

Spatial and temporal trends of BFRs in Atlantic cod and Polar cod in the North-East Atlantic.

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Introduction

Brominated Flame Retardants (BFRs) such as polybrominated diphenylethers (PBDEs) and hexabromocyclododecane (HBCD) are added to materials (e.g., textiles and electronic materials) to reduce flammability¹. BFRs are lipophilic and resistant against degradation causing them to biomagnify in the marine food chain. Thus, due to industrial activities and surface run-off from applications and dumping sites, sediments and aquatic organism in rivers, estuaries and coastal waters close to rural areas may be particularly contaminated by these chemicals¹. Furthermore, because of their semi-volatile properties BFRs may also bioaccumulate in humans and wildlife at more remote locations such as the Arctic². Their different degrees of bromination determine their actual environmental behaviour and fate. The higher brominated compounds tend to accumulate near the source whereas the lower brominated, which are more volatile, tend to end up in more remote areas such as the Arctic region³.

The aim of the present study was to measure BFR concentrations in cod (i.e., Atlantic cod [*Gadus morhua*] and polar cod [*Boreogadus saida*]) at different locations in Norwegian waters, ranging from the estuary of the largest river in Norway, Glomma, to the pristine Arctic waters of Svalbard. Glomma has its outlet near Hvaler, outer Oslofjord, and is draining water from some of the largest rivers and lakes of the more industrialised areas of Norway. An example is its connection to Mjøsa, the largest lake in Norway, where very high levels of BFRs have been reported⁴. Concentrations of BFRs in Atlantic cod sampled at Hvaler (58°59'N, 10°47'E) were therefore compared to concentrations in Atlantic cod sampled at Froan, (64°10'N, 09°20'E) situated in the more open waters of the Norwegian Sea off coast of Mid-Norway and polar cod from Bear Island, Svalbard (73°4' N, 18°3'E). A second aim was to study temporal changes in concentrations of BFRs in Atlantic cod from Hvaler in the period 1998-2003.

Material and methods

Atlantic cod were collected at Hvaler and Froan in June 2003 using fishing rods. Benthic trawl was used to collect Atlantic cod at Hvaler in April 1998⁵ and Polar cod at Bear Island in September 2003. The lipid content found in Atlantic cod sampled at Hvaler in 1998 ranged from 5-20 %, at Hvaler and Froan in 2003 the lipid content in Atlantic cod ranged from 8-48%, whereas the lipid content in Polar cod from Bear Island ranged from 5-25 %. The weight and length of Atlantic cod ranged from 220-991 g and 28-48 cm, respectively, whereas the weight and length of Polar cod ranged from 153-373 g and 27-36 cm, respectively. Both female and male Atlantic cod were collected at Hvaler in 1998, while only female Atlantic cod were collected at Hvaler and Froan in 2003. The sex of the Polar cod from Bear Island 2003 was unknown.

The chemical analyses were performed at the Laboratory for Environmental Toxicology, Norwegian School of Veterinary Science, Oslo, Norway. The procedure included blank samples to test for interference. Reproducibility was continuously tested by analysing the BFR levels in the laboratory's own reference sample (seal blubber). The laboratory is accredited for these analyses according to the requirements of NS-EN ISO/IEC 17025. Liver samples were used because the lipids, and thus the BFRs, are concentrated in the liver of cod. The samples were homogenized and the BFRs were quantified using GC/MS⁶. The following congeners were included in the analyses: BDE-28, -47, -100, -154 and HBCD. Detection limits were set as 3 times the noise. Concentrations of BFRs are expressed both on a wet weight (ng g⁻¹ ww) and on a lipid weight (ng g⁻¹ lw) basis. Distributions deviated significantly from normality, thus the Kruskal-Wallis test was applied to test spatial differences in BFR concentrations (2003 samples). Mann-Whitney test was used to test differences in concentrations between the individual sites, and between the 1998 and 2003 samples from Hvaler. A significance level of $\alpha=0.05$ was chosen.

