Lead Shot Contamination in Edible Portions of Game Birds and Its Dietary Implications

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ABSTRACT

Lead exposure for First Nation Cree of the Mushkegowuk region (western James Bay area of northern Ontario, Canada) through ingestion of game hunted with lead shot is of concern and was investigated in this study. All lead concentrations in tissues of mammals ($n = 45$) and fish ($n = 30$) harvested in the Mushkegowuk Territory were at a level below the guideline set by Health Canada for human consumption of fish protein (i.e., <0.5 μg/g wet weight [ww]). No guidelines exist for game birds and mammals. However, livers of 2% (5/233) of the game birds collected showed lead concentrations >0.5 μg/g ww. Moreover, 9% (33/371) of the gizzard (striated muscle) tissue samples obtained through harvesting of waterbirds and upland game birds employing lead shot, showed lead levels greater than the indicated arbitrary guideline. The presence of lead was shown by radiography and atomic absorption spectrometry to be the result of lead pellets and/or lead fragments being embedded in the striated muscle. People who consume *any* game species harvested with lead shot risk exposure to this metal by way of ingestion of tissue-embedded lead pellets and fragments. Although Canada will be banning the use of lead shot for all migratory bird hunting in 1999, its extension to *all* game hunting should be considered because of potential human health concerns.

INTRODUCTION

Lead has long been recognized as a developmental neurotoxin. Since many factors may influence a child's development, the establishment of a "safe" lead level is a complex task (CDC 1991; Rabinowitz *et al.* 1991; Fleming 1994; Rice & Silbergeld 1996). Further, blood-lead concentrations below the 10 μg/dl medical level of concern, defined for children by the U.S. Centers for Disease Control (CDC 1991), may impair nerve conduction in the auditory system (Schwartz & Otto 1991; Zelikoff *et al.* 1993; IPCS 1995). There is also support for the notion that there is no safe level of lead exposure (Flegal *et al.* 1990; CDC 1991; Fleming 1994; Todd *et al.* 1996).

In addition to its neurological effects, lead also exerts toxicity at the level of the kidneys, blood formation, reproduction, peripheral nervous system, and pre/postnatal development (Mushak *et al.* 1989; Mahaffey 1990; Fleming 1994; IPCS 1995). Although epidemiologic studies suggest that chronic low-level lead exposure may be linked to elevated

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blood pressure, the role of confounding variables is unclear (Sharp *et al.* 1987; IPCS 1995). Based on animal studies, Zelikoff *et al.* (1993) have suggested that inhalation of particulate lead may impact on the pulmonary immunological system in the absence of "predictive" elevated blood levels.

There has been growing concern among First Nations of the Mushkegowuk region (James Bay, Ontario, Canada) that lead shot used in harvesting activities may be adversely affecting human health. This concern can be attributed to data generated in six regional studies. Two studies found elevated blood-lead levels in children, with game harvested by lead shot being suggested as a possible source of lead in the most recent report (OMHE 1989; OMH 1993). In studies by Tsuji *et al.* (1997; unpublished work), elevated dentine-lead levels in adult and children's teeth were reported, with no obvious sources of exposure except contaminated game. Further, in a study by Hanning *et al.* (1997), elevated cord and maternal blood lead were found to correlate significantly with the consumption of a traditional diet of wild meat (fowl, mammal, and to a lesser extent fish). Moreover, Tsuji & Nieboer (1997) found that 15% of the radiographic charts examined from the Mushkegowuk region had radiographic evidence of pellets being present in the digestive tract. Consumption of lead-contaminated wild meat was suspected as the source of lead in these studies.

