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Spatial patterns of polybrominated diphenyl ethers (PBDEs) in mosses, herbivores and a carnivore from the Norwegian terrestrial biota

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ABSTRACT

The widespread occurrence of polybrominated diphenyl ethers (PBDEs) in the environment has attracted considerable attention, leading to concerns about the extent and magnitude of wildlife and human exposure. In this work, we focus on the occurrence and fate of PBDEs in a Norwegian air–plant–herbivore–carnivore system. Specifically, we have analysed for PBDEs in moss, livers from various terrestrial herbivores (moose, grouse, and European roe deer) and, for the first time, livers from the top predator lynx. The samples were collected from different sites and time periods (1990–2004) to identify possible spatial and temporal trends in contaminant levels and patterns. The general finding was that PBDEs were found in all (biotic) samples, although at lower concentrations than previously observed in mammals from the marine environment. The PBDE levels in the herbivores ranged from less than 0.5 ng/g lipid weight to 9.4 ng/g lipid weight as the highest. The median PBDE concentration in lynx was approximately one order of magnitude higher than in the herbivores. In the lynx samples there was a predominance of BDE-153 whereas BDE-47 and 99 dominated in the herbivores.

This probably reflects different bioaccumulation properties or metabolic transformation processes of the BDE-congeners, and food choice. Levels of PBDEs in both moss and herbivores showed a general decline towards the northern parts of Norway. No clear temporal trends were observed. The PBDE levels observed in this study were low and are probably of limited toxicological significance.

1. Introduction

The use of fire-preventive additives in various consumer products has been increasing over the last decades, and various brominated organic compounds have proved to be well suited for this purpose. One subgroup of special concern is the polybrominated diphenyl ethers (PBDEs), which constitutes approximately one third of the production of brominated flame retardants (BFRs) (de Wit, 2002). The PBDEs are used as additive flame retardants and are divided into three main groups, the penta-, octa-, and decaBDEs, of which the decaBDE mixture is used in highest quantities (de Wit, 2002). The extensive use of

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PBDEs has been followed by a significant release of these components to the environment (e.g. Prevedouros et al., 2004) and research has revealed that several PBDEs have potential for bioaccumulation and are ubiquitous in the environment (de Wit, 2002; Law et al., 2003, 2006). Especially PBDEs with less than eight bromines exhibit a high potential for accumulation (Gustafsson et al., 1999; Stapleton and Baker, 2003). Less is known about environmental fate of the fully brominated BDE-209. This compound is, however, of special interest due to its widespread use and because it may be degraded to more bioavailable compounds, such as less brominated PBDEs and hydroxylated PBDEs (Sandholm et al., 2003; Eriksson et al., 2004).

The fact that PBDEs can accumulate in living organisms has raised concerns about their toxic potential. There is no clear evidence yet for PBDEs being a hazard for either humans or wildlife. However, some recent laboratory studies, including a few on BDE-209, have shown potential effects on the nervous system, immune system, and hormones (Darnerud, 2003; Mariussen and Fonnum, 2003; Viberg et al., 2003; Reistad and Mariussen, 2005; Stoker et al., 2004; Lilienthal et al., 2006). These are effects similar to what has been previously shown for PCBs and some other Persistent Organic Pollutants (POPs). The penta- and octa-BDE mixtures are now prohibited in the European Union due to their potential as environmental toxicants. In recent years, the main use of pentaBDE has thus been in the North-America (Birnbaum and Staskal, 2004). This may be the reason why PBDEs are found at an order of magnitude higher concentrations in mother's milk and blood samples collected from American citizens compared to Europeans (Schecter et al., 2003; Hites, 2004). Both the penta- and the octa-BDE mixtures are currently under consideration to be classified and included as POPs under the Stockholm convention (UNEP, 2001).

Relatively little information is available concerning PBDEs in terrestrial wildlife, both with regards to levels in the environment and bioaccumulation patterns in food webs. Terrestrial animals are generally shown to accumulate less POPs than aquatic animals (Law et al., 2003, 2006) and have, therefore, been less studied with respect to their pollution status. However, data on PBDEs from the terrestrial environment and wildlife may provide additional information regarding contaminant levels, patterns, and trends and thus give further insight into their environmental transport, deposition patterns, and fate

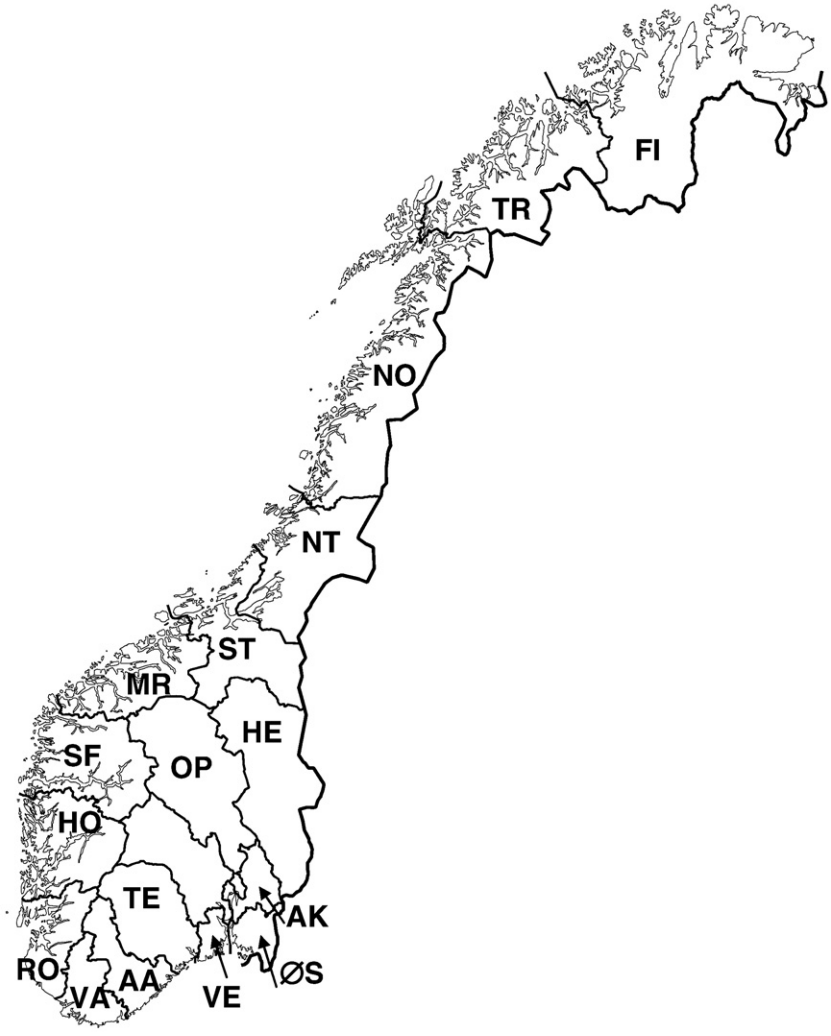

Fig. 1 – Map of Norway including the counties from which the samples were collected: Aust-Agder (AA), Akershus (AK), Finnmark (FI) Hedmark (HE), Hordaland (HO), Møre og Romsdal (MR), Nordland (NO), Nord-Trøndelag (NT), Oppland (OP), Rogaland (RO), Sogn og Fjordane (SF), Sør-Trøndelag (ST), Telemark (TE), Troms (TR), Vest-Agder (VA), Vestfold (VF), Østfold (ØS).