Classement CCEK

Titre Substances toxiques, Cadmium et césium

Type Dossiers Environementaux

Date D'ouverture 1987

Notes

10 avril 1987: Risques de contamination radioactive associés à la consommation de viande de caribous

août 1987: 2 articles photocopiés en rapport au césium (accident de Tchernobyl)(VA)

septembre 1987: Document émit par la direction de la gestion des espèces et des habitats: "Présence de césium 134 et 137 dans les caribous du Nouveau-Québec après l'accident du réacteur nucléaire de Tchernobyl"

octobre 1987: Document donnant de l'information sur le cadmium:"Il Kuujjuaq exposed to cadmium" (VA)

40.75

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Our file Notre référence
8150-1-10

Michael Barrett
Kativik Regional Government
P.O. Box 9
Kuujjuaq, Quebec
J0M 1C0

Dear Michael:

I obtained copies of these reports from my former DIAND colleagues. Both the Swedish report and the one from MLCP are relevant to the KEAC and KRG activities. I do hope your membership problems will quickly be resolved.

A useful contact within DIAND for Caribou related questions is Donna Stewart, 994-7459.

Yours sincerely,

Camille

Camille Mageau
Senior Marine Habitat Biologist
Fish Habitat and Management Branch

Canada

IS KUUJJUAQ EXPOSED TO CADMIUM?

INTRODUCTION

[illegible] health survey to ascertain that hunters and their families are not exposed to a metallic contaminant that has been identified in certain foodstuff, in North America. This metal is called CADMIUM and it is present in the general environment largely through the application of phosphate fertilizers and the deposition of airborne particles coming from minings smelting and waste incineration procedures. These man-made sources are 10 times as important as natural sources.

The metal enters the food chain through leaves of plants which absorb and concentrate cadmium. When the leaves are consumed, such as when caribou eat lichens, the metal is absorbed and stored in the liver and in the kidneys. Although only a very small amount is absorbed through food (only approximately 5%) once it is absorbed, it remains in the body for very long periods. Cadmium in also present in tobacco leaves and cigarette smokers absorb the metal through their lungs as well.

THE DISEASES RELATED TO CADMIUM

Fortunately, the concentration of cadmium are not high enough to create diseases that will become obvious rapidly. One has to think in terms of 30 to 50 years of accumulating the metal, before diseases strikes. On the other hand, we cannot wait until persons become sick to adopt the required policies if these are indeed needed.

THE HEALTH SURVEY

It is known that cadmium is stored in the liver and in the kidneys of caribou, deer, moose and other wildlife. It is also known that cadmium is present in significant amounts in the wildlife of Québec, in the North and in the South. Inuit hunters and their families have been told to avoid eating kidneys and livers of the game they catch, and we now wish to make sure this recommendation was sufficient to protect the health of persons exposed.

We propose to examine a small blood sample of residents of Kuujjuaq to determine whether abnormal quantities of cadmium may be found. We would also examine a small sample of hair, because hair will give a good idea of what has occurred in the past as far back as one year ago. The examination of 60 persons would give a fairly precise picture of what is occurring in the whole population of Kuujjuaq and would indicate whether further intervention is necessary to protect everyone against this possible source of disease.

The persons invited to provide blood and hair specimens would be chosen by the community and the specimens would be collected at the hospital, where a few questions would be asked about consumption of cigarettes and certain foodstuffs. The analysis of specimens would be carried out at the Centre de Toxicologie du Québec and the final report would be prepared by scientists from the CHUL and Laval University.

We are confident this survey would enable us to propose an accurate description of the exposure of the Inuit population to this metal.

ETUDE DU TAUX DE CADMIUM CHEZ LES INUIT DU QUÉBEC ARCTIQUE

Budget préliminaire

Dans son rapport d'août 87, le groupe de travail interministériel sur le cadmium démontrait un niveau de contamination relativement important dans les abats de caribou du troupeau de la Rivière Georges. Le rapport recommandait alors d'entreprendre une étude exploratoire afin de vérifier l'état d'exposition ou d'imprégnation des groupes les plus exposés au Québec Arctique. Le présent document vise à établir les coûts afférents à une telle étude.

Il importe d'insister en premier lieu sur la nécessité d'impliquer concrètement les organismes du milieu (CRSSS Kativik, CH de l'Ungava, Comité de santé, etc.) dès le début. En effet aucune étude sur une population humaine au Nord ne peut être entreprise sans un certain consensus au niveau local, et aucune étude ne pourrait être véritablement réussie sans une participation active des organismes locaux, laquelle suppose une association dès les premières étapes du projet. Ainsi, la détermination précise des composantes de l'étude envisagée (dont les aspects budgétaires, la répartition des tâches et les modes de diffusion des résultats) ne pourra se réaliser qu'après une discussion avec les différents partenaires (étape no 1).

Il apparaîtrait donc utile à ce stade que le MSSS dont le rôle dans le dossier est central prenne contact avec le CRSSS Kativik pour convoquer une réunion des intervenants au Nord.

1. Réunion à Kuujjuaq avec CRSSS et CH Ungava

Transport Québec-Kuujjuaq:	
3 personnes à $800. (MSSS,DSC,CTQ)	$2,400.
Séjour à Kuujjuaq:	
2 jours x $130./jour x 3	780.
Sous-total:	**$3,180.**

2. Frais de recherche (sauf laboratoire)

Elaboration d'un questionnaire: (avec traduction en inuktitut)	700.
Séjour-terrain d'une personne-ressource:	
Transport	800.
Séjour: 10 jours x $130./jour	1,300.
Frais d'interprète/assistant de recherche:	
100 heures/ $10./heure	1,000.
Frais de prélèvements	1,000.
Sous-total:	**$4,800.**

3. Coûts analytiques (CTQ)

Matériel de prélèvement:	120.
Coûts de transport:	100.
Dosage de Cd/sang à $10.	600.
Dosage de Cd/cheveux (5 segements/personne x $20./segement x 60)	6,000.
Recherches bibliographiques, secrétariat photocopies, téléphones, etc.	1,500.
Sous-total:	**$8,320.**

4. **Conclusion de la recherche**

Analyse des résultats et rapport (avec traduction):	$4,500.
Campagne d'information au Nord:	3,000.
Sous-total:	**$7,500.**
GRAND TOTAL:	**$25,100.**

CADMIUM

TECHNICAL FACT SHEET prepared by Philippe DiPizzo
23 October 1987

Cadmium (Cd) is a white, ductile, malleable metal used mostly in metallurgy to protect non-ferrous metals such as zinc and copper. Most atmospheric cadmium emanates from this industry although some comes from using fossil fuels such as coal and hydrocarbons.

Cadmium in the environment

Cadmium is found in its natural state in the Earth's crust in insignificant concentrations. The presence of cadmium is mostly due to human activities. In Quebec, the main source of atmospheric cadmium is the copper smelter in Noranda. The transportation of aerosols containing cadmium is another possible source in areas located far away from industrial centres.

Atmospheric cadmium can easily be absorbed by plants, either directly by the leaves or indirectly by root tissue. Herbivores are therefore the most vulnerable species to cadmium contamination. It accumulates mainly in their kidneys, liver, and other intestinal tissues and in smaller quantities in the soft tissues. Since man is at the end of the food chain, he is in fact the species most affected by cadmium poisoning.

Cadmium in food

The main foods likely to be contaminated by cadmium are herbivores' liver and kidneys, molluscs and crustaceans, leaf vegetables, and cereal grasses such as rice and wheat.

The World Health Organization (WHO) believes the acceptable daily intake of cadmium ranges between 57 µg and 72 µg. According to the available data, the average intake in Quebec amounts to approximately 67 µg excluding the quantity ingested in "regular" food. Furthermore, smoking a package of 20 cigarettes a day could increase cadmium absorption by 0.5 µg to 2 µg.

The consumption of cadmium-rich foods can therefore significantly increase concentrations beyond safe levels and engender serious medical complications.

Cadmium and human health

Cadmium ingested in contaminated food is transported in the blood stream and then deposited in the liver and kidneys. Its elimination from the body is very slow. In the human body cadmium has a half-life (the time in which a value is reduced by half) of 20 to 30 years and sometimes longer in the kidneys; excretion in urine and feces is consequently limited. Cadmium can therefore constitute a more serious environmental problem than mercury since mercury has a shorter half-life than cadmium.

There are two forms of cadmium poisoning: acute and chronic. Acute poisoning is mainly the result of industrial exposure and consequently will not be discussed here. Chronic poisoning is associated with the ingestion of cadmium in low concentrations in food, airborne particles, and the use of phosphatic fertilizers.

Chronic cadmium intoxication is well-documented, especially in Japan. Many people were poisoned there by the regular consumption of water and food contaminated by cadmium-rich water, from industrial sources, used to irrigate fields. The resulting ailment was named Itai-Itai disease, which means ouch-ouch in Japanese.

Respiratory (pulmonary emphysema) and renal (proteinuria) disorders and sometimes hepatic, blood, and bone disturbances can result from chronic cadmium poisoning.

Man takes in approximately 5% of all the cadmium ingested, but this percentage can rise considerably if the individual also suffers from iron, calcium, and vitamin deficiencies for example and uses tobacco.

The main symptoms associated with chronic intoxication are, by order of appearance, proteinuria (the presence of proteins in urine) and inability to metabolize calcium and phosphorus resulting in kidney stones and osteomalacia (a general softening of the bones).

Respiratory problems, such as decreased olfactory sensitivity, rhinitis (acute inflammation of the nasal mucous membranes), bronchitis, and emphysema have also been observed.

Direction de la gestion des espèces et des habitats

Présence de césium 134 et 137 dans les caribous du Nouveau-Québec après l'accident du réacteur nucléaire de Tchernobyl.

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Direction générale de la ressource faunique

Ministère du Loisir, de la Chasse et de la Pêche

Gouvernement du Québec

Septembre 1987

Résumé: Vingt-sept échantillons de chair de caribous du troupeau de la rivière George, prélevés en octobre 1986 et mars 1987, ont révélé la présence de césium 134 et 137. La concentration moyenne de l'isotope 137 était voisine de 600 becquerels (Bq) kg^{-1} en octobre, et d'environ 1400 Bq kg^{-1} en mars; l'isotope 134 était présent à des concentrations beaucoup moindres (~25 Bq kg^{-1}). Tout le césium 134 et environ 10 pour cent du césium 137 présent provenaient de l'accident de Tchernobyl. Aux concentrations actuelles, la consommation annuelle de moins de 120 kg de viande de caribou contenant 600 Bq kg^{-1} entrainerait une exposition aux rayons ionisants conforme à la norme internationale de 1 millisievert (risque de cancer fatal = 1/100 000). Suivant cette norme, la venaison contenant 1 400 Bq kg^{-1} devrait être consommée à moins de 50 kg par individu par année. Par ailleurs, durant les 25 dernières années, certaines personnes, en particulier des autochtones, ont pu être exposées au césium 137 provenant des tests d'armes nucléaires tenus en atmosphère: on a calculé que la consommation annuelle de 100 kg de chair de caribou pendant une telle période a exposé ces individus à un risque de cancer fatal additionnel de 1/1600, 1/1000 ou 1/700 selon que les rétro-calculs étaient basés sur trois concentrations comprises à l'intérieur de la fourchette mesurée en octobre 1986 et mars 1987. Aucune recommandation définitive concernant la consommation de la viande de caribou ne peut être encore formulée compte tenu du nombre limité d'échantillons examinés, mais il se pourrait que des restrictions soient nécessaires, en particulier pour les caribous tués l'hiver. La contamination de l'environnement par le césium 137 va progressivement disparaître, la demi-vie effective de cet isotope étant d'environ 8 à 10 ans dans les lichens.

INTRODUCTION

Les isotopes 134 et 137 du césium constituent des éléments nouveaux, créés par l'Homme moderne; ils sont issus de l'utilisation de l'énergie nucléaire. Ces isotopes sont instables et se désintègrent graduellement. Lors de ce processus, ils libèrent cependant des rayons ionisants qui peuvent être dommageables à la santé. À très fortes doses (10 sieverts), les rayons ionisants détruisent tellement de cellules des organismes vivants que la mort suit à brève échéance. Les doses plus faibles, qui ne sont pas immédiatement mortelles, provoquent par ailleurs des cancers qui peuvent se manifester parfois très longtemps après l'exposition. Par contre des rayons ionisants originent aussi de sources naturelles: espace cosmique et matériaux composant la terre. Ces rayonnements naturels exposent, en moyenne, toute personne à une dose annuelle de 1 millisievert. Cependant, la viande de caribou contient beaucoup de polonium 210 (United Nations Scientific Committee on the effects of atomic radiation 1982), un radioélément naturel, ce qui expose les consommateurs de cette venaison à une dose de rayonnements naturels supérieure à la moyenne générale (D. Meyerhof, comm. pers.). Une exposition annuelle de 1 millisievert entraîne des risques de développer un cancer fatal au cours de la vie dans un cas sur 100 000 (Paragraphe tiré de Johnson et Tutian 1985).

L'accident de la centrale nucléaire de Tchernobyl, survenu en avril 1986, a libéré dans l'atmosphère des quantités importantes de substances radioactives, dont le césium représentait environ 10 pour cent des particules (Bangert et al. 1986). Toutefois le césium 137 possède une demi-vie de 30 ans et sa persistance prolongée dans l'environnement le rend plus dangereux que d'autres éléments radioactifs comparables qui se désintègrent rapidement. Pour sa part, le césium 134 possède une demi-vie de 2 ans. La longue demi-vie de l'isotope 137 explique pourquoi les études environnementales portant sur la radioactivité se sont surtout concentrées sur celui-ci.

Les lichens puisent les éléments nutritifs dont ils ont besoin de l'air et des précipitations car ils n'ont pas un système radiculaire développé (Martin et Coughtrey 1982). Ils possèdent la capacité d'accumuler les éléments à des niveaux beaucoup plus élevés que leurs besoins physiologiques (Puckett 1986), ce qui les rend vulnérable à concentrer les polluants atmosphériques. Ainsi les lichens accumulent, entre autres, le césium.

Les lichens constituent une fraction très importante du régime alimentaire du caribou et du renne en hiver. Comme le césium est, physiologiquement, semblable au potassium, un élément essentiel chez les mammifères, il passe ainsi facilement dans l'organisme des caribous, et se localise dans tous les tissus. Il peut, par contre, être excrété tout comme le potassium, de sorte que sa présence chez le caribou est plus grande en hiver que l'été, suivant l'abondance des lichens dans l'alimentation (ex. Westerlund et al. 1987). Finalement le césium passe chez les prédateurs du caribou, dont l'homme (Bird 1968, Hanson 1982; Westerlund et al. 1987). La demi-vie du césium 137 est de 27 et 100 jours respectivement chez le renne et l'homme adulte (Wester-lund et al. 1987).

Au début des années soixante, au moment où un moratoire survint sur les essais atmosphériques d'armes nucléaires, on s'est rendu compte que la chaîne alimentaire lichen/caribou(renne)/homme était contaminée par le césium 137 (Bird 1968; Hanson 1982; Westerlund et al. 1987). À cette époque, une étude effectuée dans les Territoires du Nord-Ouest (Bird 1968) arriva à la conclusion que, même pendant la période où les niveaux de césium observés chez les autochtones étaient les plus élevés, les dangers de consommer la chair du caribou étaient minimes. Depuis, les niveaux de césium dans cette chaîne alimentaire ont diminué progressivement autant en Scandinavie qu'en Amérique du Nord (Westerlund et al. 1987; Santé et Bien-être social, non publ.). Aucune donnée historique n'est cependant disponible pour le Québec.

L'accident de Tchernobyl a contaminé de façon importante les pâturages des rennes scandinaves, de sorte que plusieurs milliers d'animaux sont devenus impropres à la consommation humaine. Par soucis pour les utilisateurs du caribou du Nouveau-Québec, les autochtones et les chasseurs sportifs, nous avons évalué l'impact de l'accident de Tchernobyl sur la chair et les abats de ce cervidé.

MÉTHODE

Des échantillons de tissus de caribous appartenant au troupeau de la rivière George ont été prélevés en octobre 1986 et mars 1987 (Fig. 1). Quatorze et 11 individus différents composèrent respectivement l'échantillon d'octobre et de mars. Pour les deux périodes, les caribous furent abattus dans le même secteur au cours de quelques jours; ces animaux faisaient généralement partie de groupes différents. Un échantillon d'environ 500-1000 g de muscle des quartiers arrières fut prélevé sur tous les spécimens pour en estimer la teneur en césium. En plus, au mois d'octobre, des échantillons de coeur, de foie, de poumons, de reins et d'os furent aussi récoltés pour analyse.

