Effects of reduced PCDF/PCDD discharge from magnesium production on levels in marine organisms from the Frierfjord area, Southern Norway

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Introduction

A magnesium factory may have discharged as much as 50-100 kg 2,3,7,8-TCDD-equivalents (2,3,7,8-TE, Nordic model) to the Frierfjord in Southern Norway during the past 35 years. It is assumed that the annual emissions were about one magnitude higher before 1976 when coal was replaced by coke in the process[1]. For 1976-1989 the annual discharge was estimated at about 300-500 g 2,3,7,8-TE[2]. From 1990 the process water was treated with activated charcoal reducing the annual release to about 12 g 2,3,7,8-TE in 1990 and below 10g in 1991-1992. Increased levels of PCDF/PCDD could be found in crabs as far as 50 km downstream from the source[3]. Restrictions in commercial fishing and recommendations concerning limited fish consumption have been established for the contaminated area. Concentrations of individual PCDF/PCDD congeners were determined in various species of fish, mussels and crabs in the period 1987-1992 and in some historical samples. The following presentation is focused on:

- Levels in organisms after the 95-98% reduction of the emissions.
- Variations in the accumulation patterns in species with different habitats and routes of exposure

Experimental

Fish, mussels and crustaceans were collected from a network of sampling stations or selected locations during 1987-1992. Some of them are shown in Figure 1. 2 cod liver samples from 1975 and 1976 were obtained from the Norwegian College of Veterinary Medicine (courtesy, the late G. Norheim). Pooled samples of 10-20 specimen of fish or crab, or 50 mussels were analysed as described earlier[4]. Quantification was carried out by high resolution mass spectrometry after 1990. The method fulfilled the acceptance criteria of the 3rd WHO intercalibration.

Table 1. 2,3,7,8-TE (Nordic model[5]) in cod liver (*Gadus morhua*), fillet of flounder (*Platichthys flesus*), eel (*Anguillla anguilla*), trout (*Salmo trutta*) and mackerel (*Scomber scombrus*), crab hepatopancreas (*Cancer pagurus*), peeled shrimps (*Pandalus borealis*) and common mussels (*Mytilus edulis*) from the Frierfjord/-Breviksfjord. 2,3,7,8-TE in pg/g wet weight

Species/ location	Year	2,3,7,8-TE [pg/g]	Contribution to 2378-TE in [%]						
			2378 TCDF	23478 PeCDF	123678 HxCDF	Σ HxCDF	Σ PCDF	2378 TCDD	12378 PeCDD
Cod liver	1975	37870	9	47	16	34	93	2	3
Frierfjord	1976	6820	8	49	16	35	94	2	2
	1987*	5643	3	12	43	70	86	9	4
	1991	1090	8	20	15	48	78	18	2
	1992	935	6	20	21	49	78	15	3
Breviksfj.	1988	1316	4	18	45	50	71	16	3
	1991	287	5	14	19	50	71	22	2
	1992	439	8	14	25	47	76	19	3
Flounder	1987	63,2	11	60	2	14	87	2	9
Frierfjord	1990	17,3	13	46	5	14	75	16	8
	1991	15,9	12	50	7	21	83	9	7
	1992	17,4	13	46	7	19	79	11	8
Eel	1990	52,3	<0,5	17	9	38	58	8	22
Frierfjord	1991	56,6	<0,5	14	9	41	58	4	27
	1992	44,1	<0,5	19	10	39	60	5	23
Trout	1990	83,2	2	50	4	10	63	26	10
Frierfjord	1991	20,6	4	58	4	8	71	19	9
	1992	15,0	3	61	3	9	73	15	10
Mackerel	1990	24,7	22	48	2	4	77	14	8
Breviksfj.	1991	8,5	32	43	1	3	79	14	7
	1992	5,3	26	45	1	3	75	16	9
Herring	1990	27,5	2	55	9	19	77	10	11
Breviksfj.	1991	11,3	4	62	5	12	79	8	12
	1992	13,2	7	59	5	10	76	11	11
Crab	1988	2451	9	32	19	36	80	5	10
Frierfjord	1990	2078	6	30	12	43	83	4	9
	1991	908	11	35	9	32	81	5	10
	1992	1620	10	31	9	40	86	3	7
Breviksfj.	1990	2405	9	31	11	39	82	3	10
	1991	1644	9	39	8	34	84	3	10
	1992	750	10	39	6	31	83	3	11
Shrimps	1988	20,0	18	30	22	31	84	n.d.	12
Breviksfj.	1990	13,9	19	30	6	15	68	8	18
	1991	11,5	22	23	6	17	65	8	18
	1992	9,0	30	24	5	10	66	10	19
Mussels	1989	203	12	33	12	31	82	5	7
Breviksfj.	1990	9,3	20	31	8	24	81	6	7
	1991	11,2	16	33	9	27	83	6	8
	1992	13,2	31	29	6	18	84	7	6
Klokker-	1989	47,9	18	34	10	26	84	4	6
tangen	1990	12,3	23	32	5	15	74	14	8
	1991	3,6	28	28	5	16	76	13	7