It is well known that lead from lead pellets used in hunting can mobilize and accumulate disproportionately in different organ systems of waterfowl, such as the liver and striated muscle (e.g., Jordan & Bellrose 1951; Eisler 1988). Lead pellets have also been documented as the source of lead in toxicological studies of mammals, with similar lead tissue distribution as in the waterfowl (e.g., Ma 1989; Eisler 1988). It is thus important to analyze different parts of game animals commonly consumed in the Mushkegowuk region and compare this information to permissible lead intake levels (Flegal *et al.* 1990). Lead is also known to enter the edible portions of plants and fish (Eisler 1988; Fleming 1994). However, local vegetation does not constitute a major portion of the First Nation diet in the Mushkegowuk region and rather low levels of lead (≤ 0.2 μg/g wet weight [ww]) have been reported for two fish species (northern pike, *Esox americanus*; white sucker, *Catostomus commersoni*) harvested in rivers of the region (McCrea & Fischer 1986).

It has been suggested that humans hunting waterfowl have a greater probability of harvesting lead-poisoned birds due to central nervous system disturbances that affect the birds' evasive response (Bellrose 1959; Humberg & Babcock 1982; cf. Lumeij & Scholten 1989). Using this argument, the probability is increased that tissue-bound lead will be ingested by hunters. Tissue-bound lead is chemically incorporated into the tissue; by contrast, lead pellets and fragments can also be embedded in the tissue. Although ingestion of tissue-bound lead may prove to be a source of lead exposure for animals and perhaps humans, the existing evidence is tenuous (see USDI 1986 for a review).

In this article we examine two possible routes of lead exposure that have been identified for humans who consume wild meat harvested with lead shot (Scheuhammer & Norris 1995). The two potential sources are ingestion of whole and/or fragmented lead pellets embedded in wild meats (Frank 1986; Madsen *et al.* 1988) and ingestion of game with tissue-bound lead (OMH 1993).

METHODS

First Nation Cree inhabit six communities in the western James Bay region of northern Ontario, Canada: Moose Factory, Moosonee, Fort Albany, Kashechewan, Attawapiskat, and Peawanuck. Harvesting of wildlife is a way of life to Cree of the region for spiritual as well as economic reasons (Feit 1986). Since the new lead shot regulations are ambiguous at best (Tsuji 1998), lead shot is still widely used in sport as well as Native subsistence harvesting in Canada.

Since 1993 residents from Fort Albany First Nation of the Mushkegowuk region have helped our research team collect wildlife specimens that are usual components of a traditional First Nation diet. All birds were harvested with lead shot. Walleye (*Stizostedion vitreum*) were caught by rod and reel or netted from the Albany River; hare (*Lepus americanus*) were snared; beaver (*Castor canadensis*) were trapped; and moose (*Alces alces*) and caribou (*Rangifer tarandus*) were harvested with rifles.

Specimens of waterfowl were collected in both the spring and fall since the incidence of lead shot ingestion and harvesting conditions may differ between the two hunting seasons. Other seasonal wild meats were collected only during specified times. Liver is commonly eaten by First Nation Cree of the Mushkegowuk region, although bird striated muscle (breast, gizzard, leg, wing) is the tissue most commonly consumed (Tsuji & Nieboer 1999).

Stainless steel blades were used to excise liver (whole when available) and striated muscle from mammals (rump, shoulder, leg) and birds (half the gizzard—grinding pads and any tissue contacting the lumen and grit were not taken), as well as the filet portion from fish. Samples were subsequently sealed in individually marked plastic zip-lock bags and stored frozen until preparation for analysis.

