

## Organochlorines in Codfish From Harbours Along the Norwegian Coast

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Levels of PCBs, HCB, and sum-DDT in liver from codfish caught near major harbours along the coast of Norway were determined. Samples consisted mainly of whiting (*Merlangus merlangus*) and codling (*Gadus morhua*) from the southern and northern part of the coast, respectively. These species of codfish are present all along the coast and are considered to be stationary. They have livers rich in fat, and are hence suitable for monitoring organochlorines. The purpose of this survey was to see if any of the selected harbours were especially contaminated. Results were also compared with those from a previous survey on organochlorines in cod livers from south western waters (KVESETH and BJERK 1976, BJERK 1973).

### MATERIALS AND METHODS

The sampling sites (Fig.1) were selected according to their industrial structure, geographical location, and number of inhabitants.

In June 1976, about 10 codfish were caught at each of the sampling sites. From Bergen, however, only three fish were obtained, and such a small number of samples may not give a representative contamination picture for the area. The Bergen results should thus be regarded as being indicative only.

The codfish weights varied between 0.1 and 0.6 kg for all the localities except Mo where the mean weight was 1.3 kg.

The fish were wrapped in aluminum foil and stored in a frozen state until dispatched to the laboratory either by train or air. At the laboratory, the samples were stored at  $-20^{\circ}\text{C}$  until analyses could be carried out.

Together with the samples, the laboratory received information about the sampling sites including a description of industries in the vicinity.

Analyses were carried out according to a method described elsewhere (BJERK and SUNDBY 1970). The lipids were extracted with diethyl ether, and divided into two parts which were then treated with conc. sulphuric acid and potassium hydroxide in methanol, respectively. The n-hexane extracts obtained were analysed by gas liquid

chromatography on two columns, 4 per cent SF-96 and 10 per cent QF-1 on Chromosorb W, 100/120 mesh, respectively. Wilcoxon's matched pair test was used in the statistical processing of the numerical data (HØYLAND and WALLØE 1975).

## RESULTS

The samples consisted mainly of whiting from sampling sites in the south and codling from the north. At three localities, saithe (*Pollachius virens*) and pollack (*Pollachius pollachius*) were caught together with either codling or whiting. As analyses showed only small variations in levels between species from the same sampling site, no regard is given to species identification in Table 1 and Fig.1 where all values are shown. The values discussed in the present paper are the mean levels calculated on a wet weight basis. These, and the corresponding fat per centages, are given in Table 1.

TABLE I

PCBs, HCB, and sum-DDT in codfish (liver) from harbours in Norway.

