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Risk Management Strategy for Lead

February 2013

Canada

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Risk Management Strategy for Lead
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The final *Risk Management Strategy for Lead* outlines the current and planned control actions for lead that comprise the Canadian federal risk management strategy for this substance. This document incorporates information received from program areas within Health Canada and other federal government departments. A draft proposed risk management strategy was published in July 2011 for a 60-day public comment period, during which time stakeholders were invited to submit comments on the content of the document or to provide other information that would help to inform decision making. Comments received as a result of this consultation period were taken into consideration in the finalization of the risk management strategy.

EXECUTIVE SUMMARY

Lead is a naturally-occurring element found in rock and soil and this, together with its widespread anthropogenic use, has resulted in its ubiquitous presence in the environment. Lead is found in all environmental media in Canada, as well as in food and drinking water, and it is associated with risks to human health and to the environment. Lead is currently subject to numerous federal risk management initiatives directed toward consumer products, cosmetics, drinking water, food, natural health products, therapeutic products, tobacco, and environmental media, including household dust, soil and air. Concentrations of lead in the environment have been extensively measured and reported through national, provincial and municipal initiatives across Canada, and the results have shown that concentrations of lead in most environmental media have declined markedly over the past few decades. As an example, average lead concentrations in ambient air declined by more than 99% between 1984 and 2008. Similarly, although lead is still widely detected in the Canadian population, levels in blood have fallen dramatically over the past 30 years. This decline in population blood lead levels in Canada since the 1970s can be attributed to the successful phase-out of lead in gasoline, paints and solder used in food cans, in addition to other government regulations and industry actions over this time.

However, in response to increasing scientific evidence of effects occurring at low levels of exposure to lead, Health Canada has undertaken an assessment of the most current science on lead and consolidated the information in a State of the Science Report. Studies clearly document adverse health effects - including neurodevelopmental, neurodegenerative, cardiovascular, renal and reproductive effects - at blood lead levels below 10 micrograms per deciliter (µg/dL), the current Canadian blood intervention level. There is sufficient evidence that blood lead levels below 5 µg/dL are associated with adverse health effects. Adverse health effects have also been associated with blood lead levels as low as 1-2 µg/dL, levels that are present in Canadians, although there is uncertainty associated with effects observed at these levels.

While lead can be harmful to the health of people of all ages, infants and children are a susceptible subpopulation for lead exposure. This age group is particularly susceptible to the neurodevelopmental effects of lead exposure, specifically the reduction of Intelligence Quotient (IQ) score and attention-related behaviours. Research suggests that an incremental increase in blood lead levels of 1 µg/dL is associated with approximately a 1 IQ point deficit. Furthermore, based on dose-response modeling conducted with available observational studies, no population threshold has been observed for developmental neurotoxicity over the lower ranges of

environmental lead exposures. In humans, the developmental neurotoxic effects of lead have been shown to persist until the late teenage years.

Although blood lead levels of Canadians have declined significantly over the past 30 years, there is new scientific evidence that health effects are occurring below 10 µg/dL. Therefore in response to this new evidence, Health Canada has undertaken a comprehensive review of the current toxicological and toxicokinetic data on lead. Based on the results of this review, and in consideration that it is appropriate to apply a conservative approach when characterizing risk, it was concluded that additional measures to further reduce exposures of Canadians to lead, with a particular focus on vulnerable populations, are warranted. Accordingly, the proposed risk management objective for lead is to provide continuing support for existing federal management actions under the Canadian federal *Risk Management Strategy for Lead*, and to pursue additional management measures to reduce exposure to lead, and hence associated risks, to the greatest extent practicable. The present risk management strategy provides an overview of the current health findings associated with lead and a comprehensive description of the existing management measures and progress-to-date under the Canadian federal *Risk Management Strategy for Lead*. The strategy also outlines actions to further reduce risks associated with exposure to lead that are underway or planned by the Government of Canada. The overall Government of Canada risk management objective is to reduce exposure to lead to the greatest extent practicable by strengthening current efforts in priority areas where the government can have the greatest impact upon exposure of Canadians.

1 INTRODUCTION

Lead was added to Schedule 1 of the *Canadian Environmental Protection Act* (CEPA) in 1988 (Canada 1988). It was determined that the scientific evidence of the adverse effects of lead on human health and the environment had been sufficiently demonstrated, and that determination of its adverse effects was consistent with the criteria set out in section 11 of CEPA. In 2005, in response to increasing scientific evidence of effects on human health occurring at low levels of exposure, Health Canada initiated a rigorous review of the current toxicological and toxicokinetic data on lead. Specifically, there is scientific evidence of potential adverse health effects occurring at blood lead levels below the current Canadian blood lead intervention level of 10 µg/dL. The results of this investigation are summarized in the *Human Health State of the Science Report on Lead*,[1] which documents health outcomes including developmental, neurodevelopmental, neurodegenerative, cardiovascular, renal and reproductive effects. The report also emphasizes that infants and children are a particularly susceptible subpopulation in terms of the neurodevelopmental effects of lead, and it further establishes that researchers have modelled dose-response relationships for neurodevelopmental toxicity down to the lowest blood lead levels measured. Information is also presented on current levels of lead in the Canadian environment and the general population.

Accordingly, the federal *Risk Management Strategy for Lead*, which is being published along with the *Human Health State of the Science Report on Lead*, provides an overview of the current science related to lead toxicity, and summarizes the existing federal management actions and additional risk management measures proposed to reduce risks associated with exposure to lead.

[1] Health Canada, *Human Health State of the Science Report on Lead*, 2012.

2 WHAT IS LEAD?

Lead (Pb) is an odourless, bluish-grey, lustrous metal that is malleable, ductile, and resistant to chemical corrosion. Lead occurs naturally in bedrock, soils, tills, sediments, surface waters, ground-waters, and sea-water (Reimann and de Caritat 1998). Of the heavy metals with an atomic number greater than 60, lead is the most abundant in the earth's crust (Adriano 2001). As a result of its natural presence in the environment, lead also occurs naturally at low levels in foods, due to its uptake from soil into plants, from water and sediments into fish, and from plants and animals that consume them (Adriano 2001). Lead has several oxidation states, but in nature there is one form (plumbous) that predominates (ATSDR 2007a). Measurements of lead in environmental and biological media rarely identify the form, but rather refer to the lead component contained within unspecified substances.

3 RISKS TO THE HEALTH OF CANADIANS

It is important that Canadians understand the risks that they may encounter that are associated with substances in their environment. Lead is a significant environmental pollutant, given its broad exposure among the general population and increasing evidence of its toxic potential. The following provides an overview of the health effects related to lead and factors that may influence its toxicity.

3.1 Health Effects

Lead can be harmful to the health of people of all ages, but infants and children are a susceptible subpopulation for lead exposure. Infants and children are susceptible to lead exposure because they have greater gastrointestinal absorption, less effective renal excretion, and different behaviour patterns than adults, such as the ingestion of non-food items. New scientific information shows that blood lead levels previously considered not to pose a risk to human health are associated with adverse effects in humans. Evidence of an association between neurodevelopmental impacts on infants and children exposed to lead at the lowest measurable levels has led many international governing bodies, including the United States Environmental Protection Agency (U.S. EPA) and the World Health Organization (WHO), to state that a threshold for the adverse health effects of lead has not been identified. The *Human Health State of the Science Report on Lead*[2] concludes the same. In particular, there is sufficient evidence that blood lead levels below 5 µg/dL are associated with adverse health effects. Adverse health effects including neurodevelopmental, neurodegenerative, cardiovascular, renal and reproductive effects have also been associated with levels as low as 1–2 µg/dL, levels that are present in Canadians, although there is some uncertainty associated with effects observed at these levels. Of these, the critical effect for risk characterization is developmental neurotoxicity, as the evidence of an association is strongest for neurodevelopmental effects, specifically, the reduction of intelligence quotient (IQ) score and attention-related behaviours. It should be noted that for many of the studies, the limit of quantification (LOQ) was approximately 3 µg/dL, making it difficult to interpret the lower end of the dose-response curve.

[2] Ibid.

3.1.1 Developmental Neurotoxicity

Epidemiological studies have reported an association between early-life lead exposure and adverse developmental effects on a variety of neurological, neurophysiological, cognitive and behavioural endpoints including: neuromotor function (Fraser et al. 2006; Boucher et al. 2012); academic achievement (Chandramouli et al. 2009); antisocial behaviour (Needleman et al. 2002); attention and executive function (Bouchard et al. 2009; Cho et al. 2010); auditory function (Osman et al. 1999); and visual function (Laughlin et al. 2008). In the past decade, many of these effects have been associated with blood lead concentrations less than 10 µg/dL, and there is also sufficient evidence linking lead exposure with attention-related and problem behaviours in children at blood lead levels below 5 µg/dL (Braun et al. 2006; Froehlich et al. 2009, NTP 2012). Several studies have also reported a dose-response relationship that may extend to the lowest blood lead levels studied (1–2 µg/dL) (Lanphear et al. 2000; Canfield et al. 2003a, b; Chiodo et al. 2004, 2007; Miranda et al. 2007).

IQ score is the most widely measured endpoint with which to assess developmental neurotoxicity from exposure to lead. Developmental neurotoxicity has been associated with the lowest levels of lead exposure examined to date, both in observational studies and in animal experiments. The adverse consequences of early-life lead exposure on IQ in school-aged children have been well documented based on evidence indicating a reduction of IQ score with increasing blood lead levels. This body of research demonstrates an association between early-life chronic lead exposure and decrements in school-aged children's IQ, and it is generally indicative of effects of concern at exposure levels below 10 µg/dL (Ernhart et al. 1987, 1989; Cooney et al. 1989a, b, 1991; Bellinger et al. 1991, 1992; Dietrich et al. 1992; Schnaas et al. 2006). Many of the individual epidemiological studies model a dose-response relationship for developmental neurotoxicity down to the lowest blood lead level range studied, 1–2 µg/dL (Canfield et al. 2003a; Chiodo et al. 2004; Lanphear et al. 2005; Tellez-Rojo et al. 2006; Jedrychowski et al. 2009), but not all studies report this pattern of results (e.g. Surkan et al. 2007; Chandramouli et al. 2009). Lanphear et al. (2005) in a pooled-analysis based on studies conducted in times of higher lead exposure concluded that intellectual deficits are associated with maximum BLLs of less than 7.5 µg/dL in children. However, since BLLs have declined considerably since the Lanphear (2005) study was conducted, there is uncertainty regarding the extrapolation of this dose-response curve to the current Canadian population.

It is important to note that in laboratory animals, the developmental neurotoxic effects of lead have been shown to persist after exposures have ceased, and blood and brain lead levels have returned to normal or control levels (Rice and Barone 2000). In humans, the developmental neurotoxic effects of lead have been shown to persist until the late teenage years. Lead has been shown to interact with multiple cell types in the central nervous system, and potential modes of action supported by experimental evidence have been developed to explain the observed developmental neurotoxicity of lead. These modes of action are considered relevant to humans.

3.1.2 Neurodegenerative Effects

Evidence also exists indicating a relationship between lead exposure and increased rate of neurological decline, particularly an association between bone lead concentrations and neurodegenerative effects (Shih et al. 2006). However, this is somewhat limited for blood lead levels below 10 µg/dL. Central nervous system (CNS) and peripheral nervous system (PNS) effects have also been reported at blood lead levels above 20 µg/dL (ATSDR 2007a).

3.1.3 Cardiovascular Effects

Lead exposure has been associated with cardiovascular mortality, stroke mortality, myocardial infarction mortality, cardiotoxicity, and peripheral arterial disease, and there is evidence for several of these effects at blood lead levels below10 µg/dL (Lustberg and Silbergeld 2002; Navas-Acien et al. 2004, 2007, 2008; Menke et al. 2006; Schober et al. 2006). The endpoint that has been the most studied, and for which there is the greatest evidence of an association, is lead-induced increase in blood pressure, particularly systolic blood pressure or risk of hypertension. While there is a positive association between blood lead level and blood pressure, it is not as consistent as the association between bone lead level and increased blood pressure or risk of hypertension in the aged (Cheng et al. 2001). As a whole, the epidemiological findings have identified a persistent trend in the data that supports a relatively small, but statistically significant association between blood lead levels and systolic blood pressure in adults. Biological variations such as age, diet, gender and ethnicity, which are all risk factors for cardiovascular disease, may also explain some inconsistency in results.

3.1.4 Renal Effects

Lead may also cause harmful effects on the renal system, with severe effects at blood lead levels above 50 µg/dL, enzymuria and proteinuria above 30 µg/dL, and reduced glomerular filtration below 20 µg/dL (ATSDR 2007a). Ekong et al. (2006) concluded that lead contributes to nephrotoxicity at levels below 5 µg/dL, and this is particularly true in susceptible populations, such as those with hypertension, diabetes, or chronic kidney disease.

3.1.5 Reproductive Effects

Lead adversely affects offspring development at maternal blood lead levels that do not produce maternal clinical toxicity. Key reproductive effects observed in females that are associated with low-level exposure to lead include delays in sexual maturation, risk of spontaneous abortion, effects on birth weight, and pre-term birth. Data have demonstrated an association between delayed puberty in adolescent girls and blood lead levels as low as 3 µg/dL (Selevan et al. 2003). Gonzalez-Cossio et al. (1997) reported that maternal bone lead burden is inversely related to birth weight. Hernández-Avila et al. (2002) reported a positive association between bone lead level and shorter birth length. Another study shows an inverse association between blood lead levels and length of gestation, with an increased risk of prematurity (Cantonwine et al. 2010). In males, most reported effects on the reproductive system—including decreased sperm count, morphological aberrations, and an increased risk of infertility—have been observed at blood lead levels above 10 µg/dL (Alexander et al. 1996; Sallmen et al. 2000; Bonde et al. 2002).

3.1.6 Overview of Health Effects

In summary, the studies described above document effects—including developmental neurotoxicity, neurodegenerative, cardiovascular, renal and reproductive effects—at blood lead levels below 10 µg/dL. The weight of evidence is strongest for neurodevelopmental effects in children, specifically the reduction of IQ score. Selection of infants and children as a susceptible subpopulation, and neurodevelopmental effects as the critical health effect, is considered protective for other adverse effects of lead across the entire population.

In consideration of this new evidence, especially in terms of the neurodevelopmental sensitivity of children, the European Food Safety Authority (EFSA) and the joint FAO/WHO Expert Committee on Food Additives (JECFA), an expert scientific committee that is administered jointly by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), concluded that the existing provisional tolerable weekly intake (PTWI) for lead of 25 µg/kg body weight is no longer appropriate to protect human health (JECFA 2010). In addition, JECFA (2010) concluded that based on current data, it was not possible to establish a new PTWI that would be health protective. Based on the dose-response modeling conducted by the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency (OEHHA 2007) and EFSA (2010), each incremental increase in blood lead levels of 1 µg/dL is associated with approximately a 1 IQ point deficit.

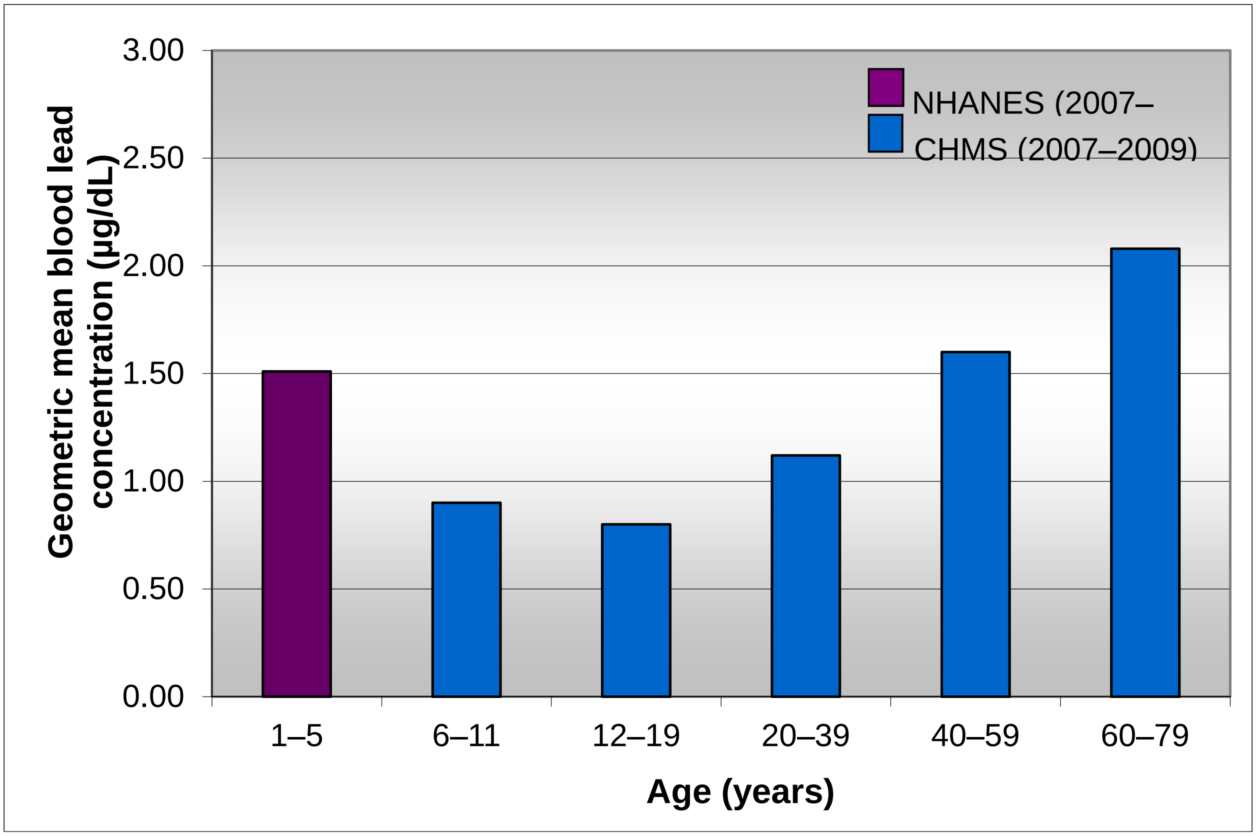
3.2 Metabolism, Age and Other Factors Contributing to Elevated Lead Levels in the Body

Nutritional iron and calcium deficiencies in children both appear to increase lead absorption (EFSA 2010). The health effects associated with lead are considered to occur via common modes of action, such as lead's ability to mimic other biologically essential metals, in particular calcium, but also iron and zinc (Kosnett 2006). This can potentially affect the nervous system (EFSA 2010), the cardiovascular system and blood pressure (Piccinini et al. 1977; Kramer et al. 1986; Watts et al. 1995; Hwang et al. 2001).

