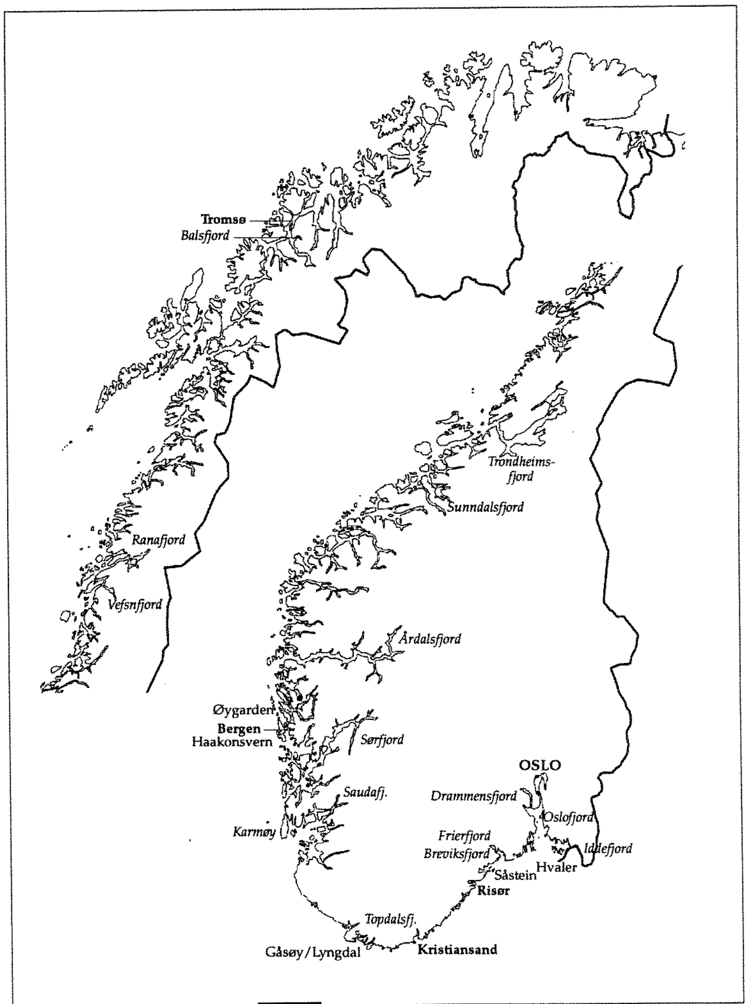
Statlig program for forurensningsovervåking

Report 618/95

Client State Pollution Control Authority

Contractor NIVA

Summary report on **levels of polychlorinated dibenzofurans/dibenzo-p-dioxins and non-ortho polychlorinated biphenyls** in marine organisms and sediments in Norway



TA -1242/1995

NIVA Norwegian Institute for Water Research

NIVA - REPORT

Norwegian Institute for Water Research NIVA

Report No.:	Sub-No.:
O-95161	
Serial No.:	Limited distrib.:
3317	

Main Office	Regional Office, Sørlandet	Regional Office, Østlandet	Regional Office, Vestlandet	Akvaplan-NIVA A/S
P.O. Box 173, Kjelsås	Televeien 1	Rute 866	Thormøhlensgt 55	Søndre Tollbugate 3
N-0411 Oslo	N-4890 Grimstad	N-2312 Ottestad	N-5008 Bergen	N-9000 Tromsø
Norway	Norway	Norway	Norway	Norway
Phone (47) 22 18 51 00	Phone (47) 37 04 30 33	Phone (47) 62 57 64 00	Phone (47) 55 32 56 40	Phone (47) 77 68 52 80
Telefax (47) 22 18 52 00	Telefax (47) 37 04 45 13	Telefax (47) 62 57 66 53	Telefax (47) 55 32 88 33	Telefax (47) 77 68 05 09

Report Title:	Date: / Printed:
Summary report on levels of polychlorinated dibenzofurans/dibenzo-p-dioxins and non-ortho polychlorinated biphenyls in marine organisms and sediments in Norway (Norwegian State Pollution Monitoring Programme, no. 618/95).	Sept., 1, 1995 NIVA 1995
	Topic group: Marine ecology
Author(s): Jon Knutzen	Geographical area: General
	Pages: 19 / Edition:

Client(s):	Client ref.:
State Pollution Control Authority (SFT)	

Abstract:

Selected data on polychlorinated dibenzofurans/dibenzo-p-dioxins ("dioxins") and non-ortho polychlorinated biphenyls in sediments and organisms from Norway and Norwegian Arctic are presented as sum TEQ (toxicity equivalents) from all 2,3,7,8-congeners of PCDF/PCDDs and PCBs 77,126,169 (also given on individual basis), The summary presentation is mainly aimed at management authorities, but is supplemented with references. Data from a couple of heavily dioxin contaminated areas indicate concentration gradients in space and time. Based on observations from reference localities tentative conclusions are drawn as to "high diffuse background levels" of dioxin - TEQ in sediments and selected seafood species from the Skagerrak/North Sea. Data are too few to do the same for planar PCBs.

4 keywords, Norwegian

1. Dioksiner
2. Non-orto PCB
3. Organismer
4. Sedimenter

4 keywords, English

1. PCDF/PCDD
2. Non-ortho PCBs
3. Sediments
4. Organisms

Project manager

Jon Knutzen

For the Administration

Torgeir Bakke

ISBN82-577-2845-4

Norwegian Institute for Water Research

O-95161

SUMMARY REPORT ON LEVELS OF POLYCHLORINATED DIBENZOFURANS/DIBENZO-P-DIOXINS AND NON-ORTHO POLYCHLORINATED BIPHENYLS IN MARINE ORGANISMS AND SEDIMENTS IN NORWAY

Oslo,	September 1, 1995.
Project manager:	Jon Knutzen

Preface

The present report is financed by the Norwegian State Pollution Control Authority (SFT) for use within the framework of OSPARCOM (Oslo and Paris Commission) and the concerted efforts to protect the North Sea.

The data covers the period 1987 - 1994, with emphasis on the most recent figures if several are available from the same localities. Through the years many persons have contributed to produce the results. In particular thanks are due to Aase Biseth, Michael Oehme and Martin Schlabach from the Norwegian Institute for Air Research (NILU) and Georg Becher from the National Institute of Public Health, who have been responsible for the analytical work.

Most of the data appear in reports within the State Pollution Monitoring Programme of Norway, sponsored by SFT. Some unpublished results are from NIVA/NILU research projects.

