HALOGENATED ORGANIC COMPOUNDS (HOCS) IN WILD LIVING TERRESTRIAL MAMMALS IN SVALBARD, NORWAY AND NORTHERN SWEDEN

Polder A[1], Skaare JU[1,2], Tryland M[1], Ropstad E[1], Gabrielsen GW[3], Vikøren T[2], Arnemo JM[4], Mørk T[2], Killengreen S[5], Leonards P[6], Lie E[1].

[1]Norwegian School of Veterinary Science, P.O. Box 8146 Dep, NO-0033 Oslo, Norway; [2]National Veterinary Institute, Pb 750 Sentrum, NO-0106 Oslo; [3]Norwegian Polar Institute, Polar Environmental Centre, NO-9296 Tromsø; [4]Hedmark University College, Campus Evenstad; [5]University of Tromsø, NO- 9037 Tromsø, Norway; [6]VU University Amsterdam, De Boelelaan 1105, NL-1081 HV, Amsterdam, the Netherlands.

Introduction

Due to their physical and chemical properties, halogenated organic compounds (HOCs) are globally distributed through the atmosphere and oceans to areas far from their sources. Because of their high lipophilicity HOCs can bioaccumulate and biomagnify in different food webs[1]. Levels of HOCs are generally lower in the terrestrial ecosystem than in the aquatic ecosystem In agreement with this, very low levels of HOCs were reported in Swedish and Finnish reindeer and moose and in Norwegian grouse, deer, moose and lynx[2,3,4]. Otherwise, there is little knowledge about fate and distribution of HOCs in the terrestrial environment[5]. In addition to legacy HOCs such as polychlorinated biphenyls (PCBs) and chlorinated pesticides (e.g. DDTs, HCHs, HCB, toxaphenes, chlordanes), there is a strong need for monitoring emerging pollutants such as brominated flame retardants (e.g. brominated diphenyl ethers [PBDEs], hexabromocyclododecane [HBCD], other “new” BFRs and perfluorinated compounds (PFCs, e.g. perfluorooctane sulfonate [PFOS]). Metabolites of the anthropogenic compounds might possess higher toxicological potencies than their parent compound. Thus, for risk assessment of the various compounds it is of great importance to gain knowledge of the metabolism of HOCs in the animals and to reveal the levels of possible metabolites. The main aims of the study were to contribute with increased knowledge on occurrence and fate of HOCs in the terrestrial environment, which might be of value for the Stockholm Convention (http://chm.pops.int/). The study is also of value from a human perspective, since some of the studied animals are consumed by humans (reindeer, red deer and moose). Reindeer husbandry is also of great economic and cultural importance for many indigenous people living in the Arctic.

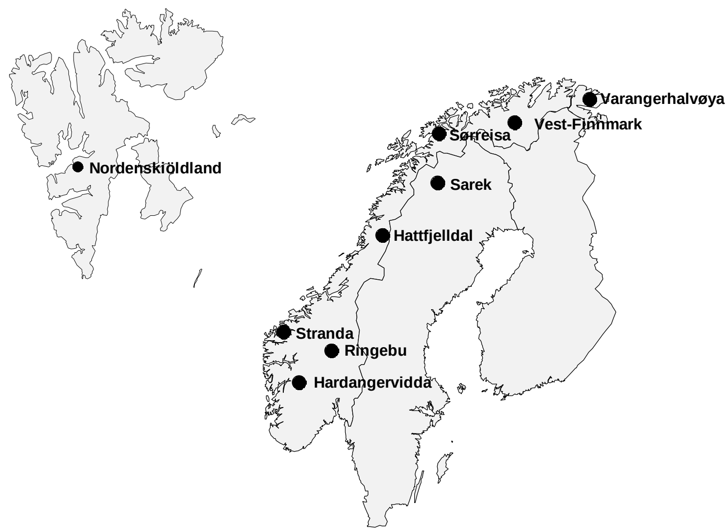

Figure 1. Map of Norway, Sweden and Finland including the locations from which the samples were collected.