Lead circulates in the bloodstream and either accumulates in bone or is excreted from the body. Bones act as a reservoir for lead and accumulate up to 90% and 70% of the absorbed lead in adults and children, respectively (Barry 1975). Lead in bone is constantly mobilized and released back into systemic circulation, but under certain conditions, the rate of remobilization can increase. Pregnancy, lactation, menopause, andropause, post-menopause, extended bed rest, hyperparathyroidism, and osteoporosis are all conditions that result in increased remobilization leading to increased blood lead levels (Silbergeld et al. 1988; Franklin et al. 1997; Gulson et al. 1997, 1999, 2003). Puberty is also a significant event, given the considerable changes in bone structure during that stage of life. Lead absorption should be of concern during puberty, especially for girls, as this is the time when much bone is formed, and lead incorporated into bone at this time will be the lead remobilized during pregnancy, which becomes the primary source of fetal lead exposure (Campbell et al. 2004; Davies et al. 2005). Lead released from maternal bone can serve as a source of lead to the fetus when calcium is mobilized and used for production of the fetal skeleton (Silbergeld et al. 1988; Franklin et al. 1997; Gulson et al. 1997, 1999, 2003). Biological variations such as gender, disease state, nutritional state, genetics and ethnicity can also influence the absorption of lead or the severity of the effects observed. Hence, the following are considered to be susceptible subgroups: children, males, aging adults, pregnant women, non-Caucasians, and people suffering from hypertension, chronic kidney disease, diabetes, and nutritional deficiencies.

There are characteristic age trends in lead levels in the body. From birth up until 6 months of age, an infant's blood lead level will reflect that of its mother (Schell et al. 2003), the reason being the transfer of maternal lead, either through the placenta or later through breast milk (Manton et al. 2000). As children become more active and mobile at around 6 months of age, environmental lead exposures gradually increase. Settled dust and soil start to represent an increasing proportion of overall exposure to lead through hand-to-mouth behaviour and the mouthing of non-food objects that may contain lead (e.g., soil, adult jewelry, leaded paint chips), which is often exacerbated during teething (Manton et al. 2000; Tulve et al. 2002; U.S. CDC 2009a). Blood lead levels tend to rise after infancy and peak between 1 and 3 years of age, declining slightly during childhood and adolescence before rising again with age in adults (Baghurst et al. 1987; Dietrich et al. 1993, 2001; Canfield et al. 2003a; U.S. CDC 2009b; Bell et al. 2011; INSPQ 2011; Richardson et al. 2011; Zahran et al. 2011). Seniors typically have the highest blood lead levels, resulting from exposure to higher environmental lead concentrations in the past and the remobilization of lead accumulated over time in bone into the blood stream. Therefore, at certain life stages, an individual's bone lead stores can represent the single greatest potential source of increased blood lead levels, which underlines the importance of decreasing overall lead exposure at all life stages. Age-related trends in blood lead levels taken from the Canadian Health Measures Survey (CHMS) (Bushnik et al. 2010) and the U.S. National Health and Nutrition Examination Survey (NHANES) (U.S. CDC 2009b) are presented in Figure 1.

Figure 1. Age-related trends in blood lead levels (Canadian Health Measures Survey 2007–2009; U.S. National Health and Nutrition Examination Survey 2007–2008)



Besides age, several additional factors are known to be associated with increased human exposure to lead and, consequently, increased blood lead levels. Maternal bone and blood lead are the major sources of exposure for the developing fetus. Maternal exposure to lead in occupational settings (e.g., lead smelting, battery manufacturing and recycling) can result in elevated blood lead levels in neonates and infants (ATSDR 2007a). Lead concentrations in breast milk are significantly correlated with infant blood lead levels. However maternal blood lead levels have a stronger influence than do breast milk concentrations, on infant blood lead levels (Ettinger et al. 2004; Koyashiki et al. 2010).

As well, blood lead levels of immigrants to the United States and Canada have been reported to be strongly dependent on time elapsed since immigration from their country of origin, with levels highest in those who had immigrated most recently (U.S. CDC 2006). This finding can be attributed to the continued use of lead in other countries, such as in leaded gasoline and lead solder in food cans, as well as less stringent regulatory measures mitigating the impact of industrial pollution. Lead levels can also become elevated as a function of poor diet, housing, and quality of life following immigration (Geltman et al. 2001).

In older communities, several exposure sources and risk factors may converge. Older communities are more likely to have lead service lines, lead-containing fittings, and lead solder in the plumbing system; lead-contaminated soil from current or historical industry or from fallout from historical use of leaded gasoline on major roads; and lead-based paint in the home. In addition, these older areas may have a higher proportion of new immigrants or families with lower household incomes. Older homes may be more likely to undergo renovations. In Canada, blood lead levels are higher in males than in females, in smokers than in non-smokers, in individuals born outside of Canada than in those born in Canada, in individuals living in older homes (50+ years) than in those living in newer homes, and in residents of households with lower income levels than in those with higher income levels (Bushnik et al. 2010).

4 ENVIRONMENTAL RISKS

Exposure to elevated concentrations of lead from natural and human sources can be hazardous to wildlife (Scheuhammer and Norris 1995). While lead is a ubiquitous and naturally-occurring metal, it can be mobilized and released into the environment at higher than background concentrations as a result of anthropogenic activity. Known hazards associated with exposure of wildlife in Canada to lead include toxicity to birds, fish and crustaceans in the water column, benthic invertebrates in sediments, and plants and earthworms in soil.

Over 5000 laboratory toxicity tests have documented the effects of lead and lead compounds on organisms in the water column, sediment and soil (ECOTOX 2006). Invertebrates such as mayflies, clams, mussels and daphnids tend to be most sensitive to lead in the aquatic environment, while for a few lead-containing substances, plants and algae are the most sensitive (ECOTOX 2006). It is also known that specific physical and chemical properties of water such as pH, alkalinity, hardness and dissolved organic carbon content may considerably alter the toxicity of lead to freshwater fish and daphnids (TNO 2005). For example, lead tends to be more bioavailable when pH, water hardness and organic matter content are low (U.S. EPA 2011).

There is evidence that lead bioaccumulates and bioconcentrates in some organisms such as algae, macrophytes and benthic organisms (U.S. EPA 2011). While it has been posited that lead can biomagnify in the lower trophic levels of ecosystems (Rubio-Franchini et al. 2008), many studies suggest either that biomagnification of inorganic lead is negligible, or that concentrations actually decrease at higher levels of the food-chain (Eisler 1988). This is due in part to the fact that, in vertebrates, lead is stored in the bones, which are not usually digested when prey is consumed.

In addition to atmospheric releases of lead, several potential sources of environmental lead exposure and lead toxicity still exist for wildlife. These include lead releases from hunting with lead ammunition; lost lead fishing sinkers and jigs; lead deposited at target-shooting ranges; lead from past gasoline combustion; and lead from mining and smelting wastes.

A comprehensive review of the environmental impacts of lead shot and fishing sinkers in Canada showed that lead from shotgun ammunition could be an important source of lead exposure for waterfowl, other game birds and their predators in Canada (Scheuhammer and Norris 1995). The study also found that the use of small (less than 50 g) lead sinkers and jigs presented a toxicological and mortality risk for common loons. Lead shot can be ingested by birds mistaking it for grit; similarly, lead sinkers can be mistaken for small pebbles and can be ingested by birds, leading to lead poisoning and possibly death. The toxic effects of lost sinkers have been documented in common loons, accounting for 20–30% of all reported deaths of adult common loons on their breeding grounds in areas where recreational angling activity is high. In addition to loons, over 28 other water bird species and two species of turtles have been documented to have ingested lead sinkers or jigs (Franson et al. 2003; Scheuhammer et al. 2003 and references cited therein).

In the past, hundreds of outdoor shooting ranges across Canada released hundreds of tonnes of lead into the environment each year. Lead levels sufficient to cause toxic effects in earthworms and water birds were found at some ranges, particularly those on acidic soils or with associated wetlands where water birds might ingest lead shot pellets. Lead concentrations in small mammals sampled on shooting ranges were generally not higher than those in animals collected off the ranges but concentrations in grasses from ranges were increased, as were concentrations in grasshoppers at one Alberta range (Health Canada 2004).

5 KEY SOURCES OF LEAD

Lead occurs in nature in bedrock, soils, tills, sediments, surface waters, ground waters, and sea water. However, the concentration of lead in Canadian surface waters and groundwater unaffected by pollution sources is generally low (Health Canada 1995). Primary natural sources of lead release include volcanic activity and natural erosion of lead deposits. Due to its natural presence in the environment, lead also occurs naturally at low levels in foods due to its uptake from soil into plants, from water and sediments into fish, and from plants and animals that consume them. In natural environments, lead is seldom found in its elemental form (Adriano 2001), but is complexed with other elements in mineral form, and it also co-exists with other metals in ore deposits (Pais and Jones 1997; Reimann and de Caritat 1998; Adriano 2001).

Canada is a significant global producer and supplier of refined lead, ranking eighth in the world in 2009 in terms of mine production (68,624 tonnes) and sixth in terms of refined lead production (101,484 tonnes) (Panagapko 2009). Most lead in Canada is produced as a co-product of zinc mining, whereas the recycling of lead, mainly from depleted car batteries, represented the primary source of Canada’s total refined production (61%) in 2009. Nearly 90% of refined lead produced in Canada is exported to the United States.

6 USES

Exposure of people to lead in the past and present has been significantly influenced by the wide variety of uses of lead. Many of these uses have been discontinued in recognition of the benefits to human health of reducing exposure to lead.

Currently, the production of batteries, used predominantly in the automotive industry, comprises the single largest global market for refined lead, since the phase-out of lead in household paints, gasoline additives and solder in food cans (OECD 1993; Keating and Wright 1994; Keating 1995; Panagapko 2009). Lead is also used extensively in a variety of other applications, including the manufacture of cable sheathing, circuit boards, lining for chemical baths and storage vessels, chemical transmission pipes, electrical components, polyvinyl chloride (as a chemical stabilizer), and radiation shielding. Lead continues to be used extensively in rolled and extruded products in the construction industry. The use of lead sheeting in the building industry has increased in recent years (IARC 2006). As well, certain lead compounds are still used by industry as paint primers for iron and steel (Panagapko 2009). Significant quantities of lead are used for the manufacture of lead shot and ammunition, which is of particular concern for the health of rural Canadians, particularly Aboriginal peoples, whose dietary protein comes to a large extent from harvested wild game. Lead also has a variety of other uses, including the manufacture of water repellents, dyes, varnishes and resins, pigments, automotive parts, explosives, paper coatings, ceramics, rubber and plastics. It is also used in analytical applications.

Tetraethyl lead and tetramethyl lead were once widely used as an anti-knock additive in motor vehicle fuels in North America prior to prohibition of the use of lead in gasoline in on-road vehicles in the 1990s. The *Gasoline Regulations* under the *Canadian Environmental Protection Act, 1999* (CEPA 1999) (Canada 1999) restrict the use of lead in gasoline to piston engine aircraft (Avgas) and in racing fuels for competition vehicles only (Environment Canada 2010a).

7 CANADA'S CURRENT RELEASE PROFILE

In order to determine how to reduce Canadians' exposure to lead, it is necessary to first understand where it occurs and what happens to it, both in nature and in the industrial world. Contamination of terrestrial and aquatic environments by lead can occur in many ways, such as deposition of lead from the atmosphere (Stafilov et al. 2010), erosion of rocks containing lead (Smith et al. 2009), disposal of lead-based products such as lead shot and pellets (Chrastný et al. 2010), historical use of lead-based pesticides (CCME 1999), and release to water and sediment from mining and other effluents (Besser et al. 2008).

There are four major sources of lead releases: primary natural sources, primary anthropogenic sources, secondary anthropogenic sources, and re-mobilization and re-emission. Primary anthropogenic sources of lead releases occur when lead in raw materials is mobilized through such activities as the smelting and refining of base metals. Secondary anthropogenic sources of lead releases occur during the use or the disposal or incineration of lead-containing products such as batteries, leaded gasoline, and electronic devices. Re-mobilization and re-emission of lead to the atmosphere occurs when previously deposited lead (from either anthropogenic or natural sources) is re-introduced into the atmosphere.

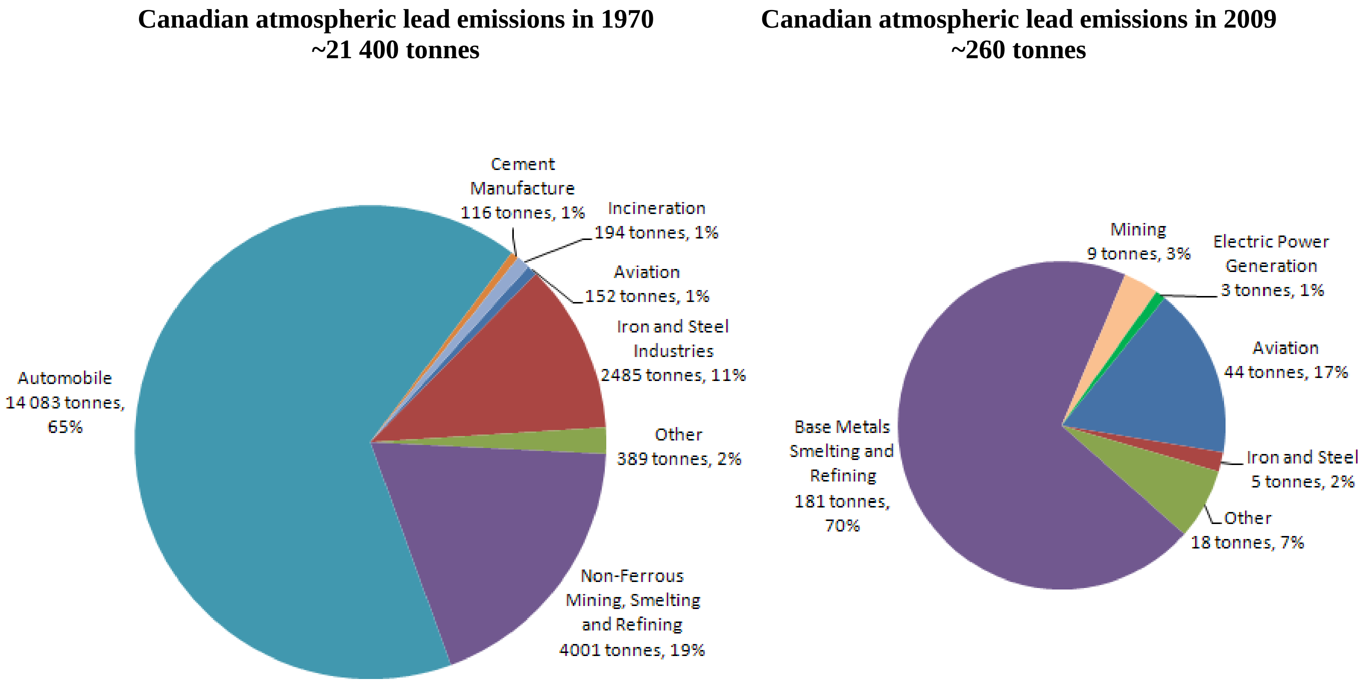
It is important that governments keep track of how much lead and other hazardous chemicals are released into the environment in order to determine the effectiveness of pollution prevention and control measures, the ultimate goal of which is to reduce risks to human health and the environment. Environment Canada maintains the National Pollutant Release Inventory (NPRI), which includes pollutant release and transfer data reported by facilities in Canada that meet certain criteria, as well as estimates for air emissions of a number of substances of concern (including lead) that factor in data reported by facilities to the NPRI.

