Residues of DDT in Cod from Norwegian Fjords

by J. E. BJERK
The Veterinary College of Norway, Department of Pharmacology and Toxicology, Oslo, Norway

Since October 1. 1970 the use of DDT as an insecticide has been prohibited in Norway. This has given the opportunity to monitor the decrease in the environment of DDT residues due to local contamination. DDT has been mainly used in fruit orchards, the most important ones being located at the south-western coast. The ban on DDT does not apply to its use against the pine weevel (Hilobius abietis L.).

In addition to the local contamination, measurable levels of DDT would be expected in marine organisms in samples from the south-western coast, due to global contamination. A branch of the Gulf Stream, originating in the Gulf of Mexico, sweeps along the Norwegian coast, and has an important effect on marine organisms and their distribution. Rain, carried by Atlantic winds, is also precipitated in this mountainous area. According to WOODWELL et al. (1971), these two routes, atmosphere and ocean, are the most dominant ones in the worldwide distribution of DDT.

This paper records the present levels of DDT residues, which are to be used as references in the further monitoring of such residues.

Material and methods

Higher levels of DDT residues have been found in samples from the south-western coast than in samples from other parts of Norway (BJERK 1971, BJERK 1972, BJERK and HOLT 1971). The heavy use of DDT in fruit orchards is believed to be the main source of contamination, although no data concerning possible contamination from the forest nurseries is available at present.

Four districts were selected for this study: A (Ulvik), B (Etne), C (Sogndal), and D (Eivindvik).

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Locality A is a well known fruit growing district. A small forest nursery is also located there. At B there is a forest nursery, but no commercial fruit production, while at C there is fruit production but no nursery. Locality D was selected as a reference locality, without any known, local source of contamination.

Annual usage of technical DDT at the nurseries at A and B is approx. 25 kg and 50 kg respectively. Prior to 1970, the amount used annually at the orchards at A was over 50 kg. The amount used for fruit growing at C is not known, but it is supposed to have been at least as large as at A. Residue values of more than 60 ppm of DDT have been found in the upper 5 cm of soil from Norwegian fruit orchards (STENERSEN and FRIESTAD 1969). The most important fruit growing districts, to which both A and C belong, were not included in these investigations. The average content in samples from the top 15 cm of soil taken at the south-western coast was about 17 ppm.

Locality A was selected for a closer study. After a preliminary test in November 1970, five specimens of cod (Gadus morrhua L.) were caught at intervals of 2-3 weeks from three sub-localities during the spring of 1971. Locality A I was at the head of the fiord, where the village, surrounded by cultivated areas, is located. Locality A II was about half way along the fiord, with only minor fruit orchards. Locality A III was just outside the mouth of the fiord. A rather large river runs into this outer fiord. The distances between localities A I-II and A II-III were 3.4 and 3.7 km respectively, measured along the sea lane.

Cod was used as test organism because it is used as food, and the liver is rich in fat. The analytical results should therefore have a direct relevance to human consumption, and the DDT content in liver should be relatively high. The species of cod involved in this investigation is nonmigratory, and could be found at all the selected places.

Analyses were carried out according to a method described elsewhere (BJERK and SUNDBY 1970). The lipids were extracted with diethyl ether, divided into two parts, and treated with conc. sulphuric acid and potassium hydroxide in methanol, respectively. The subsequent n-hexane extracts were analysed by gas chromatography on two columns, 4 percent SF-96 and 10 percent QF-1.

Results

Lindane was not found in this material. Dieldrin could have been present, but identification was not possible, due to the presence of PCBs. The latter were found in liver tissues in concentrations of between 0.2 and 2 ppm, calculated on a fat weight basis, i.e. on the amount of diethyl ether extracted lipids.

The analytical results are shown in tables 1 and 2, and in fig. 1. Three specimens showed higher levels of DDT residues than did the rest of the material. Levels, calculated on a wet weight basis, of 88 and 95 ppm were found in the livers of two fish caught in April at sublocality A II, and of 135 ppm in a fish from locality C. The mean values, excluding these specimens, are indicated in parantheses in table 1 and in fig. 1.