Materials and methods

A total of 143 blood/plasma samples from wild Svalbard (*Rangifer tarandus platyrhynchus*) and semi-domesticated reindeer (*Rangifer tarandus tarandus*), red deer (*Cervus elaphus*), moose (*Alces alces*), red fox (*Vulpes vulpes*), wolverine (*Gulo gulo*), brown bear (*Ursus arctos*) and Eurasian lynx (*Lynx lynx*) were purchased from biobanks at the Norwegian School of Veterinary Science (NVH, Oslo and Tromsø) and National Veterinary Institute (NVI, Oslo and Tromsø). The samples were previously collected for other scientific purposes and kept frozen at -20 ^{0}C or lower until analysis. The samples covered a study period from 1993-2009. The sampling locations were: Svalbard (Svalbard reindeer), Finnmark (husbandry reindeer, red fox), Hardangervidda (wild reindeer) in Norway and Sarek National Park, Sweden (wolverines, brown bears, and lynx) (Figure 1). More details on locations with latitudes, sampling methods and information on pooling of samples were described in a report for the Climate and Pollution Agency (Klif)[6]. The chemical analyses of OCPs, PCBs, PBDEs, OH-PCB and OH-BDE metabolites, HBCD, and other brominated compounds were performed at the Laboratory of Environmental Toxicology (MT-lab) at the Norwegian School of Veterinary Science (NVH), Oslo, Norway. PFCs were analysed by the laboratory of the department of Chemistry and Biology of the Institute for Environmental Studies, VU University, Amsterdam, The Netherlands.

Results and discussion:

In general, relatively low levels of HOCs were found in the studied species, except for the red fox and the Eurasian lynx from Finnmark (Figure 2). The HOC results varied greatly within species as well as between locations and years. In the herbivores generally low levels were found of HCB, OH-PCBs, PCP, PBDEs, TBP and PFCs. HOC levels were lower in herbivore than in carnivore species (Figure 2).

