk for elevated BLL. The cumulative effect of this persistent toxin merits consideration in relation to its body burden over time, particularly for children. 626

<u>At risk subpopulations for environmental lead exposure.</u>

Urban and Indigenous Artic populations are subject to increased risk for lead exposure. Within these populations, subpopulations exist that are more vulnerable to exposure, leaving them increasingly prone to health-related effects. Disproportionately, the impoverished, developing fetuses and younger children are most likely to suffer side effects linked to exposure (2,18). Arguably then, children in poverty are at heightened risk (15,18). Other sub-populations at increased risk include (Indigenous) men (1,19), smokers (1,17), older persons--due to the total body burden of leads long half-life (1), and persons subject to acute or on-going exposure (20). For this report I will focus on pregnant mothers, children, and impoverished populations.

Lead is considered the number one environmental health threat to children (17). Physiological and behavioral consequences associated with exposure in children under the age of 6 is particularly pronounced (21), with those under the age of three being most impacted (15). Child sensitivity is linked to the increased ease in which lead is absorbed in younger children and associated with relative lead concentrations per body mass (15).

Small concentrations of BLL and cord lead levels have been linked to numerous detrimental and irreversible health effects in young children. Severe risks involving neuro, immune and cardiovascular systems, kidneys, and liver are associated with low levels of exposure in children (15). Additionally, lead exposure causes many deleterious cognitive effects including ADHD (22) and reduced IQ (23,24). Behavioral impairment from BLL as low as 0.48 $\mu mol\ L^{-1}$ (2) affects school attendance and performance, invokes deviant--sometimes criminal behavior, compromises employability and quality of life. In turn, victims are disproportionately subject to a cycle of poverty (15), adding another layer of risk. Pregnant mothers are also considered high risk as lead exposure is linked to pre-mature labor and delivery (17,25), low birth weight, miscarriage, and cognitive impairments in infants (25).

Child behaviors that include crawling, sucking on toys and hands, increases exposure to lead contaminated dust, soil and toys. Note, that despite a ban on leaded products (26,27), toys contaminated with lead continue to make it onto the Canadian markets.

Studies from the Mushkegowuk Territory revealed that 3% of infants, 5% of children aged 1-2 and 4.6% of elementary aged children had elevated lead levels as high as 0.91 $\mu mol\ L^{-1}$, exceeding Health Canada limits (2). Similar testing in Toronto and Quebec City respectively found 0 and 1% of infants exceeding limits (2).

For urban residents, lead exposure is often tied to poverty (28) associated with lower incomes (29,30), minority groups, including new refugees and immigrants (15,25,31), occupational attainment (27), and educational background (32). These socio-economic factors render impoverished persons with limited safe, affordable housing options (33). Consequently, the poor are at greater risk, disproportionately inhabiting older homes with lead based paint, contaminated water (15,25) and/or contaminated soil. Compounding these dangers, is the decreased financial ability of the poor to take corrective action.

Similarly, poverty and income impact Canada's Northern Indigenous communities where lead exposures are predominately associated with respective traditional diets. As noted, traditional foods have socio-economic and socio-cultural ties making them the mainstay diet for Arctic Indigenous peoples. It is well documented, that traditional foods are often lead contaminated. Causes have been linked to animals ingesting lead pellets while grazing and/or through the hunting process itself. Communities that consume largely marine mammals and waterfowl (6) were found to be at greater risk of higher BLL (0.48μmol/L^{-1}) versus diets largely consisting of terrestrial mammals (0.35μmol/L^{-1}) (1). Socio-economic barriers support cultural dietary choices given that imported lead-free foods are generally cost prohibitive for Artic residents (1). Along these same lines, inexpensive lead pellets continue to be used in hunting rather than more expensive safe steal pellets (1).

In consideration of the above, we see that children and the impoverished are at greatest risk. Collectively then, impoverished -- often minority status-- children are particularly vulnerable and disproportionately susceptible to exposure (15). 642

Partial Line Service Replacement.

In 1975 Canada banned the use of lead service lines (LSL) (34). Since then, several municipalities have made significant financial investments to have LSL removed, particularly in residences where lead tap water concentrations (12) exceed the recommended actionable level of 15 ppb (12,35). Accordingly, jurisdictions implemented a shared-cost model whereby municipalities covered replacement costs for the public portion of the LSL, that being pipe running from the main water line to the residential property line, while owners bared costs associated with replacement of pipe on respective properties (34). Under this model, few homeowners have participated, opting to forego recommendations to have their LSL fully replaced (36). According to the Rhode Island Department of health, less than 2% of home owners opted in (37). Without the homeowner's portion remediated, only the publicly held portion was replaced. Hence the term, partial lead service line replacement (PLSLR). Considering this application is reserved for critical cases--homes with high lead tap water concentrations--it was anticipated that even a PLSLR would be worthwhile.

Unfortunately, PLSLR has not brought the results one might expect given relative reductions in LSL length, with results either unimproved or worse (12,38-40). Disappointing are studies that saw significant increases to lead concentrations in tap water after PLSLR (41). Also, unexpected and concerning, were increases in lead levels over extended time frames. In laboratory studies by St. Clair et al. that mimicked PLSLR, it was found that lead levels after 14 months, were respectively 7 and 26 times greater over that of all lead replacement lines when tested at moderate and high flow rates (42). Also concerning, post replacement data at 13-14 months showed greater lead contamination than at 8 months (42).

