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PESTICIDE RESIDUES IN SOME BALTIC ANIMALS—A REVIEW OF SELECTED LITERATURE

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ABSTRACT

During the last few years, considerable efforts have been devoted to the tracing of halogenated hydrocarbons, particularly DDT and PCB, and of mercury in Baltic animals. These investigations have already produced some important generalizations, which may be summarized as follows:

(1) The concentrations of halogenated hydrocarbons and mercury in the tissues of Baltic animals are in general higher than those found in the corresponding species on the west coast of Sweden and in the Norwegian waters.

(2) The highest levels of DDT compounds seem to occur in the animals of the southern Baltic and the Sound (Öresund).

(3) The highest contents of methylmercury in the Baltic fish occur in certain coastal areas, usually polluted by pulp mill wastes, while the fish caught in the open sea seem to be less contaminated.

(4) Especially high concentrations of pesticide residues have been observed in fish-eating birds and mammals of the Baltic, viz. in animals representing the top levels of the food chains.

(5) No fatal poisoning of fish and waterfowl due to high concentrations of pesticides has so far been observed in the Baltic area. The situation is worse with white-tailed eagles and some other raptorial birds whose populations have almost totally collapsed in many coastal regions, probably partly owing to the synergetic effects of all accumulated poisons.

The ability of aquatic organisms to accumulate undesirable compounds from the water into their cells and tissues has created new problems in the use of aquatic resources. The 'black painting' of the Baltic Sea in the recent maps of FAO is particularly due to high levels of three compounds or their derivatives in the tissues of some Baltic animals. These three compounds are: DDT, a common insecticide since 1942; PCBs, a group of industrial wastes; and methylmercury, deriving mainly from mercury compounds used in agriculture, paper and chlorine alkali industries.

The actual load of these compounds in the Baltic Sea is not exactly known, since all of them have an ability to disperse even via air, and their use has recently been restricted or forbidden in many countries around the Baltic. Jensen and Olsson[1] estimated the total use of DDT in the Baltic area to be *ca.* 1000 tons per year. In 1969 the use and sales of mercury and PCB compounds was estimated in Finland and Sweden to be *ca.* 125 and 850 tons, respectively[2–4].

A part of the used compounds reaches the water courses and the Baltic Sea via air or rivers; thus Häsänen[2] has estimated the total leaching of mercury from Finland and Sweden into water courses to be *ca.* 23 tons per year.

The pathways of different poisons in the aquatic ecosystems have been especially discussed by Jernelöv[5]. According to him, the main pathways of organochlorines and mercury in a body of water can be schematically presented as shown in *Figure 1.*

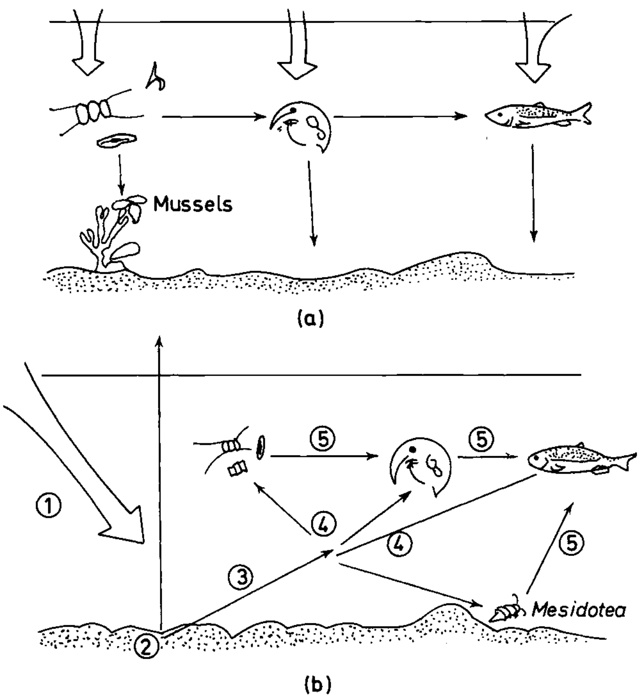

Figure 1. Possible pathways of organochlorines (a) and mercury (b) in a body of water (modified from Jernelöv[5])