Tissue samples were oven dried to constant weight at 70°C and ground in a spice mill with stainless steel blades. A single 1.00 g subsample of dried tissue was digested at room temperature overnight in 5 ml of concentrated trace-metal grade (Fisher Scientific, Pittsburgh, PA) HNO_3, followed by digestion at 100°C for 6 hr. The digest was then made up to a final volume of 20 ml with distilled deionized water (DDW), and filtered through Whatman 42 ashless filter paper. A blank of HNO_3 and bovine liver Standard Reference Material 1577b (U.S. National Institute of Standards and Technology, Gaithersburg, MD) were included in each digest run. Lead was determined by flame atomic absorption spectrometry (FAAS) employing a Perkin-Elmer Model 460 AA spectrometer and high purity multielement calibrating standards (Delta Scientific, Mississauga, Ontario) diluted with HNO_3 and DDW to match the 20% acid content of the samples. The detection limit (DL) for lead was 0.3 μg/g ww. Dry weight values were converted into wet weight equivalents using the statistically significant ($p < 0.001$) relationships generated by regression analysis: liver dry weight = (0.374) (ww liver) − 0.95 with an average moisture content of 66% of the wet weight (n = 135; 95% confidence interval [CI] of slope, lower bound = 0.359 and upper bound = 0.389); striated muscle dry weight = (0.262) (ww striated muscle) − 0.41, with an average moisture content of 77% of the wet weight (n = 38; 95% CI of slope, lower bound = 0.246 and upper bound = 0.277). Shealy (1982), DiGiulio (1982), and Scheuhammer et al. (1998) have reported similar relationships.

Because unusually high levels of lead were found in approximately 9% (31/347) of bird striated muscle samples, a further 26 striated muscle samples from Canada geese (n = 17) and snow geese (n = 9) were randomly collected in the spring of 1996 to investigate further the source of the lead by radiography. For this, individual samples were placed on a single Kodak Ultra Speed occlusal film. Tissue and film were subsequently placed under the tube of a Heliodent 70 radiographic unit. The tissue/film was then radiographed (70 kV, 7 mA, 18 msec) and the film subsequently processed. Any tissue sample with a corresponding lead signature in the radiograph was identified prior to acid digestion and lead determination by FAAS (Figure 1).

As has been pointed out by Scheuhammer and Norris (1995), no specific consumption guidelines exist for lead in tissues of game birds, although 0.5 μg/g ww has been recommended for fish protein