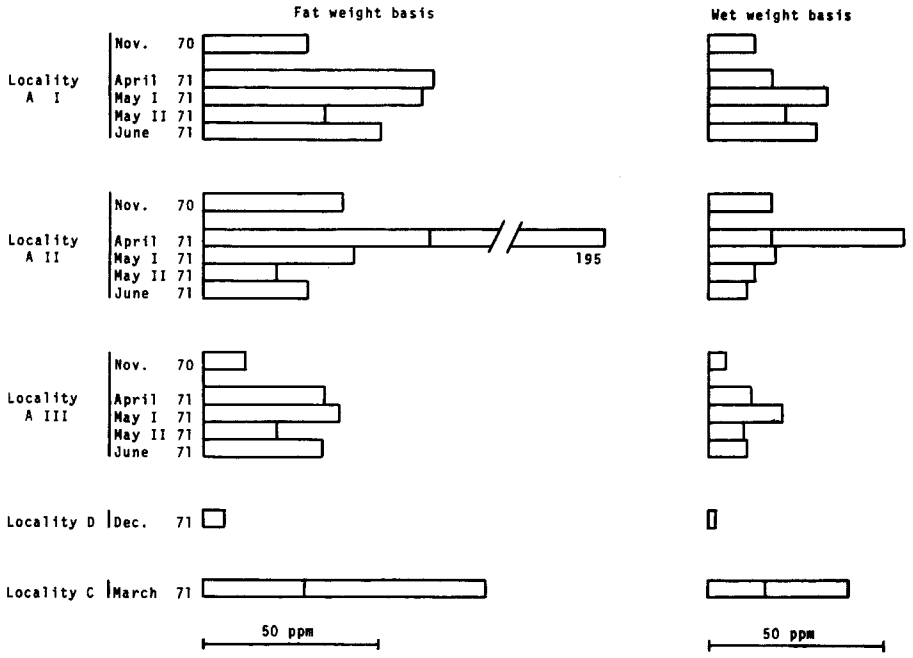

Figure 1. Residues of total DDT in cod liver according to place and date of sampling. The bars are representing mean values of 5-10 specimens.

TABLE 1

Residues of DDT in cod from Norwegian fiords

Locality	Sampling: Date	No.	Weight g	Length cm	Liver: Total DDT ppm w.w.b.	Liver: Total DDT ppm f.w.b.	Liver: Fat weight percent	Muscle: Total DDT ppm
A Ulvik	21.11.70	15	463 170-1001	32 24-41	11.7 3.5-28.7	26.5 7.7-70.0	44 29-53	0.005
	14.-24.4.71	15	631 235-1167	36 27-49	25.2(15.0) 3.8-95.6(26.2)	99.1(54.3) 7.6-576(83.3)	29 17-50	0.022
	15.-16.5.71	15	681 333-1166	36 28-45	24.9 6.9-59.5	46.2 22.9-101	53 30-72	0.022
	29.-31.5.71	15	758 247-1125	36 30-43	15.0 5.0-31.9	25.9 13.7-63.3	58 22-69	0.023
	26.-27.6.71	15	661 124-1534	34 23-44	15.1 4.7-49.9	38.7 11.6-103	43 12-71	0.012
B Etne	1.6.71	4	151 212 406 454	22 26 30 32	3.7 0.1 4.3 2.3	NC 3.3 8.3 39.0	NC 4 51 6	NC NC NC NC
C Sogndal	10.12.71	5	786 535-1158	37 31-42	39.8(16.1) 4.8-135(25.1)	80.7(29.3) 11.3-286(37.2)	51 42-67	NC
D Eivindvik	27.3.71	10	1276 1007-1621	46 46-52	1.8 0.2-4.2	6.3 2.7-10.1	32 3-57	NC

Total DDT: DDT + DDE + DDD + o,p'-DDT
w.w.b.: wet weight basis
f.w.b.: fat weight basis

Values in parantheses are excluding two respectively one specimen
NC: Not calculated

TABLE 2

Distribution of DDT residues in cod liver

Sample	Mean values %DDE	%DDD	%DDT	%o,p'-DDT
A Ulvik				
November 70	28.4	11.1	56.2	
April 71	28.8	11.3	55.5	
Medio May 71	26.1	9.4	54.9	5.5
Ultimo May 71	24.1	8.3	57.8	6.2
June 71	31.1	12.0	51.1	1.1
B Etne 1)	32.2	18.3	44.1	
C Sogndal	33.0	7.1	53.0	2.5
D Eivindvik	18.3	11.4	64.4	

1) Mean of three specimens

The A samples showed a decreasing DDT content as one moved towards the mouth of the fiord. The mean values for locality A I, A II, and A III were 22.4, 16.2 (excluding the two specimens mentioned), and 10.7 ppm, calculated on a wet weight basis. At all localities, the highest levels were found in fish caught medio May, and the time dependent variations were essentially the same for all three localities.

Four specimens from the locality with forest nursery only, B, were analysed. It is difficult to evaluate the results, as the fat content in two of the samples was extremely low. The fat content in a third sample was not determined for technical reasons. It is supposed that the level was about the same as in the fish from the locality without local contamination, D, perhaps somewhat higher.

Correlation coefficients of DDT concentrations in liver to fish length and to fish weight were calculated. Correlations were poor when DDT levels, calculated on a fat weight basis were used. In table 3 the r- and P-values are recorded, calculated on a wet weight basis.