Owing to their high solubility in fats, the organochlorines when spread into water rapidly accumulate in oil slicks or in the fat tissues of organisms. When the pelagic organisms die and decompose, a part of the organochlorines may be liberated into water but a greater part is probably deposited with silts and remains of organisms. The piles between organisms show the possible pathway of the compounds in the food chain. Thus every consument in the chain gets organochlorines by two ways, first directly from the water and then via food. In some cases the concentration factor of organochlorines from prey to predator has been estimated as up to 10 and that from water to the organisms as high as 10 000.

The primary pathways of mercury compounds are presented in *Figure 1b*, and are as follows[5].

(1) Sedimentation of mercury compounds.
(2) Transformation of other compounds to inorganic Hg^{2+}.
(3) Methylation of inorganic mercury by the activity of certain micro-organisms in the sediment and solution of monomethylmercury into the water.
(4) Accumulation of methylmercury from water into the organisms, where it is mainly bound to proteins.
(5) Probable accumulation of methylmercury in the food chain.

According to the laboratory tests made by Rissanen, Erkama and Miettinen[6], the methylation of mercury in the bottom sediments is fastest when the temperature and organic content of the sediments is high. Such conditions in the Baltic Sea are found only in shallow areas. In most of the deep waters of the Baltic, where the temperature of bottom water is usually less than 5°C, the methylation of mercury is probably very slow.

The measurements made on the contents of organochlorines and mercury in uncontaminated waters of Fennoscandia have shown very low concentrations, usually less than 1–2 ng/g (1 ng = 10^{-9} g). The mercury content of the Baltic water near Stockholm has been shown to be only 0.25 ng/g[7], but higher concentrations of mercury have been detected near some cellulose and chlorine alkali industries[8].

Even if there are hardly measurable amounts of pesticides in the water, their concentration is high in sediments and biota. The tendency of mercury to accumulate into biological materials was shown already in 1934[9]. In the Baltic animals the first discoveries of mercury were made in 1965[10] and those of DDT and PCBs in 1966[11].

Already the first analyses made on Baltic animals showed so alarming results that they soon led to an initiation of wide sampling programmes directed by international organizations. Most of the analyses were made on fish, raptorial birds and seals, since their life span is long, and they usually represent top levels of the food chains, being thus likely to be more contaminated by pesticides than other organisms are. Since the smaller organisms for practical reasons were almost totally neglected in the samplings, the transport mechanism of pesticides via the food chains is still poorly understood.

In the following tables are collected some results of the analyses obtained in different studies in the Baltic area. For practical reasons, the organisms have been grouped according to their life form, occurrence or taxonomical range, and the concentrations of organochlorines and mercury are expressed as ng/g or as mg/kg of wet tissue.

1. CONCENTRATIONS OF ORGANOCHLORINES AND MERCURY IN ANIMALS OCCURRING MAINLY IN THE PELAGIC ZONE OF THE OPEN SEA

The organisms in the pelagic waters constitute plankton-based food chains: phytoplankton–zooplankton–plankton-eating fish, etc. The levels of DDT and PCBs in pelagic organisms are presented in *Table 1*.

Table 1. Concentrations of DDT and PCBs in some pelagic organisms in the central and southern part of the Baltic proper (ng/g wet cells or tissues)

Organisms	Study year	s. DDT	s. PCB	Ref.
Plankton	1969	56	38	12
Plankton	1972	22	—	13
Herring	1966–1968	90–2 300	9–1 000	11
Herring	1971	170–7 700	60–3 400	12
Herring	1972	1 500	—	13
Sprat	1971	1 200	450	12
Sprat	1972	1 760	—	13
Harbour porpoise	1969	251 000	101 000	12

As seen in the table, the levels of organochlorines are relatively high in all organisms analysed but especially high values have been measured in porpoises, which feed mainly on herring and sprat. The pelagic organisms seem to contain more DDT than PCB.