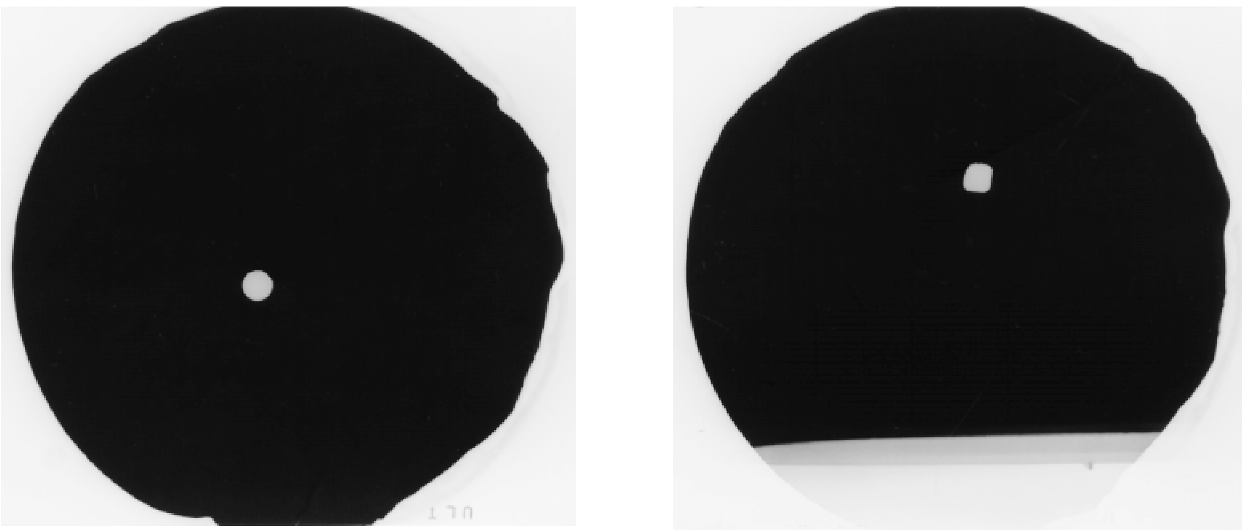

FIGURE 1. Radiographs of striated muscle samples collected from geese harvested in the Mushkegowuk region of northern Ontario, Canada. The radiograph on the left shows a whole lead pellet (the white round object) embedded in the tissue; the one on the right shows a large lead pellet fragment. The two radiographs illustrate that the use of lead shot for harvesting of waterbirds can result in embedded lead pellets and/or fragments for edible tissues. The contaminated meat constitutes a potential dietary source of lead.

by Health Canada (Health Canada 1995). Thus, 0.5 μg/g ww is the tissue concentration of concern that we will adopt in presenting the results.

RESULTS

All lead concentrations in the mammal (n = 45) and fish (n = 30) tissue samples (Table 1) were below the DL (<0.3 μg/g ww). By contrast, 9% (33/371) of striated muscle samples (edible tissue) from birds harvested with lead shot showed lead levels >0.5 μg/g (Table 2). Although all spruce grouse (*Dendragapus canadensis*), snipe (*Gallinago gallinago*), Hudsonian godwit (*Limosa haemastica*), and green-winged teal (*Anas crecca*) tissue samples had lead levels <0.3 μg/g ww, sharp-tailed grouse (*Tympanuchus phasianellus*) samples were all contaminated (Table 2). Some gizzard tissue samples from mallards (*Anas platyrhynchos*), northern pintails (*Anas acuta*), snow (*Anser caerulescens*), and Canada (*Branta canadensis*) geese also had lead levels >0.5 μg/g (Table 2), reaching concentrations as high as 19,900 μg/g ww.

Of the 26 striated muscle samples that were radiographed, two samples had radiographic evidence of embedded lead (Figure 1). These two samples had lead levels of 13 and 362 μg/g ww. The 24 samples without radiographic evidence of lead all had concentrations <0.3 μg/g ww.

Of all the livers of game birds harvested in the Mushkegowuk region, 2% (5/233) exhibited lead concentrations >0.5 μg/g ww (Table 3). The contaminated samples were limited to the northern pintail duck, snow, and Canada goose.

TABLE 1

Wild meats (mammals and fish) harvested in the Mushkegowuk region (James Bay, Ontario)

	n
Beaver	
muscle	2
liver	3
Moose	
muscle	17
heart	1
kidney	1
liver	2
Caribou	
muscle	2
Hare	
liver	17
Walleye	
muscle	30

All tissue had lead concentrations below the detection limit (DL) of 0.3 μg/g ww.

DISCUSSION

Three major changes in the last two decades have decreased lead exposure in humans living in North America: the virtual elimination of leaded gasoline, the use of lead-free solder in canned goods, and the decrease in lead content of paints (CDC 1991; Fleming 1994; Pirkle *et al.* 1994, 1998). In the Mushkegowuk area most houses were built subsequent to the lead-in-paint reduction (or were paneled) and most canned goods available in the zone are lead-free (i.e., Canadian or American). Further, lead levels in community water supplies have been found to be low (OMHE 1989; OMH 1993) and concentration in surface water from rivers of the region are also minimal (McCrea & Fischer 1986). Although some of the school drinking water supplies in the region did contain high levels of lead because of lead plumbing or lead-soldered water-pipe joints (Murray 1989; St. Pierre 1992), since the late 1980s children have used bottled water dispensers and modern water distilling systems.