Nr.	Locality	N	Extr.	Levels in ppm, wet weight basis		
			fat %	(arithmetic mean $\pm$ S.D.)		
				sum-DDT	PCBs	HCB
1.	Fredrikstad	13	35 $\pm$ 12	0.5 $\pm$ 0.3	4.8 $\pm$ 2.2	0.73 $\pm$ 0.44
2.	Moss	23	40 $\pm$ 15	0.8 $\pm$ 0.9	2.7 $\pm$ 2.5	0.07 $\pm$ 0.06
3.	Drøbak	10	53 $\pm$ 13	1.9 $\pm$ 1.0	7.5 $\pm$ 6.4	0.24 $\pm$ 0.06
4.	Oslo	5	50 $\pm$ 11	0.5 $\pm$ 0.2	3.3 $\pm$ 1.0	0.14 $\pm$ 0.05
5.	Larvik	12	29 $\pm$ 16	0.6 $\pm$ 0.4	1.4 $\pm$ 0.7	0.08 $\pm$ 0.07
6.	Kristiansand	10	44 $\pm$ 14	0.1 $\pm$ 0.1	0.8 $\pm$ 0.5	2.29 $\pm$ 1.78
7.	Lista (Farsund)	9	22 $\pm$ 15	0.2 $\pm$ 0.2	0.7 $\pm$ 0.5	0.02 $\pm$ 0.03
8.	Stavanger	12	40 $\pm$ 11	0.3 $\pm$ 0.2	1.0 $\pm$ 0.6	0.04 $\pm$ 0.02
9.	Bergen	3	51 $\pm$ 5	14.5 $\pm$ 4.7	5.9 $\pm$ 1.6	0.06 $\pm$ 0.01
10.	Molde	9	20 $\pm$ 14	0.2 $\pm$ 0.1	2.4 $\pm$ 0.8	0.02 $\pm$ 0.02
11.	Åndalsnes	10	39 $\pm$ 10	0.5 $\pm$ 0.2	1.0 $\pm$ 0.6	0.04 $\pm$ 0.01
12.	Trondheim	10	54 $\pm$ 13	0.6 $\pm$ 0.1	1.9 $\pm$ 0.8	0.08 $\pm$ 0.04
13.	Mo	6	44 $\pm$ 7	1.2 $\pm$ 0.8	1.8 $\pm$ 1.0	0.05 $\pm$ 0.01
14.	Narvik	8	36 $\pm$ 8	0.2 $\pm$ 0.1	1.9 $\pm$ 0.6	0.02 $\pm$ 0.01
15.	Tromsø	10	25 $\pm$ 14	0.3 $\pm$ 0.2	1.6 $\pm$ 1.0	0.02 $\pm$ 0.02
16.	Vardø	10	34 $\pm$ 7	0.2 $\pm$ 0.1	0.8 $\pm$ 0.3	0.06 $\pm$ 0.02

sum-DDT: The sum-DDT in cod liver from Bergen (14.5 ppm) was well above the levels found at the other sampling sites. In the Oslo fjord area Drøbak (1.9 ppm) had a significantly higher ( $P \leq 0.05$ ) level than Oslo and Fredrikstad. Results from the sampling sites further north indicate a relatively high level at Mo, but no significant difference was found between this town and Trondheim and Åndalsnes. DDT was found in liver tissues from the different sampling sites, excluding Bergen and Drøbak, in concentrations between 1.1 and 0.1 ppm.