Owing to its wide distribution and great economical value the Baltic herring has been especially favoured by pesticide analysers. Some results of herring analyses in different parts of the Baltic are presented in *Table 2.*

Table 2. Levels of DDT, PCBs and mercury in herrings in different parts of the Baltic Sea (concentration in ng/g in muscle tissue, wet-weight basis).

Area	Year	s. DDT	s. PCB	Mercury	Ref.
Bothnian Bay	1969–1970	300–670	270–800	43–182	12, 14
Bothnian Sea	1966–	150–420	30–90	—	11
Bothnian Sea	1969–1970	230–800	190–1 000	—	12
Gulf of Finland	1970	170–730	70–210	50–140	15, 16
Arch. of Stockholm	1965	90–300	70–230	—	11
Arch. of Stockholm	1969–1970	800–1 100	460–1 200	—	12
Baltic proper	1966–1968	90–230	9–1 000	—	11
Central Baltic	1969–1970	340–3 300	150–1 500	16–80	12
Southwestern Baltic	1969–1970	300–2 300	260–850	—	12

During the course of the study, the highest DDT contents in herring were observed in the central parts of the Baltic proper, while the levels of PCBs have been highest in herring caught in the archipelago of Stockholm. The fish caught in the Gulf of Bothnia were relatively free from organochlorines in 1966 but more contaminated in 1969–1970. The differences obtained in the levels of organochlorines in different years may be dependent on catching locations. As seen in the table, the contents of mercury in the open sea herrings are very low (only 16–80 ng/g), which indicates that this poison does not easily reach the open parts of the Baltic. In some herrings caught in polluted coastal waters the concentrations of mercury have been considerably higher. Thus, one herring caught off Pori (Bothnian Sea) contained 590 ng/g mercury[8] and the corresponding values in herrings caught in the Gulf of Finland ranged from 50 to 140 ng/g[16].

2. CONCENTRATION OF PESTICIDES IN SOME BENTHIC AND DEMERSAL SPECIES

The bulk of the animal biomass in most bare hard and soft bottom areas of the Baltic is made up of marine bivalvia and some relict crustaceans such as *Pontoporeia* spp. and *Mesidotea entomon.* These benthic species serve as main food objects for several demersal fish such as the Baltic cod and four-horn sculpin and in shallow water even for diving waterfowl (cf. Bagge *et al.*[17]).

The mussel (*Mytilus edulis*) especially is an important food object for many diving waterfowl and the food chain plankton–mussel–eider duck is one of the most clear marine food chains. The pesticide content of mussels in different parts of the Baltic is presented in *Table 3.*

Table 3. Levels of DDT, PCBs and mercury in mussels in different parts of the Baltic Sea (concentrations in ng/g wet tissues).

Area	Year	s. DDT	s. PCB	Mercury	Ref.
Gulf of Finland	1967	20	55	—	18
Gulf of Finland	1970	8–20	32	30–50	16
Arch. of Stockholm	1966–1967	10–60	37	—	11
Arch. of Stockholm	1970	15	17	30–80	14
Southern Baltic	1966–1967	30	30	—	11
Southern Baltic	1972	73	—	—	13

Compared with pelagic species, the levels of DDT and PCBs are relatively low in mussels, ranging from 10 to 73 ng/g and 17 to 55 ng/g, respectively. As in herring, the highest contents of DDT occurred in mussels collected in the central and southern parts of the Baltic proper, while the mean content of PCBs seemed to be highest in the Archipelago of Stockholm. In the pesticide analyses made on mussels small amounts of dieldrin, Lindane and mercury have also been detected[16,18], but the concentrations have been very small everywhere.

In addition to the mussels, some other bivalvia and crustaceans have also been analysed by Polish scientists in 1972 (*Table 4*).

