Consumption guideline for cadmium in moose meat in northern British Columbia, Canada

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ABSTRACT
Introduction. Disturbed by reports of high concentrations of cadmium in large land mammals in Arctic Canada, community members wondered if they should eat less moose (Alces alces). Study design. Risk assessment modelling. Methods. We measured cadmium concentrations in moose tissues donated by food hunters. As a conservative assumption, we took the upper limits of the 95% confidence intervals for the means. Cadmium intake from other sources we estimated using risk assessment models. Assuming a Tolerable Daily Intake of cadmium of 1 microgram per kg body weight per day, we calculated maximum allowable intakes of moose kidney, liver and muscle. Results. For a non-smoking 70 kg adult, allowable monthly intakes are: 52 kg of moose muscle, or 137 g of kidney, or 516 g of liver. Allowable intakes varied by age and in proportion to body weight. Cigarette smokers (one to 1.5 packs per day) reach the limit even if they consume no moose at all. Conclusions. Adults may continue to eat moose kidney and liver occasionally and in moderate amounts, but children and cigarette smokers should not eat these organs at all. Consumption of moose muscle need not be restricted. Monitoring of cadmium concentrations in moose should continue.

Keywords: cadmium, diet, moose, risk assessment, consumption guideline, Indians, North American

INTRODUCTION
The Tl’azt’en Nation is an Aboriginal band, of which about 700 members reside in four villages located in the band’s traditional territory, in the vicinity of the municipality of Fort Saint James, in the northern interior of the province of British Columbia, Canada. This area is at 54.5 degrees north latitude, about 400 kilometers inland from the Pacific Ocean coast. The area is a plain covered with boreal forest and with numerous lakes and rivers. Traditional food animals obtained by hunting and fishing include moose (Alces alces), deer, beaver, hare, bear, lake trout, whitefish, burbot (ling) and red sucker. Band members participate in the cash economy, the main employers are band services and forestry. The bulk of the band members’ diets consists of purchased commercial foods, but most band members supplement their diets with meat and fish obtained by local hunting and fishing.

The analysis presented in this paper is part of a larger investigation of environmental contaminants in the Tl’azt’en Nation’s traditional food animals and plants. Industrial activities within the band’s traditional territory include mercury mining and refining (before 1979), logging, lumber manufacturing, industrial wood preservation, and silviculture (including the application of pesticides to forests). There are no local cadmium-related industries, but cadmium particulate air pollution can travel great distances before settling or being washed down in rain or snow. Thus, even remote areas of the world, far from industrial sources still experience cadmium pollution. Plants and animals take up cadmium from their environment. In animals, cadmium
tends to accumulate in the kidneys and liver. Cadmium tends to become more concentrated as it is passed up the food chain, from plants to animals, and ultimately to humans. Cadmium intake has no known nutritional value or beneficial effects on humans. All people have some cadmium in their bodies, but if people accumulate too much cadmium in their bodies, it can damage the kidneys and cause bones to become fragile and more easily broken (1,2).

Tl’azt’en Nation members were aware of and disturbed by reports of potentially toxic concentrations of cadmium found in the organs of large land mammals in Arctic Canada (3-9). They wanted to know if they should restrict intake of moose, their principal traditional meat. The purpose of this analysis was to answer the question by providing people with practical and understandable consumption guidelines derived from a quantitative risk assessment model that would combine (1) local knowledge of cadmium levels in moose meat, (2) estimates of background intakes of cadmium from air, drinking water, soil contact and eating commercial food, (3) estimates of intake of cadmium from cigarette smoking and (4) recognized maximum Tolerable Daily Intakes of cadmium.

METHODS
During the period February through November 2001, community members donated specimens of moose kidney, liver and muscle tissue. Donors were paid a compensatory fee, but were asked to hunt and gather as usual (in terms of time, place and amounts). The intent was to obtain tissue samples that were representative of what people truly consumed. The laboratory measured concentrations of cadmium and other metals using analytic chemistry procedures adapted from the Recommended guidelines for measuring metals in Puget Sound marine water, sediment and tissue samples, prepared for the United States Environmental Protection Agency and the Puget Sound Water Quality Authority, 1995. The minimum detection limit for cadmium was 0.005 milligrams per kilogram, wet weight. Some of the specimens collected earlier in 2001 were analyzed by a different method, with a minimum detection limit of 0.2 mg/kg, wet weight. We also included specimens collected and analyzed in a previous study in 1998, when the laboratory measured concentrations of cadmium and other metals by using UNICP-AES (USEPA method 200.15). The minimum detection limit for cadmium then was 0.01 mg/kg, wet weight. For purposes of the data analysis, a specimen with a cadmium level below the minimum detection limit was assigned a concentration equal to one-half of the applicable minimum detection limit.

We accepted as the background intake of cadmium (i.e., from all sources except wild game meat) age-specific estimates derived by Health Canada and Environment Canada (2, p48). These are shown in Table I. As a conservative assumption (i.e., erring on the side of caution), we took the high estimates of the population averages. The total background intake is the weighted sum of the intakes from air, water, food and soil. Since absorption of cadmium is 25% from air and 5% from drinking water, compared to 2.5% from food or ingested soil (1, p92), intake from air was weighted by a factor of 10, and intake from drinking water was weighted by a factor of 2.