The NPRI, however, does not capture all pollutant releases to the environment, and some significant sources are not included in the case of lead (e.g., releases to land and water from facilities that are not required to report to the NPRI, and lead in consumer products such as lead shot and sinkers). For 2009, facilities reported the following releases of lead to the NPRI: approximately 260 tonnes released to air, 160 tonnes to land, and 16 tonnes to water.

7.1 Releases to Air

As shown in Figure 2, lead emissions decreased by approximately 99% between 1970 and 2009. Currently, major domestic sources of anthropogenic emissions to the atmosphere in Canada are base metals smelting and refining, use of leaded gasoline in aviation and for competition vehicles, mining, iron and steel industries, and electric power generation (Figure 2). The largest anthropogenic source of lead emissions in Canada is from the base metals smelting and refining sector, which represented approximately 70% of emissions in 2009. Seventeen percent of releases to air were from aviation. Risk management activities have resulted in significant reductions in lead emissions from the base metals smelting sector. In 1988, total lead emissions from the sector amounted to approximately 1600 tonnes, and by 2009, the emissions were reduced to 181 tonnes, a reduction of about 89%. In addition, two smelters that were responsible for approximately 107 tonnes of the 2009 emissions ceased operations in 2010, further reducing lead emissions from the sector.

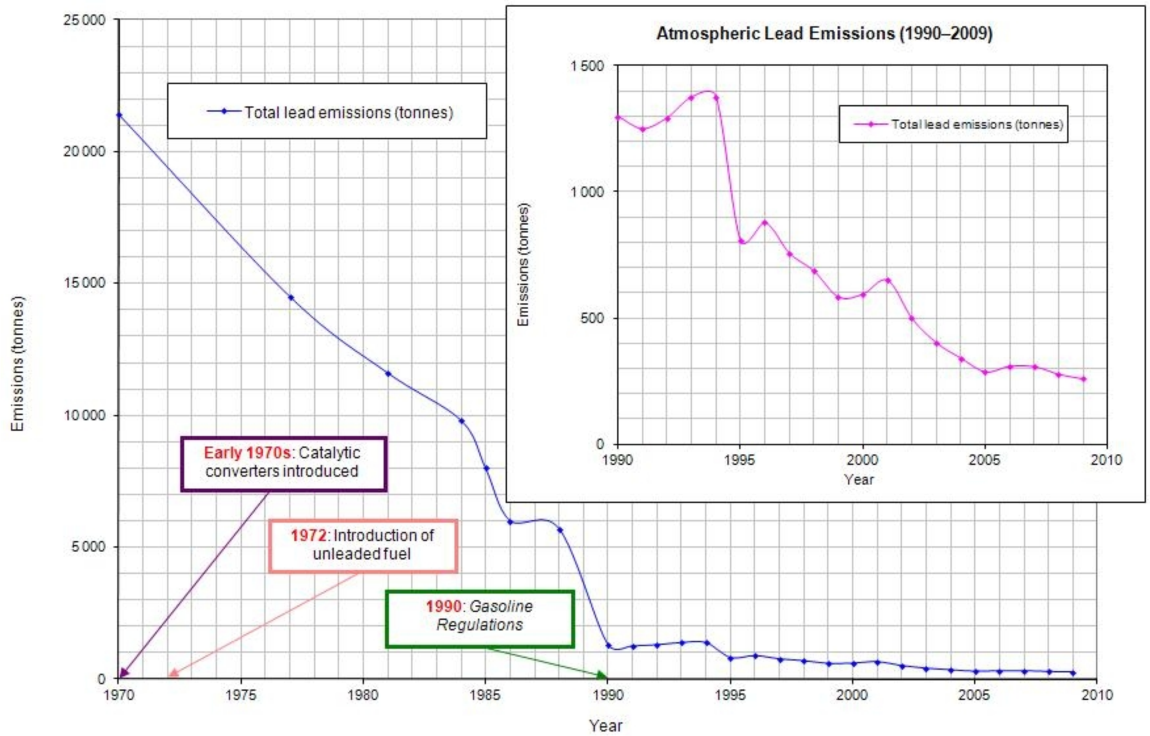
Figure 2. Comparison of Canadian anthropogenic atmospheric lead emission profiles for 1970 and 2009



Source: 1970 data from Environment Canada 1974; 2009 data from Environment Canada 2011a

Figure 3 illustrates the influence of various regulatory activities on atmospheric lead emissions that took place in Canada over the past decades.

Figure 3. Trend in Canadian lead emissions from 1970 to 2009



Sources: Environment Canada 1974, 1996, 2011a

Tools that targeted air as medium of concern	
1976	*Secondary Lead Smelter Release Regulations* (Originally promulgated in 1976 under the *Clean Air Act*)
1990	*Gasoline Regulations* (under CEPA 1999)
1991	*Secondary Lead Smelter Release Regulations* (note: replaced the 1976 regulations under the *Clean Air Act*) (under CEPA 1999)
2001	Environmental Codes of Practice for Integrated Steel Mills and Non-Integrated Steel Mills (instrument under CEPA 1999)
2006	Pollution Prevention (P2) Planning Notices in respect of specified toxic substances released from base metals smelters and refineries and zinc plants (instrument under CEPA 1999)
2006	Environmental Codes of Practice for Base Metals Smelters and Refineries (instrument under CEPA 1999)

7.2 Releases to Land

In the NPRI, approximately 140 tonnes (85% of total releases to land) of the reported releases are a direct result of the use of lead ammunition at shooting ranges for military training purposes. Not all shooting ranges meet the reporting criteria for the NPRI, and therefore not all lead releases to land are reported from that specific activity. It has been estimated that over 1,000 tonnes of lead are released to land in Canada annually from the use of lead shot and bullets (Scheuhammer and Norris 1995); however, as these releases are not monitored, the exact quantities are not known at this time. These releases can affect wildlife feeding in upland habitats. For example, Stevenson et al. (2005) found significant declines of lead in waterfowl following the ban of lead shot for waterfowl hunting. However, lead concentrations in woodcocks, a species that feeds in upland areas where the use of lead shot is still permitted, have not changed significantly (Stevenson et al. 2005). Lead shot used for hunting and pest control presents a high potential for lead exposure in scavengers and birds of prey (Hunt et al. 2006; Knopper et al. 2006). Releases of lead to land can also occur from the use of lead wheel weights that may fall off during a vehicle's service life.

7.3 Releases to Water

As reported to the NPRI, approximately 16 tonnes of lead were released to water in 2009. Of the 16 tonnes, 52% is from wastewater treatment facilities, 13% from the pulp and paper industry, 13% from the base metals mining and smelting sector, 10% from the mining sector, and the remaining 10% is from various industries such as iron and steel, petroleum, and electricity (Environment Canada 2010b). However, these releases are relatively small compared with estimates of unreported releases to water from the use of lead-containing products.

In Canada, the amount of lead entering water from the unintentional loss of lead sinkers and jigs is estimated to be 500 tonnes per year (Scheuhammer et al. 2003, based on data from DFO 1997). Also, lead shot released over water has been demonstrated to be a source of lead release resulting in exposure of wildlife, principally of birds living and foraging in wetland areas; prohibitions on the use of lead shot have led to significant decreases in lead concentrations in waterfowl (Stevenson et al. 2005). Other potential sources include lead wheel weights that fall off during use, and are then dispersed as fugitive dust and flushed by rainwater into nearby waterways and aquatic ecosystems (Root 2000).

Also, based on recent landfill leachate sampling, the concentrations of lead in raw landfill leachate at ten landfills in Canada ranged from 0.01 to 0.1 mg/L, with an average concentration of 0.062 mg/L. Lead concentrations were below the detection limits following leachate treatment. It was estimated that the contribution of lead released to water from landfills is less than 500 kg/year (Environment Canada 2011b). Despite the fact that the quantities found in raw leachate were relatively low, and since some landfills do not have leachate collection and treatment systems, it is recommended that products known to contain lead are not disposed of in landfills (Environment Canada 2009). Many provinces have established extended producer responsibility, recycling or other take-back programs that could include products that contain lead. Consumers are encouraged to contact their municipalities or retailers to find out details about the availability of collection and recycling programs in their area that accept lead-containing products (e.g., lead-acid batteries and lead-based paints).

8 EXPOSURE SOURCES

Canadians should be aware that exposure to lead can occur from many different sources and may compromise their health. Understanding the potential sources of exposure to lead will allow people to make choices that could further minimize their exposure.

Due to a long history of global industrial and consumer use—and its naturally-occurring presence—lead is ubiquitous in the environment. Canadians may be exposed to lead through environmental media, their diet and, despite stringent regulatory controls introduced in Canada, various other sources, including health and consumer products. The main route of exposure for the general adult population is currently ingestion from food and drinking water, followed by inhalation (ATSDR 2007a; EFSA 2010). However, individual exposure to other sources may be significant. Inhalation is an important route of exposure for individuals living in the vicinity of point sources (UNEP 2010). The dermal route is not considered to be a significant route of exposure. Infants and children have different behaviours from adults, including crawling, greater frequency of hand-to-mouth contact, and mouthing behaviour (a tendency to eat non-food items such as soil or paint). Therefore for infants and children, ingestion of non-food items contaminated with lead (e.g., household dust, lead-based paint, soil, consumer products), along with dietary intake through food and water, are the greatest sources of environmental exposure to lead. As concentrations of lead in water, dust, paint, or soil increase, these media become increasingly important contributors to blood lead levels.

Factors that also contribute to lead exposure for the general population include ingestion of wild game harvested using lead ammunition and oral intake from products that could contain lead (e.g., costume jewelry, leaded crystalware, art supplies). Other factors contributing to exposure to lead include living in or frequently visiting older buildings that contain deteriorating lead-based paint or lead service lines, or that are undergoing renovation activities; living with someone with occupational or recreational lead exposure; and behaviours such as smoking (CoEH 2005; ATSDR 2007a,b; Bushnik et al. 2010).

8.1 Consumer Products

Until the 1960s, lead was added in significant quantities (ranging from 10%–50%) to household and industrial paints (ATSDR 2007b; CMHC 2009). However, regulatory actions in Canada now strictly limit the lead content of consumer paints and surface coating materials. Despite decreased lead levels in newer paints and surface coating materials, opportunities for lead exposure from these sources still exist, as many older buildings may contain older paints and coatings. Lead-based paint remains a potentially significant source of exposure for those living in older homes (U.S. EPA 2010a).

Regarding other consumer products in Canada, despite stringent regulatory controls introduced in Canada, lead may be present in inexpensive jewelry. General use art supplies such as inks, dyes, paints and pastels, wax crayons, and leaded glazes for pottery or glassware may also contain lead pigments. There is a limit of 90 mg/kg total lead for all children's paints, crayons, chalks, modeling clays and similar art materials imported or sold in Canada. Artists' paints contain a much wider range of pigments than children's paint and are therefore more likely to include lead pigments (Health Canada 2009a). Lead crystalware is still used for serving beverages and may be a source of lead exposure (Health Canada 2009a). Lead is present in certain other products used in recreational activities, such as casting fishing weights, diving weights, miniature soldiers and other collectors' figurines, soldering materials, stained glass components, leaded glazes for pottery, glassblowing materials, and screen printing inks (Grabo 1997). There are strict regulatory limits in Canada for domestic manufacture, importation and sale of traditional products and cosmetics. However, there are some specialised products that may be brought into the country for personal use, which may contain lead (Health Canada 2010; U.S. CDC 2010). Hunting with lead shot is permitted for non-wetland migratory game birds, small animals, and game birds that are managed under provincial and territorial legislation (e.g., grouse, ptarmigan and turkey), as is large game hunting with lead bullets, and this may be a source of lead exposure of humans through consumption of wildlife.

8.2 Food

While there are no permissible uses for lead in food in Canada, it has been detected in a variety of foods. Lead is primarily introduced to foods through uptake from soil into plants and deposition onto plant surfaces. For example, leafy vegetables grown in lead-bearing soil will contain lead within their leaves and have lead-containing particles on their surface (ATSDR 2007a). Lead uptake into plants and silage from fertilizer and supplement products may also occur, further augmenting lead exposure. Fish can absorb lead from water and sediments, whereas other animals may be exposed to lead through the foods they eat (Health Canada 2011a). Additionally, lead may be introduced to foods during transport to market, processing, and kitchen preparation, including cooking with water contaminated with lead or using lead-containing utensils and storage of food in vessels (e.g., lead-glazed ceramic foodware and lead crystalware) containing lead (U.S. EPA 1986; Health Canada 1992; ATSDR 2007b). Lead concentrations in foods in the Canadian marketplace are currently low. Based on analyses of lead in numerous foods sampled as part of Health Canada's Total Diet Studies, estimated lead intakes from commercial foods have declined significantly since the phase-out of lead use by the food processing industry, in particular the phase-out of lead-soldered cans in Canada in the early 1980s, and in most imported products by 1990.

Traditionally harvested foods are a very important part of life for many Canadians, particularly First Nations and Inuit, and they can account for a significant proportion of their dietary protein. If lead shot is used in harvesting traditional foods (permitted except for hunting migratory birds and for use in wetlands), the quantity of potentially contaminated meat being consumed could be much greater than for the general population consuming market meats. This has been shown to directly affect the body-burden of lead for Aboriginal peoples, which is a potentially serious public health issue (Tsuji and Nieboer 1997; Tsuji et al. 2008a, 2009). The estimated daily intake of lead from food for all ages of the general Canadian population is approximately 0.1 µg/kg body weight. Overall, dietary exposures are generally higher for children and decrease with age (Health Canada 2011b). Based on data collected as part of the First Nations Food, Nutrition and Environment Study (FNFNES), the average daily intake of lead from food and tap water for B.C. First Nations people living on-reserve was estimated to be 0.23 µg/kg body weight (Chan et al. 2011).

8.3 Ambient Air

Concentrations of lead in ambient air are measured and reported as part of Environment Canada's nation-wide National Air Pollution Surveillance (NAPS) program, which is delivered via a cooperative agreement among the federal, provincial, territorial and some municipal governments. Chemical analyses of particulate matter samples are conducted at the Environment Canada laboratories in Ottawa. These data have shown that concentrations of lead in ambient air in Canada declined significantly following the introduction of unleaded gasoline in Canada in 1975 and the prohibition of leaded gasoline for use in on-road vehicles in the 1990s. Average concentrations of lead declined by more than 99% between 1984 and 2008 (Environment Canada 2010c). In addition, the imposition of greater controls on lead mining and smelting emissions further reduced concentrations of lead in ambient air such that average concentrations are now consistently below 0.02 $\mu g/m^3$.

Leaded gasoline is permitted in fuels used in small aircraft with piston engines. This use continues to be a source of lead in ambient air and is currently the largest single source of lead emissions into air, comprising approximately half of the national inventory of lead released to air in the United States (U.S. EPA 2010b). Lead concentrations in air increase with proximity to airports where piston-engine aircraft operate (U.S. EPA 2010c). In a study conducted in North Carolina, children living within 500 and 1000 m of an airport where leaded aviation gasoline was used had higher blood lead levels than did other children (Miranda et al. 2011). In Canada, based on the NPRI data, as industrial releases of lead have declined, the contribution of lead releases to air from aircraft to total releases has increased, rising from approximately 9% in 2000 to approximately 17% in 2009.

8.4 Soil

Natural concentrations of lead in soils reflect the geology of the area. Soils and sediments act as primary environmental sinks for lead compounds. Given the historical dispersive uses of lead, it is found in virtually all surface soils and can remain there indefinitely. Lead concentrations in soil tend to be higher in cities, near roadways, around industrial sources that use or release lead, near weapon firing ranges, or next to homes, buildings and structures such as lighthouses where crumbling leaded-based paint has fallen into the soil (CMHC 2009). Lead-contaminated soil can be tracked into residences and can contribute significantly to the lead content of indoor settled dust and to exposure of the occupants. Mean concentrations of lead in soil samples collected from residential areas and parklands in Canada range from 35.6 to 766 mg/kg; the majority are below the current Canadian Council of Ministers of the Environment (CCME) *Canadian Soil Quality Guidelines for the Protection of Human Health and the Environment.* Historically, there has been a strong association between blood lead levels in children and soil lead concentrations (Mielke et al. 1997, 2007; Mielke 1999), especially in cases of behaviour involving eating non-food items (LaGoy 1987; Mielke et al. 1989). One recent study conducted in North Hamilton found that modeling a doubling of lead concentrations in garden soil resulted in a 0% to 12% increase in blood lead levels in children (Richardson et al. 2011).

8.5 Indoor Air and House Dust

Canadians spend up to 90% of their time indoors, at home, at school or in the workplace (Leech et al. 1996). Therefore indoor environments have the potential to be a significant source of exposure for Canadians. Studies have frequently implicated household settled dust as a major source of lead exposure through ingestion, particularly for infants, toddlers, preschoolers and young children (Rabinowitz et al. 1985; Lanphear et al. 1996a, b, 1998; Manton et al. 2000; Roy et al. 2003). Potential sources of lead contamination of indoor settled dust can vary and includes exterior contaminated soil, deteriorating paint containing lead, home renovations involving paint removal by dry scraping, sanding or open flame burning, consumer products, various hobbies such as welding, soldering and stained-glass making, and activities such as smoking (HUD 2001; Jacobs et al. 2002; Sanborn et al. 2002).