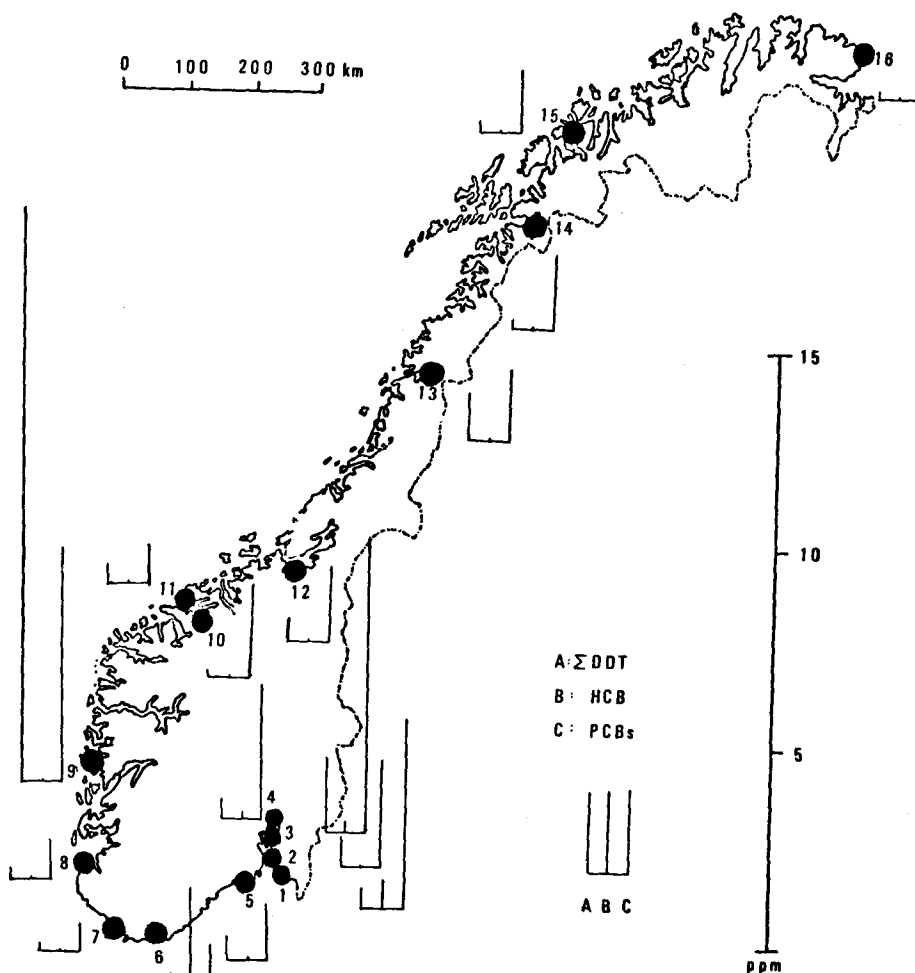


Fig.1. Levels of sum-DDT, HCB, and PCBs in codfish (liver) from major harbours situated along the coast of Norway. The localities are numbered and the names are given in Table 1. The histograms represent mean levels calculated on a wet weight basis.

HCB: There were significant differences ( $P \leq 0.05$ ) in the levels found at some of the different localities, and the following sequence of levels was indicated: Kristiansand: 2.3 Fredrikstad: 0.73 > Drøbak: 0.24 > others: less than 0.15 ppm HCB.

PCBs: The results indicate that the concentration of PCBs in liver tissues was higher at Bergen and in the Oslo fjord area, than in the rest of the sampling material. The level

at Bergen was 5.9 ppm PCBs. In the Oslo fjord area, no consistent gradient of levels was found when moving from the head to the mouth of the fjord. This is illustrated by the following levels: Oslo: 3.3, Drøbak: 7.5, Moss: 2.7, and Fredrikstad: 4.8 ppm.

Concerning the other localities, the levels varied between 2.4 ppm (Molde) and 0.7 ppm (Lista).

#### DISCUSSION

While DDT has been exclusively used as an insecticide, the PCBs have had a widespread industrial use, especially in electro- and chemical industries. HCB has been used as a fungicide, although not in Norway. QUINLIVAN et al. (1977) have reviewed its use in industrial processes and they state that the main source of contamination by this compound is assumed to be due to its synthesis as an industrial byproduct.

The intention was to collect fish samples from the main harbours in a selected number of towns along the Norwegian coast. At Mo, Drøbak and Fredrikstad, however, the sampling site was 2-3 km from the commercial harbour, while at Bergen the site was located 5 km from the harbour near to a suburb.

sum-DDT: In the Oslo fjord area, a relatively high level of sum-DDT was found in whiting (liver) caught just south of Drøbak. This locality was rather close to the mouth of the Drammens fjord, and the relative high level of sum-DDT, HCB and PCBs (Tab.1), may represent the sum of contamination from both the Oslo - and the Drammens fjord. The area north of Drammen is a typical fruit growing district, but as the distance to Drøbak is about 30 km, and the contamination due to the fruit growing is known to be rather local (BJERK 1973), the prior use of DDT in this district is not considered to be the source of the present level at Drøbak.

Concerning the northern part of the country, there seems to be a local high level of contamination at Mo, though this level was not significantly different from the levels found at Trondheim and Åndalsnes.

The fjords in the south western part of Norway have previously been monitored for sum-DDT residues. (BJERK 1973, KVESETH and BJERK 1976). The background level in cod liver from Eivindvik was 1.8 ppm sum-DDT in 1971 (BJERK 1973). Further north at Lofoten, the mean level in liver from seven cod (mean weight 5.0 kg) caught in 1976, was  $1.1 \pm 0.5$  ppm sum-DDT (unpublished data). In 1972, good correlation was found between sum-DDT in cod liver and the amount of fruit growing in the surrounding districts (KVESETH and BJERK 1976). Prior to the ban on the use of DDT in 1970, this insecticide had a widespread use. In the present study, all localities except Bergen showed levels similar to the "no fruit growing" group

(1.3+1.0 ppm sum-DDT) of 1972. The high levels found in the Bergen material, would have put this location in the "major fruit growing" group (16.3+9.0 ppm sum-DDT) of 1972, although no commercial fruit growing takes place at this locality.