Deux laboratoires ont procédé à l'analyse du dosage du césium 137 et 134 dans les mêmes échantillons de muscle de caribou prélevés à l'automne 1986: le laboratoire Slowpoke de l'Ecole polytechnique de Montréal et le laboratoire du Bureau de la radioprotection et des instruments médicaux du Ministère de la Santé nationale et du Bien-Être social à Ottawa. Au laboratoire de Montréal, l'analyse a aussi porté sur les autres tissus de caribous prélevés lors de l'autopsie.

Pour doser les radioéléments, on a détecté les rayons gamma caractéristiques qui sont émis spontanément par les noyaux des atomes. Ces rayons furent captés par un détecteur à cristal, et transmis à un analyseur multicanal qui produit, sur un écran cathodique ou sur un graphique, le spectre gamma de chaque échantillon. A partir de ces spectres, on a identifié les radioéléments présents dans l'échantillon et, d'après l'intensité des pics qui composent le spectre, on a déduit le nombre de becquerels (Bq).

Les échantillons ont été coupés en morceaux et mis dans des contenants à géométrie appropriée pour faire le comptage, géométrie identique à celle d'un étalon dont le dosage en radioéléments est bien connu. Quant aux os, ils furent concassés. Avant d'être comptés, les échantillons préparés furent pesés et placés dans une voûte de plomb où se trouvait le cristal détecteur. Les échantillons prélevés en mars 1987 furent analysés au laboratoire d'Ottawa seulement.

RÉSULTATS

Le dosage du césium fait au laboratoire d'Ottawa a donné des moyennes respectives, pour les isotopes 137 et 134, de 559 (E.S.=55; n=13) et 24 (E.S.=1; n=13) Bq kg^{-1} dans les muscles des caribous prélevés en octobre 1986. Les mêmes échantillons, dosés au laboratoire de Montréal, ont donné des valeurs moyennes assez comparables de 572 et 23 Bq kg^{-1} (Tableau 1). Quant aux échantillons prélevés en mars 1987, les résultats des dosages faits à Ottawa indiquèrent une moyenne de 1378 (E.S.=84; n=11) Bq kg^{-1} pour le césium 137 et de 25 (E.S.=2; n=11) Bq kg^{-1} pour le césium 134 dans les muscles. La comparaison des divers tissus de caribous récoltés en octobre 1986 a révélé d'un autre côté que seuls les reins étaient plus contaminés que la chair (Tableau 1).

DISCUSSION

Contamination des lichens et des caribous

Les concentrations de césium 137 retrouvées dans différentes espèces de lichens ont montré, à l'ouest de la baie d'Hudson, une variation latitudinale en cloche, avec des valeurs maximales observées entre le 60° et le 70° N (Hutchison-Benson et Svoboda 1985). Ce patron de contamination s'explique, d'une part, par les dépôts atmosphériques qui diminuent progressivement en importance en allant vers le nord, et, d'autre part, par un recyclage plus rapide de césium en allant vers le sud (Hutchison-Benson et Svoboda 1985).

Le patron de contamination des lichens n'a pas encore fait l'objet d'études au Nouveau-Québec, mais il se pourrait que la zone la plus polluée y soit située plus au sud qu'à l'endroit étudié des Territoires du Nord-Ouest. À en juger par les quantités de césium retrouvées dans la chair des caribous du Nouveau-Québec, qui étaient les plus élevées de tout le Canada à l'hiver de 1987 (D. Meyerhof, comm. pers.), il est plausible d'émettre l'hypothèse que les lichens y soient parmi les plus contaminés de toute l'Amérique du Nord, du moins dans la région située au sud du lac Bienville où fut prélevé l'échantillon de mars 1987 (55°N). Hansen (1982) a trouvé un rapport 1:4 entre la concentration de césium dans les lichens et la chair des caribous; les parties de lichens broutées par les caribous du troupeau de la rivière George devaient donc contenir autour de 350 Bq kg^{-1} en mars 1987. Une alternative serait que les caribous du Nouveau-Québec consomment plus de lichens que ceux du reste du continent.

Des échantillons de chair de caribous du troupeau de la rivière George ont aussi été prélevés en avril 1987 au Labrador par le gouvernement de Terre-Neuve. Ces échantillons étaient environ cinq fois moins contaminés que nos spécimens de mars 1987, récoltés au sud du Lac Bienville (D. Meyerhof, comm. pers.). Les échantillons terre-neuviens provenaient cependant des premiers caribous arrivant dans la région du terrain de mise bas du troupeau de la rivière George; on pense que ces animaux ont séjourné un bon moment le long de la Baie d'Ungava, près de Tasiujaq et Aupaluk, avant de migrer au Labrador. Les lichens sont moins abondants dans ce secteur et les caribous y consommaient aussi des plantes graminoïdes. Ces résultats fragmentaires suggèrent que le régime alimentaire des caribous influence leur charge en césium; ainsi des individus du même troupeau peuvent être affectés de façon fort différente.

Les habitudes alimentaires des caribous du troupeau de la rivière George font actuellement l'objet d'une étude, mais les échantillons de contenu de rumen ne sont pas encore analysés en détail. Toutefois un examen sommaire des échantillons récoltés en mars 1987 a révélé que les fragments de lichens dominaient largement les contenus de rumen à cette période. L'examen sommaire de 12 rumens provenant de caribous sacrifiés en juillet 1987 indiquait par contre que les feuilles de bouleau et les plantes graminoïdes composaient la majeur partie des végétaux consommés en été. Ainsi la variation saisonnière de la consommation de lichens explique les variations de la teneur en césium de la chair des caribous du Nouveau-Québec, phénomène aussi observé en Alaska et en Scandinavie (Hanson 1982; Westerlund et al. 1987). Une variation saisonnière de la contamination des tissus du caribou par le cadmium, un métal lourd toxique, vient aussi d'être mise en évidence pour le troupeau de la rivière George (Crête et al. 1987).

L'impact de l'accident de Tchernobyl

Le 26 avril 1986, une explosion suivie d'un incendie se produisit dans la centrale nucléaire de Tchernobyl, en Union Soviétique.

Cet accident libéra, dans l'atmosphère, une quantité importante de radioéléments dont, entre autres, l'iode 131, le césium 137 et 134. Ces polluants atmosphériques, apportés par les vents, ont atteint la côte ouest du Canada vers le 7 ou le 8 mai 1986 et se sont par la suite disséminés sur l'ensemble du territoire. Ces radio-éléments (sauf le césium 134) sont des produits de la fission de l'uranium, identiques aux éléments produits lors d'essais de bombes atomiques dans l'atmosphère, au cours des années soixante.

Les conséquences de l'accident sont notables. D'abord la présence de césium 134 dans le corps des caribous indique qu'il s'agit de retombées radioactives atmosphériques provenant de Tchernobyl. En effet, l'isotope 134, n'était pas présent dans l'environnement avant l'accident. Il vient donc d'apparaître dans les lichens et les caribous, et avec lui du césium 137 nouveau, originant de l'accident. Considérant le rapport césium 137/134 mesuré dans les retombées de Tchernobyl (2.9/1), on peut estimer que l'accident a augmenté d'environ 10 pour cent, la quantité de césium 137 présente dans les caribous. La figure 2 illustre la concentration automnale estimée de césium 137 retrouvée dans la chair des caribous du Nouveau-Québec depuis 1962.

Risque pour la santé humaine

En Amérique, l'accident de Tchernobyl n'a pas eu les mêmes conséquences qu'en Scandinavie où les lichens furent sévèrement contaminés. Cependant il a permis de prendre conscience que le césium 137 produit au début des années soixante était encore très présent dans l'environnement. Ainsi, la chair des caribous prélevés en mars 1987 renfermait encore près de 1400 Bq kg^{-1}, dont 90 pour cent étaient antérieurs à l'accident de Tchernobyl. Pour les consommateurs occasionnels de venaison de caribou, les dangers causés par la présence actuelle de césium sont minimes; ainsi un repas de 250 g de viande de caribou tué en hiver (1400 Bq kg^{-1}) équivaut, en terme de risques, à fumer moins de la moitié d'une cigarette (Santé et Bien-être social Canada, non publ.). Le véritable problème est d'évaluer le risque crée par une exposition prolongée au césium 137, exposition pouvant aller jusqu'à 25 ans pour certains individus, en particulier les autochtones.

La figure 3 présente une estimation de l'activité moyenne cumulative du césium 137 ingéré en consommant annuellement 100 kg de viande de caribou. Une telle consommation est jugée extrême et s'appliquerait surtout à certains autochtones qui vivent dans des régions où abondent les caribous. Trois scénarios furent envisagés comme point de départ des rétrocalculs à partir de 1987: de la chair renfermant environ 484, 840 ou 1197 Bq kg^{-1} (Ces valeurs proviennent des moyennes d'octobre et de mars et d'une valeur intermédiaire, desquelles on a déduit l'apport de Tchernobyl). La dernière hypothèse (1197 Bq kg^{-1}) est extrême pour deux raisons. D'abord, il s'agit de concentrations hivernales alors que souvent les caribous sont abattus à la fin de l'été ou en automne, contenant à cette période beaucoup moins de césium. En second lieu, l'échantillon de mars 1987 fut prélevé dans l'ouest du Québec, une région qui n'est utilisée que depuis le début de la décennie par le troupeau de la rivière George (Messier et al. 1987); il se peut que l'environnement ait été moins contaminé par le césium plus au nord-est, où avaient coutume d'hiverner ces animaux auparavant.

La consommation d'un becquerel de césium 137 entraîne une irradiation (un équivalent de dose), dans le corps entier de l'individu, de 1.4×10^{-5} millisievert (ICRP 1979;Johnson et Dunford 1983). Or une irradiation de 1000 millisieverts cause un risque de développer un cancer fatal au cours de la vie dans 1 cas sur 100 (ICRP 1979). Basé sur ces relations, le risque d'être victime d'un cancer fatal attribuable à la consommation annuelle de 100 kg de viande de caribou a été calculé en fonction du nombre d'années d'exposition, suivant trois concentrations de césium 137 comme point de départ des rétrocalculs (Tableau 2). La probabilité est infime pour une seule année d'exposition, et atteint, lorsque la période de consommation s'étend sur 25 ans, environ une chance sur 1600, 1000 ou 700 suivant la concentration initiale assumée. Comparé aux risques causés par la cigarette, l'automobile ou l'avion (Tableau 3), les risques causés par une consommation prolongée d'une grande quantité de caribou (100 kg/an^{-1}) s'avèrent relativement raisonnables (Tableau 3). Il se peut, d'autre part, que le facteur de conversion de dose de ICRP (1.4 X 10^{-5} millisievert) soit légèrement surestimé, si la demi-vie de césium dans le corps humain est plus courte que les 110 jours assumés par le modèle de calcul (Hansen et Eberhard 1969; D. Meyerhof, comm. pers.). Cette dernière hypothèse reste cependant à être validée.

L'exposition cumulative estimée, après 25 années d'ingestion annuelle de 100 kg de viande de caribou, aurait été de 61, 100 et 140 millisieverts dans le cas respectif d'un rétrocalcul basé sur 484, 840 ou 1197 Bq kg^{-1} (Tableau 2). Ceci excède grandement l'exposition d'environ 11 millisieverts estimée pour les éleveurs de rennes de Norvège durant l'intervalle 1951-1983 (Westerlund et al. 1987) et de 13 millisieverts pour les Inuit d'un village d'Alaska durant la période 1963-1979 (Hansen 1982). Deux raisons principales expliquent cet écart marqué. En premier lieu, les caribous du Québec sont actuellement plus contaminés que ceux d'Alaska ou que les rennes de Norvège, abstraction faite de l'apport de Tchernobyl; par extrapolation, nous avons présumé qu'il en a été ainsi depuis 1963. Deuxièmement, la consommation annuelle de viande de caribou n'a pas été la même aux trois endroits. Dans nos calculs, nous avons supposé une valeur de 100 kg an^{-1}. Les données exactes ne sont pas présentées dans les deux autres études, mais l'on peut déduire que la consommation annuelle aurait diminuée d'environ 200 à 40 kg au cours de la période à l'étude en Alaska, alors qu'elle aurait été stable à environ 13 kg en Norvège.

Il existe une norme d'exposition aux sources de rayonnement ionisant d'origine humaine proposée par la commission internationale sur la protection radiologique (ICRP 1979): toute personne du grand public devrait recevoir, au plus, une dose de radiation provenant de matières radioactives ne dépassant pas 5 millisieverts au cours d'une seule année; pour une exposition prolongée, il serait prudent de limiter cette dose à 1 millisievert par année au cours de la vie. Ainsi quelqu'un qui a consommé annuellement 100 kg de caribou pendant les 25 dernières années, a dépassé sensiblement la limite proposée de 25 millisieverts. Si nos échantillons d'octobre et de mars étaient représentatifs des conditions d'été et d'hiver, il faudrait actuellement restreindre la consommation annuelle de viande de caribou respectivement à 120 et 50 kg par individu pour suivre la norme de 1 millisievert par année. Il y a lieu de prélever d'autres échantillons de chair de caribou à différentes périodes de l'année et en différents lieux afin d'en préciser le degré de contamination par le césium; des données additionnelles permettraient de formuler des recommandations de consommation. Par ailleurs, la demi-vie du césium 137 atteint 8-10 ans dans les lichens (fig. 2) de sorte que la contamination aura diminué d'environ 70 pour cent à la fin du siècle; en autant qu'il n'y ait pas d'autres accidents nucléaires, les limites de consommation pourront dont être progressivement relevées.

Conséquences pour la commercialisation de la venaison de caribou

Au Canada, il n'existe pas présentement de réglementation précisant un niveau tolérable de césium dans les aliments. Cependant, les autorités canadiennes ont établi, à la suite de l'accident de Tchernobyl, qu'une présence de césium supérieure à 300 Bq kg-1 représentait un empêchement à l'introduction d'aliments au pays. Cette norme provisoire fait actuellement l'objet d'une revision. Dans une perspective domestique, ces mêmes autorités reconnaissent tolérable une concentration pouvant aller jusqu'à 3000 Bq kg^{-1} pour une seule année de consommation de viande de caribou, assumant une prise de 100 kg an^{-1}. Pour une consommation prolongée, la limite tolérable est de 600 Bq kg^{-1}.

S'il y avait mise en marché de la venaison de caribou au Québec, ce produit constituerait probablement un aliment de luxe que les consommateurs ne mangeraient qu'à l'occasion. Leur exposition au césium serait ainsi insignifiante. Cependant, il serait hasardeux de tenter de justifier l'écart entre la proposition de norme internationale à 300 Bq kg^{-1} et un niveau domestique à 600 Bq kg^{-1}. La venaison de caribou mise en marché devrait donc renfermer moins de 300 Bq kg^{-1}, tant que le critère d'admissibilité des denrées étrangères restera à ce niveau. Pour respecter le niveau de 300 Bq kg^{-1}, il faudrait capturer les caribous aux moments et aux endroits les plus favorables, et les garder vivants en captivité le temps nécessaire qu'ils excrètent suffisamment de césium. L'addition de potassium à leur alimentation pourrait accélérer l'élimination du contaminant.

RECOMMANDATIONS

La présence de césium 134 et 137 dans la chair des caribous du Nouveau-Québec entraîne des risques relativement petits pour la santé humaine. Cependant, si l'on désire se conformer aux normes de sécurité proposées concernant l'exposition aux irradiations de matières radioactives, il se pourrait que l'on doive recommander des limites maximales de consommation annuelle. Comme les données sur la contamination par le césium de la chair des caribous du Nouveau-Québec sont actuellement très fragmentaires, il est recommandé:

1- De procéder à un échantillonnage plus complet afin de préciser les variations saisonnières et géographiques de la présence du césium dans la chair de ces animaux.

Comme tous nos calculs sont basés sur des taux hypothétiques de consommations de chair de caribou par les autochtones, il est recommandé:

2- De réaliser une étude sur les habitudes de consommation de la viande de caribou pour les communautés autochtones qui ont accès à cette ressource.

Compte tenu que les lichens accumulent facilement les polluants atmosphériques, qu'ils sont vraisemblablement contaminés par plusieurs éléments en plus de césium (cadmium, arsenic, mercure, plomb, sélénium, etc.), et qu'ils constituent l'élément dominant de la nourriture hivernale du caribou, il est recommandé:

3- De procéder à un échantillonnage des lichens du Nouveau-Québec pour déterminer l'importance et la répartition de ces polluants dans l'environnement.

4- De mesurer les quantités de ces contaminants présentes dans les tissus de caribou et d'évaluer les risques pour la santé humaine.

