Polychlorinated Dibenzo-p-dioxins, -furans, and Co-planar PCBs in Livers of Moose (Alces alces) Consumed by New England Native Americans

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Introduction

Native Americans have relied on natural resources to provide Tribal members with food and spiritual sustenance since the beginning of time. Tribal members fear that their natural resources are increasingly being contaminated and that these contaminants pose a threat to their health and culture. The average life span for a Tribal member in New England is between the age of 50-60 years, and they have some of the highest rates of cancer and respiratory illness. To address these concerns, Tribal councils that manage their own properties and assets through their own environmental departments receive U.S. Environmental Protection Agency performance partnership grants to study environmental issues which affect the Tribal environment and the health of Tribal members.

An example of a study of this type was initiated on the Tribal lands of the Passamaquoddy and Penobscot Indian nations to evaluate the levels of the heavy metal, cadmium, in the livers of moose and deer. This study was prompted by an advisory issued by the State of Maine Department of Inland Fisheries and Wildlife that hunters should not consume moose liver and should limit their ingestion of deer liver due to elevated levels of cadmium. This organ is a very popular food source for the New England Tribes and its consumption is part of their traditional cultural heritage. According to a members of the Passamaquoddy Indian Township, “To eat the liver of an animal is a spiritual act, the energy from the liver is meant to help your own liver stay healthy . . . we always eat the liver first, I even take a bite of the raw liver when I first take it from a moose; it’s always done that way; it’s tradition.” The study conducted by the University of Maine verified that the older animals had elevated cadmium levels unacceptable for human consumption.

To date, there has been little data collected regarding the levels of persistent organic pollutants (POPs) on Tribal lands in New England and few studies assessing the levels of these pollutants in mammals from this area. To that end, Tribal Nations requested the assistance of the USEPA for the analyses of these moose liver samples for presence of dioxin-like compounds. Since the New England Tribes maintain a land-based culture, there is considerable potential for increased exposure to accumulated pollutants from their diet and, therefore, these POPs could threaten the culture and future of these indigenous peoples. Tribal members believe that their freedom to derive sustenance from their surroundings, including moose, deer, and fish, is at the heart of their survival as a native culture. To determine the levels of dioxins and co-planar PCBs in the moose liver, seventy moose liver samples collected from the Passamaquoddy and Penobscot traditional hunting grounds and previously analyzed for cadmium were shipped to the EPA’s Environmental Chemistry Laboratory and twenty-five selected samples analyzed for the presence of the seventeen 2,3,7,8-Cl substituted polychlorinated dibenzo-*p*-dioxins, -furans and selected co-planar PCBs (77, 105, 118, 126, 156, 157, 169).

Adult moose (*Alcesalces*), which average 450 kilograms and can stand as tall as 2.3 meters high at the shoulder, are the largest wild animals in North America.[1] Moose habitats range throughout northern North America and Eurasia, coinciding with that of the circumpolar boreal forests. In North America they are present throughout Alaska, Canada, and the northeastern United States and as far south as the Rocky Mountains in Colorado. In Eurasia, they can be found throughout northern Europe and eastwards through Siberia and Mongolia. Moose is an Algonquin Indian term for “eater of twigs” and are primarily browsers feeding on leaves, twigs, and buds of hardwood and softwood trees and shrubs, especially willows and aspens. In the winter they also browse on conifers, such as the balsam fir, and eat the needle-like leaves. In the summer they feed heavily on sodium-rich aquatic plants (e.g., water lilies, pondweed, horsetails, bladderworts, bur-reed). A healthy moose will eat 18-27 kilograms of browse daily. Their average expected lifespan in the wild ranges from 8 to 12 years.