Lead contamination of indoor settled dust can arise from outdoor sources such as lead-contaminated soil (Hertzman et al. 1990; Adgate et al. 1998). Houses in proximity to point sources of lead, such as a smelter or a contaminated site, can display elevated concentrations of lead in house dust (Hertzman et al. 1990; von Lindern et al. 2003; Spalinger et al. 2007). Dust contaminated with lead can also be generated during renovations in which lead-based paint is removed (Farfel and Chisolm 1990; HUD 2001), and hence renovation activities can directly affect blood lead levels in children (U.S. CDC 2009a) as well as adults. Removal or remediation of the source of lead contamination has been demonstrated to result in reduced lead concentrations in indoor dust, which directly reduced blood lead levels in resident children (Lanphear et al 2003). The Canadian House Dust Study showed concentrations of bioaccessible lead in house dust samples ranging from 7.9 to 3,916 mg/kg, with median and geometric mean concentrations of 63 mg/kg and 74 mg/kg, respectively (Rasmussen et al. 2011). A relationship between lead concentrations in household dust and blood lead levels has been noted in recent studies, particularly with respect to floor and window dust (Dixon et al. 2009; Bell et al. 2011; INSPQ 2011) and renovation dust (Dixon et al. 2009).

Rasmussen et al. (2006) reported lead concentrations in indoor air ranging from 0.0004 to 0.0027 $\mu g/m^3$, and from 0.001 to 0.0051 $\mu g/m^3$ in non-smoking rural and urban residences, respectively. A recent Canadian study investigating lead concentrations in indoor and outdoor air reported median lead concentrations ranging from 0.001 to 0.010 $\mu g/m^3$, the highest levels being found in outdoor air (Rasmussen et al. 2009).

8.6 Drinking Water

Drinking water is a source of exposure to lead. Lead may be introduced into drinking water as a result of dissolution from lead service lines, lead-based solders used to join copper pipes within homes and buildings, and plumbing fittings and faucets made of lead-containing brass components. This dissolution is the result of corrosion and can be caused by several factors, including the type of materials used, the age of the piping and fittings, the stagnation time of the water, and the water quality in the system (including its pH and alkalinity). Changes in water chemistry resulting from the use of chloramine in water systems with lead service lines and other lead-containing plumbing materials, such as brass and solder, may also increase the amount of dissolved lead in water (Edwards et al. 2009; Health Canada 2009b). Regulatory measures to prohibit the use of lead in service lines and solder have been put in place in Canada over the past decades. It should also be noted that the use of lead as a chemical stabilizer in polyvinyl chloride components for drinking water distribution systems and plumbing materials is no longer permitted in Canada. Nonetheless, pre-1990s distribution systems and plumbing materials may still be a source of lead in domestic tap water. Various municipal and provincial surveys across Canada indicate that concentrations of lead in drinking water at the point where the water leaves the treatment facility are generally less than 1 µg/L. Generally, tap concentrations above this value indicate that the lead concentrations are primarily related to lead containing materials in the distribution system (e.g., lead service lines) and in the plumbing system. In the various surveys, average concentrations at the tap are below the drinking water guideline for lead, which is a Maximum Acceptable Concentration (MAC) of 0.010 mg/L (10 µg/L). Nonetheless, some studies of drinking water in Canadian homes with lead plumbing materials or service lines have found concentrations in drinking water that exceeded this guideline value. Although average lead concentrations in drinking water are considered to be low (i.e., below 10 µg/L), drinking water is considered to be an important source of exposure to lead for Canadians when lead service lines or other lead-bearing materials are present in the distribution and plumbing systems. As lead concentrations in drinking water increase, water becomes an increasingly important source of exposure for children (Miranda et al. 2007; Edwards et al. 2009; Renner 2009; INSPQ 2011). One recent study conducted by the Institut national de santé publique du Québec (INSPQ) modelled the impact of lead concentrations in water on children's blood lead levels and found that a 10-fold increase in the concentration of lead in water resulted in a 23% increase in children's blood lead levels (INSPQ 2011).

9 TRACKING HUMAN EXPOSURE

It is important that governments keep track of people's exposure to lead in order to assess risks to human health and to determine trends in exposure to lead over time.

Exposure to lead is commonly evaluated using lead levels in blood. Blood lead levels in Canada are being measured as part of the on-going Canadian Health Measures Survey (CHMS). From 2007 to 2009, this study measured blood lead levels at the national level for the first time in 30 years, with the results published in August 2010 (Bushnik et al. 2010). The geometric mean blood lead level for Canadians aged 6–79 was 1.34 µg/dL. Blood lead levels tend to decline slightly during childhood and adolescence and then begin to rise again in adults, with age. Children aged 6–11 and teens aged 12–19 had the lowest blood lead levels. Older adults (aged 60–79) had the highest blood lead levels, reflecting exposure to higher environmental lead concentrations in the past and the mobilization of lead from bone into blood.

Currently there are no national Canadian data on blood lead levels for children under 6 years of age. Given the similarity of blood lead levels between Canada and the United States for other age groups, blood lead levels for children under 6 years of age from the U.S. NHANES are a reasonable surrogate for blood lead levels for Canadian children in this age group (U.S. CDC 2011). Blood lead levels increase beginning in late infancy, and peak between 1 and 3 years of age (Baghurst et al. 1987; Dietrich et al. 1993, 2001; Canfield et al. 2003a; U.S. CDC 2009b; Bell et al. 2011; Richardson et al. 2011; Zahran et al. 2011). The geometric mean and 95th percentile blood lead levels for children aged 1–5 in the 2007–2008 NHANES were 1.51 µg/dL and 4.10 µg/dL, respectively (U.S. CDC 2011). Measurement of lead concentrations in environmental media and human tissues is ongoing. The second cycle of the Canadian Health Measures Survey (CHMS 2009–2011) includes children aged 3–5 years, and the data obtained on blood lead levels in this age group will further inform risk management progress for lead.

In Canada, blood lead levels are higher in males than in females; in smokers than in non-smokers; in individuals born outside Canada than in those born in Canada; in individuals living in older homes (50+ years) than in those living in newer homes; and in residents of households with lower income levels than in those with higher income levels (Bushnik et al. 2010).

Lead was detected in almost 100% of the population, although concentrations have fallen dramatically over the past 30 years. The results of the first cycle of the CHMS (2007–2009) show a large decline—over 70%—in population blood lead levels since the 1970s. This can be attributed to the successful phase-out of lead in gasoline, lead-based paints, and lead solder used in food cans, in addition to other government regulation and industry action over the past 30 years. Fewer than 1% of Canadians aged 6–79 now have blood lead concentrations at or above the Health Canada guidance value of 10 µg/dL, as compared with approximately 27% in the 1970s (Figure 4). The geometric mean lead concentration for Canadians aged 6 to 79 measured by the current CHMS between 2007 and 2009 was about one-third of the concentration measured in the 1978–1979 Canada Health Survey for the same age group (Figure 4). Figure 5 provides further detail regarding average blood lead levels by age groupings in the 2007–2009 survey. Highlighting the efficacy of risk management measures for lead, studies in Ontario children also show blood lead levels declining with decreasing use of leaded gasoline between 1983 and 1992 (Figure 6) (Wang et al. 1997).

Figure 4. Decreasing blood lead levels in Canadians

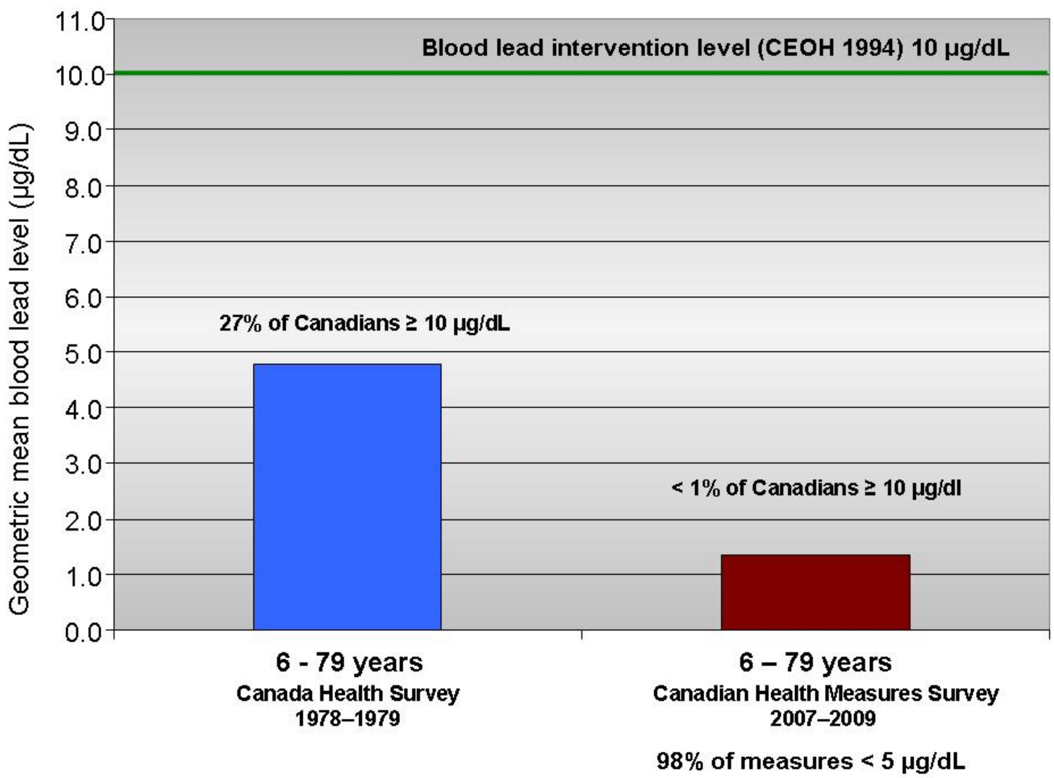


Figure 5. Blood lead levels (Canadian Health Measures Survey 2007–2009; U.S. National Health and Nutrition Examination Survey 2007–2008) Geometric mean and 95th percentile (error bars indicate 95% confidence interval)

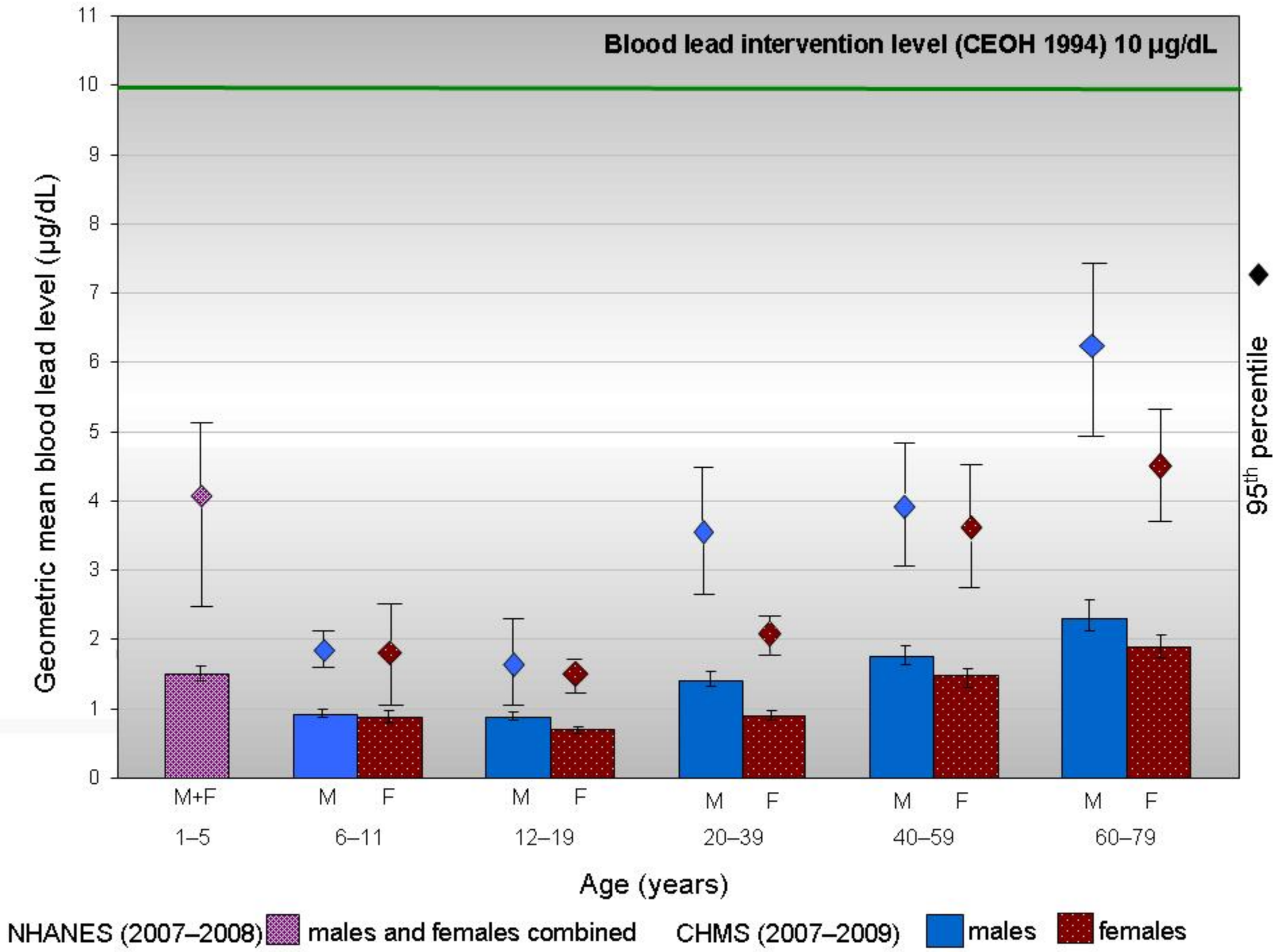
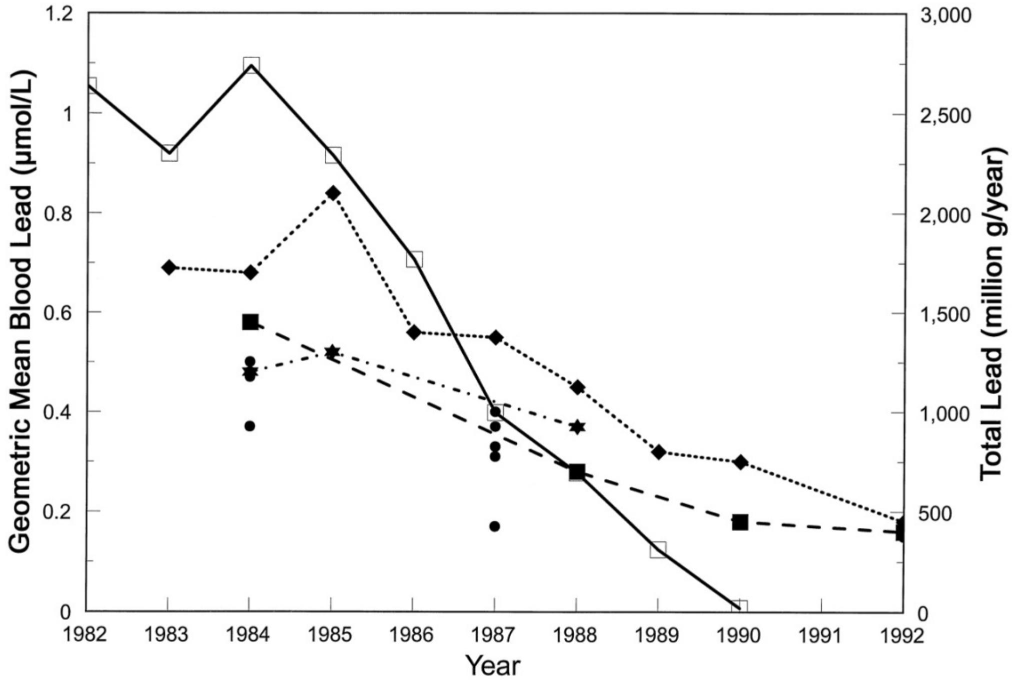


Figure 6. Decline in the geometric mean blood lead levels in children related to a decline in the lead consumed in leaded gasoline in Ontario for 1983–1992 (Wang et al. 1997)



Total lead consumed per year, (❑); blood lead levels in the Toronto Eastern Health Unit (◆), in the Toronto Western Health Unit (*), in the City of Toronto (■), and in other regions of Ontario (•).

Elevated blood lead levels have been observed in children living in Canadian communities adjoining smelters attributed to local point source contamination of lead in soil. Mean blood lead levels in children in these communities ranged from 2.70 to 5.6 µg/dL (Government of New Brunswick 2005; Trail Health and Environment Committee 2007, 2009; Intrinsik 2010).