Soil and dust may also be potential sources of lead (Sayre *et al.* 1974; Weitzman *et al.* 1993), with pica habits compounding the problem (Barltrop 1966); however, this also appears an unlikely source in the Mushkegowuk area (OMHE 1989; OMH 1993). In the most industrialized community of the region, Moosonee, soil and air lead levels have been found to be very low, with approximately 25% of air lead samples below the detection limit (OMHE 1989). "White lead" (89% $PbCO_3$, 11% linseed oil) used in boat repairs constitutes a potentially unique source of lead dust and contact/ingestion exposure in the Mushkegowuk region, although this appears unlikely since precautions are taken and its use is not widespread (Smith 1995). However, lead contaminated game is of concern, since 5–10% of ingested lead in food is absorbed in adults (Kehoe 1964) and 42–53% by children (Ziegler *et al.* 1978; Mahaffey 1990; IPCS 1995).

In the present study it was found that 9% of the edible, striated muscle sampled from game

TABLE 2

Lead content of edible striated muscle from birds harvested in the Mushkegowuk region (James Bay, Ontario)

	N (Pb)/N (S)[1]	Lead concentration or range (μg/g ww)[2]
Grouse		
Spruce	0/7 (0%)	DL
Sharptail	10/10 (100%)	207–514
Shorebirds		
Snipe	0/4 (0%)	DL
Godwit	0/4 (0%)	DL
Ducks		
Mallard	4/44 (9.1%)	19–167
Pintail	1/56 (1.8%)	9.0
Green-winged teal	0/29 (0%)	DL
Geese		
Snow (Wavey)	9/71 (12.7%)	9.0–11,500
Canada	9/146 (6.2%)	13–19,900

[1]N (Pb) represents the number of birds with lead levels in this tissue >0.5 μg/g ww and N (S) represents the number of birds examined for that species. The Health Canada tissue guideline for lead in fish of 0.5 μg/g ww is taken as the tissue level safe for human consumption.
[2] DL, at or below the detection limit.

birds had lead levels >0.5 μg/g ww (the Health Canada tissue guideline for fish protein that we have adopted as the level of concern with respect to human consumption). One extremely high value of 19,900 μg/g ww was found. These values exceed those previously reported for breast (striated) muscle in lead-poisoned Canada geese (n = 60, $\bar{x}$ = 1.8, range = 0.6–5.7 μg/g ww; Szymczak & Adrian 1978) and mallards (n = 18, $\bar{x}$ = 1.4, range = 0.6–3.2 μg/g ww; Longcore *et al.* 1974). Lead concentrations of the magnitude found in the present study are likely the result of contamination of the tissue by lead pellets and lead pieces that vary in size from fine dust particles to larger fragments (Frank 1986), as verified through radiography in the present study. The two striated muscle samples that showed radiographic evidence of lead pellets/fragments being embedded in the tissue had corresponding high lead values as determined by FAAS. The other 24 samples without radiographic evidence of lead pellets/fragments had very low lead concentrations (<0.3 μg/g ww).

Our findings corroborate two previous game bird studies. Researchers for the Canadian Wildlife Service (CWS) found that of 827 pooled breast samples from game birds killed with lead shot, 10% (92/827) contained lead levels >0.5 μg/g ww (CWS 1996; Scheuhammer *et al.* 1998). It was shown through radiography and AAS that lead from lead shot used in the harvesting of the birds was the source of lead in these wild meats (Scheuhammer *et al.* 1998). Further, Hubbard *et al.* (1965) analyzed upland game bird preserves for lead contamination. Even after the removal of most of the lead shot embedded in tissue (striated muscle) prior to processing and analysis, it was found that all samples had values ≥0.5 μg/g ww (n = 12, $\bar{x}$ = 5.9, range = 0.5–22.7 μg/g ww). This is not surprising as microscopic lead fragments have been observed in tissue of wild ruminants harvested with lead shot (Frank 1986; H. Hecht 1985 cited as personal communication in Frank 1986). It appears that any game species harvested with lead pellets risks contamination through the embedding of whole lead pellets and/or pellet fragments generated by the disruption upon impact with bone tissue (Frank 1986). It should also be mentioned that even though lead levels in the samples of big game (e.g., moose and caribou) examined in the present study were below the detection limit, 0.3 μg/g ww, this finding should be viewed with some caution for two reasons. First, Scheuhammer *et al.* (1998) in their study of game

TABLE 3

Proportion of samples with detectable lead levels (concentration and range) in livers of birds harvested in the Mushkegowuk Territory (James Bay, Ontario).