Comme finalement le facteur de conversion de dose reliant la consommation de viande et la dose de rayonnement reçu par l'organisme humain provient d'un modèle général de ICRP, il se peut qu'il diffère légèrement dans le cas précis de la chair de caribou. Il est recommandé:

5- D'estimer la charge corporelle annuelle en césium des grands consommateurs de viande de caribou au Québec et d'estimer la demi-vie effective de ce radioélément chez ces personnes.

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Nous voudrions exprimer notre reconnaissance envers D. Meyerhof et R. S. Eaton du ministère fédéral de la Santé et du Bien-être social qui ont fourni plusieurs informations non publiées et avis professionnels en plus d'avoir commenté le manuscrit initial. Merci également à L. Zikovsky de l'École Polytechnique de Montréal qui a procédé à plusieurs analyses. Finalement nous apprécions le travail de J. Bouchard qui a dessiné les figures.

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Tableau 1. Concentrations moyennes de césium 137 et 134 dans les tissus de caribous récoltés en octobre 1986 au Nouveau-Québec, d'après l'analyse faite par le laboratoire de l'Ecole polytechnique de Montréal.

	Cs 137			Cs 134		
	$\bar{x}$	E.S.[a]	n[b]	$\bar{x}$	E.S.	n
Chair	572	50	13	23	2	13
Coeur	434	38	12	14	0.8	12
Foie	265	25	13	11	0.9	13
Os	57	8	13	3	0.2	13
Poumon	244	21	11	11	0.6	11
Rein	863	61	14	33	2	14

[a] erreur standard de la moyenne

[b] nombre de caribous composant l'échantillon

Tableau 2. Probabilité de développer un cancer fatal au cours de la vie à cause de la consommation annuelle de 100 kg de chair de caribou renfermant en 1987, soit 484, 840 ou 1197 Bq kg^{-1}. Ces calculs ne tiennent pas compte des retombées de Tchernobyl; le césium considéré origine des essais de bombes nucléaires en atmosphères réalisés dans les années soixante.

Début de la consommation	Période d'exposition (année)	Teneur en césium 137 en 1987 (Bq kg^{-1})		
		484	840	1197
1986	1	1/142900 (0.7)[a]	1/71400 (1.4)	1/62500 (1.6)
1982	5	1/24400 (4.1)	1/14100 (7.1)	1/11100 (9.0)
1977	10	1/9100 (11)	1/5300 (19)	1/4000 (25)
1972	15	1/5000 (20)	1/2900 (35)	1/2000 (50)
1967	20	1/2800 (36)	1/1700 (60)	1/1100 (90)
1962	25	1/1600 (61)	1/1000 (100)	1/700 (140)

[a] nombre cumulatif de millisieverts reçus

Tableau 3. Quelques probabilités de décès au cours d'une période de 25 ans causé par des activités de pratique courante.

	Risque de mortalité après 25 ans d'exposition	Source
Fumer 1 paquet de cigarettes/jour	1/55[a]	Santé et Bien-Être Social
Circulation routière[b]	1/221	Régie de l'assurance automobile du Québec
Faire 1 voyage en avion/année		Ministère des Transports et Statistiques Canada

[a] concerne uniquement le cancer du poumon

[b] basé sur la période 1982-1986

[c] basé sur la période 1976-1986.

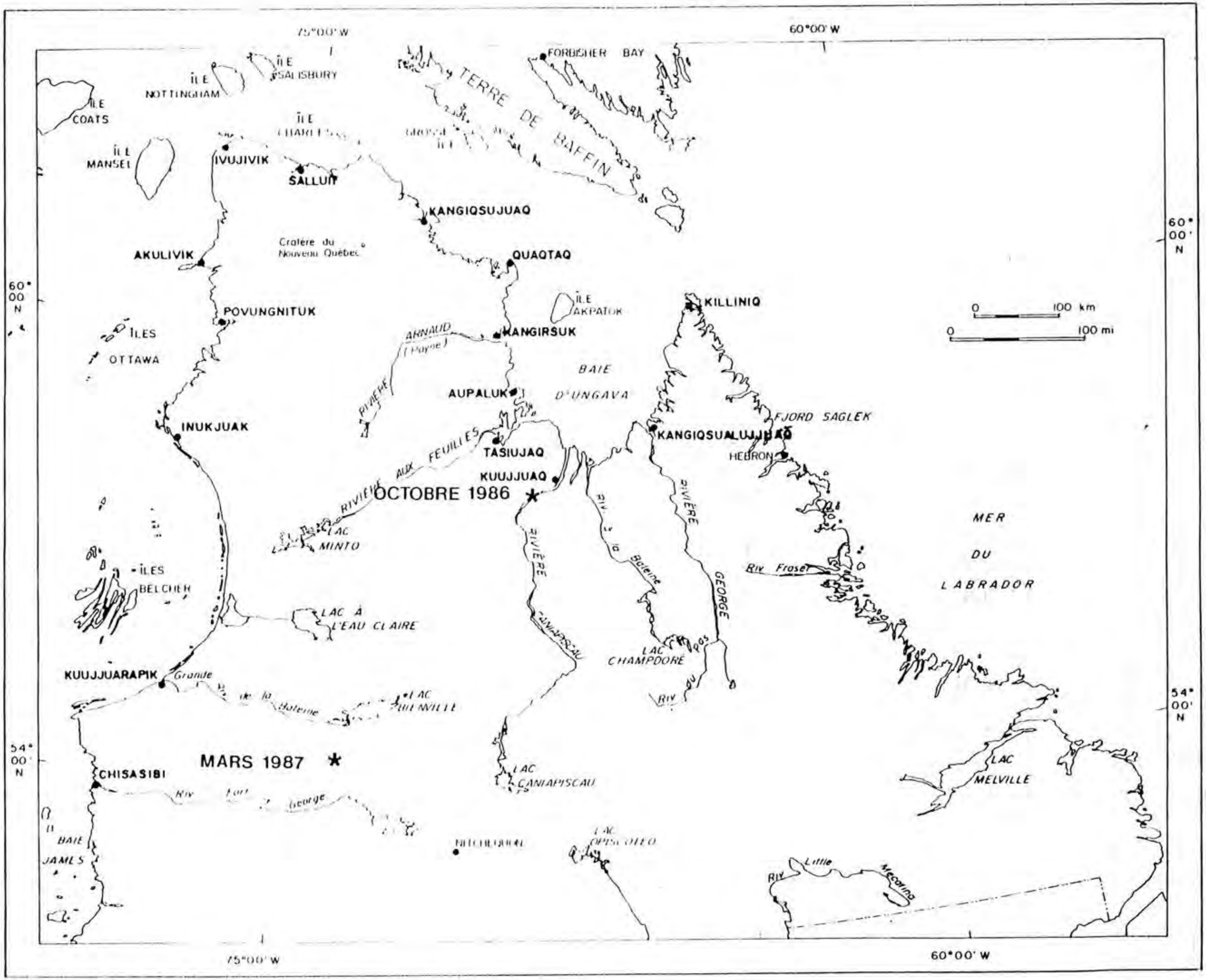

Figure 1. Localisation des deux sites où les échantillons de tissus de caribous du troupeau de la rivière George furent prélevés pour le dosage du césium.

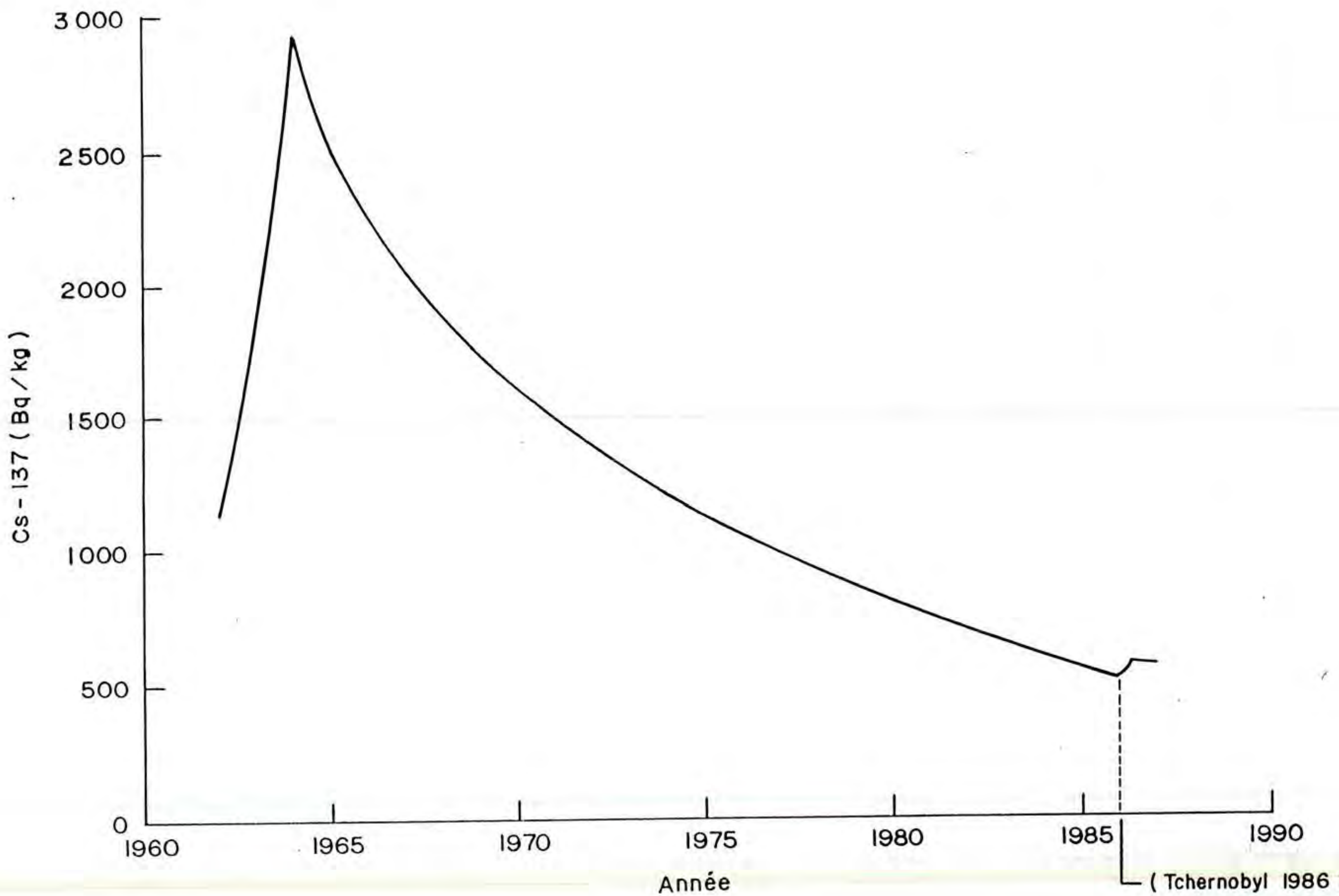

Figure 2. Concentration estimée (Bq kg^{-1}) de césium 137 présent, à l'automne dans la chair des caribous du troupeau de la rivière George entre 1962 et 1987 (adapté de Santé et Bien-être social Canada, non publ.).

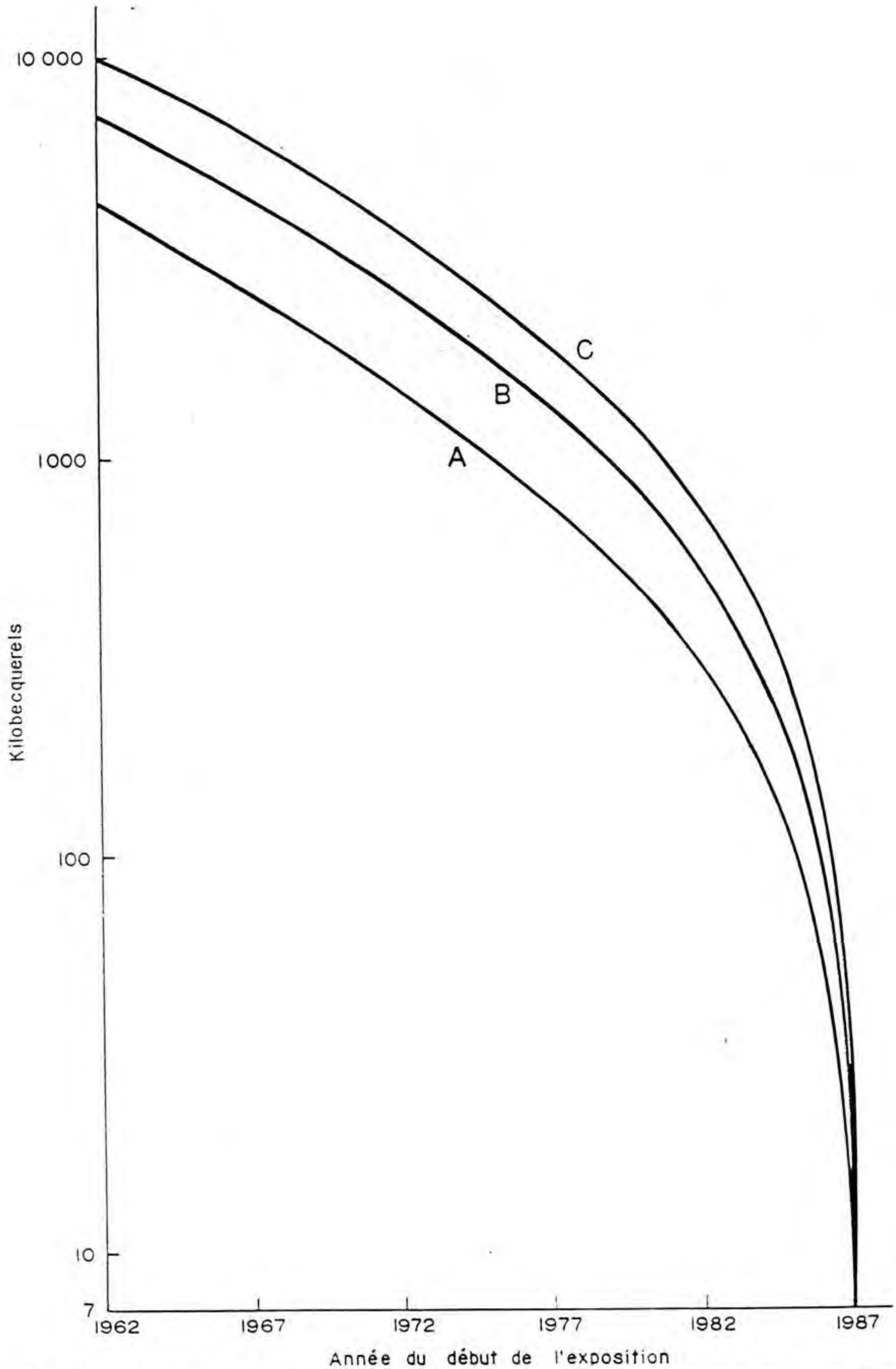

Figure 3. Activité moyenne cumulative de césium 137 (kBq) ingéré en consommant annuellement 100 kg de caribou, selon l'année du début de consommation. Les retombées de Tchernobyl ont été excluses des calculs. Trois valeurs ont été retenues comme point de départ des rétrocalculs en 1987: 484 (A), 840 (B) et 1197 (C) Bq kg^{-1}.

40.7.2 Members KEAC

Letters

Chernobyl Radiation Dose

Eliot Marshall (News & Comment, 8 May, p. 658) summarizes a report that I presented to the American Occupational Medical Association in Philadelphia. Despite my best efforts to the contrary, some confusion occurred about the difference between radioactivity and radiation dose. Marshall states that "the total amount ejected is comparable to, but slightly less than, the fallout from all atmospheric weapons tests." This reference to radioactive material is incorrect and is a problem that has arisen before. The total amount of radiocesium ejected in the atmospheric nuclear weapons tests was at least 10 or 20 times higher than the total amount of radiocesium released during the Chernobyl accident. Because of the remote location of weapons tests with respect to population, the overwhelming majority of the radioactive material was deposited in areas where there was little potential for human exposure and dose in a collective sense. Marshall should have referred to the amount of radiation *dose* solely attributed or attributable to cesium-137, not the amount of *radioactivity*. Just the amount of radiation dose absorbed by people was somewhat comparable because, in the case of the Chenobyl release, a much smaller amount was released in a more populated area. Actually the radiocesium *dose* from Chernobyl to the Northern Hemisphere in our latest calculations is about 60% of the cesium dose from weapons tests. Another point is that the total amount of radiation dose commitment to the population of the Northern Hemisphere from weapons tests includes many other radionuclides, and cesium alone constitutes perhaps a little less than half that total.