The Northern Contaminants Program blood monitoring studies undertaken in the late 1990s showed that 3%–19% of Inuit mothers sampled in the Northwest Territories, Nunavut, and Nunavik had blood lead levels above the blood lead intervention level of 10 µg/dL. In follow-up studies conducted between 2004 and 2007, blood lead levels in mothers declined in all Arctic regions over this time period, with none of the levels exceeding the blood lead intervention level (Donaldson et al. 2010). Similar declines were noted in blood lead levels of Inuit adult men and women in Nunavik (Donaldson et al. 2010). In Nunavik, the decrease in blood lead levels in mothers has been attributed to the reduced use of lead shot for hunting traditional foods (Levesque et al. 2003). However, further research is required to better understand the potential link between decreased use of lead shot in other regions of the Canadian Arctic as a result of public health efforts and declining blood lead levels (Donaldson et al. 2010).

A health survey that serves to complement the CHMS is the First Nations Biomonitoring Initiative (FNBI). This national survey targets First Nations peoples over the age of 20 years living on reserves (south of 60^{o} N latitude). A pilot project was conducted in 2010–2011, and the full survey, comprising 13 randomly selected First Nations communities across Canada, took place in 2011–2012. This survey provides for the first time, the opportunity to determine national-level data on blood lead levels of First Nations people living on reserves and serves to elucidate additional risks to vulnerable subsets of the general population. Subsequent to this study, and contrary to the exposure profile for the general population, it has been hypothesized that a major source of lead exposure for First Nations communities is ingestion of wild game harvested using lead ammunition.

Three Canadian exposure studies, conducted from 2008 to 2010, in Montreal, Quebec (INSPQ 2011), St. John's, Newfoundland and Labrador (Bell et al. 2011) and Hamilton, Ontario (Richardson et al. 2011), examined the relationships between blood lead levels in children under 7 years of age and specific sources of exposure. Data from these studies showed geometric mean blood lead levels of 1.12 µg/dL in St. John's (Bell et al. 2011), 1.35 µg/dL in Montreal (INSPQ 2011), and 2.21 µg/dL in Hamilton (Richardson et al. 2011). Seasonal trends in blood lead levels of children in the INSPQ (2011) study have also been observed, with levels being higher in the fall than in the winter (INSPQ 2011). In the same study, blood lead levels were significantly higher in children with visible minority status than those without visible minority status.

Although there are no recent Canadian data on lead concentrations in human milk, lead will be measured in breast milk in Canadian women as part of the Maternal–Infant Research on Environmental Contaminants Study (MIREC). This national 5-year study which recruited approximately 2,000 women from 10 sites across Canada was initiated in 2008 and results are expected to be available in 2013. In addition to breast milk, the study will measure a variety of contaminants in maternal blood, urine, and hair, as well as cord blood and newborn fecal matter.

Regardless of the significant decline in Canadian blood lead levels over the past 30 years, health effects have been well documented at blood lead levels as low as 1–2 µg/dL, levels that are present in Canadians today, although there is uncertainty associated with effects observed at these levels. It is considered appropriate to apply a conservative approach when characterizing risk. Therefore additional measures to further reduce exposures of Canadians to lead are warranted. Research and monitoring, including exposure studies and measurements in Canadians of effects at low-level exposures, will continue to support the assessment and management of lead.

10 ACTIONS TO DATE

Globally, governments have undertaken a broad spectrum of regulatory initiatives, both domestically and through international collaboration, to reduce human and ecological exposure to lead and other hazardous chemicals. While progress varies from country to country, it is generally acknowledged that collectively, these measures are contributing to improvements in human health.

10.1 Existing Canadian Risk Management

The Government of Canada has implemented a wide range of regulatory and non-regulatory initiatives in collaboration with provincial and territorial governments, industry and other stakeholders as part of a comprehensive lead risk management strategy. It should be emphasized that comparable regulatory measures have been enacted across Canada under provincial, territorial and municipal jurisdictions. A summary of federal initiatives is provided in Table 1. Detailed information on each measure is provided in Annex A.

Table 1. Summary of Canadian federal risk management measures for lead

Sector	Existing risk management measure	Overarching Act
Base metals smelting	*Secondary Lead Smelter Release Regulations* (1991) – Limit the concentration of particulate matter (PM) containing lead emitted into the ambient air.	CEPA 1999
	Pollution Prevention Planning Notices in respect of specified toxic substances released from base metals smelters and refineries and zinc plants, and Environmental Codes of Practice for Base Metals Smelters and Refineries.	CEPA 1999
Mining	*Metal Mining Effluent Regulations* (updated 2006) – Establish a discharge limit of 0.2 mg/L as the maximum authorized monthly mean concentration of lead in mine effluents that discharge to waters frequented by fish.	*Fisheries Act*
	Environmental Code of Practice for Metal Mines (2009) – Designed to support the *Metal Mining Effluent Regulations.*	CEPA 1999
Iron and steel	*Environmental Codes of Practice for Integrated and Non-Integrated Steel Mills* (2001) – Contain concentration limits for lead releases in effluent and recommended release limits for particulate matter emissions.	CEPA 1999
Fuels	*Gasoline Regulations* (1990) – Limit the lead and phosphorus content of gasoline that is produced, imported or sold in Canada. Gasoline is now 99.8% lead free.	CEPA 1999
	Contaminated Fuel Regulations (1991) – Prohibit the import and export of contaminated fuel, except for the purpose of destruction, disposal and recycling.	CEPA 1999
Transport	*Export Control List Notification Regulations* (2000).	CEPA 1999
	Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations (2005).	CEPA 1999
	Transportation of Dangerous Goods Regulations (2008).	*Transportation of Dangerous Goods Act*
Consumer products	*Lead Risk Reduction Strategy for Consumer Products* (LRRS) – Proposes further limits on the lead content of consumer products with which children are most likely to interact. Action has already been taken under this strategy in the form of the *Consumer Products Containing Lead (Contact with Mouth) Regulations* (2010), the *Children's Jewellery Regulations* and amendments to the *Surface Coating Materials Regulations* (2010).	Introduced under the *Hazardous Products Act* (HPA) and now continued under the *Canada Consumer Product Safety*

Sector	Existing risk management measure	Overarching Act
		Act (CCPSA)
	Consumer Products Containing Lead (Contact with Mouth) Regulations (2010) – Limit of 90 mg/kg total lead for products whose use involves mouth contact, including all toys for children under the age of 3.	HPA/CCPSA
	Surface Coating Materials Regulations (amended 2010) – Decreased the limit for total lead content of consumer paints and other surface coatings, including those applied to toys for children, from 600 mg/kg to 90 mg/kg.	HPA/CCPSA
	Glazed Ceramic and Glassware Regulations (amended 2009) – Limit the releasable lead content of glazes, coatings or decorations on ceramics and glassware used for storing, preparing, or serving food and beverages.	HPA/CCPSA
	Kettles Regulations (amended 2010) – Limit the amount of lead that may be released when water is boiled in kettles and similar products to 0.010 mg/L (10 ppb), which aligns with the maximum acceptable concentration for lead in drinking water as per the *Guidelines for Canadian Drinking Water Quality* (1992).	HPA/CCPSA
	Corded Window Covering Products Regulations (2009) – Limit the lead content of any exterior component of the corded window coverings that could be touched or ingested by a young child to 200 mg/kg total lead.	HPA/CCPSA
	Children's Jewellery Regulations (2005) – Import, advertisement or sale of jewellery items intended primarily for children under 15 years of age permitted only if the items do not contain more than 600 mg/kg total lead and 90 mg/kg migratable lead.	HPA/ CCPSA
	Tobacco Reporting Regulations (2009) – Requires manufacturers to report on the lead content of tobacco and smoke.	*Tobacco Act*
	Migratory Birds Regulations – Only non-toxic shot can be used for hunting of migratory game birds in Canada, except for five species (woodcock, band-tailed pigeon, mourning dove, thick-billed murres and common murres).	*Migratory Birds Convention Act*, 1994
	Use of fishing sinkers and jigs weighing less than 50 g was prohibited in 1997 in National Wildlife Areas.	*Canada Wildlife Act*
	The *National Parks Fishing Regulations* (1997) prohibits the use or possession of lead sinkers and jigs under 50 g while fishing in National Parks (where sport fishing is authorized).	*Canada Parks Act*
Water and soil	*Guidelines for Canadian Drinking Water Quality* (1992)	----

Sector	Existing risk management measure	Overarching Act
quality	– The maximum acceptable concentration of lead in drinking water is 10 μg/L (10 ppb).	
	Guidance for controlling corrosion in drinking water distribution systems (2009)	----
	Canadian Water Quality Guidelines for the Protection of Aquatic Life (1999 to present)	CCME 1999
	Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses (1993 to present)	CCME 1999
	Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (1998)	CCME 1999
	Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (1999 to present; currently under revision). The *Canadian Soil Quality Guidelines* are remedial guidelines to be used at contaminated sites. The values for lead published in 1999 are 70, 140, 260, and 600 mg/kg soil for agricultural, residential/parkland, commercial and industrial land uses, respectively.	CCME 1999
Fertilizer and livestock	Standard for lead in fertilizer and supplement products.	*Fertilizers Act*
	Action level for lead in total livestock diets.	*Feeds Act*
Cosmetics, food and health products	*Cosmetic Regulations* (2002) – Lead and all its associated products are prohibited ingredients in cosmetic products. The guidance limit for lead impurities in cosmetic products is 10 parts per million (ppm), based on technical feasibility, and is currently published on the Health Canada website in draft form.	*Food and Drugs Act* (F&DA)
	Food and Drug Regulations – Defines tolerance levels for the lead content of certain foods, including tomato sauce, infant formula, and fruit juice; these tolerances, as well as additional proposed guideline levels for lead in food, are in the process of being updated and aligned, where appropriate, with the maximum limits for lead in foods established by the *Codex Alimentarius Commission*.	F&DA
	Food and Drug Regulations – Limit on lead in pharmaceuticals.	F&DA
	Natural Health Products Regulations – Guidance document. Evidence for Quality of Finished Natural Health Products (2007) limits the amount of lead in natural health products.	F&DA
Other	Blood lead intervention level (1994) (currently under revision) – Provide guidance for the management of exposure to lead in individuals and communities. Current intervention level is 10 μg/dL.	----

10.1.1 Protocols Related to Lead Management

Various federal government departments and agencies in Canada have protocols in place to minimize releases of lead to the environment. Specific information on lead management practices has been provided by the Department of National Defence and the Royal Canadian Mounted Police. These practices entail environmental maintenance and monitoring procedures regarding releases of lead and other metals of concern associated with training facilities across Canada, and they are summarized in Annex B.

10.2 Existing International Risk Management

Canadian federal risk management efforts are largely consistent with international risk management efforts. In the United States and Europe, similar regulations are in place pertaining to lead in air, drinking water, soil, foods and animal feeds, various consumer products, pharmaceuticals, pesticides, industrial releases, and hazardous wastes.

In addition, under the U.S. Lead Renovation, Repair and Painting Program Rule (2010) of the *Toxic Substances Control Act* (TSCA), certification is required and lead-safe work practices are specified for contractors performing renovation, repair, and painting projects that disturb lead-based paint in pre-1978 homes, child care facilities and schools. Certified renovators are trained by U.S. EPA-approved training providers. Lead-based paint and lead-paint hazards are legally defined, and disclosure requirements are in place for landlords renting units and for homeowners upon point-of-sale in order to prevent children under six years of age from spending time in buildings with a lead-paint hazard. Several related rules have been developed or are under development, such as the Lead-Based Paint Debris Disposal Rule.

In the United States, aircraft fuel is regulated by the Federal Aviation Authority (FAA), who prescribes fuel standards to control aircraft emissions. The U.S. EPA issued an Advance Notice of Proposed Rulemaking on lead emissions from leaded-fuelled piston-engine aircraft in April 2010. The Advance Notice requested public comment that will inform U.S. EPA's potential regulatory actions on lead emissions from this source.

The United Nations Environmental Programme (UNEP) has established the Global Alliance to Eliminate Lead in Paints. Its overall goal is to prevent exposure to lead from lead-containing paints and to minimize occupational exposure to lead in paint. The broad objective is to phase out the manufacture and sale of paints containing lead, and eventually eliminate the risks from these paints. As well as programs focusing on lead-based paint, UNEP is also undertaking further actions promoting the phase-out of lead in gasoline and other activities to prevent exposure to lead and to strengthen efforts in the monitoring, surveillance and treatment of lead poisoning.

Lead and its compounds are also the focus of a variety of international guidance levels, as described below.

10.2.1 Industrial

The World Summit on Sustainable Development (WSSD) Implementation Plan calls for a renewed commitment to sound management of chemicals throughout their life cycle, and of hazardous wastes, for sustainable development as well as for the protection of human health and the environment. Included in this mandate is the reduction of respiratory diseases and other health impacts resulting from air pollution, with particular emphasis on their occurrence in women and children. This entails supporting the phasing out of lead in gasoline and in lead-based paints and other sources of human exposure; working to prevent, in particular, children's exposure to lead; and strengthening monitoring and surveillance efforts and the treatment of lead poisoning. The overall goal is that by 2020, chemicals will be used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment. This involves the use of transparent science-based risk assessment and risk management procedures, and it also takes into account the precautionary approach, as set out in Principle 15 of the *Rio Declaration on Environment and Development*. The plan also sets out to support developing countries in strengthening their capacity for the sound management of chemicals and hazardous wastes by providing technical and financial assistance, and it promotes reduction of the risks posed by heavy metals that are harmful to human health and the environment.

10.2.2 Food/Drinking Water/Drugs/Cosmetics

There is a variety of international guidance pertaining to lead in food, drinking water and drugs. The *Codex Alimentarius* Commission has established a number of maximum limits for lead in food based on an international evaluation (JECFA) of dietary exposure to, and the toxicity of, lead. The *Codex Alimentarius* Commission has also developed Codes of Practice for the Prevention and Reduction of Lead Contamination in Foods and Source Directed Measures to Reduce Contamination of Foods. The European Commission sets standards for lead in food in the European Union. NSF International and the WHO Collaborating Centre for Food and Water Safety and Indoor Environment develop standards for the leaching of lead from materials in contact with drinking water (NSF/ANSI 61, 2011) and also for lead in dietary supplements, the limit for the latter being 0.02 mg/day (NSF/ANSI 173, 2010). This limit was used to derive the Health Canada's natural health products limit of <0.29 µg/kg body weight per day by dividing 20 µg/day by the adult male reference body weight of 70 kg. The United States passed *The Reduction of Lead in Drinking Water Act*, an amendment of *The Safe Drinking Water Act*, in January 2011. This legislation, which limits the weighted average lead content of pipes, pipe fittings and plumbing fittings to 0.25%, will become effective in January, 2014. As well, various pharmacopoeia and formularies provide international guidance for lead in foods, drugs, natural health products, food additives, and colourings. Furthermore, on-going work is being performed by the International Cooperation on Cosmetic Regulation (ICCR) working group on traces in cosmetics in order to establish acceptable levels for lead impurities in cosmetic products.

It is notable that in 2010 JECFA (2010) withdrew its PTWI (*Provisional Tolerable Weekly Intake*) for lead of 25 µg/kg body weight applicable to both children and adults. It was concluded that it was not possible to establish a new intake value that would be health-protective.

10.3 Canadian Participation in International Initiatives

Recognizing the advantages of collaborative activities regarding risk assessment and management of lead, the Government of Canada is actively engaged in a number of relevant regional and bilateral programs. These include the following:

- The Great Lakes Water Quality Agreement, which commits Canada and the United States to restore and maintain their shared Great Lakes ecosystem (Environment Canada 2010d). Joint initiatives related to the agreement include the 1997 Great Lakes Binational Toxics Strategy, a multi-sectoral process that sets release reduction targets towards "virtual elimination" of certain persistent toxic substances, including alkyl-lead, from human activity in the region. Significant reductions in atmospheric loadings of lead in the Great Lakes region have been achieved under this program to date.

- The Arctic Council is a high-level intergovernmental forum among Arctic states and communities that addresses issues such as sustainable development and environmental protection. Council working groups undertaking work on lead include the Arctic Monitoring and Assessment Programme, which includes a focus on lead biomonitoring and ambient monitoring.

At the global level, Canada is party to a number of international conventions that relate directly or indirectly to lead. These include the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal*, which aims to protect human health and the environment from adverse effects resulting from the generation, management, storage, transboundary movement and disposal of hazardous wastes, including lead. Canada is also party to the Protocol on Heavy Metals to the United Nations Economic Commission for Europe's (UNECE) *Convention on Long-Range Transboundary Air Pollution*, which aims to reduce emissions of mercury, lead and cadmium from industrial sources, combustion processes and waste incineration. The UNECE region includes Europe, the Russian Federation, and Central Asia. Both the United States and Canada are Parties to the Protocol.

Canada also participates in global activities related to lead within UNEP, which since 2005 has included a review of scientific information in order to inform continued discussions on the need for (and appropriate nature of) global action. Since 2007 Canada has been party to UNEP activities proposed to assist and advise developing countries with a legacy of lead in gasoline or from other sources. Canada participates in UNEP's Partnership for Clean Fuels and Vehicles which assists developing countries in reducing vehicular air pollution through the promotion of lead-free, low-sulphur fuels and cleaner vehicle standards and technologies.