	Spring[1] N (Pb)/N (S)[2]	Concentration or range[3]	Fall N (Pb)/N (S)	Concentration or range
Grouse				
Spruce	—	—	0/4 (0%)	DL
Sharptail	0/10 (0%)	DL	—	—
Shorebirds				
Snipe	—	—	0/4 (0%)	DL
Godwit	—	—	0/4 (0%)	DL
Ducks				
Mallards	0/34 (0%)	DL	0/2 (0%)	DL
Pintail	2/18 (11.1%)	12–25	0/1 (0%)	DL
Green-winged teal	—	—	0/14 (0%)	DL
Geese				
Wavey	0/25 (0%)	DL	1/15 (6.7%)	155
Canada	1/46 (2.2%)	25	1/56 (1.8%)	15

[1]A spring and fall classification is used because lead levels may differ between seasons.
[2]N (Pb) represents the number of birds with lead levels >0.5 μg/g ww and N (S) represents the number of birds examined for that species.
[3]DL, at or below the detection limit.

birds harvested with leaded ammunition (lead shotshell) reported variability in lead levels between right and left breast tissue sampled from the same individual, as well as differences within the same samples (i.e., duplicates). This variability was attributed to the heterogeneous scattering of leaded fragments within the tissue generated from the impacting of lead pellets with hard tissue. Thus, it is conceivable that there was contamination of the big game mammals we sampled in this study. However, this might not have been readily apparent because of the heterogeneous distribution of tissue-embedded fragments generated from the disruption of leaded ammunition (i.e., leaded shotgun slugs and/or bullets from high-powered rifles) upon impacting the game animals. Second, recent raptor studies (Kramer & Redig 1998; Miller *et al.* 1998; Wayland *et al.* 1998) have suggested that big game mammals (deer, *Odocoileus* spp.), as well as upland game harvested with leaded ammunition may be a source of lead exposure for these birds (Bald eagles, *Haliaeetus leucocephalus*; Golden eagles, *Aquila chrysaetos*) through the ingestion of ammunition fragments embedded in carcasses. Kramer and Redig (1998) have even found that the timing of the greatest occurrence of lead poisoning cases in raptors for the states of Minnesota, Wisconsin, and Michigan in the United States coincided with regional deer hunting seasons; gut piles have also been reported as a food source for raptors during the deer hunting season. The significance of these findings with respect to human consumption of lead-contaminated big game meat should be an area of future research.

Only 2% of game birds harvested in the present study showed lead levels in liver >0.5 μg/g ww. Contaminated samples were limited to three species, namely, the northern pintail, snow, and Canada goose. However, the observed concentrations were considerably higher than background lead levels found in livers collected from 11 different waterfowl species and 3 different upland game bird species with no known history of lead exposure; the reported values ranged from 0.5 to 1.5 μg/g ww and 0.2–3.0 μg/g ww, respectively (Bagley & Locke 1967). By contrast, lead in livers from lead poisoned mallards (n = 18, $\bar{x}$ = 57.4, range = 32.0–83.0 μg/g ww; Longcore *et al.* 1974) and Canada geese (n = 80, $\bar{x}$ = 30.6, range = 8.4–24.9 μg/g ww; Szymczak & Adrian 1978) have been shown to be significantly elevated.

