

Airborne organic pollutants in Finnish reindeer food chain

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1 Introduction

The importance of atmospheric transport and deposition as a pathway for organic pollutants to the northern environment has been shown by intensive research (Harner et al. 1998, Hung et al. 2001, Kallenborn et al. 2002, Shatalov & Malachinev, 2000, UNEP 2002). Polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) are released into the atmosphere mainly by industrial and combustion actions (Alcock & Jones, 1996; Breivik et al. 2002; Darnerud et al. 2001). They accumulate to biota via wet deposition, dry particulate and dry gaseous deposition (McLachlan & Hutzinger, 1990).

Exposure of Finnish semi-domesticated reindeer (*Rangifer tarandus tarandus*) to airborne organic pollutants can be supposed to occur primarily via lichen contaminated by atmospheric deposition. According to a lichen-barren-ground caribou (*Rangifer tarandus groenlandicus*) -food chain in Canada and a lichen –semi-domesticated reindeer -food chain examined in Sweden, atmospheric transport of persistent substances has been ascertained to be prominent for caribou/reindeer food chain (Kelly & Gobas, 2001; Villeneuve et al. 1985). Lichens absorb water and dissolved elements across their surface and nutrients and pollutants accumulate primarily from the atmosphere (Salemaa et al. 2004). Lichens have been observed to absorb more PCDD/Fs than e.g. pine (*Pinus sylvestris*) needles and other vegetation (Augusto et al. 2007).

2 Objectives of the research

This ongoing study explores the concentrations and transfer of PCDD/Fs, PCBs and PBDEs from deposition to terrestrial food chain of Finnish semi-domesticated reindeer localized in the sub-arctic northern Finland. The results are expected to increase the understanding of the complex environmental behaviour of persistent contaminants in reindeer food chain transported via atmospheric and horizontal route through pasture.

3 Results

3.1 Deposition samples

Concentrations in the bulk deposition samples varied considerably between the sampling periods; PCDD/Fs ranged from 0.00 to 8.59 pg l⁻¹, PCBs from 0.03 to 4.57 ng l⁻¹ and PBDEs from 0.12 to 0.64 ng l⁻¹. PCBs and PBDEs showed good correlations (r=0.7-0.8) with precipitation in wintertime, that supports the pre-

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sumption of effective scavenging of these compounds from air by snow crystals. PCDD/F/PCB –ratio to total TEQ varied monthly. The highest observed WHO-PCDD/F-PCB-TEQ concentration 0.22 pg l^{-1} in October 2007 signified also the biggest PCDD/F contribution (69%). PBDE levels were on average higher than PCB levels in rain water samples, while the PCB concentration in snow sample was clearly higher than PBDEs.

3.2 Lichen samples

Compounds were observed to bioaccumulated from deposition to lichen at varying rates. A sum of PCBs was two to three orders of magnitude higher than a sum of PCDD/Fs but, on average, 70% lesser than PBDEs. As WHO-TEQs the proportion of PCDD/Fs to total TEQ was over 80%, and the correlation between the PCDD/Fs and dry matter content of lichen was quite strong ($r=0.7$). With PCBs, the most non-volatile and toxic non-ortho compounds seemed to remain effectively in lichens. The highest PCDD/F and PCB levels (as sums and WHO-TEQs) can be seen in arboreal *Usnea* sample from the middle Lapland. The structure of *Usnea* is hyphae, which increases its surface area enhancing the uptake of airborne pollutants. However, PBDE concentrations in *Usnea* were quite low (0.14 ng g^{-1}) compared to lichen samples from the other areas (level of 3.39 ng g^{-1} was reached).

Table 1 PCDD/Fs, PCBs and PBDEs in the lichen samples from different locations. No=Northern Lapland, Mi=Middle Lapland, So= Southern Lapland.

	PCDD/F $\text{pg g}^{-1} \text{ ww}$	PCB $\text{ng g}^{-1} \text{ ww}$	PBDE $\text{ng g}^{-1} \text{ ww}$
No <i>Cladonia</i>	3.28	0.26	0.19
No <i>B. fuscescens</i>	6.55	0.46	0.74
Mi <i>Cladonia</i>	8.32	0.58	2.92
Mi <i>B. fuscescens</i>	6.99	0.28	0.07
Mi <i>Usnea</i>	18.8	1.57	0.14
So <i>Cladonia</i>	6.79	0.73	3.39

3.3 Transfer of organic pollutants to reindeer food chain

Bioaccumulation measurement through the deposition to reindeer food chain showed compounds were concentrated from one to three orders of magnitude in reindeer milk, while examination of deposition-reindeer tissues resulted three to five orders of magnitude higher levels in reindeer. Reindeer muscle was seen to be concentrated by PCBs and PBDEs, while there was an indication of PCDD/F accumulation in livers. According to previous studies there are regional differences between the contaminant concentrations in reindeer; the most contaminated individuals are found in the middle Lapland where reindeer browse in natural pastures (Suutari et al. 2009).

4 Relevance of the research

The research gives valuable information of PCDD/F, PCB and PBDE concentrations in northern environment and food chain. It offers material that can be utilized by risk assessment purposes. The results would be applied by authorities in decision making concerning emission control policy and scientific research in many fields including environmental sciences and technical improvements in emission prevention actions.

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