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Learning Science

I find myself in boisterous agreement with F. H. Westheimer's cogent critique of so-called "core" curricula (Policy Forum, 5 June, p. 1165), even though my own college apparently does rather better about science requirements than the highly visible colleges and universities that Westheimer cites. It is truly appalling that a student can receive a B.A. degree from a serious college or university and not know *one single thing* about evolution, about mathematics, about principles of behavior, about genetics, or about simple physical laws, let alone molecular biology. Westheimer notes another appalling fact: the *science* faculty at Harvard voted for a core curriculum that "all but ignores science." He asks how this is possible and, in answer, avers that scientists and mathematicians do not want to teach science and mathematics to the "unwashed," presumably students who are majoring in sociology, history, English, philosophy, literature, and the like. As evidence of this, Westheimer says, "scientists frequently state that it is not possible to teach anyone who does not want to learn. That is true." Thus, to my point: as wretched as the scientific knowledge of our students is, the quality of instruction in science at many colleges and universities is probably equally wretched. Yet Westheimer seems willing to rely wholly on selection as a possible solution to the problem of scientific ignoramuses. Universities could select for their student bodies only those who are eager to learn science. Or, among the students now in our universities, there must be many who could learn science if that was what the faculty expected of them. Westheimer does not address the role of science faculty as teachers. This position leaves the job of arranging conditions so that students "want to learn" entirely to our students' precollege teachers. Universities then select from these products and their own science faculty is absolved of motivational responsibility. Surely this is a profound mistake. C. S. Slichter, a mathematician, put it as well as anyone: "It is not the teacher's task to teach interesting things, as the quacks proclaim, but to make interesting the things that must be taught" (*1*, p. 179).

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"Progress" in Evolution

"I cannot, by the progresse of the Starres, Give guesse how neere to day." "Progress," in that statement by Brutus in Shakespeare's *Julius Caesar*, is indeed culturally laden, but not at all in the sense that Stephen Jay Gould *et al.* (Articles, 12 June, p. 1437) claim for the term. The *Oxford English Dictionary* (1933) gives a series of definitions for "progress," the first three of which concern various senses of motion, with no teleological or culturally offensive implications at all that I can see. The fourth definition gives the figurative sense of "advance to better and better conditions, continuous improvement." That is the sense in which "progress" has been used in evolutionary biology, but it still embodies nothing objectionable. Curiously, "improvement" was recently espoused by Gould (*1*) as a more objective, less offensive replacement for "progress."

Certainly, to make an a priori assumption that life progresses is indefensible. But it is equally indefensible to deny that increased mechanical efficiency or structural effectiveness for the conditions in which organisms live has not occurred or cannot be recognized. In the phylum with which I am most familiar (the Bryozoa, one of the eight abundantly fossilized invertebrate phyla), several progressive, long-term trends in the fossil record have been varyingly well demonstrated (*2*), in some instances within a clade and in others where a clade of mechanically better-suited forms replaces clade(s) with more ill-suited forms. These include trends in resistance to breakage (*3*), changes in growth patterns to delay interference between branches within a colony (*3*), replacement of encrusting species that lack frontal budding by competitively superior encrusters with frontal budding (*4*), and slow but inexorable rise to dominance of erect forms with the least mechanically awkward pattern of feeding currents (*5*). The Bryozoa are tightly constrained by their *Bauplan*, and many aspects of their morphology and ecology go nowhere (*6*). However, I know of no examples of trends within Bryozoa that operate in the opposite direction from those cited here. These trends support directionality in the history of life at least as well as real, but slight, asymmetry of clade diversity diagrams and also indicate that the history of life embodies improvement, mechanical enhancement, advancement, or any other synonym or circumlocution that one wishes to use to avoid the term "progress."

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Radioactive Cesium from the Chernobyl Accident in the Greenland Ice Sheet

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Measurements of cesium-134 and cesium-137 in Greenland snow together with models of long-range transport have been used to assess radionuclide deposition in the Arctic after the Chernobyl accident. The results suggest that a well-defined layer of radioactive cesium is now present in polar glaciers, providing a new reference for estimating snow accumulation rates and dating ice core samples.

Nuclear weapons tests in the 1950s, 1960s, and 1970s emitted large amounts of man-made radioisotopes into the atmosphere. Some of this material eventually reached glaciers in the Arctic and Antarctic regions, providing a permanent record of the deposition of radioactivity associated with specific tests. These radioactive signatures have been used to determine snow accumulation rates, to date ice core samples analyzed for other contaminants, and to study long-range atmospheric transport (*1*). Emissions from the explosion and fire at the Chernobyl nuclear reactor in April 1986 have resulted in an additional radioactive layer in polar glaciers. This layer is of considerable interest: unlike weapons tests, which injected radioactive material into the stratosphere where residence times are more than a year, the Chernobyl emissions were confined to the troposphere where residence times are at most a few weeks (*2*). The resulting deposition thus occurred over a relatively short period, and this enables us to assign a narrow time interval to the radioactive layer. In the present study, we identify the Chernobyl signature in the Greenland Ice Sheet. We also attempt to relate characteristics of the deposited radioactivity to the atmospheric transport pathways and deposition processes involved.

Samples were collected from a snowpit 23 km southwest of Dye 3, Greenland, in late July 1986. This location is near the ice coring site established by Mayewski *et al.* (*3*). The snowpit walls were sampled in continuous adjacent layers to a depth of 1.5 m under strict contamination control (*3–5*). The density was measured in each 5-cm layer, and the presence of ice strata and other distinguishing characteristics was recorded. Samples were collected each 5 cm for $\delta^{18}O$ analysis (*6*), and each 10 cm for radioactive cesium analysis (*7*).

Results of these analyses show that detectable levels of ^{134}Cs and ^{137}Cs occurred only in one layer, between 10 and 20 cm below the surface. The concentrations in three identical samples extracted from this layer are 2.0 ± 0.8 pCi/liter for ^{134}Cs and 6.2 ± 1.4 pCi/liter for ^{137}Cs (average ± standard deviation). If we take into account the thickness of the layer and the density of the snow, these values correspond to total (wet plus dry) deposits of 0.072 ± 0.030 mCi/km^2 for ^{134}Cs and 0.22 ± 0.05 mCi/km^2 for ^{137}Cs. All of the data have been corrected to 1 May.

These deposition rates are much smaller than corresponding values measured in Europe shortly after the accident. For example, deposition onto soil and vegetation was highly variable throughout Scandinavia, Germany, the United Kingdom, and the Mediterranean region, with values for both radionuclides ranging from <1 to several thousand millicuries per square kilometer (*2, 8*). Deposition rates to bulk wet-dry collectors in North America were closer to, but still somewhat greater than, the Dye 3 snow values. Seven sites in the Canadian Arctic had total deposition rates averaging 0.3 mCi/km^2 for ^{134}Cs and 0.7 mCi/km^2 for ^{137}Cs during May (*9*). Total deposition rates of ^{134}Cs at sites in the western United States were typically 1 to 2 mCi/km^2, with Midwest and East Coast locations reporting 0.1 to 1 mCi/km^2 (*10, 11*). Values for ^{137}Cs in the United States were generally two to three times as large as those for ^{134}Cs, consistent with the $^{137}Cs/^{134}Cs$ activity ratio of 3.0 ± 0.24 observed in Greenland. A single sample of the 10- to 20-cm layer was also analyzed for ^{90}Sr, giving $^{137}Cs/^{90}Sr$ equal to 20.2 corrected to 1 May (*12*). In comparison, values of this ratio in accumulated deposition on soil and vegetation were 19.0 in Denmark (*13*) and 24.4 in Italy (*14*).

Figure 1 shows the calculated dispersion of ^{137}Cs from Chernobyl during late April and early May, based on an Eulerian long-range transport model. The simulation was developed by Pudykiewicz specifically for assessing atmospheric transport of emissions from the accident (*15*). This figure indicates that a portion of the radioactive cloud crossed Greenland near the end of April. The cloud continued moving south and west, reaching Canada and eventually the United States in early May. This scenario is consistent with available data: airborne measurements show that ^{134}Cs and ^{137}Cs from Chernobyl first reached the community of Alert in the northeastern Canadian Arctic on 1 May, the area north of Hudson Bay on 2 May, and sites in Alaska, southern Canada, and continental United States sometime between 6 and 10 May (*9, 11*). Furthermore, comparisons between results of the model and measured ground-level concentrations at several locations in Canada show good quantitative agreement (*15*). The dispersion patterns in Fig. 1 are similar to those calculated by Lawrence Livermore National Laboratory with a different simulation technique (*16*).

How did this atmospheric material reach the surface of the Greenland Ice Sheet? To explore this question, the $\delta^{18}O$ data from the snowpit have been compared with the meteorological records from Dye 3 to identify the most probable time period and the specific storms represented by the 10- to 20-cm layer. The method has been discussed elsewhere (*5*). The procedure indicated that this layer corresponds to a time interval containing the following storms (with accumulation rates in centimeters of snow): 9

C. I. Davidson, J. R. Harrington, M. J. Stephenson, Departments of Civil Engineering and Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213.
M. C. Monaghan, Department of the Geophysical Sciences, University of Chicago, Chicago, IL 60637.
J. Pudykiewicz, Environment Canada, 2121 Trans-Canada Highway, Dorval, QC H9P 1J3 Canada.
W. R. Schell, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA 15261.

April (1.9 cm), 18 April (0.3 cm), 21 May (0.6 cm), 5 June (3.5 cm), and 7 June (3.2 cm).

It is noteworthy that very little precipitation fell for nearly 6 weeks after the accident. By the first significant snowfall on 5 June, airborne concentrations of ^{134}Cs and ^{137}Cs had already peaked and were declining throughout most of North America. If we assume that airborne concentrations at Dye 3 during May were similar to those measured in the Canadian Arctic and eastern provinces (*9*), dry deposition can account for roughly 25 to 50% of the observed ^{134}Cs and ^{137}Cs content of the snow. This estimate assumes a dry deposition velocity in the range 0.05 to 0.10 cm/sec, which is based on deposition data for submicrometer aerosol species such as sulfate and lead onto a snow surface (*4, 5, 17*). Cesium-134 and cesium-137 emitted from Chernobyl have activity median aerodynamic diameters of 0.2 to 0.7 μm (*18*), similar to those of sulfate and lead (*19*). It is therefore likely that a fraction of the measured radioactive cesium in Dye 3 snow is due to dry deposition, which has resulted in a narrow, concentrated layer. The small cesium deposition rates at Dye 3 relative to other North American sites reflect the very small precipitation rates on the ice sheet during May and June. The total amount of radioactive cesium reaching the earth's surface will generally be greatest in areas of high precipitation, since wet deposition is a far more efficient removal mechanism than dry deposition.

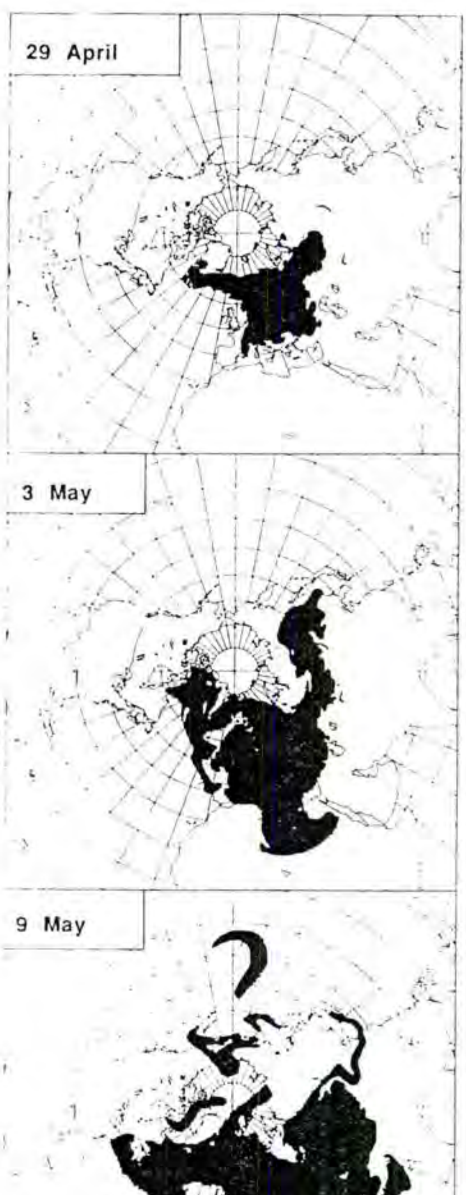

Fig. 1. Spread of ^{137}Cs emitted from Chernobyl as of the indicated date in 1986. Winds at 850 mbar have been used as inputs. The shaded areas indicate calculated airborne concentrations greater than 3 fCi/m³, based on estimates of the source strength.

Wet deposition during the 21 May, 5 June, and 7 June storms also probably influenced concentrations in the snow. Joshi (*20*) reported that southern Ontario rainwater contained 0.6 to 3 pCi/liter of ^{134}Cs and 1.5 to 5 pCi/liter of ^{137}Cs during May and June. Other values similar to the Dye 3 data have been reported for precipitation in the continental United States (*10, 11*).

Overall, the measured airborne concentrations from several monitoring programs and results of the transport model indicate that the radioactive cloud from Chernobyl spread rather uniformly across North America in the weeks after the accident. Considered in light of the Greenland snow data, these results suggest that an identifiable signature is now present in glaciers throughout the Arctic.

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21. We thank W. Dansgaard, and N. Gundestrup for conducting the $\delta^{18}O$ analyses; K. Kuivinen, S. Watson, K. Swanson, R. Tillson, and J. Klinck for assistance in the field; J. Cragin for providing sampling equipment; L. A. Barrie, B. L. Tracy, D. Meyerhof, P. E. Cobbold, S. R. Joshi, and Z. R. Juzdan for providing radionuclide data from other monitoring programs; and R. S. Tsay and M. J. Small for help in data interpretation. The manuscript was prepared by S. A. Knapp. This work was supported by National Science Foundation grants DPP-8315452 and DPP-8618223, a scholarship from the Richard K. Mellon Foundation, and a grant from the Louis Block Fund of the University of Chicago.

24 February 1987; accepted 8 June 1987

Comité conjoint -
chasse, pêche et piégeage
Hunting, Fishing and Trapping
Coordinating Committee

Reçu 13/4/87 AO
(39.19.1) 40.7.

Le 10 avril 1987
À : Tous les membres
DU : Secrétaire

La Présidente a, conformément à la décision prise par le Comité à sa séance des 17-18 février 1987, contacté Santé et Bien-être social Canada pour demander de l'information sur les risques de contamination radioactive associés à la consommation de viande de caribou. Vous trouverez ci-joint copie de la réponse de D.P. Meyerhof, "Chief Environmental Radiation Hazards Division", datée du 2 avril 1987, de même que de la documentation pertinente jointe à sa réponse.

Ces trois documents, en langue anglaise, sont énumérés de 1 à 3 ci-dessous.

Nous avons aussi reçu d'autres renseignements de nature plus générale; ces documents sont disponibles pour consultation au secrétariat.

April 10, 1987
TO: All Members
FROM: Secretary

Following a decision by the Committee at the meeting of February 17-18, 1987 the Chairperson contacted Health & Welfare Canada requesting information on the hazards of radiation in consuming caribou meat. You will find enclosed a copy of the return letter dated April 2, 1987 and signed by D.P. Meyerhof, Chief Environmental Radiation Hazards Division together with copies of pertinent literature which were also included in the response.

1. News Release. Canadian Caribou Safe to Eat, Despite Chernobyl. 1987-11. March 19, 1987. HWC.

2. Background Information on Cesium-137 in the Arctic Food Chain. Anon. 3 pp.

3. Background Information on Radiation and its associated risks. Anon. 3 pp.

Further information of a more general nature was also provided and is on file at the Secretariat for consultation.

Secrétariat:
800, boul. de Maisonneuve Est
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PROGRAM: EMISSION:	RADIO NOON	DATE: DATE:	SEPTEMBER 15, 1987
NETWORK / STATION: RESEAU / STATION:	CBC/CBM MONTREAL	TIME: HEURE:	12:45 PM

Michael : we should request briefing material reports, data from MLCP - this is now public
Camille — Michel may be looking for a new job soon!

TAINTED CARIBOU IN NORTHERN QUEBEC Camille

CBC: The Provincial Department of Leisure, Fish and Game says caribou in Northern Quebec have alarmingly high levels of cadmium in some of their organs. Michel Crête(?) works for the Department. He's on the line now from Quebec City. Good afternoon Mr. Crête.

MICHEL CRÊTE: Good afternoon.

CBC: Why is cadmium being found in caribou?

CRÊTE: It is a bit surprising but it is a problem of atmospheric pollution I think. The caribou are eating much lichen in the winter and those plants are catching(?) cadmium from the air.

CBC: Is it because of pollution in the air?

CRÊTE: Yes, we think so. Yes.

CBC: How much cadmium are you finding in some of their organs?