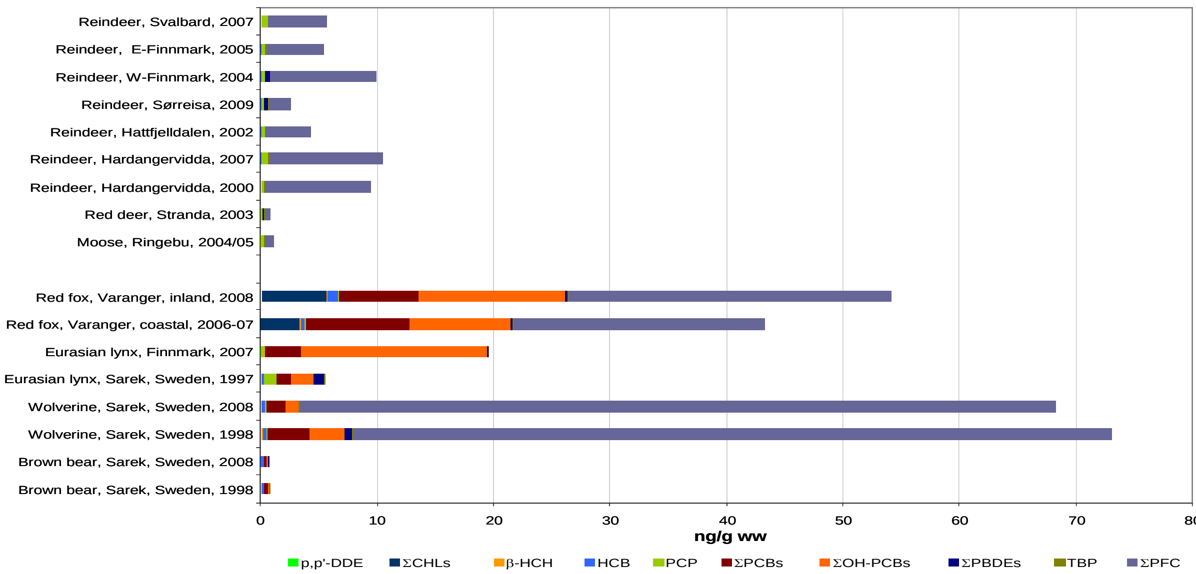

Figure 2. Levels of p,p'-DDE, ∑CHLs, β-HCH, HCB, PCP, ∑PCBs, ∑OH-PCBs, ∑PBDEs, TBP and ∑PFCs (ng/g ww) in reindeer from Svalbard, East- and West-Finnmark, Sørreisa, Hattfjelldal and Hardangervidda; red deer from Stranda; moose from Ringebu; red fox from Varangerhalvøya; wolverine and brown bear from Sarek, Northern Sweden; and Eurasian lynx from Sarek, Northern Sweden (1997) and Finnmark (2007) (brown bear and Eurasian lynx were not analysed for PFCs).

PFCs were present in all species and were dominating the HOC pattern (based on wet weight concentrations). PFC levels ranged from 0.5-9.8 ng/g ww in herbivores, and 22-65 ng/g in carnivores. High levels of PCBs (>3000 ng/lipid weight (lw)) were found in red fox and were just below PCB levels reported to influence the immune system in polar bears. BDE-209 was found in most species, in levels of <MLOD-1180 ng/g lw in herbivores, and <MLOD -187 ng/g lw in carnivores.

Surprisingly high BDE-209 levels were found in some of the reindeer samples (Figure 3). The finding of this highly particle bound compound in species at low trophic level supports the theory that intake of BDE-209 in herbivores is mainly caused by consumption of vegetation together with soil and dust which are contaminated by the deposition of BDE-209. On a global scale, current review data show that levels of BDE-209 in general are found more frequently and in higher levels in terrestrial than in aquatic and marine species http://publications.environment-agency.gov.uk/pdf/SCHO0909BQYZ-e-e.pdf.