Results and discussion

The PCDF/PCDD concentrations expressed as 2,3,7,8-TE and the percentage contribution of selected single congeners are given in Table 1. The emission reduction of about one order of magnitude between 1975/1976 and 1987 caused a corresponding decrease in cod liver. A further decrease of >95% in summer 1990 is fully reflected merely in mussels but has not led to a comparative reduction of the levels in fish. In most fishes the reduction so far has been limited to about 70-80%. However, no trend is seen in eel which appears to have particular accumulation characteristics with comparatively low concentrations on fat weight basis. Reduction in crabs and shrimps have been in the order of 40-60%. Furthermore, the lack of any significant decrease from 1991 to 1992 is of particular concern for local fisheries.

The concentrations found in mackerel and herring indicate that wandering species are still markedly contaminated even after the last strong emission reduction. It seems that exposure via food maintain the high levels of PCDF/PCDD. Shrimps and other vertically wandering crustaceans feeding on contaminated bottom probably have a key role in this food chain accumulation.

As in the discharged water and in sediments[1,4], PCDF isomers contribute most to the 2,3,7,8-TE levels (Table 1) in all species with some reservation for eel. In general, the relative contribution from 2,3,7,8-chlorine substituted HxCDF is reduced compared to waste water (>60%) and sediments. In detail, however, there are considerable differences in the isomer accumulation patterns. The importance of these HxCDF is relatively well conserved in cod, eel and crabs, whereas it is significantly lower in trout, mackerel and herring. Furthermore, large differences can be seen between the various species concerning the relative contribution of 2,3,7,8-TCDF, 2,3,4,7,8-PeCDF and 1,2,3,7,8-PeCDD to the 2,3,7,8-TE levels. Species dependent differences of single isomer accumulation have also been observed by de Wit et al.[6].

Conclusions

The rapid but not proportionate decrease in fish and crustaceans after the >95% reduction of the PCDF/PCDD emissions to the Frierfjord seems to have levelled out after 1991. The levels found in 1992 still exceed those from non polluted remote areas by a factor of 10-50. The reasons might be food chain accumulation via contaminated bottom fauna and/or residual and diffuse discharges (leakage from shallow water sediments/run-off from local catchment areas).

References

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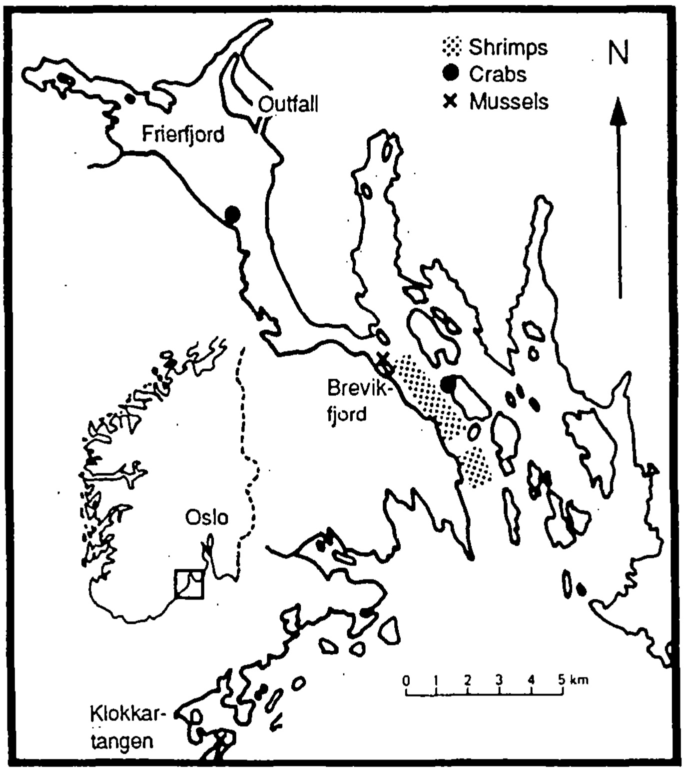

Figure 1. Investigated areas and sampling sites for marine organisms