The Organisation for Economic Cooperation and Development (OECD) Declaration on Risk Reduction for Lead (1996) pledges its support to continue cooperation among member countries on risk reduction efforts, to monitor the environment for lead concentrations, to work with industry in implementing voluntary risk reduction activities, to share information on lead exposure among all countries, and to continue to raise the issue of lead exposure at an international level. Canada, Mexico and the United States are all OECD members. Subsequent to the signing of the Miami Declaration in 1997, the G7/G8 Environment Leaders, which include Canada and the United States, committed to fulfill and promote the OECD Declaration on an international level. Among various commitments regarding lead, agreement was reached by each of the member countries to develop and share individual country actions to accomplish the goals of the OECD Declaration, in particular, further actions that will result in reducing blood lead levels in children to below 10 µg/dL. The Declaration also cites the importance of maternal exposure to lead to child health and the benefits to child health of reducing maternal exposure. Parties also agreed to share information regarding lead hazards in toys and other products to which children might be exposed, including imported products, and to consider joint actions as appropriate. As well, they have agreed to provide access, on a timely basis, to new technological developments on blood lead-level testing.

Canada is a Party to the *Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade*. This Convention aims to ensure that chemicals and pesticides subject to the PIC procedure are not exported to Parties to the Convention unless the importing Party has provided its "prior informed consent" to the shipment. Canada administers and enforces the *Export of Substances under the Rotterdam Convention Regulations* to implement its obligations under this Convention. These regulations apply to the export of CEPA 1999 Schedule 3 substances, which include certain lead-containing chemicals, to other Parties to the Convention.

Regarding food issues, Canada participates in the Joint FAO/WHO Expert Committee on Food Additives (JECFA) on exposure to hazardous chemicals, including lead, in foods. Canada often considers JECFA assessments in the development of its own national evaluations. Canada also participates in the development of NSF International standards for drinking water and WHO drinking water guidelines.

11 MOVING FORWARD—ELEMENTS OF A CANADIAN APPROACH

The Government of Canada, while recognizing the progress that has been made in reducing domestic releases of lead, is committed to taking further actions to ensure that it makes an ongoing contribution to the reduction of lead exposure. This risk management strategy reflects that commitment and outlines further actions currently under consideration by the Government of Canada. In identifying and designing these proposals, the Government of Canada has considered a variety of factors.

11.1 Alternative Chemicals and Technologies

There are on-going comprehensive efforts in Canada and international jurisdictions to manufacture products with replacements for lead, thereby minimizing or eliminating the presence of lead in these products. Suitable substitutes would vary according to the item of manufacture. For example, lead solder has been replaced with mixtures of tin, antimony, copper, and, for food-grade applications, silver. Lead in paint has also been widely replaced with mixtures of titanium, silicon, zinc, and aluminum. Lead in brasses used for plumbing fittings is being replaced with mixtures of selenium and bismuth. In the manufacture of shotgun shells, products made from steel, bismuth, zinc, tin, tungsten, molybdenum, and several alloys of these metals, are available instead of lead. In the case of lead sinkers and jigs, there are a number of alternative products available on the market, such as limestone, steel, and tungsten fishing sinkers. With respect to lead wheel weights, steel or other metal alloys can be used instead of lead. It is important to note that many of these substitutes have not undergone an assessment to determine whether they meet the criteria for toxicity under CEPA 1999.

In Canada, as elsewhere, risk management activities have required the adoption of pollution prevention and control technologies by lead-releasing industries such as base metals mining and smelting, and steel manufacturing. There is also a ban on leaded gasoline for use in on-road vehicles. All these actions have resulted in significant decreases in releases of lead to the environment.

11.2 Socio-Economic Considerations

Lead exposure in Canada imposes a variety of socioeconomic costs on Canadians, reducing the effectiveness of the workforce and increasing medical costs, as well as other impacts of poor health on quality of life. The analysis presented here quantifies the socio-economic costs of reduced IQ as a result of early childhood exposure to lead.

Exposure to lead can result in a number of health problems, such as neurodevelopmental, neurodegenerative, cardiovascular, renal, and reproductive effects.[3] The strongest weight of evidence is related to children's intellectual development, most commonly observed as reduced IQ scores and attention-related behaviours with increasing blood lead levels.

In this analysis, the socio-economic burden caused by early childhood lead exposure in Canada is estimated as the present value of foregone lifetime earnings resulting from reduced intellectual development.[4] The estimated range of the impact is from $1.5 billion to $9.4 billion (2010 Canadian dollars) per year. Viewing this estimate from a social welfare perspective, the assumptions and analysis described below indicate that an economic benefit valued at over $9 billion per year could be gained if the exposure of Canadian children to lead could be eliminated.

Key factors in estimating the economic impact of lead exposure on Canadian children include:

- average blood lead level of Canadian children;
- blood lead level used as the basis for comparison with current levels;
- impact of exposure on intellectual development (as measured by IQ);
- effect of changes in IQ on lifetime earnings;
- expected future earnings and discount rates used to calculate their present value; and
- number of Canadian children exposed each year.

Issues involved in defining and measuring these parameters are discussed below. It should be noted that this analysis relies on population averages of blood lead levels, IQ and lifetime earnings. Across the population, blood lead levels and economic variables for any particular child may differ significantly from the average.

The impacts of lead on intellectual development, and hence on lifetime income, are most significant for early childhood exposure. Although there are currently no national measures of blood lead levels for Canadian children under 6 years of age, levels for this age group from the US's 2007–2008 NHANES can be used as proxy data, given that levels for other age groups in Canada and the United States are comparable. In the United States, the geometric mean blood lead level for children 1–5 years of age is 1.51 µg/dL.[5] This analysis thus proceeds on the assumption that the average Canadian child under 6 years of age has a blood lead level of 1.51 µg/dL.

[3] See Section 3 for a discussion of health effects. Due to difficulties in quantifying other health effects, they are not included in this analysis and, as a result, the estimates presented here for costs associated with early childhood exposure to lead may underestimate the total socioeconomic burden of lead exposure in Canada.

[4] The methodology used here for estimating the annual economic burden of lead impacts is based on Muir and Zegarac (2001), Grosse et al. (2002) and Nevin et al. (2008).

[5] As indicated by Bushnik et al. (2010), blood lead levels for 6 to11 year olds were 0.9 and 1.0 µg/dL, as measured by the CHMS and NHANES respectively; for 12 to19 year olds blood lead levels were 0.8 µg/dL in both CHMS (2007–2009) and NHANES (2007–2008). Thus levels were essentially the same between the two nationally representative surveys in these other age groups. Blood lead levels for Canadian 3 to 5 year olds from the 2009–2011 CHMS will be available in 2013.

To estimate the impacts of average blood lead levels, this analysis compares current exposure levels with a hypothetical zero blood lead level. It should be noted that a zero exposure level is used here only as a basis for comparison. In practice, children are exposed to lead from numerous sources, and even if exposure to lead resulting from human activity were reduced to zero, children could still be exposed to naturally occurring sources of lead. A zero blood lead level is, therefore, not an attainable target. However, it is used here for illustrative purposes to estimate the total impact of lead from all sources (both human and natural) on the lifetime earnings of Canadians.

To define the impact of lead exposure on IQ, this analysis follows the methodology used by the California Office of Environmental Health and Hazard Assessment (OEHHA) (OEHHA 2007), which concluded that each 1 µg/dL increase in blood lead level is associated with a 1 point decrease in IQ on a population basis.[6] Applying the OEHHA relationship to the scenario considered here, in which the average blood lead level for children under 6 years of age decreases from 1.51 µg/dL to 0 µg/dL, gives a predicted average increase in IQ of 1.51 points.

There is evidence showing negative impacts of lead exposure on human health and intellectual development at very low levels of exposure and, indeed, dose-response modeling conducted with available observational studies does not currently demonstrate a population threshold for developmental neurotoxicity. It is also accepted that the dose-response relationship varies depending on the level of exposure and has yet to be precisely defined at the lowest levels of exposure. As a result, the OEHHA's position, that the relationship between blood lead levels and IQ is approximately linear may be subject to revision in future, and its use here slightly increases the overall uncertainty in the estimates presented.

Average Canadian lifetime earnings have been calculated using Statistics Canada data on gross wages for the year 2005 and then adjusted for inflation and increases in real productivity (1.58% per year) to the year 2010. The annual increase in productivity is held constant over an assumed working lifetime that spans from 15 to 67 years of age, inclusive. Using these parameters, the total lifetime earnings for the average Canadian child born in 2010 are expected to be $3.6 million.[7] Since income earned in the future is generally not valued as much as income earned today, the present value of future earnings is typically calculated by applying a discount rate to account for time preferences and lost interest. If future lifetime earnings of $3.6 million are discounted at 3% per year, their present value would be $980,449. If the same future earnings are discounted at 8%, their present value would be $158,383.[8]

If exposure to lead for children under 6 years of age is reduced from 1.51 µg/dL to 0 µg/dL, then the average child's IQ would be expected to be 1.51 points higher upon entering school. To

[6] The OEHHA relationship does not differ greatly from the -1.2 relationship used by EFSA (2010), but it is slightly more conservative.

[7] *Industrial Economics* (unpublished report submitted to Health Canada). The values also include the probability of survival at each age.

[8] For revenue streams of a purely financial nature, such as industry profits, the present value of future income is typically discounted based on the expected rate of return on capital investments, or about 8% per year. For future benefits that are more social in nature (such as intergenerational improvements in health and environment), a much lower "social discount rate" of around 3% is more common. In this analysis, the benefits are financial in nature, but the context is more focused on social benefits and intergenerational equity. Therefore, the analysis will be done using both 3% and 8% discount rates. From a social welfare perspective, the 3% rate should generally be considered the more appropriate of the two.

calculate the effect of IQ on lifetime earnings, this analysis follows Grosse et al. (2002) in estimating that each 1 point increase in IQ increases lifetime earnings by 1.66%. Multiplying the expected increase in IQ by the percentage change in expected earnings per IQ point (1.51 x 1.66%) would result in an approximately 2.5% increase in average lifetime income per child. This increase in earnings would mean that an average child in this scenario would earn $91,315 more over the course of his or her lifetime. Discounted at 3% per year, the present value of the expected average increase in lifetime earnings would be $24,576 per child. Discounted at 8%, the present value of the expected average increase in lifetime earnings would be $ 3,970 per child.[9]

Finally, to determine population impacts, expected average changes in lifetime earnings per child are multiplied by the number of children affected. From July 1, 2009 to June 30, 2010, Statistics Canada reported that there were 383,585 babies born in Canada.[10] Multiplying the expected increase in undiscounted average earnings by the 383,585 children born in that year gives a total value of $35 billion. In other words, reducing childhood blood lead levels from 1.51 µg/dL to 0 µg/dL would generate an additional $35 billion in production for the Canadian economy, spread out over the working lives of this cohort. If another 383,585 children are born each year, reducing the blood lead levels of each cohort to 0 µg/dL would generate an additional $35 billion worth of production over the working life of each cohort. If the present value of this additional productivity is calculated at a 3% per year discount rate, reducing the blood lead levels of Canadian children from 1.51 µg/dL to 0 µg/dL would save the Canadian economy $9.4 billion per year. If this additional productivity is discounted at 8% per year, its present value would be $1.5 billion per year.

11.3 Children's Exposure and Exposure of Other Vulnerable Populations

The Government of Canada considered, where available, risk assessment information relevant to children's exposure to lead. Given the information available, it is proposed that additional risk management actions to specifically protect children are warranted for this substance, particularly in view of its neurological effects. As well, because maternal bone and blood lead are major sources of exposure for the developing fetus, women of childbearing age are, by extension, susceptible to the effects of lead exposure. Current knowledge also suggests that children, aging adults and those with particular health problems such as hypertension, chronic kidney disease, diabetes, and nutritional deficiencies, are similarly at increased risk for specific health effects related to lead exposure, and therefore would be considered within the "vulnerable" category. Biological variations such as gender, disease state, nutritional state, genetics and ethnicity can also influence the absorption of lead or the severity of the effects observed. Hence, the following individuals are considered to be susceptible subgroups: children, males, aging adults, pregnant women, non-Caucasians and people suffering from hypertension, chronic kidney disease, diabetes, and nutritional deficiencies. Selection of infants and children as a susceptible subpopulation and neurodevelopmental effects as the critical health effect is considered protective for other adverse effects of lead across the entire population. Children and infants of families who harvest wild game using lead ammunition, particularly Aboriginal peoples, are at risk for elevated lead exposure through regular consumption of lead-contaminated dietary protein (Greensher et al.1974; Tsuji et al. 2008b).

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[9] *Industrial Economics* (unpublished report submitted to Health Canada).

[10] Statistics Canada. "Births: Estimates by Province and Territory."
Available from: www.statcan.gc.ca/tables-tableaux/sum-som/101/cst01/demo04a-eng.htm

12 WHAT IS OUR MANAGEMENT OBJECTIVE?

The proposed risk management objective for lead is to provide continuing support for existing management actions under the Canadian federal *Risk Management Strategy for Lead*, and to pursue additional management measures to reduce exposure to lead, and hence associated risks, to the greatest extent practicable.

13 PROPOSED RISK MANAGEMENT

In order to achieve the risk management objective, the Government of Canada is focusing its efforts and resources on reducing exposure to lead in ways that make the most difference for population health over the long term. In accordance with this, the risk management being considered for lead includes the initiatives described below.

13.1 Food

Health Canada will update the tolerance levels for lead in foods in the *Food and Drug Regulations* and align them, when appropriate, with the maximum levels for lead in food in the *Codex Alimentarius Commission.*

Since dietary exposure to lead should be reduced to as low as reasonably achievable (the ALARA principle), this will prompt an increasing focus by Health Canada on establishing whether or not a food is contaminated beyond what is considered good production and manufacturing practice. There will also be increasing emphasis on the identification and control of potential point sources of lead in the diet (i.e., reducing the use of lead shot) which is particularly appropriate for managing lead exposure through wild harvested sources of dietary protein for Aboriginal peoples. Specifically, this would entail risk communication and education in First Nation communities and also discussions with ammunition distributors toward facilitating a voluntary ban on the use of lead ammunition. Voluntary bans have been achieved through similar means by the public health authorities of Nunavik, as well as Alaska. In Alaska, a subsidy to offset the cost of alternative ammunition was also included as an incentive. Health Canada is currently exploring options to minimize the use of lead ammunition for hunting with the intent of consuming the harvested foods.

13.2 Drinking Water

Health Canada will be reviewing the lead guideline in the *Guidelines for Canadian Drinking Water Quality.* This review will specifically address exposure from drinking water, including sampling and monitoring strategies. The guideline review will be conducted in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water, and it will include peer review and public consultation. Lead exposure from drinking water can occur as the result of leaching of lead-bearing materials such as plumbing fittings. An important consideration for reducing exposure to lead is to address leaching from these materials through health-based and plumbing standards. Health Canada has been an active participant on the technical committee for the ASME A112.18.1/CSA B125.1 (CSA 2011a) and CSA B125.3 (CSA 2011b) standards. This ensures continued support for initiatives to address health-based issues, including the proposal to include requirements to reduce the lead content in fittings as a way to help reduce potential exposure to lead from fittings intended to convey or dispense water for human consumption through drinking or cooking. In addition, Health Canada has been actively participating in the development and revision of health-based NSF/ANSI standards, including a new requirement under NSF/ANSI standard 61 which became effective July 1, 2012 and reduced the limit of lead that could be leached from materials from 11 µg/L to 5 µg/L (NSF/ANSI 61, 2011).

13.3 Consumer Products

The Government of Canada has stringent lead content restrictions in place under the *Canada Consumer Product Safety Act* (CCPSA) for toys, children's jewellery, applied paints and other surface coatings on children's products, consumer paints and surface coatings, ceramic and glass foodware, kettles, and corded window coverings. The Government continues to introduce new lead content restrictions for products that are most likely to pose an exposure risk to children under its Lead Risk Reduction Strategy for Consumer Products, including toys, children's jewellery, child care products, and children's clothing and accessories. The CCPSA also includes a General Prohibition which could be used to remove any consumer product containing dangerous levels of lead from the Canadian marketplace.

13.4 Natural Health Products

A review and potential revision of the current tolerable daily limit for lead in natural health products is planned. At present, Health Canada has a tolerable limit of 0.29 µg/kg body weight per day for lead in finished natural health products (NHPs) (Health Canada 2007), which is based on the daily intake standard (0.02 mg/day) established by NSF International (NSF/ANSI 173, 2010). The onus is on the product licence holder to ensure that before a natural health product is sold, each batch is tested using suitable analytical methods to meet the specifications authorized by Health Canada. Should the amount of chemical contaminants exceed Health Canada's tolerance limits, the product is considered contaminated, and it may not be sold as it does not comply with the approved specifications. Recently, the US Pharmacopeia (USP) has proposed revised limits for elemental impurities, including lead. If these are adopted for natural health products, the current tolerable limit for lead in finished natural health products could be decreased by half. Further discussion will be required in order to determine the feasibility of a potentially lower lead limit for natural health products.