CRÊTE: Well it is comparable to what we found in Whitefield here in Southern Quebec in the Outaouais region and in the region of Montreal and it is about the same level as we found for moose on the Gaspé Peninsula.

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CBC: And how high is that? Is that pretty important levels?

CRÊTE: Oh it is. I am asked to suggest a (inaudible) to consume kidneys and liver.

CBC: Really!

CRÊTE: Oh yes and if we compare to other countries it is caribou in Northern Quebec are more affected by cadmium than reindeer in Scandinavia.

CBC: Do you know why?

CRÊTE: Probably because Quebec is a very good place for atmospheric pollution. It seems that we receive much pollution from the continent. You know it is raining sometimes here and with the rain comes cadmium and many things too.

CBC: You're saying this is related to the acid rain problem?

CRÊTE: It is yes. It is another pollutant(?) that we can find in the atmosphere in the precipitation.

CBC: How extensive is the problem? How many caribou are affected?

CRÊTE: Oh they are all affected, but where. We have to be careful. It is not so dangerous for caribou. They won't die because of that.

CBC: The only risk you're saying is for humans.

CRÊTE: Well it could be because if--when we consume cadmium then it gets--stick in our organisms so we cannot

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eliminate cadmium. So we have to be careful with food that contains much cadmium as it is for kidneys and liver of caribou and other service(?) that live in Quebec.

CBC: You're saying it's a very long process?

CRÊTE: Oh yes it is very long. The act(?) time of cadmium in the human body is 30 years.

CBC: Oh boy!

CRÊTE: So it is better not to consume.

CBC: Do people eat a lot of organs from the caribou? Is it very popular in Quebec?

CRÊTE: It should be for hunters. I don't know if yourself you are a hunter, but generally speaking it is quite a feast to eat the liver at the camp and so on.

CBC: What about Quebec's native people, the Inuit?

CRÊTE: Oh I think they eat too. They eat kidneys and liver.

CBC: Are you going to be sending out a special message to them?

CRÊTE: We were working with the Health Department and they will inform people they should not consume those organs any more.

CBC: How long are you going to have this warning for?

CRÊTE: Oh it will be a long process because it is linked to atmospheric pollution so I don't think it will

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change very rapidly.

CBC: How soon do you think you might get some change? Are we talking about years and years and years.

CRÊTE: You have to ask the question to politicians. When we will decide to have clean industries and clean cars and clean aircrafts so it will be long I think.

CBC: And then the caribou will say thank you.

CRÊTE: Oh yes. We have to say thank you too. We will have to do something I think, not only for caribou but for human beings.

CBC: Mr. Crête, thank you very much.

CRÊTE: You're welcome.

CBC: Good-by.

CRÊTE: Bye.

CBC: Michel Crête is with the Quebec Department of Leisure, Fish and Game.

*****

Health and Welfare Canada — Santé et Bien-être social Canada
Health Protection Branch — Direction générale de la protection de la santé

Bureau of Radiation and Medical Devices
775 Brookfield Road
Ottawa, Ontario
K1A 1C1

April 2, 1987

Mme Mimi Breton
Hunting, Fishing and Trapping
Coordinating Committee
800, boul. de Maisonneuve Est
Montréal, Quebec
H2L 4L8

Dear Mme Breton:

Thank you for your letter of March 4, 1987 with questions related to cesium-137 in caribou meat. Your letter arrived while I was on leave, hence the delay on replying.

For your information I am enclosing a copy of a news release on radioactivity in caribou in other areas of Canada. This may help put the issue in perspective as radioactive cesium has been present in caribou since the early 1960's at levels higher than now are present due to atmospheric nuclear weapon tests. Radioactive cesium levels in the population have always been less than those set for the purpose of health protection. The Chernobyl reactor accident has attend about 15% to the "background" of radioactive cesium from the atmospheric nuclear weapons tests.

To answer your questions:

1. Acceptable levels for radioactivity in food:

Canada is currently applying an Interim Screening Limit of 300 becquerels per kilogram to imported food products containing radioactive cesium as a result of the Chernobyl accident. This limit was established immediately after the accident. Consideration is being given to the adoption of international guidelines for radioactivity in food in international trade.

A federal provincial Task Force has been established to develope guidelines for radioactivity in Canadian foods as a result of a nuclear accident. Recommendations have not yet been made.

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2. Toxicology of radioactivity in food for humans:

I have enclosed 2 pamphlets that explain radiation in general. The assumption used in protecting the public from exposure to radiation is that all exposures, no matter how small, carry with them some risk of cancer. This assumption is based on observations at very high exposures to radiation. There is no direct evidence for this at levels that have been observed in caribou, now or in the past. Following this assumption to its logical conclusion, it would seem reasonable to avoid all exposures to radiation and radioactivity. This is not possible, however, even if there were no man-made radioactivity. Natural radioactivity is present everywhere in all living and inanimate objects, foods, soil, air and water. Looking at this assumption another way, there is no "safe" level of radioactivity. The establishment of limits is based on a level of risk that is seen to be acceptable.

3. The present situation of radiation levels in the diet of Canadians:

Radioactivity from both the Chernobyl reactor accident and the atmospheric nuclear weapons tests has virtually disappeared from Canadian foods with the exception of the lichen-caribou-man food chain. Some specific imported food items are still being checked for radioactivity as a result of the Chernobyl accident.

4. Current research:

My Division is continuing to conduct analysies of radioactivity levels in caribou meat in Northern Canada. Analyses have been done on fish, wild geese, and other land animals that don't eat lichen. There has been no effect on these items.

I hope this has answered your questions.

Sincerely,

Dorothy Meyerhof

D.P. Meyerhof
Chief
Environmental Radiation
Hazrds Division

cc. Michel Crête
Gouvernment du Québec
Ministére du Loision, de la
Chasse et de la Pêche

news release

1987-11

March 19, 1987

CANADIAN CARIBOU SAFE TO EAT, DESPITE CHERNOBYL

OTTAWA - Radioactive fallout from the Chernobyl nuclear accident has not made Canadian caribou a hazardous source of food, according to a preliminary study recently undertaken by the federal and Northwest Territories governments.

This conclusion is based on studies of radioactivity levels in both caribou and northern residents undertaken during the 1960s nuclear testing and since the Chernobyl accident. Concern over the safety of caribou as a human food source arises because they feed largely on lichen (which has a unique ability to absorb and retain radioactivity) and thus they may pass on that radioactivity to people who eat them.

Radioactivity in caribou rose during the early 1960s but has declined steadily since that time. Pre-Chernobyl levels were just one-sixth of those found 20 years ago. Fallout from the nuclear accident increased the caribou radioactivity by an average of only 15 per cent, keeping the total amounts well below earlier levels.

Tests done on those who ate caribou during the 1960s showed that they did not exceed the radioactivity dose limit set for the general population. Since caribou now contained much less radioactivity, even including the effects of Chernobyl, northern residents for whom caribou is a staple food need not change their dietary habits.

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Health and Welfare Canada is continuing to monitor radioactivity levels and will advise the public of any change in the current situation.

- 30 -

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Tel.: (613) 957-1803

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Background Information on Radiation and its associated risk

A person can be exposed to environmental radioactivity in two ways:

- external exposure to radiation from radioactive material in the person's surroundings
- from internal exposure to alpha and beta particles and gamma radiation emitted by radioactive material which is inhaled, consumed with food or drinking water or swallowed in some other way.

The amount of radiation received by a person, whether externally or internally, is measured according to the amount of energy the radiation deposits in the living tissue which in turn determines how much damage each type of radiation can do. A commonly used unit of radiation is the millisievert. The average person receives about two millisievert of radiation each year from natural radioactivity and cosmic rays. Natural radioactivity is present in our bodies, in rocks and soil, in the air, in our houses and in our food. On average we also receive about half as much radiation as this from medical and dental x-rays. In normal circumstances, a radiation worker is not allowed to receive more than 50 millisievert per year in the course of his or her employment.

Very large amounts of radiation, considerably more than 1000 millisievert, received over a short period, can cause serious illness and death. The symptoms occur within a few weeks and are distinctive and readily identifiable as being due to radiation. Large exposures like this have occurred at Hiroshima and Nagasaki and at Chernobyl amongst emergency workers.

The human body is capable of absorbing considerable amounts of ionising radiation without suffering any detectable harm. When radiation energy is absorbed by the living cells of a person's body those cells may be damaged, killed, altered genetically or, in the majority of cases, remain completely unchanged. In an extremely small percentage of such cases, an ordinary cell can be changed into a cancer cell and this will result in a diagnosable cancer several (e.g. 10 to 20) years after the irradiation.

The probability of causing cancer in a human has been calculated from the incidence of cancer in Japanese survivors of atomic bomb explosions and from other abuses of radiation earlier this century. It has been observed that exposures to large amounts of radiation can cause an increased incidence of cancer. A few percent (less than 5%) of survivors of the atomic bombs in Japan, who received as much as 4000 millisievert, have contracted leukemia believed to have arisen from their radiation exposure.

At the levels at which occupationally exposed workers and members of the public are exposed the chance of contracting a radiation-induced cancer is very much less. Although the exact mechanism by which the radiation causes cancer is not completely known, there are good reasons for believing that, at worst, the chance of causing cancer from low exposures to radiation is directly proportional to the amount of radiation. The problem is that the chance is so low, and the normal incidence of cancer is quite high (about 20%), that it is very difficult to observe any effects of small amounts of radiation. Furthermore, there is no feature of a radiation-induced cancer which identifies it as being caused by radiation.

International bodies such as the United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR, and the International

Commission on Radiological Protection, ICRP, have investigated the relationship between radiation dose and the rate of induction of cancer. While not all scientists agree on the question of the effects of low levels of radiation, there is a considerable consensus of opinion among experts working in the field which is expressed in the recommendations of these major international scientific bodies. As a result of their recommendations, in assessing the risk from radiation it is assumed that small amounts of radiation can cause cancer, and that the chance is less as the amount of radiation exposure is reduced. This is similar to the situation with cigarette smoking, where not everyone who smokes a cigarette will get lung cancer, and the risk increases with the number of cigarettes smoked.

If a person receives one millisievert of radiation it is estimated that the odds are about 100,000 to 1 against it causing a fatal cancer. There is a similar risk of contracting a cancer which will prove non-fatal. This is about the same risk of death as faced when working for one month in the average work place. It is about the same as the risk of getting lung cancer from smoking 100 cigarettes.

For man-made sources of radiation the ICRP has recommended that the radiation dose from exposure to radioactive materials for members of the public be limited to 5 millisievert in any one year and for prolonged exposure it would be prudent to limit this to 1 mSv per year over a lifetime.

Background Information on Cesium-137 in the Artic Food Chain

Although nuclear weapons tests had taken place since 1945 the period 1961-1962, prior to the introduction of the Limited Test Ban Treaty in 1963, was one of intensive nuclear weapons testing in the atmosphere. This gave rise to a widespread increase in the levels of long-lived fission products, strontium-90 and cesium-137 and other radionuclides in the environment.

Studies in both North America and Scandanavia during the early 1960's revealed a unique situation in the Arctic food chain involving the specific uptake of cesium-137 by lichen, the primary diet item of caribou and reindeer in the Arctic regions. The transfer of this radioactivity to the native populations for whom caribou and reindeer meat comprised a significant part of their diet gave rise to considerably higher than average body burdens of cesium-137 in these people.

Since the early 1960's cesium levels in lichen and caribou have decreased substantially. Additional scientific studies have shown that there is a 50% decrease in Cs-137 levels in lichen over a period of 8-10 years. Because this time is shorter than would be predicted solely by radioactive decay (50% reduction over 30 years) it is concluded that other environmental factors are responsible for this decrease.

Cesium-137 is taken up by the body quite readily but has a relatively short biological lifetime in humans; the biological half-time varying from about 15 days in infants to 100 days in adults. The concentration of cesium-137 in the body is affected by not only the dietary levels of the radionuclide but also by the levels of potassium in the diet and the body weight because of the chemical similarity between potassium and c esium. Unlike some other radionuclides cesium-137 does not concentrate in a particular organ of the body but is distributed fairly generally throughout soft tissues such as muscle, liver, kidneys etc. Infants and children are at no greater risk than adults through the uptake of cesium-137.

There are several ways to estimate the radiation dose to which a person has been exposed as a result of ingestion of radioactive material:

- direct measurement of the individual using sensitive radiation detectors and calculation of the levels of radioactivity in the person's body.
- measurement of the levels of the radioactivity excreted by a person and estimation of the remaining amount in their body from a knowledge of the biological behaviour of the particular radioactive species.
- measurement of the radioactivity levels in food comprising the person's diet and estimation of the radiation dose to the individual using data related to the uptake of the particular material into the human body and its subsequent biological behaviour.

In the case of the uptake of cesium-137 into the Arctic food chain in Northern Canada and Alaska all three approaches have been adopted at some stage over the past 25 years. Consideration of the extensive set of data which has been acquired over these years has led to a number of conclusions:

a. Cesium-137 levels in caribou and reindeer have been steadily decreasing since 1963-4 in line with the observed decrease in the cesium-137 content of lichen.

b. There is a considerable seasonal variation in cesium-137 levels in caribou and consequently in the native population who utilize them as food. This variation reflects the dietary habits of the caribou for which lichen provides the only source of food during the winter months. Within a herd there is also a considerable variation in radioactivity in meat.

c. During the early 1960's when cesium-137 levels were at their peak, the average radiation doses received by those individuals within the native population, for whom caribou and reindeer meat comprised a major part of their diet, would not have exceeded the recommended limit of 5 mSv in any one year and are, at present, below the recommended long-term limit of 1 mSv per year.

d. The current estimated radiation doses to the population due to cesium-137 in caribou meat are probably less than 50% of the amount of radiation received by these people from natural sources.

e. It is quite likely that there has been a significant change in the lifestyle for the native communities over the past 25 years which has produced a decrease in their exposure to environmental radioactivity.

(Liberal Translation)
(Secretariat)

To: Members, HFTCC

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THE CARIBOU OF NOUVEAU-QUÉBEC AFTER CHERNOBYL - more detailed studies are required

Québec (MLCP) - MLCP in collaboration with the department of the environment (ministère de l'Environnement), the department of health and social services (ministère de la Santé et des Services sociaux) and MAPAQ have made public a study of the presence of radioactive cesium in tissue of caribou belonging to the George River herd. Twenty-seven samples taken in October 1986 and March 1987 revealed that the Chernobyl incident has increased the amount of cesium in the flesh of caribou by about ten percent over that present before the catastrophe. However, no recommendation concerning the consumption of caribou meat can be made because of the limited number of samples analyzed.

The highest concentrations of cesium in Canada

The concentrations of cesium found in caribou from Nouveau-Québec during this study are the highest in all of Canada. Even though the levels are high enough to justify further studies, especially to increase the number of the samples, they are still relatively low and represent a limited health risk. Cesium already present in caribou meat prior to the Chernobyl incident came from the testing of nuclear weapons in the atmosphere in the early sixties.

Cesium and cancer

Cesium 137 is an artificial radioactive element produced by the utilization of nuclear energy and can cause cancer. The presence of radioactive elements in the meat of caribou is more likely to affect Native people, some of which consume high quantities of this meat. Thus, according to different hypotheses, for a person who has consumed 100 kg. of caribou meat annually for the last 25 years, the risks of contracting terminal cancer could vary between 1 chance in 1600 to 1 in 700. By comparison, the smoking of a packet of 20 cigarettes a day over the same period would generate a risk of contracting terminal lung cancer of 1 in 55.

.../2.

More detailed studies required

The department of health and social services (ministère de la Santé et des Services sociaux) will base their recommendation on the consumption of caribou meat on existing international standards on exposure to radioactivity. Beforehand, the level of contamination of caribou in Nouveau-Québec must be evaluated as well as the importance of caribou meat in the diet of Native peoples and the degree of exposure to radiation by the heavy consumers of caribou.

Fortunately, the problem should diminish progressively as cesium decays in the environment. Barring further nuclear incidents, the quantities of cesium found at present in caribou meat will diminish by about 70% by the turn of the century.

Source: MLCP

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DOCUMENT 87-88D:19

Background Information on Cesium-137 in the Artic Food Chain

Although nuclear weapons tests had taken place since 1945 the period 1961-1962, prior to the introduction of the Limited Test Ban Treaty in 1963, was one of intensive nuclear weapons testing in the atmosphere. This gave rise to a widespread increase in the levels of long-lived fission products, strontium-90 and cesium-137 and other radionuclides in the environment.

Studies in both North America and Scandanavia during the early 1960's revealed a unique situation in the Arctic food chain involving the specific uptake of cesium-137 by lichen, the primary diet item of caribou and reindeer in the Arctic regions. The transfer of this radioactivity to the native populations for whom caribou and reindeer meat comprised a significant part of their diet gave rise to considerably higher than average body burdens of cesium-137 in these people.