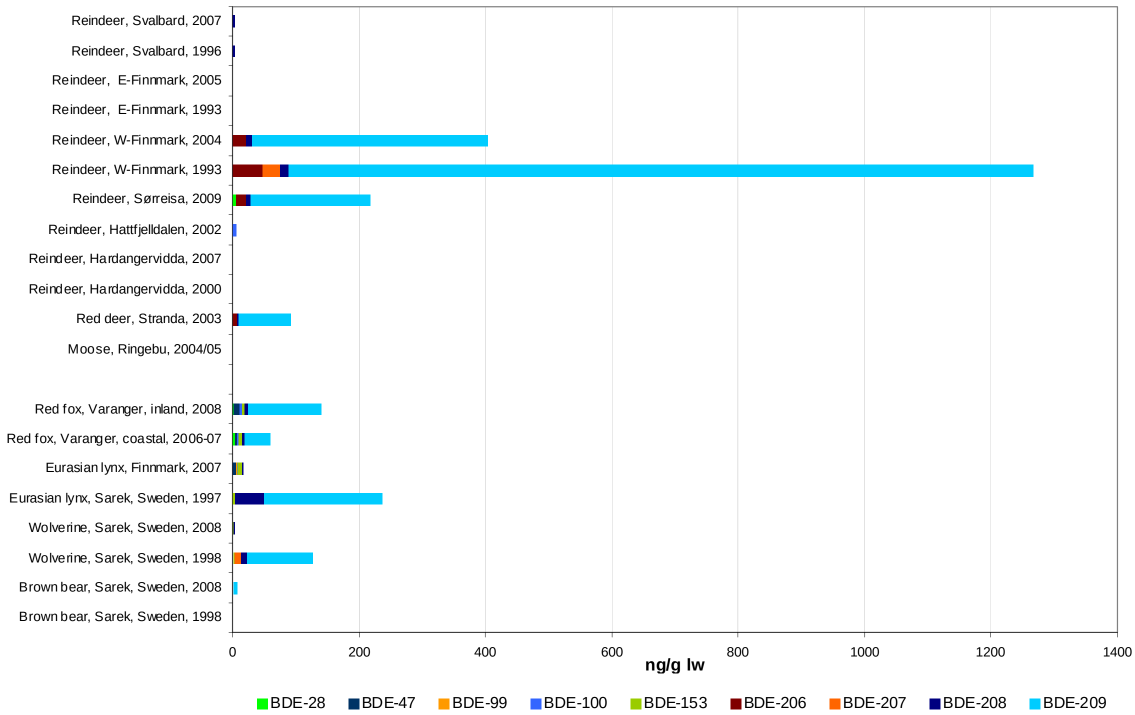

Figure 3. Levels of BDE-28, -47, -99, -100, -153, -206, -207, -208 and -209 (ng/g lw) in pooled plasma/serum samples of reindeer, read deer, moose, red fox, wolverine, brown bear and Eurasion lynx.

In red fox PCBs, CHLs and OH-PCBs were important contributors to the total of HOCs in contrast to PFC dominance in wolverine. In most species, the PCB patterns were dominated by PCB-153 and PCB-180. In brown bear however, PCB-118 contributed more to ∑7PCBs than in the other carnivores. The bear's different feeding strategy compared to the other carnivores might be an explanation for this. The PFC patterns differed between the species. In red fox, PFOS was the dominant compound. In wolverine, PFOS, PFPeA, and PFNA were the most abundant PFCs. In general, levels of PFCs in reindeer were higher than in red deer and moose. PFOA, PFNA, PFDA, and PFUdA were present in all samples of reindeer. Interestingly, in some samples of reindeer (e.g. Finnmark and Hardanger-vidda) the levels of PFPeA and PFNA are higher than levels of PFOS, which was also the pattern found in one of the samples from Svalbard.

Conclusions
The results together with indications of spatial and temporal trends clearly demonstrate long range transport of the studied HOCs and the potential risk for specific terrestrial species in the north. The measured PCB levels in the present red fox were just below PCB levels reported to influence the immune system in polar bears. The red fox might therefore be at threat concerning the immune system, but possibly also regarding reproduction and development.

Acknowledgements:
We would like to thank Ellen Dahl (NVH) for assistance with collection of the samples and Katharina B. Løken, Mahin Karimi, Siri Føreid and Vidar Berg (NVH) for performing the OC and BFR analyses and Kees Swart and Riet Vooijs for performing the PFC analyses at IVM. We acknowledge the project: "Fjellrev i Finnmark" at University of Tromsø for photos of red fox. Funding for this study was provided by the Climate and Pollution Agency (Klif).

References:

1. de March BGE, de Wit CA, Muir DCG, Braune BM, Gregor DJ, Norstrom RJ. (1998); *AMAP Assessment Report: Arctic Pollution Issues, Oslo, Norway*. AMAP: 183 pp.
2. Danielsson S, Odsjö T, Bignert A, Remberger M. (2008); *Report nr 7: Swedish Museum of Natural History, Department of Contamination Research, P.O. Box 50 007, SE-104 05 Stockholm, Sweden.*
3. Mariussen E, Steinnes E, Breivik K, Nygård T, Schlabach M, John Atle Kålås JA. (2008); *Sci Tot Environ*. 404: 162-70.
4. Suutari A, Ruokojärvi P, Hallikainen A, Laaksonen S. (2009); *Chemosphere*. 75: 617-22.
5. Kelly BC & Gobas FAPC. (2001); *Environ Sci technol*. 35: 325-34.
6. Polder A, Skaare JU, Tryland M, Ropstad E, Gabrielsen GW, Vikøren T, Arnemo JM, Mørk T, Killengreen S, Leonards P, Lie E. (2010). *SPFO-report 1064/2009; TA-2572/2009, Klif, Oslo, Norway*.