We set as the Tolerable Daily Intake (i.e., maximum safe dose) an ingested dose of 1 microgram of cadmium per kg body weight per day (as a long-term average). This is the United States Environmental Protection Agency’s reference dose (RfD) for chronic oral intake of cadmium (1, p107). For risk assessment purposes, Health Canada (Food Directorate, Health Protection Branch) also suggests a Tolerable Daily Intake of cadmium of one microgram of cadmium per kilogram body weight per day as a long-term average (10). The difference between the Tolerable Daily Intake and the background intake is the allowable excess, i.e., the amount of extra cadmium that a person could safely take in from the optional sources: eating wild game meat, or smoking cigarettes.
The allowable excess of cadmium divided by the measured concentration of cadmium in a particular type of wild game meat is the allowable intake of that type of meat. Again, as a conservative assumption, we used the upper limit of the 95% confidence interval for the mean cadmium concentration in each type of tissue (moose muscle, liver and kidney).

We assumed that cadmium absorption from cigarette smoke would be 25%, the same as from inhaled air. Thus, the allowable excess of cadmium divided by ten times the estimated average cadmium content of a cigarette, 0.187 micrograms (2, p48) would be the "allowable intake" of cigarettes, with respect to cadmium. Of course, this does not mean that cigarette smoking is acceptable. Cigarette smoke contains many harmful substances other than cadmium.

RESULTS
Among the 29 specimens of moose tissue, 27 had detectable cadmium concentrations. One specimen of liver and one of kidney had cadmium levels below the minimum detection limit for the specific analytic batch (0.2 mg/kg wet weight).

Among 17 specimens of moose liver, the mean cadmium concentration was 2.31 mg/kg (wet weight), standard deviation: 1.82 mg/kg, upper 95% confidence limit for the mean: 3.20 mg/kg. Among 6 specimens of kidney the mean was 7.59 mg/kg, SD=5.09 mg/kg, upper 95%CL: 12.05 mg/kg. Among 6 specimens of muscle the mean

Table I. Estimated allowable intake of Cadmium from moose meats.

| Age: | 0 to 6 mo | 7 mo to 4 yr | 5 to 11 yr | 12 to 19 yr | 20 to 70 yr |
|------|-----------|-------------|------------|-------------|------------|
| Body Weight Units | kg | 7 | 13 | 27 | 57 | 70 |
| Background daily intake from: | | | | | |
| Air [1] µg/kg/day | 0.0011 | 0.0015 | 0.0018 | 0.0015 | 0.0013 |
| Drinking water [1] µg/kg/day | 0.0026 | 0.0014 | 0.0010 | 0.0008 | 0.0005 |
| Food [1] µg/kg/day | 0.6200 | 0.6400 | 0.5100 | 0.2900 | 0.2100 |
| Soil [1] µg/kg/day | 0.0057 | 0.0044 | 0.0015 | 0.0004 | 0.0003 |
| Total background intake [2] µg/kg/day | 0.6419 | 0.6622 | 0.5315 | 0.3070 | 0.2244 |
| Total background intake µg/day | 4.5 | 8.6 | 14.4 | 17.5 | 15.7 |
| Tolerable maximum [3] µg/day | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Allowable excess [4] µg/kg/day | 0.3581 | 0.3378 | 0.4685 | 0.6930 | 0.7757 |
| Allowable excess µg/day | 2.5 | 4.4 | 12.6 | 39.5 | 54.3 |
| Concentration in moose kidney [7] µg/g, wet | 12.05 | 12.05 | 12.05 | 12.05 | 12.05 |
| Allowable intake [5] g, wet/month | 6 | 11 | 32 | 100 | 137 |
| Concentration in moose liver [7] µg/g, wet | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 |
| Allowable intake [5] g, wet/month | 24 | 42 | 120 | 375 | 516 |
| Concentration in moose muscle [7] µg/g, wet | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Allowable intake [5] g, wet/month | 2.421 | 4.241 | 12.218 | 38.153 | 52.442 |
| Concentration in cigarettes µg/cig | 0.187 | 0.187 | | | |
| Allowable intake [6] cig/day | 21 | 29 | | | |

Notes:
[1] Reference 2, p48.
[2] Weighted sum of Cd intake from air (25% absorption, weighted by a factor of 10), drinking water (5% absorption, weight factor 2), food and soil (2.5% absorption, weight factor one) [reference 1, p92.].
[3] USEPA reference dose (RfD) for chronic oral intake of cadmium [reference 1, p107.].
[4] Allowable excess Cd intake = Tolerable maximum - total background intake.
[5] Allowable intake of foodstuff = Allowable excess Cd intake / concentration of Cd in foodstuff x time interval.
[6] Assuming 25% absorption, Cd in smoke is weighted by a factor of 10. Allowable intake of cigarettes = Allowable excess Cd intake / (concentration of Cd in cigarettes x 10).
[7] Upper limit of the 95% confidence interval for the mean cadmium concentration.
was 0.023 mg/kg, SD=0.010 mg/kg, upper 95%CL: 0.032 mg/kg.