Oslo, September 1, 1995

Jon Knutzen

CONTENTS PAGE

1. INTRODUCTION

The present compilation is a brief account of a large volume of data. Possibly, the worlds largest point source of PCDF/PCDDs has been the magnesium factory of Norsk Hydro, situated at Frierfjorden in southern Norway (figure). During the period 1976 - 1989 yearly outlet to this land-locked fjord was of the order 500 g TEQ, from 1990 reduced 95 - 98% and now amounting to 2 - 5 g per year. In a period before 1976 the annual discharge was perhaps several kilos. Presence of PCDF/PCDD in the waste water was suspected in the early 80s, but lack of advanced analytical instrumentation delayed disclosure of the serious contamination of fish and shellfish in the fjord area. (Nevertheless, restrictions on seafood consumption had already been imposed due to massive contamination with hexachlorobenzene and octachlorostyrene in the magnesium factory effluent (Baumann Ofstad et al., 1978)).

The first dioxin analysis of Norwegian marine samples with advanced technique was performed by Prof. C. Rappe and P.-A. Bergquist on 1982 - 1984 fish from the Kristiansandsfjord (figure 1), which receives waste from a smaller point source (Knutzen & Martinsen, 1986).

After baseline studies in 1987 - 1988 (Oehme et al., 1989; Knutzen & Oehme, 1989) the two above mentioned fjord areas have been regularly monitored, in particular the heavily contaminated Frierfjord and neighbouring fjords and coastal areas ("Grenland fjords"). A small number of other (modest) point sources of PCDF/PCDDs have also been disclosed.

PCB contamination has been shown to be abundant in Norwegian harbour areas (Konieczny & Juliussen, 1995a, b). So far, however, data on non-ortho PCB are rather scarce, as recording of this group in the marine environment have started just recently (Johansen et al., 1993). Registration of heavy contamination with non-ortho PCB is limited to the vicinity of the naval base Haakonsvern on the west coast (figure 1: Knutzen & Biseth, 1994). Other studies may indicate serious PCB contamination of fish in the harbour area of Bergen (Skei et al., 1994).

The main purpose of the present report is to present a concise overview of the large amount of data resulting from measurement of the more than a dozen highly toxic PCDF/PCDD congeners. Consequently, information relating to PCDF/PCDD is limited to sum TEQ (toxicity equivalents). TEQ has been calculated according to TEFs (toxic equivalency factors) from Ahlborg (1989, PCDF/Ds, Nordic model) and Ahlborg et al. (1994, n.-o. PCB). (The Nordic model for $TEQ_{PCDF/PCDD}$ deviates only slightly from the international model, cf. Ahlborg et al., 1992).

The report is mainly aimed at authorities of water pollution control and water resources management. Those interested in the scientific aspects are referred to details and discussions in the quoted reports and publications.

The scientific basis for TEQ and the proposed TEFs for individual compounds is not discussed (see Ahlborg et al., 1992, 1994). It should be emphasized, however, that calculation of total TEQ also requires analysis of all mono-ortho and di-ortho PCBs contributing to dioxin like toxicity (cf. Ahlborg et al., 1994), besides planar polychlorinated naphtalenes (Hanberg et al., 1990). The latter group has recently been shown to contribute significantly to TEQ in Frierfjord cod (Schlabach et al., 1995). With regard to mono- and di-ortho PCBs it has been shown that in some cases TEQ from these substances may exceed sum TEQ from dioxins and non-ortho PCB (e.g. in herring 1993 from Norwegian reference localities, cf. table 3).

All the referred data are from analyses performed at the Norwegian Institute for Air Research (NILU) or the National Institute of Public Health. Both laboratories have participated in WHO intercalibration exercises and NILU is also accredited for dioxin analysis. For description of analytical methods it is referred to Oehme et al. (1995) and Johansen et al. (1993), respectively.

Even for the sum parameter TEQ presented PCDF/PCDD data are far from complete. When observations from several years are available, with a few exeptions only the most recent have been selected. These few cases serve to demonstrate concentration gradients in space or time or to support conclusions about "normal" levels. To illustrate gradients merely the extremes are presented, as an interval of the recorded concentrations. Emphasis has been on species and tissues most relevant for food control authorities or indicator purposes. Consequently, data for fish livers not normally consumed by humans have been excluded. The same applies to scattered data for saithe, pollock, whiting and haddock in areas where results from analysis of cod are available. The net accumulation properties of these species appear to be closely similar to cod. At heavily polluted sites different layers of sediment cores have been analyzed. The report only presents results most relevant for the situation today, i.e. data for the upper 0 - 2 cm.

Being the grams of facts to support tons of public opinion, baseline data on PCDF/PCDDs and other planar compounds still are too scarce to form a sound basis for judgement of the pollutional state of the marine environment in Norway. Lack of knowledge is particularly evident with regard to the total contribution to TEQ from PCBs.

Finally, except for mammals, data are reported on wet weight basis. Fat content is routinely analyzed, and concentrations on lipid basis are presented or may be calculated from raw data in the referred reports.

2. DATA AND COMMENTS

Results from analysis of sediments, marine mammals, fish and invertebrates are presented in the tables 1 - 4, in the given order. For each sample type (sediment, species/tissue) the results are given for localities along the coast, beginning with the most eastern or southern site and ending with localities to the west or north. The most important geographical names used are found in figure 1.

To evaluate the degree of contamination it is practical to have data from reference sites, i.e. localities merely receiving a diffuse background loading (outside the traceable influence of point sources). Due to the expensive analysis of dioxins and non-ortho PCBs such data are sparse. With this general reservation the below tentative "high diffuse background levels" in the Skagerrak/North Sea region are indicated from the PCDF/PCDD data listed for surface sediments and indicator species of fish, crabs and mussels (ng TEQ/kg d.w. in sediments, ng TEQ/kg w.w. in organisms, cf. table 1 for sediments and tables 3/4 for fish/shellfish):

Sediments:	5 - 10
Cod liver:	10 - 20
Cod fillet:	0.1
Flounder fillet:	0.1 - 0.2
Herring fillet:	1 - 2
Mackerel fillet:	≈ 1
Edible crab, hepatopancreas:	10 - 20
Common mussel:	0.1 - 0.2

It may be added that background data for sediments rather should be given with organic matter as basis. In organisms wet weight basis is required by food control authorities, for ecotoxicology normalization to lipid content is more suitable for some purposes. However, accurate analysis of low fat tissue is difficult, and the relation between accumulation of persistent organochlorines and fat content is far from fully understood (sometimes order of magnitude variations, question of different lipid fractions).

A newly started project on TEQ in seafood organisms from mostly reference localities, organized by the Norwegian Food Control Authority (SNT), will give baseline information for further species.