Since the early 1960's cesium levels in lichen and caribou have decreased substantially. Additional scientific studies have shown that there is a 50% decrease in Cs-137 levels in lichen over a period of 8-10 years. Because this time is shorter than would be predicted solely by radioactive decay (50% reduction over 30 years) it is concluded that other environmental factors are responsible for this decrease.

Cesium-137 is taken up by the body quite readily but has a relatively short biological lifetime in humans; the biological half-time varying from about 15 days in infants to 100 days in adults. The concentration of cesium-137 in the body is affected by not only the dietary levels of the radionuclide but also by the levels of potassium in the diet and the body weight because of the chemical similarity between potassium and c esium. Unlike some other radionuclides cesium-137 does not concentrate in a particular organ of the body but is distributed fairly generally throughout soft tissues such as muscle, liver, kidneys etc. Infants and children are at no greater risk than adults through the uptake of cesium-137.

There are several ways to estimate the radiation dose to which a person has been exposed as a result of ingestion of radioactive material:

- direct measurement of the individual using sensitive radiation detectors and calculation of the levels of radioactivity in the person's body.
- measurement of the levels of the radioactivity excreted by a person and estimation of the remaining amount in their body from a knowledge of the biological behaviour of the particular radioactive species.
- measurement of the radioactivity levels in food comprising the person's diet and estimation of the radiation dose to the individual using data related to the uptake of the particular material into the human body and its subsequent biological behaviour.

In the case of the uptake of cesium-137 into the Artic food chain in Northern Canada and Alaska all three approaches have been adopted at some stage over the past 25 years. Consideration of the extensive set of data which has been acquired over these years has led to a number of conclusions:

a. Cesium-137 levels in caribou and reindeer have been steadily decreasing since 1963-4 in line with the observed decrease in the cesium-137 content of lichen.

b. There is a considerable seasonal variation in cesium-137 levels in caribou and consequently in the native population who utilize them as food. This variation reflects the dietary habits of the caribou for which lichen provides the only source of food during the winter months. Within a herd there is also a considerable variation in radioactivity in meat.

c. During the early 1960's when cesium-137 levels were at their peak, the average radiation doses received by those individuals within the native population, for whom caribou and reindeer meat comprised a major part of their diet, would not have exceeded the recommended limit of 5 mSv in any one year and are, at present, below the recommended long-term limit of 1 mSv per year.

d. The current estimated radiation doses to the population due to cesium-137 in caribou meat are probably less than 50% of the amount of radiation received by these people from natural sources.

e. It is quite likely that there has been a significant change in the lifestyle for the native communities over the past 25 years which has produced a decrease in their exposure to environmental radioactivity.

news release

1987-11

March 19, 1987

CANADIAN CARIBOU SAFE TO EAT, DESPITE CHERNOBYL

OTTAWA - Radioactive fallout from the Chernobyl nuclear accident has not made Canadian caribou a hazardous source of food, according to a preliminary study recently undertaken by the federal and Northwest Territories governments.

This conclusion is based on studies of radioactivity levels in both caribou and northern residents undertaken during the 1960s nuclear testing and since the Chernobyl accident. Concern over the safety of caribou as a human food source arises because they feed largely on lichen (which has a unique ability to absorb and retain radioactivity) and thus they may pass on that radioactivity to people who eat them.

Radioactivity in caribou rose during the early 1960s but has declined steadily since that time. Pre-Chernobyl levels were just one-sixth of those found 20 years ago. Fallout from the nuclear accident increased the caribou radioactivity by an average of only 15 per cent, keeping the total amounts well below earlier levels.

Tests done on those who ate caribou during the 1960s showed that they did not exceed the radioactivity dose limit set for the general population. Since caribou now contained much less radioactivity, even including the effects of Chernobyl, northern residents for whom caribou is a staple food need not change their dietary habits.

... 2

Health and Welfare Canada is continuing to monitor radioactivity levels and will advise the public of any change in the current situation.

- 30 -

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Client's No.—Nº du client	Department — Ministère	Division/Branch — Division/Direction	City — Ville
2693002	NHW	Health Protect./Environmental Radiation Hazards	Ottawa
Bureau No.—Nº du bureau	Language — Langue	Translator (Initials) — Traducteur (Initiales)	
	Swedish	AC	

Kostråd för dig som äter mycket vilt, ren och insjöfisk från nedfallsdrabbade områden, The Swedish Food Administration, pp 1 - 16, Uppsala 1987 (Swedish)

Diet advice for those who eat large quantities of game, reindeer and lake fish from areas subject to radioactive fallout

Information from the Swedish Food Administration on radioactivity in food caused by the accident at Chernobyl.

Diet advice for those who eat large quantities of game, reindeer and lake fish from areas subject to radioactive fallout (1)*

Contents

*) Numbers in the right-hand margin refer to the corresponding pages in the original text.

Limit value and radiation dose (2)

The aim of the Swedish Institute of Radiation Protection and the Swedish Food Administration is to reduce the radiation dose from food to 1 mSv per year. This means that in the future, the yearly intake of cesium 137 should be reduced to 50 000 Bq.

In order to keep the yearly consumption under this level, the Swedish Food Administration has set a limit value of 300 Bq per kilogram or litre for cesium 137 in staple food.

The term staple food refers to meat and meat products from domestic cattle, grain products, fruit and berries, vegetables, potatoes and root crops, milk and dairy products, baby food and sea fish. Measures can be taken at lower contents than 300 Bq with regard to milk, other dairy products and baby food. The limit value for other foodstuffs is 1500 Bq per Kg. Products with contents above these levels will not be permitted to be put on sale.

You can still eat food with contents above these levels. What determines the radiation dose you get, is not occasional consumption of food with high contents, but the total intake of cesium during a long period of time. It is, however, inappropriate to eat food with contents above 10 000 Bq cesium 137 per Kg.

A yearly dose of up to 10 mSv may be acceptable, from a radiation protection point of view, for those who are of the opinion that the social or economic consequences will be too far-reaching with the stricter limit of 1 mSv per year. This corresponds to an intake of up to 500 000 Bq cesium 137. It is then presumed that the individual knows and accepts the estimated risk at that dose level.

The rule for pregnant women and children is, however, that the radiation dose from food should not exceed 1 mSv per year.

Cancer risk (3)

An additional radiation dose of 1 mSv per year will cause few health hazards. Such a radiation dose may, according to theoretical calculations, mean that the risk of dying from cancer increases from the normal of about 20% to 20.1%. The increase is far below the variations in cancer risk due to place of residence and changes in cancer frequency with time. The risk of dying from cancer may increase from 20% to 21% at an additional radiation dose of 10 mSv per year.

3

Purchased food (4)

The Swedish Food Administration has, in collaboration with the local authorities and others, carried out an extensive analysis program to test food and beverages for cesium content. Content in practically all food is at present far below existing limit value.

Studies show that a person who feeds himself with a varied assortment of food sold in stores will get a considerably lower yearly radiation dose than 1 mSv. Consequently you can buy and eat all food available in the stores.

Food acquired in other ways (5)

Many households acquire food through gardening, berry-picking, hunting and fishing. Contents of cesium in homegrown vegetables, fruits and berries have, generally speaking, been low, even in areas with heavy deposition on the ground. This food may be consumed as usual. Cesium intake might above all be high if you eat large quantities of reindeer, game and lake fish from the areas subject to radioactive fallout. In that case you should find out what the cesium content is in that particular food. To make inquiries, call your local public health and environmental protection committee.

Cesium in game, reindeer and lake fish (6)

Reindeer

Reindeer eat large quantities of lichen, which has a special ability to absorb and keep radioactive substances. This is why reindeer in certain areas may have high cesium content. Worst affected are the reindeer herds in Jämtland, Kopparberg, Västerbotten and southern Norrbotten counties. The cesium content in the rest of Norrbotten was lower. During the slaughter season 1986/87 the percentages were found to be higher during winter slaughter than during autumn slaughter.

The studies by the Swedish Food Administration show that the cesium content of blood, marrow, hooves, fat, intestines and stomachs is about one tenth of the content in the muscle meat. The content in liver is somewhat lower than in the muscle meat, while in heart and kidney, for example, it is comparable to that of the meat.

Game

Roe deer and small game eat lowgrowing plants and graze on large areas. The cesium content of game may consequently be high in the areas that have received the heaviest fallout. Moose generally have lower percentages than roe deer and hare, but the content in moose rises as they turn to winter grazing. Higher cesium percentages were demonstrated during 1986, mainly in the counties of Västerbotten, Västernorrland, Gävleborg and in certain parts of Uppsala and Västmanland counties. Current information on cesium content in game is available at the public health and environmental protection committees of the municipalities concerned.

Lake fish

Locally there may be heavily increased cesium percentages in fish from lakes and watercourses in areas subject to the heaviest fallout. Algae and plankton have absorbed radioactive substances which through plant-eating fish are transferred to predatory fish. Fish have a low metabolic rate and so the problems may remain for several years.

In 1986, the Swedish Food Administration classified municipalities with regard to the cesium content of fish. They have been unable to analyse fish from all lakes in the affected areas, so the following grouping is only intended as a guide. More information on cesium content in fish from the tested lakes is available at the public health and environmental protection committees concerned.

(7)

Content of cesium 137 in fish from areas subject to large fallout (8)

Content Bq/Kg	Väster-botten	Jämt-land	Väster-norrland	Gävle-borg	Väst-manland	Uppsala
300-1500	Malå Norsjö Robertsfors Skellefteå Sorsele Vännäs	Bräcke Härje-dalen Krokom		Hofors Ljusdal Ockelbo Ovanåker	Sala	Tierp Uppsala Älvkarleby
Above 1500	Bjurholm Dorotea Lycksele Nordmaling Storuman Umeå Vilhelmina Vindeln Åsele	Ström-sund Ragunda Åre	All lakes	Bollnäs Gävle Hudiksvall Nordanstig Sandviken Söderhamn	Heby	

In other areas usually less than 300 Bq/Kg.

This is how much you can eat

From food that you purchase in the store or that you grow yourself, you will receive 2000 - 10 000 Bq cesium 137 per year. The margin up to 50 000 Bq is thus very wide. The table below shows how much can be consumed per year of other types of food, game and lake fish, for example, with different contents of cesium, without exceeding the limit of 1mSv (50 000 Bq) per year. You may, for example, eat about 75 Kg per year of game that contains 600 Bq/Kg.

	Content cesium 137 per Kg				
	300	600	1000	1500	3000
Consumption (Kg/year)	150	75	45	30	15

What can you do yourself?

Inquiries can be directed to the public health and environmental protection committee of the municipality with regard to questions on the radiation environment, percentage of cesium in food, and so on. There they know the local conditions and can help you to have analyses carried out.

Boiling

Different preparation and cooking methods may have an effect on the content of cesium in the finished dish. Boiling of meat and fish in small pieces (on low heat and with a lid) results in considerable leaching of cesium into the boiling water. The same applies when mushrooms and nettles, for example, are parboiled. There will be a substantial reduction of the cesium content if the water is poured off and not used in cooking. There is, however, at the same time also a loss of other minerals and vitamins. A great deal of cesium remains in the berry pulp in the process of making juice from berries. Cooking jam does not result in any reduction of cesium content, however, as the berries are included in the jam.

Salting

Traditional salting of meat and fish in brine for a long period of time also results in a reduction of cesium content. But pan-frying or roasting in the oven have an insignificant effect on cesium content. Smoking or drying do not result in any reduction of cesium content either.

The methods of reducing cesium intake through boiling or salting should generally not be used. The risk is that the intake of vitamins and minerals will be low, or that the salt intake becomes unnecessarily high.

Diet advice for those who eat extra large quantities of game, reindeer and lake fish (10)

The following diet advice is based on a yearly consumption of game, reindeer and lake fish of totally 100 - 150 Kg. The calculated radiation doses become lower with lower consumption, and salting, etc. will not be needed then.

If you choose 1 mSv as an upper limit

Reindeer

Content cesium 137 up to about 300 Bq/Kg

The reindeer may be used as usual.

Content 300 - 1500 Bq/Kg

Occasional reindeer may be used for

- traditional salting of meat and organs in brine for production of dried or smoked meat.
- boiling of meat and organs in small pieces if broth is poured off.

Content above 1500 Bq/Kg

Meat and organs should only be consumed occasionally. Blood, stomachs, intestines, marrow, hooves and fat may be used without restrictions, even if the content in the meat is up to 3000 - 4000 Bq/Kg.

Game

The same diet advice as for reindeer applies.

Fish

Fish that contains up to 300 Bq/Kg may be consumed in normal proportions.

Fish containing 300 - 1500 Bq/Kg should not be consumed more often than once weekly or so.

Fish with higher content should not be consumed more than a few times per year. Suitable cooking methods are salting or boiling in small pieces (broth is poured out).

Perch, pike, pike-perch and burbot should not be consumed more than once a week due to the mercury content. Pregnant women should for the same reason completely refrain from eating these fish.

Berries

May be consumed as usual.

Other foodstuffs

May be consumed as usual.

If you choose 10 mSv as an upper limit (11)

Reindeer

Content cesium 137 up to 3000 Bq/Kg

The reindeer may be used as usual.

Content 3000-10 000 Bq/Kg

Occasional reindeer may be used for

- traditional salting of meat and organs in brine for drying or smoking.
- boiling of meat and organs in small pieces, the broth is poured off.

Blood, stomachs, intestines, marrow, hooves and fat may be used as usual.

Game

The same diet advice as for reindeer meat applies.

Fish

Fish with contents up to 3000 Bq/Kg may be consumed as usual.
Fish that contains 3000 - 10 000 Bq/Kg should be consumed only occasionally.
Suitable cooking methods are salting or boiling in small pieces (broth is poured out).
Fish with higher content than 10 000 Bq/Kg should not be consumed at all.
Perch, pike, pike-perch and burbot should not be consumed more than once a week, due to the mercury content. Pregnant women should for the same reason completely refrain from eating those fish.

Berries

May be consumed as usual.

Other foodstuffs

May be consumed as usual.

Calculation of cesium intake (12)

You yourself can estimate how much cesium your food contains, and thereby how large the additional radiation dose might be. Use the example on the next page.

Below are examples of how to calculate the cesium intake.

Food	Consumption Kg/year	Content Bq/Kg	Intake Bq/year
Reindeer meat	90	250	22 500
Moose meat	14	300	4 200
Fish	35	250	8 750
Cloudberries	20	200	4 000
Mountain cranberries/blue-berries	2	100	200
Other food	-	-	3000-10 000
		Total per year:	42 650-49 650

Example for one person (13)

Food	Consumption Kg/year	Content Bq/Kg	Intake Bq/year
Reindeer meat	....	......	....
Moose meat	....	......	....
Other game	....	......	....
Fish (cleaned, without head Kgx0.7)	....	......	....
Cloudberries	....	......	....
Mountain cranberries/ blueberries	....	......	....
Milk (litres per day x 365)	....	......	....
Other food (5 Bq per person and day)	....	......	....
		Total per year	

Eat a variety of foods! (14)

Our health is affected by the food we eat. Through a varied diet we help our body to prevent illness. This is also applicable to risks associated with radiation.

To use a varied diet means to eat daily from the seven groups of food in the balanced diet chart:

* Vegetables

* Fruit and berries

* Potatoes and root vegetables

* Milk and milk products
* Meat, fish and eggs
* Bread and grain
* Edible fats

Individual food groups may, however, be excluded without making the diet faulty.

Food that we need to eat more of is vegetables, fruit and berries, potatoes, bread and grain products and fish.

From a radiation protection point of view, there is no cause for limiting consumption of vegetables, fruit and berries, bread and grain products or sea fish.

If the contribution of cesium from reindeer, game or lake fish turns out to be so high that the target of the Swedish Institute of Radiation Protection is exceeded, an effort should be made, if possible, to choose corresponding products with lower cesium content. An example would be to get lake fish from a different area or substitute it with sea fish from the store.

Differentiate between activity and radiation dose (15)

Activity is measured in becquerel

The atoms of a radioactive substance disintegrate and emit radiation. The disintegration speed of the substance, the activity, is measured in a unit called becquerel. It is abbreviated Bq.

If the activity is 1 Bq, it means that one atom disintegrates per second. The activity in milk, water and other foodstuffs is indicated as becquerel per litre (Bq/L) or becquerel per kilogram (Bq/Kg). The activity on the ground is shown in becquerel per square metre (Bq/m^2) and in air as becquerel per cubic metre (Bq/m^3).