Table 4. Concentration of DDT and its metabolites (as per cent of s. DDT) in some benthic animals in the southern parts of the Baltic proper (Slacza, unpubl.)

	s. DDT (ng/g w.w.)	DDT	DDE (as % of s. DDT)	DDD
Mytilus edulis	73	42.7	9.9	47.1
Cardium edule	98	17.7	31.3	51.0
Macoma baltica	172	30.0	55.2	16.8
Mya arenaria	22	19.7	26.6	53.5
Cyprina islandica	257	17.8	0.8	81.3
Crangon crangon	167	35.9	33.6	30.5
Mesidotea entomon	562	12.3	9.1	78.6

These preliminary results indicate that the marine bivalvia of the Baltic are relatively free from DDT, while some benthic crustaceans such as *Mesidotea entomon* are capable of concentrating this compound in considerable amounts, though it is mainly present in animals as metabolites DDE and DDD.

As mentioned earlier, one of the most important demersal fish in the Baltic is cod (*Gadus morhua callarias*), which feeds mainly on benthic crustaceans and some pelagic fish. Compared with most other Baltic fish, the fat content of the muscle tissue of cod is very low (less than 1% in cods analysed by Otterlind *et al.*[12]). Concentrations of organochlorines and mercury in the muscle tissue of cod are presented in *Table 5*.

Table 5. Levels of DDT, PCBs and mercury in cod in different parts of the Baltic Sea (concentrations in ng/g in muscle tissue, wet-weight basis).

Area	Year	s. DDT	s. PCB	Mercury	Ref.
Bothnian Sea	1965–1967	86	52	150–340	10, 11
Central Baltic	1969–1970	27–110	12–57	—	12
Southwestern Baltic	1969–1970	33–340	29–270	—	12
The Sound (Öresund)	1967–1970	23– 70	71–180	240–2 700	14

As seen in *Table 5*, the levels of DDT and PCBs in the muscle tissue of cod are relatively low everywhere, while the concentration of mercury may be locally very high. One of the possible reasons for the low accumulation rate of organochlorines into the muscle tissue is its low fat content. In tissues higher in fats the contents of DDT and PCBs have been higher. Thus, Westöö and Norén[19], have shown the DDT contents in the liver of Baltic cods to be as high as 22 000 ng/g and PCB contents up to 4 900 ng/g, while the corresponding values in cods caught in the west coast of Sweden have been only 4 100 ng/g and 3 400 ng/g, respectively.

3. COASTAL FRESHWATER FISH

An important part of the stock of the coastal fish, especially in less saline parts of the Baltic Sea, is made up by freshwater species such as northern pike (*Esox lucius*), perch (*Perca fluviatilis*), bream (*Abramis brama*) and burbot (*Lota lota*). Of these species, the pike especially has been frequently used as an object for mercury analyses since it is a rather stationary species and tolerates even slightly polluted conditions. Some concentration values of organochlorines and mercury in coastal freshwater fish are presented in *Table 6*.

Compared with the pelagic marine fish, especially the mercury contents are high in all raptorial coastal fish. Maximum levels of mercury have been detected in perch and pike caught in the sea area off Kotka in the Gulf of Finland, which receives waste waters, etc., from cellulose and chlorine alkali industries. High levels of mercury in fish and sediments have also been detected off the cities of Pori and Oulu (in the Gulf of Bothnia)[21].

Table 6. Levels of DDT, PCBs and mercury in some freshwater fish in the Finnish coastal areas (concentrations in ng/g in muscle tissue, wet-weight basis).

	s. DDT	s. PCB	Mercury	Ref.
Pike				
Bothnian Bay	8–110	26–55	130–1 500	15, 8
Bothnian Sea	31	134	300–1 100	15, 8
Gulf of Finland	6–26	35–180	150–4 600	15, 8, 20
Perch				
Bothnian Bay	22–49	24–37	mean 1 450	15, 21
Gulf of Finland	<95	40–50	630–5 800	15, 20, 8
Bream				
Gulf of Finland	20–30	40	60	15, 20, 8
Burbot				
Bothnian Bay	10–20	26–29	mean 1 070	15, 21
Gulf of Finland	11	26	—	15, 20

