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Dietary, age and trans-generational effects on the fate of organohalogen contaminants in captive sledge dogs in Greenland

Jonathan Verreault [a,b,*], Robert J. Letcher [a,b], Christian Sonne [c], Rune Dietz [c]

[a] Wildlife and Landscape Science Directorate, Science and Technology Branch, Environment Canada, National Wildlife Research Centre, Carleton University, Ottawa, Ontario, Canada K1S 5B6
[b] Carleton University, Department of Chemistry, Ottawa, Ontario, Canada K1S 5B6
[c] University of Aarhus, National Environmental Research Institute, Department of Arctic Environment, DK-4000 Roskilde, Denmark

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ABSTRACT

Studies on the fate of organohalogen contaminants (OHCs) in wild top predator mammals in the Arctic have often been a challenge due to important knowledge deficiencies in the life history of the sampled animals. The present study investigated the influence of age, dietary and trans-generational factors on the fate of major lipophilic chlorinated and brominated OHCs in adipose tissue of a potential surrogate captive species for the polar bear (*Ursus maritimus*), the sledge dog (*Canis familiaris*) in West Greenland. Adult female sledge dogs (P) and their sexually-mature (F1) and/or pre-weaning pups (F1-MLK) were divided into an exposed group (EXP) fed blubber from a Greenland minke whale (*Balaenoptera acutorostrata*) and a control group (CON) given commercially available pork fat. Large dietary treatment-related differences in summed and individual congener/compound adipose tissue concentrations of polybrominated diphenyl ethers (PBDEs), hexachlorobenzene (HCB), chlordanes (CHLs) and polychlorinated biphenyls (PCBs) were found between the EXP and CON groups for all the sledge dog cohorts. However, among the F1-MLK, F1 and P dogs in both of the EXP and CON groups, little or no difference existed in PBDE, HCB, CHL and PCB concentrations, suggesting higher state of equilibrium in adipose tissue concentrations from a very early stage of life. In contrast, the distribution pattern (proportions to the summed concentrations) of OHC classes, and the major congeners/compounds constituting those classes, varied on a dietary group- and/or cohort-dependent manner. The present captive sledge dog study demonstrated the importance of the confounding effects of diet composition, mother–pup association (maternal transfer), reproductive status (nursing), and to a lesser extent age in the fate of OHCs in adipose tissue of a large top carnivore mammal.

1. Introduction

Research on the fate of organohalogen contaminants (OHCs) in arctic wildlife, particularly in mammals occupying high trophic positions in the marine and terrestrial food webs, can be a challenge due to important knowledge gaps on the animal's life history. The characteristics that can affect the OHC fate (*e.g.*, bioaccumulation and biotransformation) in an individual include, among others, the age, gender, genetics, diet, metabolic capacity and selectivity for contaminant substrates, and reproductive status and nutritional condition. Insufficient characterization and thus limited consideration of these toxicokinetic factors has been the foremost confounding aspect in OHC monitoring programs and health risk assessments of free-ranging top predator mammals. The top marine carnivore species in the Arctic that has received by far the most focused attention with respect to OHC fate, monitoring and exposure-related health effects is the polar bear (*Ursus maritimus*) (de Wit et al., 2004; Fisk et al., 2005).

Recently, the sledge dog (*Canis familiaris*) has been examined as a potential surrogate captive species in the study of exposure-associated effects of OHCs for the East Greenland polar bear, and potentially also for other arctic species within the *Canoidea* superfamily such as the Arctic fox (*Alopex lagopus*). Hitherto, examinations of the captive sledge dogs fed a naturally OHC contaminated diet consisting of the blubber of a minke whale (*Balaenoptera acutorostrata*) harvested in the waters off West Greenland have shown that relative to control individuals fed pork fat, the exposed sledge dogs exhibited liver and kidney lesions (Sonne et al., 2007a, 2008a), altered liver and kidney functions (Sonne et al., 2007a, 2008a,b), insufficient immune response (Sonne et al., 2007b) and impaired cellular immunity (Sonne et al., 2006a). Despite a number of characteristic physiological and ecological differences between captive sledge dogs and wild polar bears of known sex and age, these potentially chemically-induced effects observed in sledge dogs have thus far shown notable similarities with those reported in East Greenland polar bears (Kirkegaard et al., 2005; Sonne et al., 2005, 2006b,c, 2007c, 2008c). Polar bears from East Greenland have been reported to accumulate some of the highest adipose tissue

* Corresponding author. Tel.: +1 613 998 6689; fax: +1 613 998 0458.
E-mail address: jonathan_verreault@carleton.ca (J. Verreault).