The amount of data for non-ortho PCBs are far from sufficient to indicate even tentative "high diffuse background levels". The results from Oehme et al. (1993) indicate, however, that in surface sediments sum TEQ from these compounds are about the same as sum TEQ from dioxins.

It appears that observations of levels in marine mammals are particularly scarce (table 2), in spite of the fact that these species, together with fish eating and raptorial birds, are most exposed to accumulating micropollutants. Hopefully, registrations within the Arctic Monitoring and Assessment Programme (AMAP) will improve this situation. Possibly, the need for data are even greater as regards more southern species like mink and otter (and birds). From Swedish results birds appear to be more at risk with regard to biomagnification than mammals (de Wit et al., 1994).

From table 1 it is seen that extremely high levels of PCDF/PCDDs in sediments have been found in Frierfjorden (and its small inlet Gunnekleivfjorden) outside the above mentioned magnesium factory. The extreme values exceed tentative "background levels" with factors of about 2000 and 5000, respectively. Even at the open coast of Telemark, some 20 km from the waste outfall the "background" was exceeded 5 - 100 times. The considerable contamination (in a smaller area) of the Kristiansandsfjord is also evident.

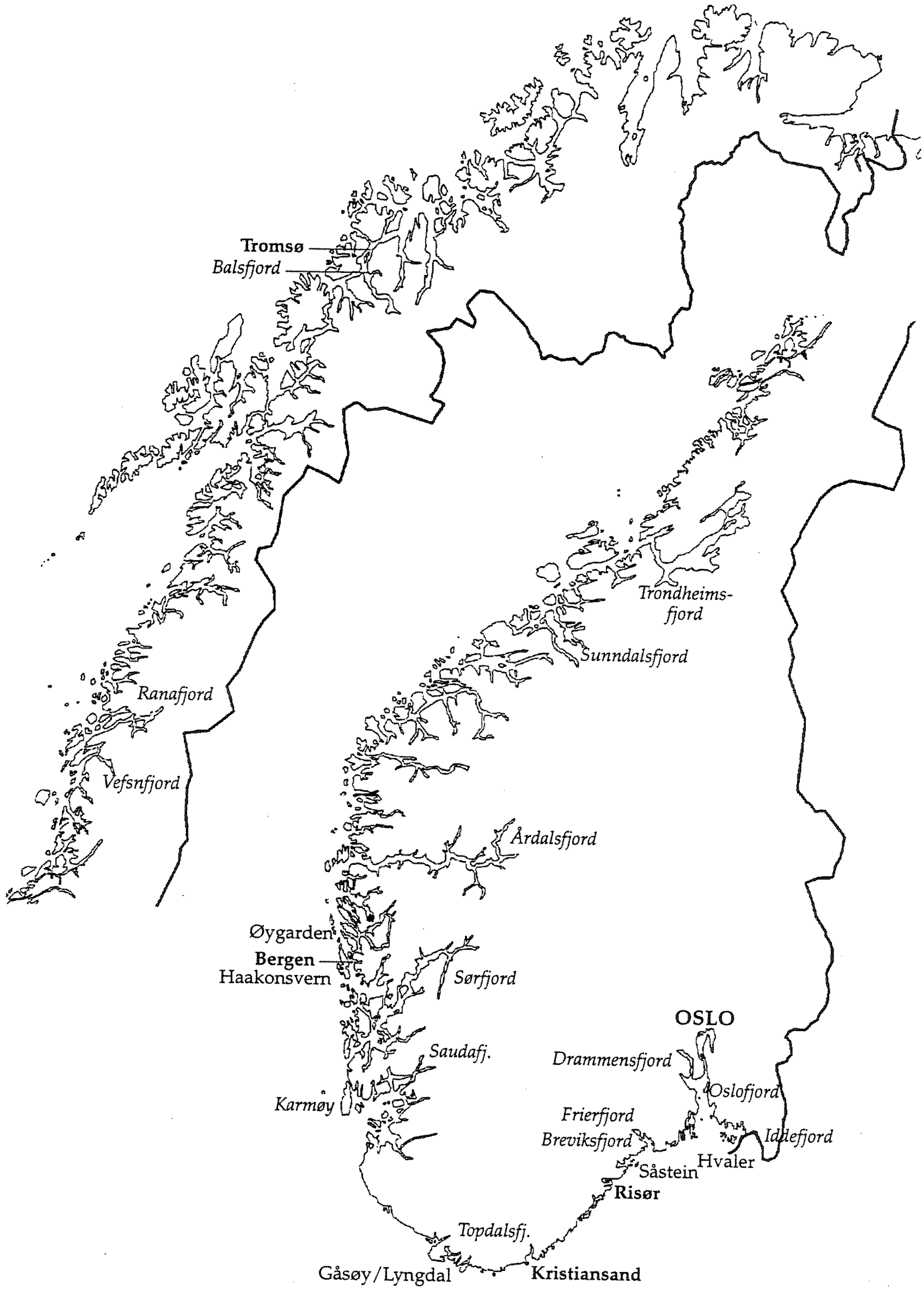


Figure 1. Most important localities and fjord areas mentioned in the tables.

Table 1. PCDF/PCDD and non-ortho PCB in marine surface sediments (0 - 2 cm) in Norway, ng TEQ/kg d.w. TEF according to Ahlborg (1989, PCDF/D, Nordic model) and Ahlborg et al. (1994, n.-o. PCB).

Localities/year	PCDF/D	Non-ortho PCB 77	126	169	Σ TEQ [1])	References
Iddefj., 1992	7-19	-	-	-	-	Berge and Helland, 1993
Håøya, Inner Oslofj., 1989	≈ 10	-	-	-	-	Berge og Knutzen, 1991
Gunnekleivfj., 1988	19600-60000	-	-	-	-	Næs, 1989
Frierfj., 1989	4150-18000	-	-	-	-	Næs and Oug, 1991
Outer Grenlandsfj., 1989	2500-4300	-	-	-	-	"
Open coast, Telemark. 1989	60-880	-	-	-	-	"
Inner Kristiansandsfj., 1988	1622	-	-	-	-	Knutzen et al., 1991
I.-O. Kristiansandsfj., 1994	9.4-2025	0.03- [2])	1.11- [2])	0.05- [2])	≈ 10.5- > 2000	NIVA/NILU, unpubl.
Topdalsfj., 1994	4.46	0.01	0.50	0.05	5.12	"
Haakonsvern, Hordaland, 1993	10-41	1.5-17	5.5-74	0.07-0.8	23-115	Knutzen and Biseth, 1994
Bergen harbour, 1993	26-36	-	-	-	-	Skei, et al., 1994
" " 1993	22.6/28.7	1.5/1.5	7.5/9.3	0.5/1.1	31.0/40.6	NIVA/NILU, un-publ.
Sørfj./Hardanger, 1991	4.2-8.9	-	-	-	-	Skei, 1992
Skagerrak/North Sea, 1990	0.74-12.3	Sum n.-o.: 0.82-17.3			1.56-29.6	Oehme et al., 1993
Barents Sea, 1991	0.31-1.06	Sum n.-o.: 0.15-0.71			0.46-1.56	"
Kongsfj., Spitzbergen, 1992	0.89	0.14	0.09	0.01	1.14	Skei, 1993

[1]) Sum of TEQ from PCDF/D and n.-o. PCB.
[2]) Masked in the sample from the inner fjord.