In the United States, The Netherlands, and Norway, the use of lead shot has been banned for waterfowl hunting because of the deleterious effect of lead on waterfowl (USFWS 1988; Pain 1992; Annema *et al.* 1993). In Canada, on August 19, 1997, Environment Canada, through a news release, announced that there would be a delay to the proposed nationwide ban on the use of lead shot for the harvesting of migratory game birds (CWS 1996). Lead shot is now scheduled to be banned nationwide in Canada for migratory bird hunting in 1999. We maintain that the use of lead shot should be banned for *all* game hunting, because any animal harvested with lead shot is subject to the risk of contamination with lead pellets and/or fragments (Hubbard *et al.* 1965; Frank 1986; Scheuhammer *et al.* 1998; the present study). Human health may potentially be affected by an increase in lead exposure for people who subsist on or regularly consume large quantities of wild meats harvested with lead shot. An increase in body lead burden may occur from the ingestion of tissue-embedded lead shot or shot fragments. Indeed, elevated dentine-lead levels in adult and children's teeth collected from First Nation Cree of the western James Bay region has been reported with no other identifiable source of exposure than contaminated wild meats (Tsuji *et al.* 1997; unpublished work). Furthermore, radiographic evidence from randomly selected charts has shown that 15% of First Nation Cree examined at Weeneebayko General Hospital (regional hospital for the western James region) had lead pellets located intraluminally in the gastrointestinal tract (Tsuji & Nieboer 1997).

Two recent studies in northern Quebec, Canada, have also found compelling evidence supporting the hypothesis linking elevated lead levels in humans to the use of lead shot in harvesting activities. Preliminary, sex-adjusted data for First Nation Cree inhabiting the eastern James Bay region revealed elevations in blood-lead levels (compared to baseline data) two months following the goose harvest for all age groups examined (Kosatsky 1998). In a study by Levesque *et al.* (1998), it was reported that 7.6% of 238 Inuit newborns from Nunavik had cord blood-lead levels ≥10 μg/dl, compared to 0.2% of 955 newborns sampled from southern Quebec. The source of lead exposure was determined using the stable isotope ratio technique for 60 Inuit and 89 southern Quebec newborns. A significant difference was found between data for Inuit (mean Pb 206/207 = 1.195) and southern Quebec (mean Pb 206/207 = 1.167) newborns. The mean isotope ratio for Inuit newborns compared well to that reported for four major brands of leaded ammunition used in Nunavik (n = 10, mean Pb 206/207 = 1.193). Similarly, the mean isotope ratio for southern Quebec newborns corresponded to that found for lichens collected from Nunavik (n = 4, mean Pb 206/207 = 1.164). This latter observation is consistent with ambient atmospheric deposition as the contamination source (Levesque *et al.* 1998).

It should be mentioned that other routes of lead exposure, other than ingestion of contaminated wild meats, may be of concern for people using lead shot to harvest game animals. Airborne lead is generated during the use of guns from the ignition of primer (contains lead styphnate) and from mechanical abrasion of leaded ammunition as it passes through the barrel (Valway *et al.* 1989). Animal studies suggest that particulate lead inhaled into the lungs may have toxic consequences (Zelikoff *et al.* 1993). Furthermore, lead exposure may result from the handling of ammunition and the cleaning of firearms; thorough washing of hands is recommended (e.g., Union Metallic Cartridge Company "warning" on lead ammunition box). Thus, the use of leaded ammunition in Native subsistence hunting and sport hunting in general may be a source of lead exposure and thus constitutes a health concern.

It should be emphasized that recent research has shown a downward trend in the exposure levels that are considered neurotoxic. In young children, a link has been established between low-level lead exposure during early development and later neurobehavioral deficits (Mushak *et al.* 1989; Needleman *et al.* 1990; IPCS 1995; Rice & Silbergeld 1996). Furthermore, researchers have suggested that there may be no threshold to lead toxicity in humans, with any food contamination by lead constituting a potential health concern (Flegal *et al.* 1990; Fleming 1994; Todd *et al.* 1996). Thus, the use of nontoxic shot (e.g., steel) for harvesting of *all* game species would eliminate significant sources of lead for First Nation people and all individuals who eat wild meat harvested with lead shot.

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