TABLE 3

Correlation of DDT residues in liver tissues to fish length and to fish weight

Sample	No.	Fish length r	Fish length P	Fish weight r	Fish weight P
Ulvik					
November 70	15	0.64	1	0.59	2
April 71	15	0.69	< 1	0.76	0.2
Medio May 71	15	0.25	> 25	0.25	> 25
Ultimo May 71	15	0.53	5	0.43	10
June 71	15	0.60	2	0.56	< 5
Eivindvik					
April 71	10	0.30	> 25	0.08	> 25

DDT residue levels in muscle are shown in table 2. With one exception, the fat content was low, being between 0.1 and 0.4 percent. In muscle from specimens caught at locality A III medio May, the fat content averaged 7.6 percent. DDT values in muscle tissues were low, and because they give little information they are not included in the discussion.

Discussion

The analytical results divide into two groups with high levels in samples from the fruit growing districts, A and C, and low levels in samples from B and D. This demonstrates the local character of the contamination, and indicates that the use of DDT in nurseries is responsible for a minor part only. DDT-dipping of plants is done manually, and care is taken to avoid waste of the suspension. The resulting mud is deposited on the soil away from running water. Prior to 1970 the mud was deposited directly into the sea at A, a procedure which was stopped a couple of years earlier at B.

It is known that DDT does not move vertically into the soil, but stays in the upper layer. The climate in this area, with long, cold winters, should inhibit degradation by soil organisms, and a pH of about 5 in soil (locality A) should prevent dehydrohalogenation.

The valleys in these fiords, however, are very narrow, and the cultivated areas are very steep. It is probable that DDT used in fruit orchards is washed out by heavy rain and water from melting ice and snow during the spring breakup. Transport by surface water has been described by other authors (WOODWELL et al. 1971, LICHTENSTEIN et al. 1966). SMITH and COLE (1970) found seasonal variations of DDT content in nonmigratory winter flounder, and associated this with different runoff conditions.

The presence of o,p'-DDT can also be explained by the runoff conditions. Isomerization of p,p'-DDT to the o,p'-isomere is not believed to occur (BITMAN et al. 1971), but o,p'-DDT has been shown to be more stable than p,p'-DDT in soil (LICHTENSTEIN et al. 1971).

The correlation of DDT content to fish size in samples from locality A was significant, except during the spring breakup. At the locality without local contamination, D, no correlation was found, but STENERSEN and KVALVÅG (in press) found some relationship between DDT content in liver and body weight in cod from a comparable fiord. BUTLER (1969) did not find any correlation between DDT residues and fish size.

The poorer correlation of DDT content, calculated on the basis of extractable lipids, to fish size may have several explanations. For example the immature specimen's lesser tendency to store fat, and changes in fat content due to high levels of DDT. MACEK et al. (1970) found that rainbow trout given DDT and/or dieldrin in the diet for 140 days showed an increase in carcass lipid content. It should also be mentioned that the spawning season is in March.

The DDT-content in cod liver from A is approx. of the same level as found in cod samples from the Baltic Sea (JENSEN et al. 1969), and the appropriate authorities in the Scandinavian countries have enforced restrictions against trade with cod liver from this area. In the Norwegian fiords, cod is not an object for commercial fishing, and no restrictions have as yet been laid down. On the other hand, fishing for domestic use are rather usual in Norway, and does include species which are richer in fat in muscle tissue than cod is. Samples of Norwegian, commercial cod liver oil, which have been analysed by this laboratory, show a total DDT content of about 2 ppm. The results will be published in detail later.

Mortality in fish caused by DDT is associated with residue levels of 1-26 ppm, usually 4-7 ppm, on a total body weight basis (WOODWELL et al. 1967, SPRAGUE and DUFFY 1971). Even though the cod liver comprises only approx. 2-5 percent of the total weight of the fish, the levels of DDT residues found at localities A and C are precariously high.

Summary

Samples of cod from four fiords located at the south-western coast of Norway have been analysed for DDT residues. At locality A there are large fruit orchards and a small forest nursery. At C there are fruit orchards, while at B there is a forest nursery only. The fourth locality, D, had none known source of contamination. At A samples were collected at intervals during the spring of 1970.

The DDT content in cod liver in samples from A and C was high. The mean values of 10-15 specimens ranged between 12 and 40 ppm, calculated on a wet weight basis, and between 26 and 99 ppm, calculated on the basis of extractable lipids. Three specimens of cod showed residue levels of 90-135 ppm DDT in liver tissue. DDT values in cod from the two other localities were less than 5 ppm.

The specimens from A were caught at three sub-localities, and it was found that DDT levels decreased as one moved away from the head of the fiord, where the majority of fruit orchards are located. Significant correlations were found between fish size and DDT content in liver tissue, but not in the sample from locality D. The correlations were destroyed during the spring breakup, the DDT content increasing during this period. o,p'-DDT was also found in samples taken during May and June. The high DDT levels are attributed to the runoff from fruit orchards, which are located on steep slopes in this mountainous area.

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