So far no high levels of non-ortho PCB have been recorded in sediments, but are to be expected in the above mentioned PCB contaminated harbour sediments (Konieczny & Juliussen, 1995a, b) and also at the naval base Haakonsvern.

To comment upon the few data for PCDF/PCDDs in mammals (table 2) would require comparison with results from other areas, which is outside the scope of this summary of data. The registrations from Spitzbergen probably reflect atmospheric transport.

Table 2. PCDF/PCDDs in marine mammals from Norway and Spitzbergen, ng TEQ/kg lipid. TEF according to Ahlborg (1989).

Species/tissue, localities, year	Σ TEQ	% fat	References
Mammals			
Harbour seal (*Phoca vitulina*)			
blubber, Oslofj., 1988	12/16	82-96	Oehme et al., 1990.
Ringed seal (*Phoca hispida*),			
blubber, Kongsfj./Spitzbergen, 1986	5-31	82-96	Oehme et al., 1990.

The very high degree of non-ortho PCB contamination in the Haakonsvern area is seen from cod liver data in table 3. The 1253 ng TEQ/kg wet weight is probably at least 20 times more than the expected "high background" in cod liver from relatively unpolluted coastal areas.

With the recommended tolerable weekly - life-long - intake of 0 - 35 pg/kg body weight, corresponding to 2 - 2.5 ng per week for grown-ups, only 2 - 5 grams cod liver from Haakonsvern or Frierfjorden/Breviksfjorden suffice to reach the dose limit.

The present high contamination level in the Frierfjord and neighbouring fjords none the less reflect a considerable improvement in recent years. In cod liver from 1975 and 1976, before and after the first round of mitigating measures, it was recorded about 38000 and close to 7000 ng TEQ/kg wet weight (Knutzen & Oehme, 1993), against the present level of 500 - 1000 ng/kg (table 3). Likewise, the dioxin levels in crab hepatopancreas (brown meat) and mussels before the 1990 reduction in load were above 2000 and about 200 ng TEQ/kg w.w., respectively (Knutzen & Oehme, op. cit. cf. table 4). The problem is that concentrations in edible species at least in part appear to stop decreasing at a level which is not acceptable. Decrease in contamination has been slow or inconsistent after 1991 (Knutzen et al., 1995a and unpublished 1994 data).

It also appears from table 4 that muscle tissue of crabs have a comparatively low dioxin level . Consequently, claw meat and other muscle tissue may be relieved of consumption restrictions when hepatopancreas of crabs in the same population still is heavily contaminated. Similar practical management questions arise from the relation between hepatopancreas and the rest of the carapace content (50 - 60%), and also possible sex differences in accumulation (fishermen claim that consumers prefer female crabs). Choice of monitoring matrice is based on the high fat content of hepatopancreas and the less migratory habit of males compared with females (Hallbäck, 1987). However, mixed samples of both sexes and analysis of the whole carapace content would be more practical and relevant to management purposes. Introductory studies have not shown any consistent accumulation differences between the two sexes (NIVA/NILU, unpubl.).

The reason for slow improvement in contamination of several seafood species in the Frierfjord area most probably is caused by the persistently contaminated sediment and food chain transport. Very high dioxin concentrations have been found both in mixed soft bottom fauna and stomach content of cod, also demonstrating the difference in exposure via this route between Frierfjorden and Breviksfjorden (table 4). Results from introductory elimination studies with the edible crab and cod/flounder from Frierfjorden, transferred to uncontaminated environment, are not promising with respect to reaching acceptable levels in seafood from this fjord in the next few years (Knutzen et al., 1994c, 1995b).

Table 3. PCDF/PCDDs and non-ortho PCB in marine fish from Norway, ng TEQ/kg wet weight. TEF according to Ahlborg (1989, PCDF/PCDD) and Ahlborg et al (1994, non- ortho PCB). Not analyzed or calculated:

Species/tissue, localities, year	PCDF/D	Non-ortho PCB 77	126	169	ΣTEQ	References
COD (*Gadus morhua*), liver						
Iddefj., 1992	5,1	0,6	42,9	8,9	68	Berge & Helland, 1993
Hvaler area, 1989	7,3-12,3	-	-	-	-	Berge, 1991
Outer Oslofj, 1988	81,9	-	-	-	-	Knutzen & Oehme, 1991
Inner/Outer Drammensfj., 1991	22,2/36,6	2,3/1,0	93,1/26,7	3,1/0,4	121/65	Knutzen et al., 1993
Frierfj., 1993	506	0,1	90,0	13,4	610	Knutzen et al., 1995a
Breviksfj., 1993	276	0,5	124,0	11,2	412	"
Open coast, Telemark, 1993	93,1	0,6	70,2	3,6	167	"
Inner Kristiansandfj., 1992	40,2	0,8	233,6	14,3	289	Knutzen et al., 1994a
Outer Kristiansandfj., 1992	5,7	0,4	33,5	0,4	40	"
Haakonsvern, Hordaland, 1993	11,4	36	1200	6	1253	Knutzen & Biseth, 1994
Byfj./Bergen, 1993	8,1/10,8	3,2/2,3	125/103	1,2/1,6	138/117	Skei et al., 1994
Vefsnfj., 1989	25,8	-	-	-	-	Knutzen, 1991
Inner Ranafj., 1989	1,95 (?)	-	-	-	-	Green et al., 1993
Inner Varangerfj., 1989	6,8/8,5	-	-	-	-	Færden, 1991
COD, fillet						
Frierfj., 1993	1,91	<0,01	0,31	0,04	2,26	Knutzen et al., 1995a
Open coast, Telemark, 1988	<0,32	-	-	-	-	Knutzen & Oehme, 1988
Haakonsvern, Hordaland, 1993	0,09	0,46	4,92	<0,02	5,49	Knutzen & Biseth, 1994
Inner Kristiansandsfj., 1992	0,18	<0,01	1,19	0,03	1,40	Knutzen et al., 1994a
Outer Kristiansandsfj., 1992	0,07	<0,01	0,24	0,01	0,32	"
COD, roe						
Frierfj., 1994	20,5	<0,01	1,87	0,39	22,76	NIVA/NILU, unpubl.
Breviksfj., 1994	7,69	0,02	3,27	0,18	11,16	"
Såstein, 1994	2,58	0,01	1,34	0,06	3,99	"
FLOUNDER (*Platichthys flesus*), fillet						
Hvaler area (5 st.), 1988	~0,1-0,3	-	-	-	-	Monfelt & Lindestrøm, 1989
Tofte area (5 st), Oslofj., 1988	~1-10	-	-	-	-	
Frierfj., 1993	9,91	<0,01	0,67	0,03	10,61	Lindestrøm et al, 1989
Breviksfj., 1993	3,52	0,01	0,68	0,01	4,22	Knutzen et al., 1995a
Inner Kristiansandsfj., 1990	~5,3/2,0	-	-	-	-	Knutzen et al., 1995a
Inner Kristiansandsfj., 1992	3,34	0,03	2,95	0,07	6,39	Knutzen et al., 1991
Byfj., Bergen, 1993	0,40	0,09	1,50	0,02	2,01	Knutzen et al., 1994 a
Inner Ranafj., 1988, 1989	~0,08 (?)	-	-	-	-	Skei et al., 1994
						Green et al., 1993
PLAICE (*Pleuronectes platessa*), fillet						
Kristiansandsfj., 1992	0,16	<0,01	0,14	<0,01	~0,30	Knutzen et al., 1994 a