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Table 1
Sample size (sex-categorized) and mean (±1 standard error) or range (for sample sizes ≤2) age, body mass, total minke whale blubber or pork fat intake amount, and lipid content and OHC concentrations in the two experimental diets (pooled samples) and in adipose tissue of captive control (CON) and exposed (EXP) sledge dogs comprised of adult females (P) and their first- and second-generation pups, including sexually-mature (F1) and pre-weaning pups that received maternal milk exclusively (F1-MLK)

	CON group				EXP group			
	Pork fat diet	F1-MLK-CON	F1-CON	P-CON	Greenland minke whale blubber diet	F1-MLK-EXP	F1-EXP	P-EXP
N	3	5 M, 5 F	3 M, 2 F	3 F	3	3 M	2 M, 1 F	2 F
Age (days)	–	20±1	358±0	561±90	–	10±0	342±0	381–666
Body mass (kg)	–	0.9±0.1	21.3±1.4	22.8±1.5	–	0.7±0.01	22.7±1.1	21.3–22.3
Total blubber/fat intake (kg)	–	–	30.6±1.0	46.7±9.0	–	–	32.3±0.8	32.9–59.5
Adipose tissue								
Lipid content (%)	96.8±1.7	80.8±1.1	89.6±2.4	87.5±3.1	67.5±2.4	72.5±2.3	95.0±1.1	86.5–91.9
∑PBDE[a] (ng/g wet wt.)	2.1±0.4	4.2±1.4	6.5±2.4	11.7±9.0	41.9±0.7	46.5±3.0	132±9.4	71.8–147
HCB (ng/g wet wt.)	N.D.	1.7±1.1	1.2±0.4	0.8±0.3	18.6±0.3	33.8±1.6	57.3±5.6	25.1–75.4
∑CHL[b] (ng/g wet wt.)	N.D.	90.7±36.5	9.2±1.2	35.6±19.3	196±5.4	1308±76.7	1256±184	943–2057
∑PCB[c] (ng/g wet wt.)	N.D.	93.9±49.7	39.6±4.0	69.0±31.7	1147±58.8	1410±178	2534±333	1958–4633

N.D.: not detected.
[a] Sum of 36 congeners: BDE17, 25, 28, 47, 49, 54, 66, 75, 77, 85, 99, 100, 116, 119, 138, 139, 140, 153, 154, 155, 171, 180, 181, 183, 184, 190, 191, 196, 197, 201, 202, 203, 206, 207, 208 and 209.
[b] Sum of six compounds: heptachlor epoxide, oxychlordane, *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor and *cis*-nonachlor.
[c] Sum of 59 congeners: CB16/32, 17, 18, 22, 31/28, 33/20, 42, 44, 47/48, 52, 56/60, 64/41, 66, 70/76, 74, 85, 87, 92, 95, 97, 99, 101/90, 105, 110, 114, 118, 128, 130, 137, 138, 141, 146, 149, 151, 153, 156, 157, 158, 170/190, 171, 172, 174, 176, 177, 178, 179, 180, 183, 187, 189, 194, 195, 196/203, 199, 200, 202, 206, 207 and 208.

concentrations of chlorinated (Norstrom et al., 1998; Verreault et al., 2005) and brominated OHCs (Muir et al., 2006) relative to other circumpolar sub-populations.