13.5 Soil

Health Canada is undertaking revision of the soil quality guidelines for lead for the protection of human health. These guidelines, which will be subject to public review and input, are being derived for lead solely for human exposure and may be used as the basis for consistent assessment and remediation of contaminated sites in Canada.

13.6 House Dust

Health Canada is undertaking the development of dust screening concentrations for a number of substances including lead, for residential as well as commercial environments that may be impacted by contaminated sites. Screening approaches will be based on results from the Canadian House Dust Study, which was designed to provide population-based percentile values for concentrations of lead and other substances in household dust. These national baseline levels will provide a basis for comparison for local residential or individual studies, and they will inform future decisions regarding management of health risks associated with lead in indoor environments.

13.7 Environmental Releases

13.7.1 Primary Base Metals Smelting

The Base Metals Smelting sector has been subject to a Pollution Prevention Plan Notice, under CEPA 1999, requiring the preparation and implementation of pollution prevention plans in respect of specified toxic substances released from the sector. Under this notice, 2008 and 2015 site-specific emission target limits for particulate matter emissions containing metals, including lead, were set. In 2011, most of the facilities had already met their 2015 target limits.

A proposed new Air Quality Management System (AQMS) has been developed under the direction of the CCME to better protect human health and the environment. The proposed new air quality management system includes the development of new Canadian ambient air quality standards, air-shed and air zone-based air quality management, and Base Level Industrial Emissions Requirements (BLIERs) for various air pollutants discharged by the various industrial sectors. For the Base Metals Smelting sector, in addition to a sulphur dioxide BLIER, a particulate matter BLIER was also developed.

The particulate matter target established in the Pollution Prevention Plan Notice and the BLIERs is expected to reduce overall particulate matter emissions from the sector by 75% from that of 2006. This reduction in particulate matter emissions will have a co-benefit in the reduction of lead emissions from primary base metals smelters.

13.7.2 Electrical Power Generation

On September 12 2011, the Government of Canada published regulations to reduce carbon dioxide emissions from coal-fired electricity generation in Canada, to take effect on July 1 2015. These regulations will require coal-fired electricity generation units within Canada to meet a stringent performance standard which, in turn, would ensure a transition from coal-fired electricity generation—which is associated with high emissions of greenhouse-gases—towards types of generation that are associated with low or no emissions of greenhouse gases, such as renewable energy, high-efficiency natural gas, or thermal power with carbon capture and storage. It is proposed that coal-fired electricity generation units would need to comply with this performance standard beginning on July 1 2015. The proposed approach is expected to result in significant reduction of not only greenhouse gas emissions, but also of air pollutants such as lead.

13.7.3 Lead-Containing Commercial Products

- Leaded gasoline for use in competition vehicles: Environment Canada, with the support of Health Canada, is conducting a 5-year review, to be completed by 2016, to assess whether further action is warranted based on science, technology and fuel replacement developments. This includes a review of actions in other jurisdictions.

- Leaded gasoline for use in aircraft: the Government of Canada will continue to monitor and support international efforts to phase out lead in aviation gasoline.

- Lead ammunition: a potential future action by Environment Canada is to gather additional information on current ammunition use and its environmental impact.

- Lead sinkers and jigs: Environment Canada will encourage the use of alternatives to lead sinkers and jigs.

- Lead wheel weights: Environment Canada will investigate the need for actions to encourage the use of alternatives to lead wheel weights in Canada.

- Lead sheeting in the building industry: Environment Canada will study this issue in the Canadian context, and if warranted, will engage with the building industry in examining the use of alternatives to lead sheeting in Canada.

13.8 Blood Lead Guidance

The Federal-Provincial-Territorial *Committee on Health and the Environment* (CHE) is revising the 1994 *Update of Evidence for Low-Level Effects of Lead and Blood Lead Intervention Levels and Strategies*. The revised guidance will provide health care practitioners and public health officials with guidance on choosing actions that are appropriate for the management of specific blood lead levels. Anticipatory and preventive measures that can be taken to effectively decrease blood lead levels at the individual, sub-population and community level will be proposed for use, when interventions to reduce atypical exposures to lead are indicated.

14 SCIENCE IN SUPPORT OF DECISION-MAKING

There remain areas associated with lead toxicity and its impact on human health and the environment that merit further research. Additional characterization of sources of exposure and exposure levels for Canadians, as well as toxicity at relatively low blood lead levels, would be beneficial. Further quantification of infant exposure through maternal placental transfer, breast milk and formula, exposure through household dust, migration of bone lead at various life stages in particular during pregnancy, and measures to minimize mobilization of skeletal lead, are warranted. In particular, sources of lead in indoor settled dust require additional focus. Information generated by this research will assist in efforts to mitigate the health effects of lead. Consideration should be given to special requirements related to risk management of lead in First Nations and Inuit communities, as well as northern or remote communities.

Health Canada is continuing to contribute to work undertaken to improve the understanding of the impact of indoor air quality on human health. In 2009, information regarding ongoing research focused on improving the accuracy of exposure assessments for particulate-bound metals in urban environments was presented at the annual Metals in the Human Environment Strategic Network (MITHE) symposium (MITHE 2009). The results of this on-going work, which include an investigation of factors and sources affecting measurement uncertainty associated with monitoring metals in airborne particulate matter, are presented in Niu et al. (2010).

15 MEASURING PROGRESS

As part of a consolidated risk management strategy, Health Canada and Environment Canada will develop a systematic process for measuring progress in minimizing Canadians' exposure to lead to the greatest extent practicable. This performance review process will cover the extensive network of risk management actions established and updated over the past four decades, and it will include new and amended actions as they come into force. A performance review report will be produced regularly and will reflect new data and/or data sources.

Existing accountability mechanisms provide the starting point for a comprehensive review of federal risk management actions on lead. *CEPA 1999 Annual Reports* (www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=39419FFB-1) provide information on reductions in sources, uses and releases, while *Progress Reports on Pollution Prevention Planning by Base Metals Smelters and Refineries and Zinc Plants* (www.ec.gc.ca/planp2-p2plan/default.asp?lang=En&n=F02C15C9-1) report on releases of hazardous chemicals, including lead.

Comprehensive performance measurement will use data from ongoing research and monitoring programs and pollutant inventory data to highlight relationships between human actions and their consequences, as reflected in environmental conditions and human health. Specifically, performance measurement will examine links among economic drivers of lead pollution and exposure, levels of lead contamination in universal media of exposure, baseline biomonitoring data, associated health endpoints and selected measures of socioeconomic well-being, situating these variables in relation to risk management strategies over time to illustrate cycles of causality, as far as currently available evidence allows.

Performance measurement will focus on key relationships in the causal chain of events that risk management actions seek to influence and examine relationships among projected impacts to build an understanding of progress on the human health and risk management objectives for lead. Where sufficient evidence is not yet available to establish cause and effect relationships with confidence, individual indicators of socioeconomic factors, pollution levels and health outcomes can help to chart progress to date and point to future challenges in minimizing Canadians' exposure to lead.

This performance review process will help the Government of Canada effectively measure its progress in protecting the health of Canadians and their environment from the impacts of exposure to anthropogenic sources of lead, now and in the future.

16 REFERENCES

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ANNEX A—EXISTING CANADIAN RISK MANAGEMENT

A.1 Industrial Sources

A.1.1 Base Metals Smelting and Refining

In 2006, under the *Canadian Environmental Protection Act, 1999* (CEPA 1999), Environment Canada published in the *Canada Gazette*, Part I, a "Notice requiring the preparation and implementation of pollution prevention plans in respect of specified toxic substances released from base metals smelters and refineries and zinc plants" (2006). The Pollution Prevention (P2) Planning Notice established reduction targets for 2008 and 2015 for sulphur dioxide and particulate matter. It was expected that reductions in particulate matter as a result of the P2 Planning Notice would result in reduced emissions of lead and other metals. In the preparation and implementation of P2 plans, facilities are required to take into consideration a number of factors, including the recommendations of the Environmental Code of Practice for Base Metals Smelters and Refineries (2006), which recommends that each facility develop emission reduction targets for various substances, including lead. The Code also contains guidelines for lead releases in effluent. An amendment to the P2 Planning Notice requiring facilities to provide additional detail in reporting progress was published in the *Canada Gazette* on June 11 2011.

A.1.2 Secondary Lead Smelters

The *Secondary Lead Smelter Release Regulations* were originally published in 1976 under the federal *Clean Air Act,* and later rolled into CEPA 1999. The regulations apply to facilities conducting secondary lead smelting, which is the chemical reduction of recycled lead compounds, and set limits on the concentration of total particulate matter containing lead emitted into ambient air from these smelters. In 2009, Environment Canada undertook a study to review the secondary lead smelting sector in Canada, as well as to assess its performance against the *Secondary Lead Smelter Release Regulations* and compare this performance with other jurisdictions. It was noted that although the current limits in the *Secondary Lead Smelter Release Regulations* are less stringent than those in US, European and Canadian provincial regulations, the secondary smelters are reporting emissions that are consistent with these more stringent limits.

A.1.3 Mining

The *Metal Mining Effluent Regulations* under the *Fisheries Act* (updated 2006) establish a discharge limit of 0.2 mg/L as the maximum authorized monthly mean concentration for lead in mine effluents that discharge to waters frequented by fish. These regulations require sampling of effluent and the submission of quarterly and annual reports of the results. The results are published in an annual report that is distributed to representatives of industry, provinces, territories, and environmental non-governmental organizations.

The Environmental Code of Practice for Metal Mines, published in 2009, is designed to support the *Metal Mining Effluent Regulations* and identifies best practices to facilitate continual improvement in the environmental performance of mining facilities throughout the mine life cycle. Other federal initiatives in place to manage potential environmental concerns from tailings and waste rock include the Mine Environment Neutral Drainage Program and the National Orphaned/Abandoned Mines Initiative.

A.1.4 Iron and Steel

Environmental Codes of Practice for Integrated and Non-Integrated Steel Mills (2001), which contain concentration limits for lead releases in effluent, are also in place under CEPA 1999. The Codes also contain recommended release limits for particulate matter emissions and note that effective control of particulate emissions will result in attendant reductions of metal emissions.

A.1.5 Fuels

The *Lead-Free Gasoline Regulations* were published in the *Canada Gazette*, Part II, in November 1973. Starting July 1974, the regulations set a maximum concentration of 0.06 g per imperial gallon of lead in gasoline that could be represented as lead-free or as having had no lead added. The *Leaded Gasoline Regulations* were published in the *Canada Gazette*, Part II, in August 1974, and specified as of January 1976, a 3.5 g per imperial gallon maximum concentration of lead in gasoline. Then in 1990, the *Gasoline Regulations* replaced the *Leaded Gasoline Regulations* and the *Lead-Free Gasoline Regulations*, essentially eliminating lead in gasoline in Canada. Until 2008, the *Gasoline Regulations* provided an exemption for leaded gasoline used in farm machinery, boats and trucks over 3,856 kg. Currently, the *Gasoline Regulations* under CEPA 1999 continue to limit the lead and phosphorus content of gasoline that is produced, imported or sold in Canada. Leaded gasoline for use in aircraft and for use in competition vehicles is permitted. With respect to leaded gasoline for use in competition vehicles, Environment Canada, with the support of Health Canada, is conducting a 5-year review, to be completed by 2016, to assess if further action is warranted based on science, technology and fuel replacement developments. A work plan for the 5-year review is available upon request (Oil, Gas and Alternative Energy Division, Environment Canada). As for the use of leaded gasoline in aircraft, the Government of Canada continues to monitor and support international efforts to phase out lead in aviation gasoline. Additionally, the *Contaminated Fuel Regulations* (1991) under CEPA 1999 prohibit the import and export of contaminated fuel except for the purpose of destruction, disposal and recycling in accordance with applicable federal or provincial laws.

A.2 Products Containing Lead

Lead content limits were established for various consumer products under the *Hazardous Products Act* and regulations, and carried over to the 2011 *Canada Consumer Product Safety Act*. The *Glazed Ceramic and Glassware Regulations* under the *Canada Consumer Product Safety Act* limit the releasable lead content of glazes, coatings or decorations on ceramics or glassware used for storing, preparing, or serving food or beverages. The original regulatory limits were established in 1971, and amendments to introduce more stringent limits came into force in 1998. An amendment to further reduce the releasable lead content limits for the lip and rim of drinking vessels (e.g., the portion that touches the mouth when in use) was made in 2009. Lead crystalware, which by definition contains lead, is widely used for serving beverages (Health Canada 2009a). The leachable lead content of lead crystal used for serving food or beverages is strictly limited under international industry standards.

The *Surface Coating Materials Regulations* (amended 2010) under the *Hazardous Products Act* and now the *Canada Consumer Product Safety Act*, decreased the limit for the total lead content from 600 mg/kg to 90 mg/kg in consumer paints, varnishes, epoxy resins and other coating materials that dry to a solid film on the application surface. This limit also applies to applied paints and other surface coating materials on toys, equipment, and other products for use by a child in learning or play, furniture and other children's articles, and on pencils and artists' brushes. This amendment follows action that had seen the original 1976 limit of 5,000 mg/kg reduced to 600 mg/kg in 2005. General artists' paints, other than those intended for use by children, are exempt from the 90 mg/kg total lead limit, but if they contain lead, their label must include a lead content warning. Artists' paints contain a much wider range of pigments than children's paints and therefore are more likely to contain lead-based pigments (Health Canada 2009a).

As well, the *Children's Jewellery Regulations* under the *Canada Consumer Product Safety Act* permit the import, advertisement or sale of jewellery items intended primarily for children under 15 years of age only if the items do not contain more than 600 mg/kg total lead and 90 mg/kg migratable lead. The *Canada Consumer Product Safety Act* also prohibits the use of lead and other heavy metals in plastics used for toys intended for children under 3 years of age. The total lead limit for such plastics is 90 mg/kg. The *Corded Window Covering Products Regulations* (2009) limit the total lead content of any exterior component of the corded window coverings that could be touched or ingested by a young child to 200 mg/kg (200 ppm).

Also in place is the *Lead Risk Reduction Strategy for Consumer Products*, which proposes further limits under the *Canada Consumer Product Safety Act* on the lead content of consumer products with which children are most likely to interact. The *Consumer Products Containing Lead (Contact with Mouth*) *Regulations* (2010) limit the total lead content to 90 mg/kg for products advertised, imported or sold in Canada whose use involves mouth contact, including all toys for children under 3 years of age. These regulations cover consumer products such as baby bottles, soothers, rattles, bibs, cups, drinking straws, and mouthpieces of musical instruments and sports equipment, as well as crayons, finger paints, chalks, modeling clay, and similar products likely to be ingested. Health Canada proposes to extend the 90 mg/kg total lead limit under these regulations to include all toys for children under 14 years of age, child care articles and equipment, and children's clothing and accessories.

The *Kettles Regulations* (amended 2009) limit the amount of lead that may be released when water is boiled in kettles and similar products. The limit was reduced from 0.05 to 0.01 ppm (from 50 ppb to 10 ppb) by a 2010 amendment for consistency with the *Guidelines for Canadian Drinking Water Quality.*

In complement with the *Canada Consumer Product Safety Act* requirements, regulations and codes of practices are in place for various other categories of products. The *National Plumbing Code of Canada* (updated 2005) established by the National Research Council of Canada permitted the use of lead as an acceptable material for drinking water service pipes until 1975, and the use of lead solders until 1986. The use of solder containing lead in new plumbing and in repairs to plumbing for drinking water supplies was prohibited under the code as of 1990. Under a Memorandum of Understanding with the Canadian Vehicle Manufacturers Association, reductions in lead have been achieved. A National Code of Practice for Automotive Recyclers developed by the Automotive Recyclers of Canada Association and Environment Canada includes practices for recycling of lead acid car batteries and lead wheel weights. As well, the Canadian Original Equipment Manufacturers reduced the concentration of lead used in electro coat primer paint formulations, in electronics manufacturing and as a paint pigment. For tobacco products, the *Tobacco Reporting Regulations* (2009) under the *Tobacco Act* require manufacturers to report on the lead content of tobacco and smoke.

Management of hunting for migratory birds (as defined in the *Migratory Birds Convention Act,* 1994) falls under the jurisdiction of federal authority, whereas the management of hunting of other game birds and mammals falls under provincial legislation. For species under federal jurisdiction, the *Migratory Birds Regulations* of the *Migratory Birds Convention Act, 1994*, specify that for migratory game birds, only non-toxic shot (as determined by Environment Canada) can be used for hunting in Canada for all species except for woodcock, band-tailed pigeon, mourning dove, thick-billed murre and common murre. Also in 1997, under the *Canada Wildlife Act,* Environment Canada banned the use of fishing sinkers and jigs weighing less than 50 g in National Wildlife Areas where sport fishing is permitted. Also in 1997, under the *National Parks Fishing Regulations* of the *Canada Parks Act*, Parks Canada prohibited the use or possession of lead fishing sinkers or lead jigs weighing less than 50 g by anglers fishing in National Parks. However, these two regulations are of limited geographic scope, covering less than 3% of Canada's land mass, and they affect only about 50,000 (< 1%) of the estimated 5.5 million recreational anglers in Canada.