Table 3 (cont.)

Species/tissue, localities, year	PCDF/D	Non-ortho PCB 77	126	169	ΣTEQ	References
WITCH ***(Glyptocephalus cynoglossus)*****, fillet**						
Breviksfj. /Langesundsb. 1992	1,83/0,29	-	-	-	-	Knutzen et al., 1994 b
LEMON SOLE ***(Microstomus kitt)*****, fillet**						
Haakonsvern/Hordaland, 1993	0,11	0,05	0,48	<0,01	0,64	Knutzen & Biseth, 1994
EEL ***(Anguilla anguilla)*****, fillet**						
Hvaler area (5st.), 1989	0,16-1,21	-	-	-	-	Berge, 1991
Frierfj., 1993	41,07	0,01	2,96	1,01	45,05	Knutzen et al., 1995a
Frierfj./Breviksfj./Såstein, 1992	~44/48/7	-	-	-	-	Knutzen et al, 1994 b
Gjernestangen (Risør), 1991	1,9/2,0	-	-	-	-	NIVA/NILU, unpubl.
Røynevardefj., 1991	1,8	-	-	-	-	NIVA/NILU, unpubl.
Inner Kristiansandsfj., 1992	1,39	0,01	3,98	0,29	5,67	Knutzen et al., 1994 a
SEA TROUT ***(Salmo trutta)*****, fillet**						
Frierfj., 1993	11,53	0,01	1,37	0,06	12,97	Knutzen et al., 1995a
Breviksfj. 1993	5,14	0,01	0,84	0,03	6,02	"
I. Kristiansandsfj., 1992	3,84	0,03	1,73	0,02	5,62	Knutzen et al., 1994 a
SALMON ***(Salmo salar)*****, fillet**						
Skien river (Frierfj.), 1993	0,81	0,01	1,05	0,02	1,89	Knutzen et al., 1995a
Farmed, West/North coast (4 loc.) 1989-90	0,25-0,91	-	-	-	-	Færden, 1991
HERRING ***(Clupea harengus)*****, fillet**						
Breviksfj.-Langesundb., 1993	2,66	0,02	1,39	0,03	3,10	Knutzen et al., 1995a
North Sea, 1990	~1,5-2,0	-	-	-	-	Færden, 1991
West/North coast (3 loc.), 1993	1,02-1,29	0,01-0,02	0,57-0,88	0,03	1,63-2,21	SNT,[1] unpubl.
MACKEREL ***(Scomber scombrus)*****, fillet**						
Breviksfj., 1993	3,52	0,06	2,26	0,02	5,86	Knutzen et al., 1995a
Inner Kristiansandsfj., 1988	2,6	-	-	-		Knutzen et al., 1991
Karmøy (North Sea), 1990	~0,8	-	-	-	-	Færden, 1991
3 open West coast loc., 1993	0,44-0,67	0,03-0,05	0,74-1,21	0,01	1,22-1,94	SNT, [1] unpubl.

[1] Norwegian Food Control Authority

Table 4. PCDF/PCDD and non-ortho PCB in marine invertebrates from Norway, ng TEQ/kg w.w. TEF according to Ahlborg (1989, PCDF/D) and Ahlborg et al., (1994, n.-o. PCB). Not analyzed:

Species/tissue, localites, years	PCDF/D	Non-ortho PCB 77	126	169	ΣTEQ	References
EDIBLE CRAB (*Cancer pagurus*) male, hepatopancreas						
Iddefj., 1990	19,6	-	-	-	-	Berge, 1991
Tisler (Hvaler), 1990	17,1	-	-	-	-	NIVA/NILU, unpubl.
Frierfj., 1993	708	0,3	18,9	2,1	729	Knutzen et al., 1995a
Inner Breviksfj., 1993	481	0,4	21,5	2,0	505	"
Outer Breviksfj., 1993	51,9	0,2	6,1	0,3	58,5	"
Såstein (open coast), 1993	60,3	0,2	7,2	0,5	68,2	"
Jomfruland (open coast), 1993	41,8	0,2	6,4	0,4	48,8	"
Skagerak coast (4 loc.) 1989-90	22,4-29,2	0,3-0,4	10,0-20,1	0,4-0,9	34,7-43,9	NIVA/NILU, unpubl.
Inner Krstiansandsfj., 1992	53,8	0,3	39,2	0,9	94,2	Knutzen et al., 1994 a
Outer Kristiansandsfj., 1992	10,3	0,1	6,7	0,2	17,3	"
Øygarden, Hordaland, 1989	18,7	-	-	-	-	NIVA/NILU, unpubl.
Bergen harbour, 1993	56,2	8,6	127,6	3,0	195,2	Skei et al., 1994
Herdlafj., 1994 (ref. loc., prel.results.)	~5,0	~0,3	~6,2	~0,2	13,5	NIVA/NILU, unpubl.
EDIBLE CRAB, male, rest carapace content, compare above						
Inner Breviksfj., 1993	85,2	0,1	2,8	0,2	88,3	Knutzen et al., 1995a
Outer Breviksfj., 1993	14,8	<0,1	1,3	<0,1	16,2	"
EDIBLE CRAB, male, claw meat						
Frierfj., 1987	~44	-	-	-	-	Knutzen & Oehme, 1988
Outer Breviksfj., 1987	~5,5	-	-	-	-	"
Såstein (open coast), 1987	~5,5	-	-	-	-	"
SHRIMPS (*Pandalus borealis*) edible parts						
Svenner/O. Oslofj., 1989	~0,35	-	-	-	-	Knutzen & Oehme, 1990
Jomfruland, 1989	~0,70	-	-	-	-	"
Breviksfj., 1988	~20,0	-	-	-	-	Knutzen & Oehme, 1988
W. of Såstein, 1988	~2,4	-	-	-	-	"
Breviksfj., 1993	6,64	-	-	-	-	Knutzen et al., 1995a
Håøyfj., 1993 (parall.)	5,34/4,22	-/0,01	-/0,25	-/0,01	-/4,49	"
Kristiandssandsfj., 1987	~1,4	-	-	-	-	Knutzen et al., 1988
CRAB (*Hyas coarctatus*), hepatopancreas.						
Hopen,/Bear Isl. (Artic)	~0,5-2,0					NILU unpubl.