It is speculated that galvanic corrosion is the primary reason for increased contamination following PLSLR (12). In this chemical process, when two electrochemically different metals--such as lead and copper--are connected by way of an electrolytic solution--tap water with salt-- a charged current is created (43). This results in the corrosion and disposition of the weaker metal (43). Hence, in the case of a lead/copper coupling, lead rust is formed (43).

Flow rate, connector materials, crevices, and corrosivity of water (pH, Calcium concentrations, hardness, particulates and temperature) all affect the degree of galvanic corrosion, complicating efforts to advance outcomes (44). Researchers continue to explore connector materials and iron main lines that might offer cathodic protection from galvanic corrosion (42). Application of brass connectors are one example that has been unsuccessful in offering cathodic protection from lead corrosion. It is hypothesized, that cervices at the connector site may be the source of the problem, perhaps countering benefits of cathodic protection (42). Interestingly, plastic connections are showing reduced lead contaminants following PLSLR over baseline results (42). To date, PLSLR appears to lack any advantages.

Short and long-term strategies to reduce Canada's risk from lead.

On-going education related to lead exposure, risk, and remediation (35), that is relevant (17) and culturally based (15), is essential to reducing lead BLL (45).

Short Term Solutions

Testing is key to targeting action (15). Provisions by government bodies that offer cost effective soil, water, and dust testing are recommended. Partnerships with Universities and other agencies equipped to perform assessments need exploring. Given the disproportionate risk of those who are economically disadvantaged, opportunities to provide subsidies for testing and remediation are essential to long term goals to create lead free environments (15).

Soil Contamination:

Gardeners, children and those suffering from geophagia are at increased risk of soil-based lead exposure. As per EPA recommendations, lead levels should not exceed 400ppm for play or garden areas (46). To reduce risk of lead exposure in play areas, ground covers such as mulch are recommended (16,46). For gardeners, recommendations to reduce exposure include: wearing gloves while working outdoors, followed by washing hands; washing all produce; use of raised beds with barriers to separate contaminated and non-contaminated soils (note: uncontaminated soils can become contaminated over time and should be monitored); positioning gardens or use hedges to protect soils from high traffic area contamination (16); along with regular application of phosphorus rich organic compost. (46).

Water Contamination:

It is suggested that the flushing time required to reduce tap water lead concentration is greater than previously thought (37). Additionally, flushing fails to remove all traces of lead in contaminated tap water (47), rendering it a weak solution. Filtration systems are an effective solution (48). However, as efficiency/effectiveness of filtration systems are correlated with costs (48) subsidy programs are essential to equity.

Lead-based paint Dust: To reduce household contamination, it is important to keep floors and other surfaces dust free, ensure that wall surfaces are in good condition to avoid increased exposure from paint chips, minimize transfer of outdoor soil into the home (46) and to avoid indoor renovations around children (15).

Contaminated Traditional Foods:

According to Van-Oostdam, education to impart the invisible dangers of lead in food among Indigenous Artic populations is needed (17). Information must be delivered in a clear, easy to understand, direct fashion that allows for feedback (17,45). Additionally, as lead bullets remain the preferred hunting pellet of choice, despite contributing to lead contamination in traditional diets (1,7), communicating the risks to Indigenous hunters is essential. To address concerns raised by Tsuji et al. (7), a complete ban on lead pellets along with programs that offer the free exchange of stockpiled lead-based bullets for steal based bullets will support reductions related to direct and indirect contamination of hunted food while supporting inequities tied to poverty. Subsidized efforts to encourage increased consumption of imported lead-free foods that closely mimic nutritional elements of traditional foods, especially for children would address concerns noted by Van-Oostdam et al (17). This latter recommendation is controversial given nutritional, sociological and economic benefits tied to traditional food (17).

Contaminated Products:

Improved education that encourages individuals to test imported products, for lead contamination is required.

Longer term

Addressing concerns by Schuch et al., governments in conjunction with inter-agency groups must implement policies that encourage: the full replacement of LSL in areas with high lead tap concentrations (15,35), the removal of lead paint (15), and implement a full ban on lead hunting pellets. Identification of high-risk communities using GIS can facilitate abatement efficiencies (15). It will be crucial that policies and supporting regulations are meaningful and equitable to mitigate population risk, at local, regional, national and international levels. This means policy and partnerships that support built-systems of regulatory monitoring that hold persons/institutions accountable (49). Also, necessary are global policies that target other anthropogenic lead sources. According to commentary by Schuch et al., "The best scenario for primary prevention is the provision of a lead-safe environment through housing and properties devoid of sources of environmental lead" (p.616) (15).

For Canada's poor one might argue that all forms of remediation are cost prohibitive. Add to this that more effective modes of mitigation are often costly (48) and we see the disconnect between the haves versus the have nots. Local, regional and national agencies should seriously weigh the cost-benefits subsidies offer. Long-term cost savings associated with subsidized abatement are likely considering long-term health, educational, judicial and employment consequences tied to exposure (50).

Given the link between poverty and risk of exposure (15), efforts to eliminate poverty should be part of any long-term strategies. Additionally, governments would be well advised to seek strategies to reduce hunger and malnutrition, as children are disproportionately subject to increased lead absorption that are exacerbated under these conditions (18).

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