Results and discussion

Spatial trends of BFRs:

All BFRs were found in highest concentrations in the cod from Hvaler, followed by cod from Froan and Bear Island (Table 1, Fig 1). These differences were particularly apparent when the data were expressed on a ww basis (Table 1, Fig 1). The degree of difference varied among the BFRs, being between 1 and 2 orders of magnitude higher at Hvaler as compared to Bear Island for BDE-28, -47, -100 and -154. The difference in HBCD was relatively modest among the three different study sites (Table 1, Fig 1). The concentrations of PBDEs in Atlantic cod from Hvaler 2003 (present study) showed considerably lower concentrations of all BFR compounds except HBCD, as compared to concentrations in Atlantic cod from the southern parts of the North Sea⁷. This may indicate that the Glomma River may have a limited effect on the PBDE concentrations in Atlantic cod at Hvaler. The present study clearly document that the Atlantic cod from the southern parts of the North Sea are more contaminated by PBDE⁷.

BROMINATED COMPOUNDS: BIOTIC LEVELS, TRENDS, EFFECTS

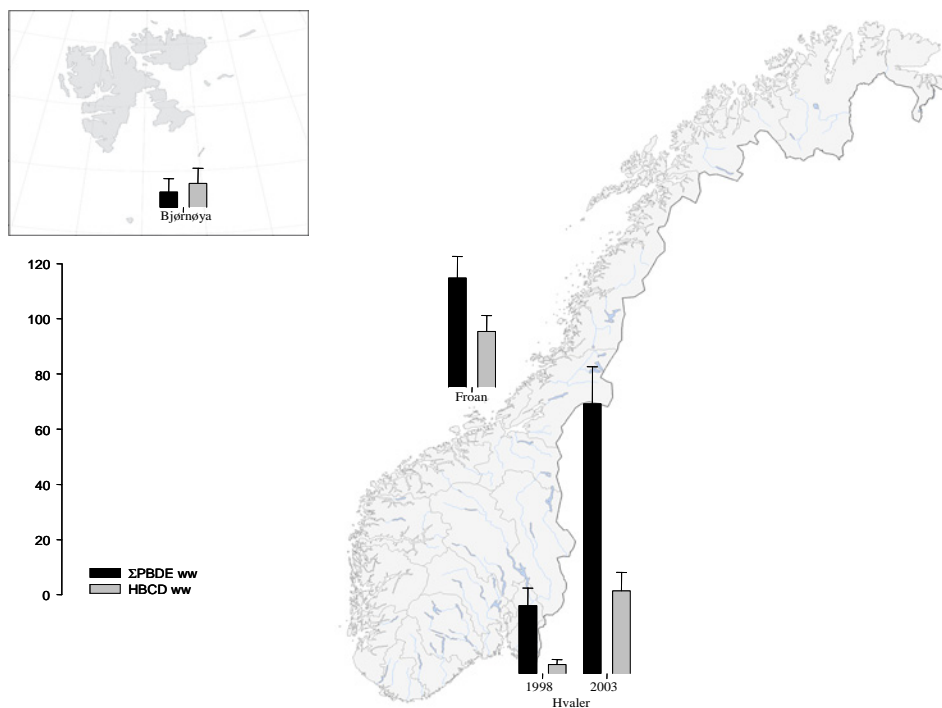


Figure 1. Mean (\pm 95% CI) concentrations of Brominated Flame Retardants in Atlantic cod (*Gadus morhua*) from Hvaler, outer Oslofjord and Froan, Norwegian sea, and in Polar cod (*Boreogadus saida*) from Bear Island, Barents Sea.

BROMINATED COMPOUNDS: BIOTIC LEVELS, TRENDS, EFFECTS

Table 1. Spatial trends of BFRs in Atlantic cod (*Gadus morhua*) from Hvaler and Froan, and Polar cod (*Boreogadus saida*) from Bear Island.