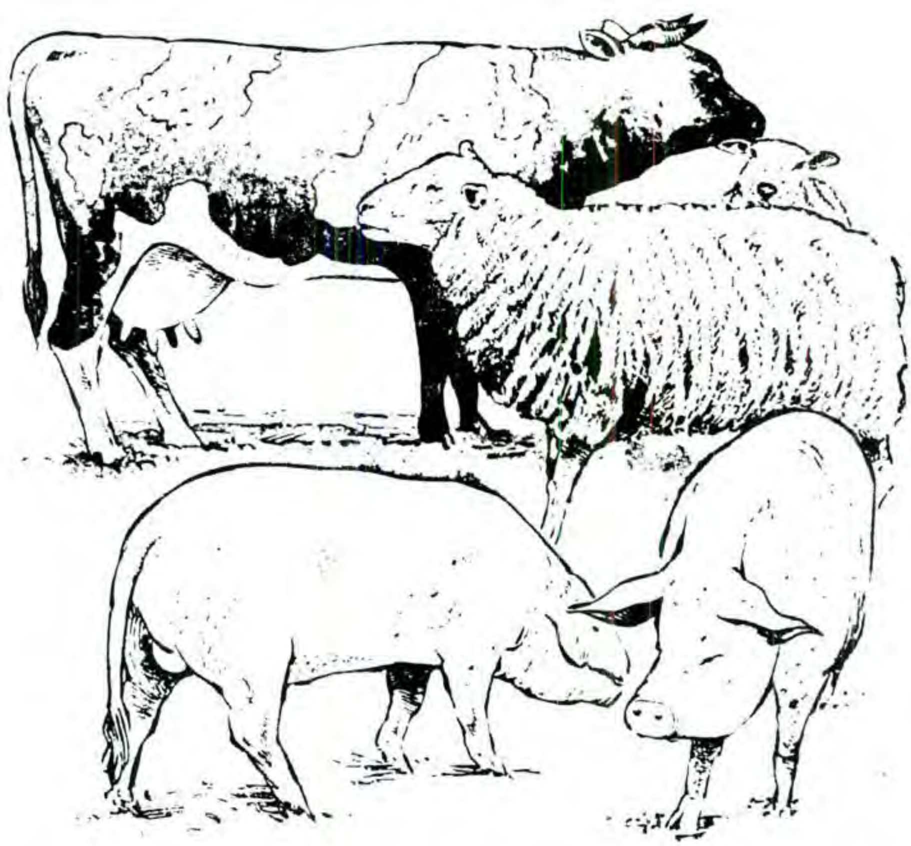
The radioactivity of the substance decreases as the atoms disintegrate. The speed by which the activity decreases is indicated as the half-life of the substance, i.e. the time needed for the activity to decrease by half. Of the radioactive substances deposited on the ground in Sweden after the accident at Chernobyl, the most important ones are cesium 134 and cesium 137. The half-life of cesium 137 is approximately 30 years and for cesium 134 two years.

Most substances added to the body are continuously secreted. Such is also the case with cesium. The amount of cesium is halved in approximately three months in an adult and in about one month in babies. This transformation is called biological half-life. The cesium content of the body thus diminishes rather quickly if no additional cesium is ingested.

Radiation dose is measured in sievert

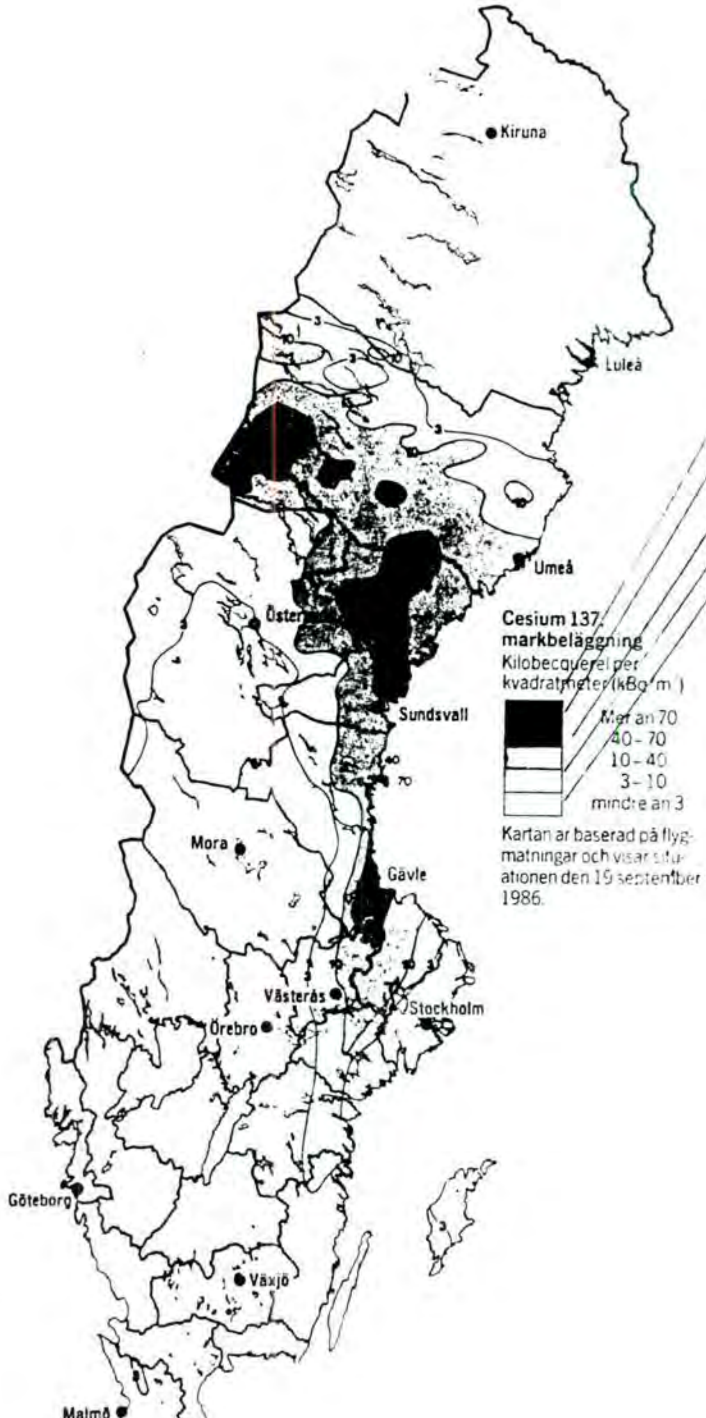
The body of a human being absorbs radiation energy after exposure to radioactive substances. The quantity of radiation energy absorbed is called radiation dose. Radiation dose is measured in the unit sievert, which is abbreviated Sv. It is a very large unit. It is therefore customary to express radiation doses in millisievert, abbreviated mSv. 1 Sv = 1000 mSv.

The more radioactive substances a person is exposed to, the larger is the radiation dose received. The connection between activity and radiation dose is complicated. During calculations of the radiation dose, consideration has to be given to several physical and biological factors.



(16)

If you mainly eat meat from domestic cattle which is purchased in a store, you do not need to consider cesium content. The limit value for staple food is 300 Bq/Kg. In reality, store-bought food contains considerably lower proportions. So there is a margin for even quite large quantities of game, reindeer and lake fish in your diet.



<u>The radioactive fallout in Sweden</u> (17)

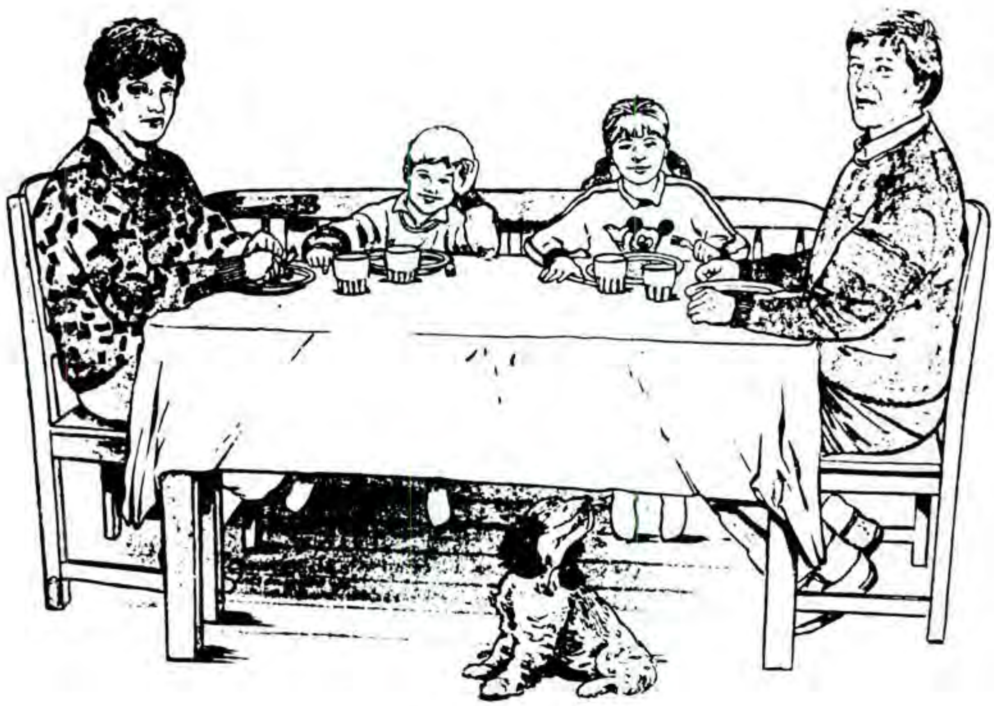
<u>Cesium 137, deposition on ground</u>
Kilobecquerel per square metre (KBq/m^2)

More than 70
40-70
10-40
3-10
less than 3

The map is based on aerial measurements and shows the situation on September 19, 1986.

This brochure is aimed at persons with a diet largely based (18) on reindeer, game and lake fish from the areas subject to radioactive fallout.

This brochure is available at the local public health and environmental protection committees. It may also be ordered from the Swedish Food Administration.



The Swedish Food Administration
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[TRANSLATION]

Direction de la gestion des espèces et des habitats

Cadmium Contamination in the George River Caribou Herd

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Direction générale de la ressource faunique

Ministère du Loisir, de la Chasse et de la Pêche

Québec

August 1987

Abstract

Samples of kidney, liver, heart, mesentery, skeletal muscle and the lining of the rumen were taken from 121 caribou from the George River herd at various times of the year. Tissue analysis showed that the caribou of Nouveau-Québec were contaminated by cadmium, a toxic heavy metal. Their contamination was similar to that observed in the most seriously affected white-tailed deer in Québec (Estrie, Outaouais-Laurentides) and in the least contaminated moose (Gaspésie, Bas-Saint-Laurent, Anticosti). Scandinavian reindeer were generally less affected than Québec caribou. The study confirmed that, in caribou, cadmium accumulates in the kidneys and liver, while the other tissues are much less affected. Seasonal variations in cadmium concentration in tissue was also found, with higher values in the winter than summer. The seasonal variation may be due to greater consumption of lichens in winter and to the size of the liver and kidneys, which varies with the season. Because of the high levels of cadmium contamination, it is recommended that the kidneys and liver of caribou not be eaten.

INTRODUCTION

During the 1986 year, wildlife specialists suddenly realized that cadmium, a toxic heavy metal, had contaminated the moose (Alces alces) and the white-tailed deer (Odocoileus virginianus) in eastern North America (Scanlon et al, 1986; Crête et al, 1987b; Glooschenko et al, in preparation). In Québec, the concentrations found in kidney and liver, the organs most likely to accumulate the toxic substance, had reached very high levels compared to those found in the United States and Scandinavia (Crête et al, 1987b). The levels were particularly high in Abitibi and Témiscamingue. After close examination of the results, it was recommended that for the time being, consumers refrain from eating the liver and kidneys of wild ungulates in Québec (Crête et al, 1986).

Furthermore, fragmentary evidence indicated that despite their distance from sources of pollution, the caribou (Rangifer tarandus) in the Québec tundra were also suffering from cadmium contamination (Crête et al, 1986). Caribou are a prime source of animal protein for the Native communities of Nouveau-Québec (C.R.R.A., 1982a,b). Furthermore, studies are now under way on the possibility of marketing caribou meat (Québec, 1984), and the species is being harvested in sport hunting (Roy, 1986). Thus, it was important to determine the extent of cadmium contamination in the caribou of Nouveau-Québec. In addition to the kidneys and liver, samples of flesh, heart, the lining of the rumen and the mesentery were also examined.

AREA STUDIED AND METHOD

Tissue samples were taken from caribou belonging to the George River herd that had been harvested between December 1985 and November 1986 at five sites in the basins of the George, Whale and Caniapiscau-Koksoak rivers (Figure 1). The number of caribou sampled at each site was as follows: Site 1 = Dec. (11), March (45); Site 2 = March (5); Site 3 = June (4); Site 4 = June (3), Sept. (9); Site 5 = Nov. (44). The largest samples were thus from Site 1 in March and Site 5 in November.

It was impossible to collect samples of all the tissues from each animal. In June 1986, tissue from liver, kidney and muscle only was taken; subsequently, samples were also collected from the heart, mesentery and the lining of the rumen. In all cases, at least 100 g of tissue were collected. The kidney samples included the cortex and the medulla. After collection, the specimens were kept cold and were frozen as quickly as possible before being shipped to the laboratory at the Centre de Toxicologie du Québec.

In March 1986 and 1987 and in June 1986, samples of the content of the rumen were taken from several carcasses. These specimens were preserved in formaldehyde and then analyzed to determine the relationship between the levels of contamination observed in the tissue and the food eaten by the animals.

Age was an important factor in the analysis and thus the animals were divided into three age groups based on size and whether the milk teeth had been replaced: calf (0-11 months); yearling (12-23 months) and adult (> 24 months).

Cadmium Dosage

The samples were analyzed by atomic absorption spectrophotometry (A.A.S.) in a graphite furnace Two methods were employed: one for liver and kidney, the second, for other types of tissue (rumen, flesh, heart and mesentery).

The first method (M-143-A), used on liver and kidney, covers levels from 0.1 to 2 mg kg^{-1} (wet weight); it employs a conventional graphite tube and ammonium nitrate as the matrix modifier. The second method (M-156-A), used on the other tissues, in particular flesh, covers levels between 0.002 and 0.100 mg kg^{-1} (wet weight) and employs a graphite platform with ammonium phosphate as the matrix modifier (Subramanian, 1985).

The possibility of cross-contamination was carefully controlled, especially during the critical homogenization phase. Each sample was homogenized in a mixer with rotating knives; about 100 g of tissue were treated, except in the case of the kidneys which were homogenized whole. A standardized procedure was employed to clean the mixer between samples. Moreover, the effectiveness of the cleaning procedure was continuously tested by introducing a sample of commercial beef liver, with known cadmium content, into the mixer after every tenth homogenized tissue sample. (M-140-A.)

The samples were digested using 10 ml of concentrated nitric acid in a final volume of 20 ml for every 0.5 g of homogenized wet tissue (M-142-A). Digestion took place in a polypropylene container placed in a microwave oven, employing the most recent techniques (Kingston and Jassie, 1986).

The results were thus originally obtained in mg kg^{-1}, wet base. To convert them to dry weight, the percentage of humidity in the tissues was determined: the weight loss in a sample of about 7 g of wet tissue dried at a temperature of 90° C for 24 hours was measured.

The results were carefully controlled using accepted standard samples: the beef liver from N.B.S. (S.R.M. 1577) with a titer of 0.27 + 0.04 mg kg^{-1}, dry weight. Every series of 45 readings, a set of results, included 31 samples of digested tissue uniformly separated by 14 control samples. Control sheets from the N.B.S. (S.R.M. 1571) with a titer of 0.11 + 0.01 mg kg^{-1} and a standard from the Nippon Institute of Environmental Studies (N.I.E.S.) certified at 0.20 + 0.03 mg kg^{-1}, dry weight, were also used. The doses in the control samples were all within .95 of the expected means.

Statistical Analysis

The data were analyzed to determine the role of age, date of collection and sex in determining the extent of cadmium contamination in the animals. An analysis of variance was performed to determine the probability of an influence of the three factors. The initial model included the factors and all their possible interactions; when a factor or interaction was not significant ($p > 0.05$), it was withdrawn from the model and the analysis was repeated. The G.L.B. procedure in the SAS program (SAS Institute, 1985) was used for the analysis. Only the cadmium concentrations in the liver and kidneys were subjected to the statistical analysis because of either too few samples or extremely low levels of cadmium. The data were converted into $\log_{10}$ to decrease the effects of aberrant data and to stabilize the variance (Norstrom et al, 1986).