Materials and Methods

Moose liver samples were collected from kills made on Tribal lands from September to November, 1999 using pre-determined QA/QC procedure. Samples were collected primarily by trained Tribal environmental staff and volunteers with the assistance of the warden services of both tribes. Tribal members were given sample kits and trained at a workshop to remove the liver, clean and bag it before bringing it to the lab accompanied with a completed form that records the identification of the collector, the location determined by global positioning (GPS), date, weight, sex, age, etc. Samples were collected from three geographically distinct Passamaquoddy and Penobscot traditional hunting areas: the Western Zone, the Mid-State Zone and the Indian Township areas. The Appalachian Mountain Range and the Kennebec River were the boundaries for the purpose of this study. Seven samples from each area were selected for screening. This effort was one of the first by a Tribal Government to produce a quality assurance project plan for testing of pollutants.

Approximately 50-100 gram samples that had been previously homogenized and homogeneity tested were re-homogenized, fortified with ^{13}C labeled recovery surrogates and processed using a modified version of EPA's Method 1613 described previously.[2] The samples were fortified with ^{13}C internal standards, and 2/20ul analyzed by high resolution gas chromatography/ high resolution mass spectrometry (HRGC/MS) on a Kratos Concept. Detection limits as low as 0.01 ppt were substituted for non-detected dioxin/furans.

Results and Discussion

The results from the analyses of the moose livers are presented in Table 1. The individual sample concentrations from each zone were averaged and the average concentrations on a whole weight basis are provided. The average WHO TEQs from each zone are provided in both a whole weight and lipid adjusted basis as are the ranges of the individual sample TEQs (minimum and maximum) for each zone. An examination of the Western Zone samples indicated a possible outlier . This sample was tested by both the Dixon and Grubbs Outlier Tests at a 1% risk of false rejection and was found to be an outlier.[3] It was removed from the data base for the Western Zone and the average recalculated without the outlier. As expected the three average TEQ summation values are more similar with its removal. The average WHO TEQs in the table were calculated by substituting the detection limits for non-detects and thus represent the upper-bound TEQ limit. A total of twenty-one samples were analyzed from the three zones, representing approximately 500 measurements. There were approximately 100 non-detects comprised primarily of the tetra- through hexa-dioxins and the tetra- and penta-furans. The lower-bound TEQ was also calculated by substituting zero for the non-detects: 0.808, 0.704, 0.420, and 0.644 pg/g TEQ for the Western (Adj), Mid-State, Indian Township, and Overall Averages, respectively. As is evident when one compares these values with the TEQs in the Table, the magnitude of the difference is minimal and illustrates that the detection limits are sufficiently low and the manner of substitution of the non-detects has little consequence.

Several features of the congener distributions are of note; the relative concentration of PCB 126 is higher than expected when compared to congener profiles seen in domesticated animals and represents over ninety percent of the PCB TEQ for all the samples. PCB 126 was also the major contributor to the TEQ in caribou taken from the Canadian Arctic.[5] The relative concentration of 2,3,4,7,8-PeCDF is relatively high and contributes over 50 percent of the D/F TEQ. The 2,3,4,6,7,8-HxCDF is the dominant toxic hexa-furan congener and in the eleven samples that had detectable amounts of all three toxic hexa-dioxin congeners, 1,2,3,4,7,8-HxCDD was the dominant congener in eight. The average lipid adjusted PCDD/Fs TEQ of 7.4 for the moose livers compare very well with the 7.1 for deer liver from a reference area in Canada.[4] The 2,3,4,7,8-PeCDF was also the major contributor to the D/F TEQ in the deer liver.

In addition to the value inherent in the information provided by the analyses, this project represents the kinds of studies that need to be developed and implemented in order to provide meaningful information applicable to the unique cultural and resource utilization patterns of Native Americans. The Maine Tribes are working cooperatively with the USEPA to develop scientifically sound exposure pathways to determine historic natural resource utilization patterns and identify specific traditional foods, medicinal, spiritual and recreational practices that need to be considered in order to conduct risk assessments designed to protect the most vulnerable members of Tribal populations.