We recently reported in a comparative investigation the fate of OHCs, including polybrominated diphenyl ethers (PBDEs), hexachlorobenzene (HCB), chlordanes (CHLs) and polychlorinated biphenyls (PCBs), in adult female East Greenland polar bears, which consume mainly the blubber of ringed seals (*Pusa hispida*), and minke whale blubber-fed adult female sledge dogs (Verreault et al., 2008). In this study, a number of differences, but also similarities, depending on the OHC class and parameter examined, were observed between sledge dogs and East Greenland polar bears. More specifically, characteristic OHC bioaccumulation profiles (concentrations and patterns), biomagnification dynamics, as well as inferred biotransformation capacity (hydroxylated (OH) PCB and PBDE metabolite concentrations) distinguished, to some extent, these two top carnivore species in Greenland. We hypothesized that inherent factors such as age, genetics, capacity and selectivity for substrate metabolism (CYP enzyme-mediated), diet composition and reproductive and nutritional status may have contributed to the disparities in OHC profiles observed between adult female sledge dogs and polar bears. These physiological and toxicokinetics factors have been suggested to play an important role in the OHC concentration and pattern variation in circumpolar polar bear populations (Bernhoft et al., 1997; Dietz et al., 2004; Gebbink et al., 2008; Muir et al., 2006; Norstrom et al., 1998; Polischuk et al., 1995, 2002; Verreault et al., 2005). In the present study, we examined in greater depth the age, dietary and trans-generational effects on the fate of major lipophilic OHCs (PBDEs, HCB, CHLs and PCBs) in adipose tissue of exposed (Greenland minke whale blubber) and control (pork fat) adult female sledge dogs, as well as their first- and second-generation pups (sexually-mature and pre-weaning pups). Although based on a very small sample size, the present investigation provides a more detailed, overall examination and understanding of some key factors related to the fate, and by extension the toxicokinetics of OHCs in captive sledge dogs. As a consequence, potential caveats are revealed with respect to OHC monitoring and toxicological assessments in free-ranging top carnivore *Canoidea* species inhabiting the Arctic such as the polar bear, and possibly also the Arctic fox.

2. Materials and methods

2.1. Sample collection

Two-month-old female sledge dogs (P cohort) from the community of Aasiaat (Disco Bay, West Greenland) were assigned to two experimental groups: an exposed (EXP) and a control (CON) group (Table 1). The CON and EXP groups were composed of paired sisters, one sister in each group, in order to minimize genetic differences between those groups. Over the nearly two-year study duration (2003–2005), three and two of the P-CON and -EXP dogs, respectively, were mated by one single male, and their first- and second-generation male and female pups were integrated in the study design. The CON and EXP pup cohorts were composed of pre-weaning (F1-MLK) and sexually-mature individuals (F1). The P- and F1-EXP dogs were fed with blubber from one minke whale harvested as part of the controlled Greenlandic native subsistence hunt, whereas the P- and F1-CON cohorts were given pork fat (lard) classified for human consumption (Blume, Randers, Denmark). Neither the minke whale blubber nor the pork fat included the epidermis. The mean daily intake of minke whale blubber or pork fat was 112 g/day and the cumulative diet intake for the entire study duration in the F1 dogs was on average 33% inferior to the P dogs ($p=0.01$). This corresponded to a roughly 15 kg-difference in total blubber/fat ingested, while no difference ($p\geq0.30$) was found for the F1 and P cohorts between the CON and EXP treatment groups (Table 1). The ten and three pre-weaning F1-MLK-CON and -EXP pups, respectively, received exclusively maternal milk from their respective mothers. The minke whale blubber/pork fat-feeding regimes were supplemented with standardized Royal Canin Energy 4300 and 4800 diets (http://www.royalcanin.com/) to compensate for differences in fatty acid,

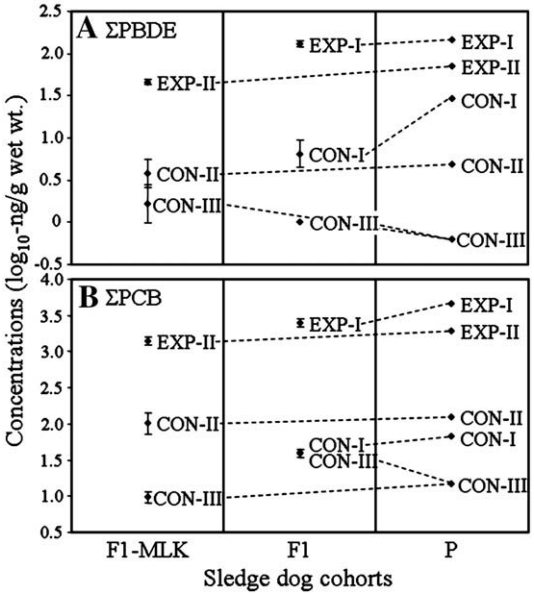

Fig. 1. Unadjusted mean (±1 standard error as vertical bars) or individual concentrations (log_{10}-transformed ng/g wet wt.) of ∑PBDE (A) and ∑PCB (B) in adipose tissue of control (CON) and exposed (EXP) adult female sledge dogs (P) and their first- and second-generation pups, including sexually mature (F1) and pre-weaning pups that received maternal milk exclusively (F1-MLK). Pup–mother pairs are identified by stippled lines.