RESULTS

Since very few samples were collected in December, June and September, the data were combined for statistical analysis. The average cadmium concentrations in the liver and kidneys were briefly examined for each sex and by sample period (Table 1). In the males, the mean values in the two organs indicated similar levels in December, March and June as well as in September and November. The distinction was less clear in the females. For the analysis of variance, the samples were therefore divided into two periods: winter (December to June) and fall (September and November).

The analysis showed that age and season had a significant effect ($p < 0.0008$) on the cadmium concentrations in the livers and kidneys. As had already been shown for other ungulates (Kocan et al, 1980; Mattsson et al, 1981; Woolf et al, 1982; Müller, 1985; Sileo and Buyer, 1985; Crête et al, 1987b), contamination in caribou liver and kidney increased with age (Tables 2 and 3). The marked seasonal variation found in this study, however, with higher concentrations in winter than in fall, had never been clearly described in the scientific literature. Another surprising and original finding was an inversion by sex in the amount of contamination in liver: contamination was greater in the males than in the females during the winter but lower in the fall; the trend was so pronounced as to produce a significant sex-by- season interaction ($p = 0.048$) in the analysis of variance. Finally, the cadmium in calf kidney increased sharply between the fall and winter, tripling in level in just a few months (Table 3). This increase resulted in a significant age-by-season interaction ($p = 0.0017$) in the analysis of variance.

The comparison of cadmium concentrations in the different caribou tissues confirmed that the contaminant tends to accumulate in the kidneys and liver (Table 4); the mean values were at least 20 times higher in the liver than in the lining of the rumen, the muscles, heart and mesentery. There were enough muscle samples for the two periods to allow for analysis. The result was even greater seasonal variation than that observed in the kidneys and liver. The humidity levels in the various types of tissue, however, were stable over the two harvest periods (Table 5).

The level of contamination in the George River caribou in the fall months was similar to that observed in the most affected deer and the least exposed moose in Québec (Tables 6 and 7). The Québec caribou seemed to be more affected by cadmium than the Scandinavian reindeer, apart from one population in southern Norway (Froslie et al, 1984; Table 6).

DISCUSSION

Contamination in the caribou

The passage of cadmium through the body is well documented in humans. After being absorbed by the digestive tract or lungs, it is transported in the blood, mainly by the red cells, to other parts of the body. It then binds, primarily in the liver, with a protein of low molecular weight, methallothionein, in which it induces synthesis. Along with the cadmium bound to it, this protein passes through the glomerular membrane and is then reabsorbed at the proximal tubule, thus leading to cadmium retention in the kidney, especially in the cortex. In the case of chronic exposure, most of the absorbed cadmium is therefore found in the liver and kidneys (Friberg et al, 1986). It is assumed that the process is the same in ungulates.

If caribou consume cadmium-contaminated forage during a particular period of the year, it will be absorbed during that period, and the blood will contain much greater amounts of the metal then than at other times. Although the diet of the George River caribou has not been described, it is clear that lichens make up a large part of their winter food intake, but lichens are very vulnerable to atmospheric pollution (Froslie et al, 1984) and they accumulate heavy metals (Puckett, 1986).

The seasonal variation in cadmium in caribou tissue can thus be partially explained by the importance of lichens in the animal's diet. In winter, the high level of consumption of these plants results in considerable absorption, and the blood, and thus the muscles, contain much more cadmium than in summer, when the caribou eat practically no lichens. The seasonal variation in cadmium intake was confirmed by the levels found in the rumens in March and June (Table 8). In both the unstrained and strained samples, the means in March were significantly higher than in June ($t = 4.29$ and 3.49; p 0.01). This difference would probably have been greater if samples taken of the rumen in summer or fall could have been compared with the March samples.

The winter and fall differences in cadmium concentration in the livers and kidneys can be explained otherwise: both organs undergo large seasonal variations in weight, as high as about 50 % of the mean (Dauphiné, 1975; Leader-Williams and Ricketts, 1982). These fluctuations are associated with the annual cycle of wild ruminants, which store energy during the growing season and deplete their reserves in winter. There are some data indicating that the situation is the same in Northern Québec caribou, but the variations in kidney mass do not seem to be synchronized in the males and females (Table 9). Therefore, since the humidity content of the organs was constant in winter and fall (Table 5), the total amount of cadmium retained by the liver and kidneys was most likely about the same from one season to the next, especially in the adults. It would be interesting to determine the exact location and/or possible redistribution of cadmium within the kidney.

The variations in cadmium levels associated with sex can be explained in a similar way. Such a difference has also been found in moose (Scanlon et al, 1986; Crête et al, 1987b). In cervidae, the males and females have a different physiological cycle: the males experience enormous physiological stress during the rut, while the end of gestation and beginning of nursing are the most demanding period for female reindeer (Leader-Williams and Ricketts, 1982). Kidney and liver mass could therefore be related to this annual cycle, as is suggested by the data in Table 9. Leader-Williams and Ricketts (1982), however, found considerable sexual synchrony in the seasonal variations of liver and kidney mass. It is possible that their sample was too small to reveal such differences or that the situation in Québec is different from that in their study area. The seasonal and sexual variations observed here also indicate that, in comparisons within a population, there should be standardization of the period in which the data are collected and in the male-female composition of the samples.

Consequences for human health

Health problems in humans associated with exposure to cadmium have been found in workers exposed through their occupation and in populations exposed to environmental contamination. Crête et al (1986) have reviewed the acute and chronic toxic effects of this metal on human health. In brief, chronic environmental exposure, like that described in Japan ("Itai-Itai" disease) results in a clinical picture characterized mainly by renal dysfunction similar to that described in industrial settings (proteinuria) and serious bone damage (osteomalacia).

The acceptable weekly intake of cadmium temporarily set by a group of World Health Organization (W.H.O.) experts is between 400 and 500 µg, corresponding to an acceptable daily intake of from 57 µg to 72 µg (W.H.O., 1979). The acceptable intake figures are for such sources as food, drinking water and ambient air.

In Canada, dietary intake used to be estimated at between 50 µg and 98 µg a day (Sandi, 1979; Environnement Canada, 1986), based on studies dating from the early 1970s; an overall average of 67 µg a day was estimated from results over a few years (Santé et Bien-Etre Social, Canada, 1983); this value is similar to the maximum acceptable limit proposed by the W.H.O. A recently published study based on 1981 data (Dabeka et al, 1987) estimates a dietary intake of 13.8 µg of cadmium a day, representing just 20% of the previous estimate.

The results of the latest study should, however, be interpreted with caution. The study was conducted on only 24 people (6 of them in Montreal), who were asked to provide a sample of equal quantity of the food they had eaten in a single day for analysis. All the subjects worked for Health and Welfare Canada or were married to employees of that body. It is likely that these people were better educated and more aware of the importance of a good diet than the Canadian population as a whole, and therefore may not have been representative. In addition, because of the design of the study, it is very likely that food items containing considerable amounts of cadmium (e.g., internal organs) that are eaten only occasionally were under-represented. According to the Dabeka et al (1987) study, current daily cadmium intake in Canada is the second lowest in the world, followed by Sweden. The 67 µg daily intake estimate by Sandi (1979) is considered too high and there have been suggestions that the overestimate was due to the analytical methods used at the time (Environnement Canada, 1986; Dabeka et al, 1987). The findings in the Dabeka et al (1987) study could, however, be underestimates.

Consideration should also be given to groups at risk in any discussion of cadmium intake from diet, since it is much higher in people with particular eating habits (Crête et al, 1986), i.e., those who:

- eat internal organs on a regular basis;

- eat foods that are not on the list of foodstuffs eaten by the general population and that could contain strong concentrations of cadmium (dark meat of crab, certain mushrooms, liver and kidneys of adult horses);

- eat leafy vegetables and fish.

The following statements seem warranted by the findings on caribou internal organs and meat in this study:

- ingestion of a serving (250 g fresh weight, or about 60 g dry weight) of caribou liver, with a cadmium content of 4 mg kg^{-1} could represent a cadmium intake of 240 µg;

- a single serving of the same amount of caribou kidneys, with a cadmium content of 50 mg kg^{-1} (dry weight), represents a cadmium intake of 3000 µg.

These values (240 µg and 3000 µg) are 4 to 50 times the acceptable daily intake level set by the W.H.O. If a cadmium dietary intake of 13.8 µg is accepted as the true Canadian value, these levels are 17 to 217 times above the estimate.

As for caribou meat, it appears that, although slightly higher than in most domestic animals (Vos et al, 1987), its contamination is minor. Thus, consumption of a serving of caribou meat containing 0.03 mg kg^{-1} (250 g) of cadmium represents an intake of only about 2 µg of cadmium. The problem with caribou meat is therefore not that it contains any more cadmium in winter than other foods of the same type, but rather that it is consumed on a regular basis by Native communities and by certain sport hunters, and this may put these two groups at high risk. Smokers would also be at increased risk because consumption of a pack of 20 cigarettes represents a cadmium intake of from 10 to 40 µg (Crête et al, 1986).

While the most recent findings in Canada indicate that the cadmium consumed in everyday foods is far below the acceptable maximum level proposed by the W.H.O., we believe that caution is necessary when it comes to consumption of highly contaminated foods, such as the internal organs of caribou. Such caution is warranted by the questions concerning the latest estimates of cadmium intake that remain unanswered because of a lack of detailed data specifically on Québec, where cadmium pollution seems to be particularly high (Crête et al, 1987b), a lack of recent data on tobacco and the existence of a number of groups at risk.

RECOMMENDATIONS

1. Given the relatively high level of contamination of caribou internal organs, it is recommended that consumers refrain from eating the liver and kidneys.

2. Since caribou make up a substantial part of the diet of certain Native populations, it is recommended that the communities most at risk be identified and that a preliminary study be carried out to ascertain the extent of cadmium exposure and/or absorption in the most exposed members of these communities.

3. Since lichens, the main winter forage of caribou, accumulate various atmospheric pollutants and can be contaminated by other elements besides cadmium (arsenic, cesium, mercury, lead, selenium, etc.), it is recommended that:

   - the lichens in Nouveau-Québec be sampled to determine the extent and distribution of these pollutants in the environment;

   - the quantities of these contaminants be measured in caribou tissue to determine whether certain elements could represent a threat to human health.

4. Given the lack of published Québec data on cadmium contamination in the principal dietary items, it is recommended that a study taking regional variations into account be carried out.

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Table 1 Average concentration of cadmium (mg kg^{-1}, dry weight), by sex, observed in liver and kidney of caribou killed between December 1985 and November 1986. The means are not weighted for age.

	Males			Females		
	$\bar{X}$	S.E.M.	N	$\bar{X}$	S.E.M.	N
Liver						
December 7-16, 1985	3.4	0.73	5	3.0	0.6	7
March 10-22, 1986	4.5	1.00	19	5.0	0.4	34
June 2-17, 1986	4.1	0.70	3	5.8	0.2	2
September 26 - October 9, 1986	1.2	0.30	2	3.8	1.5	6
November 3-12, 1986	1.1	0.05	9	2.5	0.3	24
Kidney						
December 7-16, 1985	28.1	16.20	3	36.7	12.3	6
March 10-22, 1986	30.3	5.40	15	56.7	8.3	33
June 2-17, 1986	51.2	11.80	3	35.7	10.5	3
September 26 - October 9, 1986	6.0	0.70	2	44.2	16.6	6
November 3-12, 1986	13.6	6.20	11	30.1	3.6	32

Table 2 Cadmium concentration (mg kg^{-1}, wet weight) in caribou liver, by age, sex and season collected. The means were weighted using LSMEANS in the SAS program (SAS institute, 1985).

	$\bar{X}$ (mg kg^{-1})	S.E.M.	N
Age			
calves	1.7	0.2	41
yearlings	2.0	0.4	8
adults	4.0	0.2	62
Males			
winter	3.4	0.2	28
fall	1.6	0.5	11
Females			
winter	2.9	0.2	43
fall	2.0	0.2	29

Table 3 Cadmium concentration (mg kg^{-1}, wet weight) in caribou kidney, by age and season collected. The means were weighted using LSMEANS in the SAS program (SAS institute, 1985).

		$\bar{X}$ (mg kg^{-1})	S.E.M.	N
Winter				
	calves	14.8	0.6	18
	yearlings	18.6	1.6	4
	adults	51.3	1.1	41
Fall				
	calves	5.6	0.4	20
	yearlings	13.5	1.5	3
	adults	40.7	1.2	27

Table 4 Cadmium concentration (mg kg^{-1}, dry weight) in tissue of caribou harvested in the winter and in the fall, both sexes and all age groups.

	Winter			Fall		
	$\bar{X}$	S.E.M.	N	$\bar{X}$	S.E.M.	N
Kidney	45.9	5.0	63	27.5	3.5	50
Liver	4.5	0.3	71	2.3	0.3	40
Lining of the rumen	0.177	---	1	0.102	0.010	17
Muscle	0.031	0.015	52	0.002	0.001	33
Heart	---	---	--	0.003	0.003	7
Mesentery	---	---	--	0.023	0.006	15

Table 5 Percent humidity in tissue of caribou harvested in the winter and in the fall

	Winter			Fall		
	$\bar{X}$	S.E.M.	N	$\bar{X}$	S.E.M.	N
Kidney	78.8	1.2	55	79.7	0.2	50
Liver	71.6	0.2	59	72.1	0.3	40
Lining of the rumen	76.2	---	1	79.3	0.3	17
Muscle	74.1	0.4	54	76.8	0.8	33
Heart	---	---	--	77.0	0.5	7
Mesentery	---	---	--	33.1	3.9	15

Table 6 Cadmium concentration (mg kg^{-1}, dry weight) in liver of white-tailed dear, moose and reindeer killed in Québec and Norway, by hunting zone and sex.

	Males			Females		
	$\bar{X}$	S.E.M.	N	$\bar{X}$	S.E.M.	N
White-tailed deer (Québec)[a]						
Zone 20	1.0	0.11	20	0.8	0.23	7
Zone 1, 2	1.8	0.20	72	1.2	0.34	8
Zone 3, 4, 5, 9, 10, 11	2.6	0.23	62	2.0	0.30	12
Moose (Québec)[a]						
Zone 1, 2, 20	3.6	0.29	49	2.9	0.35	39
Zone 3, 4, 5, 9, 10, 11, 12, 14, 15, 18	8.2	0.61	86	7.0	0.76	95
Zone 13	15.9	3.50	17	15.1	2.21	20
Reindeer (Norway)[b], sex unknown						
Least contaminated area	0.9	NA[c]	5			
Most contaminated area	4.7	NA	5			

[a] Crête et al. 1987b

[b] Froslie et al, 1984

[c] not available

Table 7 Cadmium concentration (mg kg^{-1}, dry weight) in kidney of white-tailed dear and moose killed in Québec, by hunting zone and sex (from Crête et al, 1987b).

	Males			Females		
	$\bar{X}$	S.E.M.	N	$\bar{X}$	S.E.M.	N
White-tailed deer						
Zone 20	21.1	2.4	21	20.9	5.0	7
Zone 1, 2	25.3	3.5	8	---	---	0
Zone 3, 4, 5, 9, 10, 11	39.0	10.0	7	---	---	0
Moose						
Zone 1, 2, 20	38.9	49.0	13	31.8	8.0	11
Zone 3, 4, 5, 9, 10, 11, 12, 14, 15, 18	57.9	8.0	34	44.0	5.4	37
Zone 13	73.1	5.8	13	100.0	12.0	17

Table 8 Cadmium concentration (mg kg^{-1}, dry weight) in samples of rumen content in caribou, strained and unstrained samples (strainer with 4.75-mm openings, side measurement), by site and month in which the sample was taken.

Site	Month	Unstrained	Strained
1	March	0.10 (0.007; 15)[a]	0.07 (0.007; 7)
2	March	--	0.05 (0.02; 2)
6	March	0.17 (0.02; 12)	0.08 (0.007; 13)
1, 2, 6		0.13 (0.01; 27)	0.07 (0.005; 22)
3	June	0.06 (0.003; 3)	0.05 (0.01; 3)
4	June	0.08 (0.02; 4)	0.04 (0.01; 3)
3, 4		0.07 (0.01; 7)	0.04 (0.007; 6)

a (S.E.M.; N)

Table 9 Mass (g) of kidney in adult caribou in Nouveau-Québec, by sex of animal and period in which the animal was killed. The average of the two kidney was used as the basis for the calculations. Eight samples (2 males and 6 females), taken in early June, were from the Leaf River herd; all the others were from the George River herd.

Harvest period	Males			Females		
	$\bar{X}$	S.E.M.	N	$\bar{X}$	S.E.M	N
February 15 - March 19	135	19	4	180	9	18
May 31 - June 16	266	54	4	127	9	8
July 25-29	219	13	2	196	11	10

Figure 1. Locations of tissue sampling sites for the George River caribou herd; December 1985-November 1986.