Table 4 (cont.)

Species/tissue, localites, years	PCDF/D	Non-ortho PCB 77	126	169	ΣTEQ	References
COMMON MUSSEL (*Mytilus edulis*), edible parts						
Outer Iddefj., 1989	~1,5	-	-	-	-	Berge, 1991
Hvaler, 1989	~0,9/1,2	-	-	-	-	Berge, 1991
Drøbak,/Missingen, Oslofj, 1989	~0,43/0,41	-	-	-	-	NIVA/NILU, unpubl.
Inner Breviksfj., 1993	5,45	0,02	0,46	0,02	5,95	Knutzen et al., 1995 a
Klokkartangen, Telemark, 1993	1,82	0,02	0,33	0,01	2,18	"
Risøy (JMPst. 76A), 1990	0,56	-	-	-	-	Green et al., 1995
Inner Kristiansandsfj., 1992	1,33	0,06	1,47	0,02	2,88	Knutzen et al., 1994a
Gåsøy/Lyngdal (JMPst. 15 A) 1990	0,48	-	-	-	-	Green et al., 1995
Inner Saudafj., 1992	0,26	-	-	-	-	Knutzen & Berglind, 1993
Øygarden/Hordal. (ref.loc.), 1989	0,23	-	-	-	-	
Sørfj./Hardanger, 1991	~0,42/0,25	-	-	-	-	NIVA/NILU, unpubl.
Haakonsvern/Hordaland, 1993	0,78	0,26	1,68	0,01	2,73	"
Sunndalsfj., 1991	0,21	-	-	-	-	Knutzen & Biseth, 1994
Trosavik/Trondheimsfj., 1989	~0,20	-	-	-	-	Iversen et al., 1993
I.-O. Vefsnfj., (4 loc.), 1989	~0,5-2,2	-	-	-	-	NIVA/NILU, unpubl.
I.,-O., Ranafj. (3 loc.), 1990	~0,2	-	-	-	-	Knutzen, 1991
Ramfj.(Balsfj).,Troms, 1989	~0,13	-	-	-	-	Green et al., 1993
						NIVA/NILU, unpubl.
HORSE MUSSEL (*Modiolus modiolus*,), edible parts						
Haakonsvern/Hordaland, 1993	0,48	0,10	0,50	0,01	1,09	Knutzen & Biseth, 1994
Inner Årdalsfj./Sogn (2 loc.), 1994	0,17/0,22	0,01/ 0,03	0,08/ 0,19	<0,01	0,26/ 0,44	Knutzen, 1995
Ramfj. (Balsfj.), Troms, 1989	0,12	-	-	-	-	NIVA/NILU unpubl.
Mixed soft bottom fauna						
Inner Frierfj., 1989 [1)]	659	-	-	-	-	Berge & Knutzen, 1991
Inner Breviksfj., 1990 [1)]	112	-	-	-	-	"
Rauerkollen/Oslofj. I [2)] 1994	0,54	0,02	0,33	0,01	0,90	NIVA/NILU, unpubl.
Rauerkollen/Oslofj. II, 1994	0,35	0,01	0,14	<0,01	0,50	"
Frierfj., 1994	312	0,03	1,55	0,20	~313,8	"
Breviksfj., 1994 I [2)]	26,8	0,01	0,42	0,04	~27,3	"
Breviksfj., 1994 II [3)]	63,6	0,01	0,82	0,14	~64,6	"
Plankton (*vertical net haul sample*) Breviksfj., 1994	0,18	<0,01	0,01	<0,01	~0,20	NIVA/NILU, unpubl.
COD, stomach content						
Frierfj. I, 1994 (whole prey)	208	0,03	3,40	0,47	~212	NIVA/NILU, unpubl.
Frierfj. II, 1994 (half digested)	104	0,01	1,61	0,23	~106	"
Breviksfj. I 1994 (whole prey)	12,3	0,03	0,84	0,03	~13,2	"

[1] Predominant in the two samples were the polychates *Cf. Priapulus caudatus and Nephtys sp*., respectively. Mussels, ophiuroids and irregular echinoids removed before analysis (due to their high content of inorganic matter).

[2] Hyperbenthos

[3] Dominated by polychaetes

3. REFERENCES

Ahlborg, U.G., 1989. Nordic risk assessment of PCDDs and PCDFs. Chemosphere 19: 603-608.

Ahlborg, U.G., A. Brouwer, M.A. Fingerhuit, J.L. Jacobson, S.W. Jacobson, S.W. Kennedy, A.A.F. Kettrup, J.H. Koeman, H. Poiger, C. Rappe, S.H. Safe, R.F. Seegal, J. Tuomisto and M. van den Berg, 1992. Impact of polychlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls on human and environmental health, with special emphasis on application of the toxic equivalency factor concept. Europ. J. Pharmacol. 228: 179-199.

Ahlborg, U.G., G.C. Becking, L.S. Birnbaum, A. Brouwer, H.J.G.M. Derks. M. Feely, G. Golor, A. Hanberg, J.C. Larsen, A.K.D. Liem, S.H. Safe, C. Schlatter, F. Wärn, M. Younes and E. Yrjänheikki, 1994. Toxic equivalency factors for dioxin-like PCBs. Report on a WHO-ECEH and IPCS consultation, December 1993. Chemosphere 28: 1049-1067.

Baumann Ofstad, E., G. Lunde, K. Martinsen and B. Rygg, 1978. Chlorinated aromatic hydrocarbons in fish from an area polluted by industrial effluents. Sci. Total Environ. 10: 219-230.