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Disclaimer: This paper reflects the views of the authors and does not necessarily reflect the views of the Environmental Protection Agency and no official endorsement should be inferred. The mention of trade names or commercial products constitutes neither an endorsement nor a recommendation of use.

References

1. University of Michigan Museum of Zoology (2005). Animal Diversity Web, http://animaldiversity.ummz.umich.edu/site/accounts/information/Alces_alces.html.

2. Ferrario, J., Byrne, C., Dupuy, A., Winters, D., Lorber, M., Anderson, S. (1998) *Organohalogen Compounds* 35: 29-31.

3. Taylor J.K. (1987) in: Quality Assurance of Chemical Measurements, Lewis Publishers, ISBN 0-87371-097-5.

4. MacKenzie, A., Gabos, S., Chen, W., Ikonomou, l., Schopflocher, D. (2004) *Organohalogen Compounds* 66: 1971-1976.

5. Hebert, C., Gamberg, M., Elkin, B., Simon, M., Norstrom, R. (1996) *Sci. Total Env.* 185: 195-204.

Table 1. Results of the Analyses of Moose Livers (pg/g, whole weight) and (pg/g, TEQ)

Location	Western	Western (Adj)	Mid-State	Indian Township	Overall Avg
Number of Samples	**7**	**6**	**7**	**7**	
PCBs:					
PCB 77	1.520	0.553	0.392	0.409	0.451
PCB 118	409.683	94.095	58.988	43.170	65.417
PCB 105	162.843	42.453	23.926	18.394	28.258
PCB 126	8.657	4.905	3.713	1.920	3.513
PCB 156	33.855	8.477	4.316	2.786	5.193
PCB 157	9.744	2.572	1.271	0.878	1.574
PCB 169	0.669	0.170	0.182	0.058	0.137
PCB TEQ SUM	0.952	0.511	0.384	0.275	0.390
PCDDs/PCDFs:					
2,3,7,8-TCDF	0.033	0.023	0.038	0.025	0.029
1,2,3,7,8-PeCDF	0.020	0.016	0.027	0.025	0.023
2,3,4,7,8-PeCDF	0.554	0.347	0.301	0.148	0.265
1,2,3,4,7,8-HxCDF	0.300	0.212	0.131	0.068	0.137
1,2,3,6,7,8-HxCDF	0.241	0.179	0.131	0.068	0.126
2,3,4,6,7,8-HxCDF	0.356	0.259	0.195	0.119	0.191
1,2,3,7,8,9-HxCDF	0.034	0.027	0.028	0.028	0.028
1,2,3,4,6,7,8-HpCDF	0.446	0.415	0.106	0.078	0.200
1,2,3,4,7,8,9-HpCDF	0.064	0.061	0.044	0.052	0.053
OCDF	0.309	0.338	0.061	0.069	0.146
2,3,7,8-TCDD	0.031	0.014	0.015	0.015	0.014
1,2,3,7,8-PeCDD	0.084	0.035	0.052	0.043	0.043
1,2,3,4,7,8-HxCDD	0.107	0.051	0.064	0.059	0.058
1,2,3,6,7,8-HxCDD	0.105	0.061	0.055	0.045	0.054
1,2,3,7,8,9-HxCDD	0.067	0.043	0.042	0.052	0.046
1,2,3,4,6,7,8-HpCDD	0.524	0.346	0.251	0.356	0.318
OCDD	1.051	0.729	0.251	0.611	0.530
PCDD/F TEQ	0.528	0.317	0.291	0.184	0.264
TOTAL TEQ (ww)	1.480	0.828	0.709	0.458	0.665
INDIV SMPL TEQ (Min)	0.197	0.197	0.260	0.207	
INDIV SMPL TEQ (Max)	5.388	1.945	1.477	1.142	
TOTAL TEQ (Lipid)	19.758	19.632	19.409	13.157	17.400
INDIV SMPL TEQ (Min)	4.545	4.545	3.525	2.811	
INDIV SMPL TEQ (Max)	59.319	59.319	49.962	28.163	