As shown in Table I, for non-smokers, calculated allowable intakes of moose muscle ranged from 2.4 kilograms per month for infants (aged 6 months or less) to 52 kg per month for adults (aged 20 years or older). Allowable intakes of kidney ranged from 6 grams per month for infants to 137 g per month for adults. Allowable intakes of liver ranged from 24 grams per month for infants to 516 g per month for adults. Cigarette smokers (one to 1.5 packs per day) would reach the Tolerable Daily Intake of cadmium even if they consumed no moose tissue at all.

In each age category the assumed average body weight is also shown in Table I. If a person has a body weight much different from this average, then the allowable intake should be adjusted proportionate to the person’s body weight. For example, the allowable monthly intake of moose liver is 516 grams per month for a 70-kg adult. An adult weighing 1.5 times as much (105 kg) could afford to eat up to 1.5 times as much liver (774 g per month).

CONCLUSIONS

Based on the calculated allowable intakes, we advised adults that they may safely continue to eat moose kidney and liver in a manner consistent with the tradition of eating these meats in modest quantities at seasonal feasts. However, children under 12 years of age and cigarette smokers of any age should not eat these organs at all. At any age, consumption of moose muscle need not be restricted. We cannot say if pregnant women should follow any different guidelines, because we do not know what effects (if any) chronic low-dose oral intake of cadmium may have on pregnant women or fetuses (1).

The advice is based on analysis of a small number of moose meat specimens. Therefore our estimates of the mean concentrations of cadmium in moose kidney, liver and muscle are statistically imprecise (i.e., the 95% confidence intervals around the estimates of the mean are very wide.) Because we use the upper limit of the 95% confidence interval as the mean cadmium concentration input to our risk assessment model, our calculations of the maximum amounts of moose kidney, liver and muscle that a person can safely eat are probably underestimated. A person could probably safely eat more. This is consistent with our intention to err on the side of caution. We intend to continue monitoring cadmium concentrations in moose tissues. As we collect and analyze more specimens we will revise our estimates. We expect that in the future we can relax our recommendations and increase the amounts of moose kidney and liver that we advise people that they may safely eat.

We plan to use this risk assessment modelling method to develop locally relevant consumption guidelines regarding other environmental contaminants and other traditional food animals and plants, for example, methyl mercury in fish. We suggest that our methods can provide a useful model for other Aboriginal communities.

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REFERENCES

1. Taylor J, Ennever FK. Toxicological Profile for Cadmium. Atlanta, GA: 1993 Apr; Agency for Toxic Substances and Disease Registry, Public Health Service, US Department of Health and Human Services. NTIS no.: PB93-182418.
2. Environment Canada, Health Canada. Canadian Environmental Protection Act, Priority Substances List Assessment Report: Cadmium and its compounds. Ottawa, ON: 1994, Minister of Supply and Services Canada. Cat. no. En 40-215/40E, ISBN 0-662-22046-3.
3. Crête M, Potvin F, Walsh P, Benedetti J-L, Lefebvre MA, Weber J-P, Paillard G, Gagnon J. Pattern of cadmium contamination in the liver and kidneys of moose and white-tailed deer in Quebec. Sci Tot Environ 1987, 66:45-53.
4. Kim C, Chan HM, Receveur O. Risk assessment of cadmium exposure in Fort Resolution, Northwest Territories, Canada. Food Additives and Contaminants 1998, 15(3):307-17.
5. Glooschenko V, Downes C, Frank R, Baun H, Addison EM, Hickie J. Cadmium levels in Ontario moose and deer in relation to soil sensitivity to acid precipitation. Sci Tot Environ 1988, 71:173-86.

6. Data supplied courtesy of Doug Heard, BC Ministry of Environment, Land and Parks, 1011 - 4th Ave., Prince George, BC V2L 3H9. Tel: (250) 565-6425, e-mail: doug.heard@gems7.gov.bc.ca

7. Larter, NC, Nagy JA. A comparison of heavy metal levels in the kidneys of high Arctic and mainland caribou populations in the Northwest Territories of Canada. Sci Tot Environ 2000, 246:109-19.

8. Gamberg M, Scheuhammer AM. Cadmium in caribou and musk oxen from the Canadian Yukon and Northwest Territories. Sci Tot Environ 1994, 143:221-34.

9. Crête M, Nault R, Walsh P, Benedetti J-L, Lefebvre MA, Weber J-P, Gagnon J. Variation in Cadmium content of caribou tissues from northern Québec. Sci Tot Environ 1989, 80:103-12.

10. Personal communication from Dr. Mei-tein Lo, Food Directorate, Health Protection Branch, Health Canada, April 19, 2001.

11. Crête M et al. Presence de cadmium dans la foie et les reins d’orignaux et de cerfs de Virginie et Quebec. 1986, Direction generale de la faune, Ministere du loisir et de la chasse et de la peche, Quebec, 49pp.

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