Berge, J.A. and A. Helland, 1993. Overvåkingsundersøkelser i Iddefjorden 1991/1992. Miljøgifter i sediment, ål, torsk og taskekrabbe. State Pollution Monitoring Programme. Report 531/93 (NIVA-report 2953, 56 p.). ISBN 82-577-2378-9.

Berge, J.A. and J. Knutzen, 1991. Sedimentenes betydning for forurensningstilstanden i Frierfjorden og tilgrensende områder. Rapport 3: Eksperimentelt opptak av persistente klororganiske forbindelser og kvikksølv i skrubbe og krabbe, opptak/utskillelse i blåskjell og registrering av miljøgiftinnhold i bunndyr fra Frierfjorden og Breviksfjorden. NIVA-report 2573, 143 p. ISBN 82-577-1897-1.

Berge, J.A., 1991. Miljøgifter i organismer i Hvaler/Kosterområdet. State Pollution Monitoring Programme. Report 446/91. (NIVA-report 2560, 192 p.). ISBN 82-577-2011-9.

Færden, K., 1991. Dioksiner i næringsmidler. Oppsummering av dioksinanalyser i 1989 og 1990. Report 4/1991 from the Norwegian Food Control Authority, 37 p. ISSN 0802-1627.

Green, N., J. Knutzen, L. Berglind and L. Golmen, 1993. Undersøkelse av miljøgifter i sediment og organismer fra Ranfjorden 1989 - 90. State Pollution Monitoring Programme. Report 516/93 (NIVA-report 2872, 157 p.). ISBN 82-577-2240-5.

Green, N.W., J. Knutzen, A. Helland and E.M. Brevik, 1995. Overvåking av miljøgifter i marine sedimenter og organismer 1981 - 92. Joint Monitoring Programme of the State Pollution Monitoring Programme. Report 593/95(NIVA-report 3184, 195 p.). ISBN 82-577-2676-1.

Hallbäck, H., 1987. Preliminary results from dioxin investigations of some crustaceans along the Swedish west coast. ICES. C.M. 1987/E:14. (Manuscript, 4 p. + tables).

Hanberg, A., F. Wærn, L. Asplund, E. Haglund and E. Safe, 1990. Swedish dioxin survey: Determination of 2,3,7,8-TCDD toxic equivalent factors for some polychlorinated biphenyls and naphtalenes using biological tests. Chemosphere 20: 1161-1164.

Iversen, E., H. Kolderup, R.M. Konieczny, L. Golmen, E.R. Lømsland and M. Oehme, 1993. ALUSCAN AS. Miljøvurdering ved behandling av saltslagg fra sekundæraluminiumsindustrien. NIVA-report 2883, 78 p. ISBN 82-577-2255-3.

Johansen, H.R., O.J. Rossland and G. Becher, 1993. Congener specific determination of PCBs in crabs from a polluted fjord region. Chemosphere 27: 1245-1252.

Knutzen, J., 1991. Overvåking i Vefsnfjorden for Elkem Aluminium Mosjøen 1989 - 91. Delrapport 2: Miljøgifter i organismer. NIVA-report 2622, 48 p. ISBN 82-577-1926-9.

Knutzen, J., 1995. Overvåking av PAH i o-skjell fra Årdalsfjorden 1994, med orienterende analyser av dioksiner og non-orto PCB. NIVA-report 3248, 18 p. ISBN 82-577-2715-8.

Knutzen, J. and L. Berglind, 1993. PAH og metaller i fisk og muslinger fra Saudafjorden 1991 - 1992. NIVA-report 2960, 25 p. ISBN 82-577-2365-7.

Knutzen, J. and Aa. Biseth, 1994. Undersøkelser av non-ortho polyklorerte bifenyler og polyklorerte dibenzofuraner/dibenzo-p-dioksiner i organismer og sedimenter fra omegnen av marinebasen ved Haakonsvern 1993. NIVA-report 3073, 45 p. ISBN 82-577-2510-2.

Knutzen, J. and K. Martinsen, 1986. Tiltaksorientert overvåking av miljøgifter i fisk og andre organismer fra Kristiansandsfjorden 1985. State Pollution Monitoring Programme. Report 262/86 (NIVA-report 1940, 62 p.). ISBN 82-577-1168-3.

Knutzen, J. and M. Oehme, 1988. Undersøkelse av klorerte dioksiner og dibenzofuraner i fisk, skalldyr og sedimenter fra Frierfjorden med tilgrensende områder 1987 - 1988. NIVA-report 2189, 143 p. ISBN 82-577-1477-1.

Knutzen, J. and M. Oehme, 1989. Polychlorinated dibenzofuran and dibenzo-p-dioxin (PCDD) levels in organisms and sediments from the Frierfjord, Southern Norway. Chemosphere 19: 1897-1909.

Knutzen, J. and M. Oehme, 1990. Klorerte dibenzofuraner og dioksiner i krabber, fisk og reker fra Frierfjorden, tilstøtende områder og referansestasjoner 1988 - 89. NIVA-report 2346, 110 p. ISBN 82-577-1629-4.

Knutzen, J. and M. Oehme, 1993. Effects of reduced PCDF/PCDD discharge from magnesium production on levels in marine organisms from the Frierfjord area, Southern Norway. Pp. 203 - 206 in H. Fiedler, H. Frank. O. Huitzinger, W. Parzefall, A. Riss and S. Safe (eds.). DIOXIN'93. 13th Int. Suymp. on Chlorinated Dioxins and Related Compounds. Vienna, Sept. 1993. Short Papers vol. 12. Federal Environmental Agency, Vienna, Austria.

Knutzen, J., K. Martinsen og M. Oehme, 1988. Tiltaksorientert overvåking av miljøgifter i organismer og sedimenter fra Kristiansandsfjorden 1986 - 1986. State Pollution Monitoring Programme. Report 312/88 (NIVA-report 2114, 110 p.). ISBN 82-577-1392-9.

Knutzen, J., K. Martinsen, K. Næs, M. Oehme and E. Oug, 1991. Tiltaksorientert overvåking av miljøgifter i organismer og sedimenter i Kristiansandsfjorden 1988 og 1990. State Pollution Monitoring Programme, Report 441/93. (NIVA-report 2554, 183 p.). ISBN 82-577-1873-4.

Knutzen, J., I. Kopperud, J. Magnusson and J.U. Skåre, 1993. Overvåking av miljøgifter i Drammensfjorden. NIVA-report 2838, 50 p. ISBN 82-577-2203-0.