A.3 Food and Health Products

Under the Cosmetic Ingredient Hotlist of the *Cosmetic Regulations* (2002) of the *Food and Drugs Act*, lead and all its associated compounds are prohibited ingredients in cosmetic products marketed in Canada. The *Food and Drugs Act* prohibits the sale of a cosmetic that contains any substance that causes harm to the user. The Cosmetic Ingredient Hotlist is used to inform manufacturers and importers of which substances in cosmetics Health Canada considers to be in violation of the *Food and Drugs Act*. The guidance limit for lead impurities in cosmetic products is 10 parts per million based on technical feasibility, and is currently published on the Health Canada website in draft form. Health Canada monitors all cosmetic products under the mandatory notification requirements set out in the *Cosmetic Regulations*. New and existing products have their formulation verified for the presence of lead-based ingredients and other substances on the Cosmetic Ingredient Hotlist. Health Canada also carries out testing for lead and other heavy metals in cosmetic products. Any cosmetics that are found to contain unsafe levels of lead are removed from the Canadian marketplace.

The *Food and Drug Regulations* under the *Food and Drugs Act* define tolerance levels for the lead content of certain foods, including tomato sauce, infant formula, and fruit juice. These tolerances, as well as additional proposed guideline levels for lead in food, are in the process of being updated and aligned, where appropriate, with the maximum limits for lead in foods established by the *Codex Alimentarius Commission.* The Canadian Food Inspection Agency monitors the Canadian domestic and imported food supply for multiple hazards including lead. The results of this testing are available upon request from the Canadian Food Inspection Agency's website. If these monitoring activities find elevated levels of lead in a certain foods, Health Canada would then conduct a human health risk assessment to determine if this concentration is unsafe. If a safety concern is identified, risk management measures are taken by the Canadian Food Inspection Agency. Health Canada also regulates and monitors levels of lead in foods on an ongoing basis through various surveillance mechanisms such as the Total Diet Study. The Food Directorate at Health Canada uses this information to identify and control potential point sources of lead in the diet.

Health Canada's Natural Health Products Directorate guidance document *Evidence for Quality of Finished Natural Health Products* (Health Canada 2007) establishes limits based on a standard set by NSF International (NSF/ANSI 173, 2010), a recognized authority in quality standards for dietary supplements. The tolerance limit set by the Natural Health Products Directorate for lead in natural health products is <0.29 µg/kg body weight per day. Compliance is monitored for natural health products along with other marketed health products by Health Canada. If lead concentrations in these products exceed the tolerance limit, compliance and enforcement action may be taken by Health Canada to mitigate any potential health risk posed to Canadians. The Natural Health Products Directorate continues to consult with its international partners on heavy metal issues, with a view to potential revision of its tolerance limits as new scientific information becomes available.

The limit for lead in pharmaceuticals is regulated under the *Food and Drugs Act.* Health Canada guidance for lead in these products is based on international guidance provided by various pharmacopoeia and formularies.

A.4 Transportation

Regulations have been established under CEPA 1999 regarding the export of materials containing lead. For instance, the *Export Control List Notification Regulations* (2000) require exporters to provide notice to the Minister of the Environment of the proposed exports of substances on the Export Control List of CEPA 1999 and to submit annual reports. Some lead compounds are classified as restricted substances under these regulations. The *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations* (2005) control transboundary movement of hazardous waste and hazardous recyclable materials, including those containing lead or lead compounds. These regulations help ensure that hazardous wastes and hazardous recyclable materials containing lead or lead compounds crossing international borders between countries are characterized and managed properly.

In addition, under the *Transportation of Dangerous Goods Regulations* (2008) of the *Transport of Dangerous Goods Act*, there are risk management measures required for the transport of numerous lead compounds, which govern the mode and quantity of transport pertaining to these compounds.

A.5 Guidelines and Standards

The Government of Canada has undertaken a number of additional actions to protect Canadians from exposure to lead. There are numerous guidelines pertaining to lead in environmental media established under CEPA 1999 that establish recommended environmental concentration limits according to water and land use. The Canadian Council of Ministers of the Environment (CCME) Water Quality Task Group and the Soil Quality Guidelines Task Group produced the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (1999), the *Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses* (1993), the *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (1999), and the *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health* (1999). Generally implemented on a voluntary basis, jurisdictions may use Canadian Environmental Quality Guidelines directly or in combination with their own environmental quality guidelines and standards.

Regarding drinking water, Health Canada established a maximum acceptable concentration of 0.010 mg/L (10 µg/L) for lead in drinking water as part of the *Guidelines for Canadian Drinking Water Quality* (1992). As with environmental media, each jurisdiction is then responsible for setting its own guidelines, objectives or enforceable regulations. Health Canada also published the *Guidance for Controlling Corrosion in Drinking Water Distribution Systems* document on corrosion control (Health Canada 2009b). Given that these systems could contribute to lead releases into drinking water, this document provides tools to identify and address corrosion issues, particularly lead leaching, and it complements the existing guidelines for lead.

There is also the 1994 *Update of Evidence for Low-Level Effects of Lead and Blood Lead Intervention Levels and Strategies: Final Report of the Working Group*, by the working group reporting to the Federal-Provincial-Territorial-Committee on Environmental and Occupational Health (CEOH), which provided guidance for the management of exposure to lead in individuals and communities. This report is currently being revised by the Federal-Provincial-Territorial Committee on Health and the Environment (CHE). The revised guidance will provide health care practitioners and public health officials with guidance on choosing actions that are appropriate for the management of specific blood lead levels.

Soil contamination with trace metals such as lead may also lead to potential contamination of food crops grown on land fertilized with contaminated materials through plant root uptake, foliar absorption, or adsorption to plant surfaces. Fertilizers and supplements may represent important sources of largely unintentional lead addition to soils and the food production continuum. The Canadian Food Inspection Agency has a standard under the *Fertilizers Act* for lead in fertilizer and supplement products when sold or imported into Canada. All regulated fertilizer and supplement products must be safe for humans, plants, animals, and the environment, efficacious for their intended purpose, and properly labelled. Waste-derived fertilizers and supplement materials that are manufactured, sold or represented for use as plant nutrients, including processed sewage, meet the definition of a fertilizer and are also regulated under this Act. The Canadian Food Inspection Agency conducts routine marketplace monitoring of regulated products to verify their compliance with the *Fertilizers Act*. Contaminant standards are based on cumulative environmental load and, therefore, long-term impacts of product use. This approach further ensures that repeated fertilizer application does not significantly affect or alter the background levels of metals in soil and lead to net deterioration of soil quality from generation to generation. Product-specific application scenarios reflect exposure probabilities for the general population, applicators, and bystanders, as well as terrestrial and aquatic species. The current application limit is 100 kg/ha (10,000 $m^2 \times 0.355$ m) over a 45-year period, or a fertilizer applied at a rate of 2,200 kg/ha, and it is evaluated using a limit of 500 mg/kg dry weight of fertilizer. This is in keeping with the current CCME Soil Quality Guidelines. The Canadian Food Inspection Agency also has an action level for lead in total livestock diets under the *Feeds Act*. The action level developed for lead is 8 ppm in total livestock diets and is based on the level that may be fed to livestock that would not produce unsafe residues in human food derived from that animal.

Voluntary initiatives have also been undertaken with respect to lead. The Government of Canada has recognized voluntary industry efforts, such as the Accelerated Reduction/Elimination of Toxics (ARET) program, a voluntary release-reduction program that ran from 1994 to 2000. The program challenged participants to reduce releases of 117 toxic substances, including lead, and was successful in reducing releases of these substances by over 72% from base year levels.

ANNEX B—PROTOCOLS RELATED TO LEAD MANAGEMENT

B.1 The Canadian Department of National Defence

B.1.1 Department of National Defence and the Canadian Forces Context

The Department of National Defence (DND) and the Canadian Forces (CF) are mandated to provide the Government of Canada with trained and effective operational military forces. Along with this important mandate comes the responsibility of ensuring that activities and operations are conducted in an environmentally sustainable way and that defence establishments are managed in an environmentally responsible manner.

Range and training areas (RTAs) are of particular importance, as they are critical to the training and testing of personnel, equipment and procedures to meet DND and CF operational objectives. Integrating sustainability planning and concepts into the current and future management of RTAs can preserve long-term use while still applying sound environmental, usage and risk mitigation considerations. Any restriction, degradation and/or loss of usage of RTAs, including small arms ranges, will seriously affect the ability of DND and the CF to meet operational objectives and requirements.

For the purpose of the federal Risk Management Strategy for Lead, it is important to note that most of the lead discharges to land are the result of live-fire training of CF members in RTAs, specifically on land-based small arms ranges across Canada. Other users including police forces and private interest groups also utilize the DND/CF land-based ranges through land use agreements or other types of agreements.

B.1.2 Limitations Regarding Lead Ammunition Usage

At present, lead is an integral component of military munitions. The military procures ammunition that has been tested and evaluated to meet stringent requirements in accordance with test protocols in the North Atlantic Treaty Organization (NATO) Standardization Agreements. As a member of NATO, Canada has agreed to purchase ammunition in strict compliance with these standards to ensure interoperability with its allies on joint NATO missions—that is, the ability of different military organizations to conduct joint operations. NATO allies share common doctrine and procedures, each other's infrastructure and bases, as well as equipment and supply.

The general military bullet is designed for the optimum terminal effect using the current projectile compositions—a lead core and copper jacket that provides the optimum terminal effect of the ammunition and is currently used in many of the CF weapon systems. Changes to the core and/or design will have limitations that will impact on the designed purpose. While the DND and CF Ammunition Safety and Suitability Board considers the environmental impact of ammunition and explosives coming into service, small arms and ammunition containing lead will continue to be used for the foreseeable future. The use of alternative forms of weapons training—such as simulation—augment, but cannot replace, live-fire training.

B.1.3 Applicable Environmental Policy

The DND environmental policy (Defence Administrative Order and Directive 4003-0) recognizes that the responsible stewardship of the assets with which DND and the CF are entrusted is an imperative. In support of this policy, DND has developed a multi-faceted environmental protection and stewardship program that addresses legacy issues, and it focuses on the establishment of management processes to minimize the impact of its activities, such as RTA management, including small arms ranges.

B.1.4 Lead Risk Management

Approximately 25 million rounds of live ammunition are fired annually by the CF—the number and type of which are tracked through the CF Range Information System. Since ammunition composition information is typically proprietary, annual lead releases to land from live-firing in RTAs are calculated for the NPRI using composition estimates. It should be noted that discussions are now taking place to determine if NPRI reporting spreadsheets can be incorporated into the CF Range Information System to assist Environmental Officers with their reporting.

Small-arms ranges are facilities that are constructed for the express purpose of live-fire small-arms qualification at known distances, on a fixed axis using a permanent danger area template. The range is usually equipped with a mantlet, markers' gallery, target frames, stop butt and firing points at 100 m intervals. Although this is the typical set-up, it may vary from one location to another.

The following highlight some of the measures used by DND and the CF to reduce, limit and/or mitigate the releases of lead to land from small-arms ranges:

- *B-GW-100-D56/AA-001; CF Policy for Controlling Civil Access to Dangerous DND Lands, Ranges and Training Areas* (DNDP 56): This document contains broad policy guidance and direction pertaining to the control of civil access and protection of the public from injury or death. This policy applies to all land - by all elements of the CF for training and testing purposes.

- *B-GL-381-002/TS-000; Operational Training—Range Construction and Maintenance*: This publication is the CF policy for land-based RTA construction and maintenance. The aim of this document is to establish the basic requirements for design, functionality and maintenance in support of operational training. These basic standards are to be used by facility managers and Engineer Officers when developing plans for future RTAs. As well, personnel who are responsible for RTA maintenance are to refer to this manual for information on the inspections that must be performed and the standards of maintenance to be attained.

- *Site-Specific Standard Operating Procedures*: Historically, a policy instrument limited the number of rounds per shooting lane to 100,000, after which the stop butts were to be cleaned with the removal of the soil and disposal as hazardous waste in accordance with applicable legislation. This limit was set in the past as a safety measure to prevent ricochet from already partially fractured bullets in the stop butts. To this day, some sites have maintained the 100,000 round limit to determine when their ranges need to be sifted.

- As well, migration of lead-impacted soil at the Navy's outdoor firing ranges is monitored and lead impacts are minimized and managed through the use of site-specific erosion control structures and standard operating procedures.

- *Range and Training Area Management Plans*: The Navy has developed RTA Management Plans to ensure the sustainable management of small-arms ranges. As well, environmental assessments have been completed for training areas and small-arms ranges to identify routine activities, potential impacts and mitigation measures to minimize environmental impacts. These standing mitigations for routine activities are incorporated into the Range Standing Orders for these properties.

- *MARCORD G-16, Maritime Command Order—Operational Range and Training Area Management*: The aim of this order is to provide within Maritime Command a standard procedure for the inspection and licensing of Regular Force, Reserve and Cadet Unit land range facilities.

- *Environmental Management System Program, Guidance Sheet—Small Arms Range*: This guidance document focuses on environmental issues that may arise due to the lead accumulation in the butts at Air Force-managed small-arms ranges. It describes the type and frequency of activities, such as monitoring, licensing, inspections, etc., that should take place to ensure appropriate lead risk management at small-arms ranges.

- *Canadian Air Division Orders—Management of Skeet and Trap Ranges*: This order is designed to provide direction on the remediation of abandoned or closed skeet and trap ranges found on Air Force properties. It also provides direction with regards to the operation of existing ranges to ensure that minimal negative environmental impacts occur.

- *Revolutionary, Insensitive, Green and Healthier Training Technology with Reduced Adverse Contamination:* DND and the CF have implemented a project to demonstrate the feasibility of insensitive and green ammunition for future operations. The main objective of this project is to ease environmental pressures on CF RTAs, decrease health hazards for users, and eliminate potential sources of improvised explosive devices in operations.

- *Bullet Catchers:* The Army has been collaborating with Defence Research and Development Canada to develop bullet catchers to replace the stop butts in the small-arms ranges. The development of the bullet catcher was initiated in 2008. Its goal is to capture the bullets in a sealed container that will prevent the lead from being exposed to weather conditions and from entering the soil (the butt).

- *Small Arms Modernization Project:* The Army has initiated a Small Arms Modernization project that aims to modernize its small arms, as well as the munitions, by changing the composition to reduce weight, increase the effectiveness against shielding materials and increase the lethality to the target.

- *Range and Training Area Sustainment System*: The Army has begun to critically analyze both the current state and future management of its RTAs. Once completed, the RTA sustainment system—the method by which the Army is selecting, developing, monitoring and reporting on indicators of environmental sustainability—will be implemented. The RTA sustainment system will ensure that Army RTAs are managed in an environmentally sustainable manner, and that all activities conducted within, including the use of small-arms ranges, comply with applicable environmental legislation as well as departmental policy.

- *RTA Characterization:* Since 2000, the Army has been working with various scientific partners to assess the impact of live-firing in its RTAs, including the small-arms ranges. Vulnerability maps—which take into account various criteria including soil type, annual rainfall, distance to groundwater and surface water, age of the small arms range and stop butt, and frequency of use—are currently under development. These vulnerability maps will allow a better assessment of the risks associated with specific small-arms ranges and will provide information for mitigation and/or remediation purposes.

- *DND Contaminated Sites Management Program*: Through this program, direction is provided with regards to the remediation of legacy, abandoned or closed ranges.

B.2 The Royal Canadian Mounted Police

The Royal Canadian Mounted Police (RCMP) Office of Environment and Sustainable Development has measures in place to ensure that activities are conducted in an environmentally-sustainable manner. The RCMP manages both indoor and outdoor firing ranges across Canada, and in some cases, it has arrangements in place to use DND facilities. Some outdoor firing ranges have been closed over the past few years by the RCMP and have been subject to environmental remediation.

There are a number of management protocols in place that vary according to the type of facility. At one of the RCMP's larger training facilities in western Canada, the range is covered and paved, and ventilation modelling was conducted as part of the facility design. Ammunition is collected in berms behind targets and is disposed of by qualified contractors twice a year. Special equipment is used to filter the lead and other metals from berm material. For some facilities, dry sweeping of ranges is performed after each day of use, and washing of the ranges may be undertaken several times per year, depending on usage. Air flow velocity at indoor ranges is monitored and exhaust fans are equipped with a pre-filter and a high-efficiency particulate arresting (HEPA) filter to remove contaminated particles.

There are a number of monitoring protocols in place for firing ranges. These include surface lead testing, groundwater monitoring, and indoor air monitoring for indoor ranges. Staff assigned to indoor range duties are subject to testing to determine lead levels in their blood.

Regarding disposal practices, disposal of hazardous waste is carried out in accordance with provincial requirements, often by qualified contractors who collect the range waste using a HEPA-filtered vacuum.

The use of lead-free ammunition for training has been implemented for some facilities and is being considered for others in order to reduce operating and maintenance costs related to health and safety measures and monitoring. The high costs associated with the maintenance of ventilation systems, replacement and disposal of lead-contaminated filters, and other aspects of site maintenance involving lead-containing ammunition are also a factor. Some ranges use low-lead ammunition for periods of their training programs and regular ammunition for qualification testing. Firearm simulators may also be substituted to reduce the amount of ammunition used.