		Hvaler 2003		Froan 2003		Bjørnøya 2003	
		ng g ⁻¹ lw	ng g ⁻¹ ww	ng g ⁻¹ lw	ng g ⁻¹ ww	ng g ⁻¹ lw	ng g ⁻¹ ww
BDE-28	Mean (median)	2.51 (2.46)	0.78 (0.73)	2.21 (1.58)	0.57 (0.59)	N.D.	N.D.
	Min-max	1.01-4.91	0.34-1.20	0.98-4.95	0.28-1.06	N.D-0.74	N.D-0.18
	N	17 B	17 AB	16 C	16 AC	4 BC	4 BC
BDE-47	Mean (median)	73.6 (79.7)	22.7 (25.6)	37.7 (26.9)	9.19 (9.98)	9.9 (9.96)	1.56 (1.51)
	Min-max	28.4-126.9	11.80-30.2	12.0-81.9	4.75-14.6	9.07-10.6	0.63-2.57
	N	17 AB	17 AB	16 AC	16 AC	6 BC	6 BC
BDE-100	Mean (median)	14.1 (15.1)	4.36 (5.02)	5.23 (4.67)	1.27 (1.28)	1.90 (1.92)	0.29 (0.28)
	Min-max	5.23-24.7	2.17-5.84	1.48-12.0	0.62-2.00	1.76-2.0	0.14-0.44
	N	17 AB	17 AB	16 AC	16 AC	6 BC	6 BC
BDE-154	Mean (median)	2.31 (2.29)	0.71 (0.7)	N.D.	N.D.	N.D.	N.D.
	Min-max	1.01-5.07	0.42-1.16	N.D-5.51	N.D-1.26	N.D-0.68	N.D-0.14
	N	17 B	17 AB	15 C	15 AC	5 BC	5 BC
HBCD	Mean (median)	N.D.	N.D.	N.D.	N.D.	14.7 (13.8)	2.39 (1.99)
	Min-max	N.D-56.9	N.D-16.9	N.D-51.2	N.D-13.3	7.67-23.4	0.53-5.66
	N	16 AB	16 A	14 A	14 AC	6 B	6 BC

A; Statistically significant difference between Hvaler and Froan (Mann-Withney, lw.p ≤ 0.001, ww.p ≤ 0.034).

B; Statistically significant difference between Hvaler and Bjørnøya (Mann-Withney, lw.p ≤ 0.008, ww.p ≤ 0.003).

C; Statistically significant difference between Froan and Bjørnøya (Mann-Withney, lw.p ≤ 0.005, ww.p ≤ 0.004).

Temporal trends of BFRs in Atlantic cod at Hvaler from 1998 to 2003:

An increase of 3-4 times was seen in ww concentrations of all BDE congeners, when comparing Atlantic cod from Hvaler in 1998 and 2003. The concentration of HBCD was about 8 times higher in 2003 as compared to 1998 (Table 2). When expressed on a lw basis, the increase was more modest, with levels 1.5 times higher for all BDEs, whereas HBCD showed an increase of 3-4 times.

Table 2. Temporal trends of BFRs in Atlantic cod (*Gadus morhua*) at Hvaler in 1998 and 2003.

		Hvaler 1998		Hvaler 2003	
		ng g ⁻¹ lw	ng g ⁻¹ ww	ng g ⁻¹ lw	ng g ⁻¹ ww
BDE-28	Mean (median)	1.91 (1.5)	0.22 (0.2)	2.51 (2.46)	0.78 (0.73)
	Min-max	1.05-3.37	0.10-0.48	1.01-4.91	0.34-1.20
	N	14	14A	17	17A
BDE-47	Mean (median)	49.6 (45.0)	5.73 (6.07)	73.6 (79.7)	22.7 (25.6)
	Min-max	31.6-82.5	3.14-10.2	28.4-126.9	11.8-30.2
	N	14	14 A	17	17 A
BDE-100	Mean (median)	9.37 (7.69)	1.07 (0.97)	14.1 (15.1)	4.36 (5.02)
	Min-max	5.04-16.2	0.54-1.68	5.23-24.7	2.17-5.84
	N	14	14 A	17	17 A
BDE-154	Mean (median)	1.71 (1.7)	0.20 (0.17)	2.31 (2.29)	0.71 (0.7)
	min-max	0.82-2.81	0.09-0.38	1.01-5.07	0.42-1.16
	N	14	14 A	17	17 A
HBCD	(median)	N.D.	N.D.	N.D.	N.D.
	min-max	N.D-22.67	N.D-2.70	N.D-56.9	N.D-16.9
	n	11 A	11 A	16 A	16 A

A; Statistically significant difference (Mann-Withney, p < 0.0001).

This study indicates that, there has been an increase in concentrations of both PBDEs and especially HBCD, in the Hvaler, outer Oslo fjord area during the last five years. A geographical trend was found comparing the three localities, Hvaler, Froan and Bear Island, with decreasing concentrations from south to north. The most apparent increase was found from Hvaler and Froan compared to Bear Island. This study points out that the concentration of HBCD, in particular, has been increasing the last years, and that HBCD is now present in relatively high concentrations even in remote areas like Bear Island.

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