Knutzen, J., G. Becher, A. Kringstad and M. Oehme, 1994a. Overvåking av miljøgifter fra Kristiansandsfjorden 1992. State Pollution Monitoring Programme. Report 574/94 (NIVA-report 2996, 111 p.). ISBN 82-577-2430-0.

Knutzen, J., L. Berglind, E. Brevik, N. Green, M. Oehme, M. Schlabach og J.U. Skåre, 1994b. Overvåking av miljøgifter i fisk og skalldyr fra Grenlandsfjordene 1992. State Pollution Monitoring Programme. Report 545/93 (NIVA-report 2989, 127 p.). ISBN 82-577-2427-0.

Knutzen, J., M. Schlabach and E. Brevik, 1994c. Utskillelsesforsøk 1992 - 1993 med polyklorerte dibenzofuraner/dibenzo-p-dioksiner og andre persistente klororganiske stoffer i taskekrabbe (*Cancer pagurus*) fra Frierfjorden. NIVA-report 3125, 59 p. ISBN 82-577-2585-4.

Knutzen, J., G. Becher, Aa. Biseth, E. Brevik, N. Green, M. Schlabach and J.U. Skåre, 1995a. Overvåking av miljøgifter i fisk og skalldyr fra Grenlandsfjordene 1993. State Pollution Monitoring Programme. Report 589/95. (NIVA-report 3195, 147 p.). ISBN 82-577-2675-3.

Knutzen, J., Aa. Biseth, E. Brevik and M. Schlabach, 1995b. Introductory studies of elimination of polychlorinated dibenzofurans/dibenzo-p-dioxins, hexachlorobenzene, octachloro-styrene and decachlorbiphenyl in cod and flounder from Frierfjorden (S. Norway). NIVA-report No. 3328. ISBN 82-577-2855-1. (In Norwegian with English summary).

Konieczny, R. and A. Juliussen, 1995a. Sonderende undersøkelser av miljøgifter i norske havner og utvalgte kystområder. Observasjoner i sedimenter på strekningen Narvik - Kragerø. State Pollution Monitoring Programme. Report 587/94 (NIVA-report 3275, 185 p.). ISBN 82-577-2780-6.

Konieczny, R. and A. Juliussen, 1995b. Sonderende undersøkelser av miljøgifter i norske havner og utvalgte kystområder. Observasjoner på strekningen Kirkenes - Ramsund. In prep.

Lindeström, L., C. Monfelt and M. Notini, 1989. Recipientundersökningar vid Tofte, Oslofjorden, sommaren och hösten 1988. Report F 89/031:2 from Environment Research Group, 56 p. + annex.

Monfelt, C. and L. Lindeström, 1989. Undersökning av skrubbskädda (*Platichthus flesus* L.) fångad i Hvaler- och Singlefjordsområdet hösten 1988. Report F 9/037 from Environment Research Group, 19 p. + annex.

Næs, K., 1989. Miljøgifter i Gunnekleivfjorden. Delrapport 1: Konsentrasjoner og mengde av miljøgifter i sedimenter. NIVA-report 2192, 76 p. ISBN 82-577-1482-8.

Næs, K. and E. Oug, 1991. Sedimentenes betydning for forurensningstilstanden i Frierfjorden og tilgrensende områder. Rapport 1: Konsentrasjon og mengder av klororganiske forbindelser, polysykliske aromatiske hydrokarboner, kvikksølv og pyrolyseolje. NIVA-report 2570, 193 p. ISBN 82-577-1885-8.

Oehme, M., J. Klungsøyr, Aa. Biseth and M. Schlabach, 1993. Quantitative determination of ppq-ppt levels of polychlorinated dibenzo-p-dioxins and dibenzofurans in sediments from the Arctic (Barents Sea) and North Sea. Anal. Meth. Instr., 1: 153-163.

Oehme, M., M. Ryg, P. Fürst, Chr. Fürst, H,A, Memken og W. Groebel, 1990. Re-evaluation of concentration levels of polychlorinated dibenzo-p-dioxins and dibenzofurans in Arctic seal from Spitzbergen. Chemosphere 21: 519-523.

Oehme, M., M. Schlabach, K. Hummert, B. Luckas and E.S. Nordøy, 1995. Determination of levels of polychlorinated dibenzo-p-dioxins, dibenzofurans, biphenyls and pesticides in harp seals from the Grenland Sea. Sci. Total Environ. 162: 75-91.

Oehme, M., S. Manø and B. Bjerke,1989. Formation of polychlorinated dibenzo-furans and dibenzo-p-dioxins by production processes for magnesium and refined nickel. Chemosphere 18: 1379-1389.

Schlabach, M., Aa. Biseth, H. Gundersen and J. Knutzen, 1995. Congener specific determination and levels of polychlorinated naphtalenes in cod liver samples from Norway. Manuscript to DIOXIN '95, 4 p.

Skei, J., 1992. Tiltaksorienterte miljøundersøkelser i Sørfjorden og Hardangerfjorden 1991. Delrapport 1. Vannkjemi og sedimentundersøkelser. State Pollution Monitoring Programme. Report 500/92. (NIVA-report 2804, 53 p.). ISBN 82-577-1873-4.

Skei, J., 1993. Miljøgeokjemiske undersøkelser i Kongsfjorden 1991 og 1992. NIVA-report 2987, 42 p. ISBN 82-577-2413-0.

Skei, J., J. Knutzen and J. Klungsøyr, 1994. Miljøgiftundersøkelser i Bergens havneområde og Byfjorden 1993. Fase 1. Miljøgifter i spiselige organismer og bunnsedimenter. NIVA-report 3018, 88p. ISBN 82-577-2469-6.

Wit, C.A. de, U.G. Järnberg, L.T. Asplund, B. Jansson, M. Olsson, T. Odsjö, I.L. Lindstedt, Ö. Andersson, s. Bergek, M. Hjelt, C. Rappe, A. Jansson and M. Nygren, 1994. The Swedis dioxin survey: Summary results from PCDD/F and coplanar PCB analyses in biota. Pp 47-50 in F. Fiedler. O. Hutzinger, Å. Bergman, M. Oehme, S. Ramamoorthy and S. Sakai (eds.): DIOXIN '94. 14th Int. Symp. on chlorinated dioxins, PCB and related compounds. Kyoto, Nov. 1994. Short Papers, vol. 20. Dept. Environ. & Sanitary Engineering, Kyoto University, Kyoto 606-01, Japan.

NIVA

Norwegian Institute for Water Research
P.O.Box 173, Kjelsås N-0411 Oslo, Norway
Phone: + 47 22 18 51 00 Fax: + 47 22 18 52 00

ISBN-82-577-2845-4