PCBs: The results indicate that levels were higher at Bergen and in the Oslo fjord area, than at the other sampling sites. The mean level at Bergen was 5.9 ppm PCBs and in the Oslo fjord area levels varied between 2.7 and 7.5 ppm PCBs. As for the Oslo fjord area, such a contamination picture could be expected, since the largest and most diversified industries in Norway are located in this district. The present data, however, does not seem to allow the further pinpointing of sources of contamination.

Concerning the samples from Bergen, no explanation can be given for the high level found. Local "industrial" activities which may influence PCB-levels in fish, comprise a nearby Navy base and a yacht harbour, since PCBs have been used in boat bottom paints (Jensen et al. 1972).

As regards the other localities, special mention may be made of Molde and the nearby Åndalsnes, as the respective levels found at these two sites differed significantly ( $P \leq 0.01$ ). This could indicate a local contamination at Molde, but compared with most of the localities further north, no such difference could be seen between the levels at Molde and for example those at Mo and Narvik. Consequently, there seems to be no reason to further discuss the minor differences between these localities.

On the basis of the data given by KVESETH and BJERK (1976), one can conclude that cod from uncontaminated fjord areas in the south western part of Norway contain 1.6+1.1 ppm PCBs in their livers. The mean level in liver from seven cod (mean weight 5.0 kg) caught further north at Lofoten in 1976, was 1.0+0.6 ppm PCBs (unpublished data). Comparison of this data with the present results, showed that the sampling sites which appeared to be especially contaminated were the Oslo fjord area and Bergen.

HCB: Since HCB is reported to be generated as a waste product in the manufacture of a number of chemicals and metals (QUINLIVAN et al. 1977), the highest levels would be expected in the Oslo fjord area for the same reason as given for PCBs. The present study supports this assumption, as the mean level in codfish liver from the Oslo fjord area was seven times higher than the mean level for the other localities (excluding Kristiansand) 0.30 and 0.04 ppm HCB, respectively.

The highest level was found in codfish (liver) from Kristiansand, followed by Fredrikstad, Drøbak and Oslo. Levels at the remaining sites were below 0.10 ppm HCB and are assumed to reflect the general contamination level in codfish (liver) from the harbours along the coast of Norway. Since this is the first report including HCB in the monito-

ring programme, it is impossible to discuss any trends at the moment.

Fredrikstad is located at the estuary of Glomma, the largest river in Norway. The district around the navigable 15 km of the river is heavily industrialized and includes two towns. The level of 0.73 ppm HCB in codfish liver from the harbour of Fredrikstad was about ten times higher than at the nearby industrial town of Moss, indicating a local contamination at the former harbour.

Kristiansand has a considerable metallurgic industry and is the largest town in the southern part of Norway. The present investigation revealed a relatively high level at this location, 2.3 ppm HCB. The present degree of contamination was of the same order of magnitude as that found in codfish from the same harbour in 1975 (BREVİK in press). These investigations indicate that the harbour of Kristiansand has been relatively heavily contaminated with HCB for several years. The level was of the same order of magnitude as that reported for cod (muscle) from the Frierfjord, Porsgrunn, during the period from 1972 to 1975 (BØCKMAN et al. 1976).

#### CONCLUSIONS

Levels of PCBs, HCB and sum-DDT found in codfish liver obtained near the harbours of several towns located along the coast of Norway, are generally low. The degree of contamination appeared to be somewhat higher in the Oslo fjord area than at the other sampling sites. Exceptions to this general picture were Bergen (high levels of sum-DDT and PCBs) and Kristiansand harbour (high levels of HCB).

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