4. BALTIC BIRDS

Many bird species inhabiting the coasts of the Baltic Sea are more or less linked with aquatic food châins, but such birds as terns, diving ducks and white-tailed eagles are especially considered to represent the top levels of the Baltic food chains. Since the published analyses concerning the pesticide levels of aquatic birds are relatively few, only four species are chosen for further discussion. These four species are: eider duck (*Somateria mollissima*), a typical mussel feeder occurring almost throughout the Baltic Sea; goosander (*Mergus merganser*) and guillemot (*Uria aalge*), typical fish feeders; and white-tailed eagle (*Haliaetus albicilla*), which consumes both fish and birds. Some values for the concentrations of pesticides in the wet tissues of birds and their eggs are presented in *Table 7*. Deviating from the previous tables, the concentrations are presented as mg/kg.

Table 7. Levels of DDT, PCBs and mercury in some Baltic birds and their eggs (concentrations in mg/kg in wet tissues).

	s. DDT	s. PCB	Mercury	Ref.
Guillemot				
eggs	20–51	7.9–21	—	11
White-tailed eagle				
pectoral muscle	220–400	150–240	0.1–8.5	11, 22, 23
liver	68	130	4.6–27.1	23, 24
brain	68–110	29–70	8.1	11, 23, 24
Goosander				
pectoral muscle	—	—	0.1–6.1	22
eggs	—	—	0.3–3.7	22
Eider				
pectoral muscle	—	—	0.1–3.9	22, 23
eggs	0.34–2.14	0.68–3.4	0.1–0.64	16
liver	—	—	(12.9)	23

Compared with the other Baltic animals, the concentrations of both DDT and PCBs are extremely high in the tissues of white-tailed eagles, while the mercury contents do not deviate much from those found in other bird species analysed. The poor breeding success of the white-tailed eagles and their decreasing population in many areas of the Baltic are generally considered to be due to the accumulation of poisons.

5. SEALS

The mammal fauna of the Baltic Sea is very poor, consisting mainly of seals of arctic origin. Two of the seal species—grey seal (*Halichoerus grypus*) and ringed seal (*Pusa hispida*)—inhabit mainly the northern gulfs of the Baltic, while the harbour seal (*Phoca vitulina*), like the whale (harbour porpoise), occur mainly in the southwestern parts of the Baltic. All of the larger sea mammals are fish feeders and contain plenty of fat in their tissues and are thus likely to concentrate especially organochlorines. We have already noticed the high levels of DDT and PCBs in the tissues of harbour porpoise. The corresponding levels in seals are presented in *Table 8*.

Table 8. Concentration of organochlorines and mercury in seals in different parts of the Baltic Sea (mg/kg wet weight).

	s. DDT		s. PCBs		Mercury	Ref.
	in tissue	in fat	in tissue	in fat	in tissue	
Ringed seal						
Gulf of Bothnia	58–68	110–130	5.0–8.5	9.7–16.0	—	11
Gulf of Finland	—	—	—	—	0.1–5.9	22
Grey seal						
Gulf of Finland (pup)	24–26	41–43	3.4–4.4	6–7	—	11
Arch. of Stockholm	35–36	97–310	5.7–6.4	16–56	—	11
Scania, Falsterbo	—	4600	—	2500	—	25
Grey and Harbour seal						
Baltic proper	58–74	110–150	8.5–21	16–43	—	11

As seen in *Table 8*, the DDT values of the Baltic seals calculated on a fat basis range normally from 41 to 310 p.p.m. and those of PCBs from 6 to 56 p.p.m. The abnormal concentration found in the carcass of a grey seal in Falsterbo (Scania) exceeds all previous records. The recent decline in the populations of, especially, grey seal in the Baltic has been explained as being due to high concentrations of poisons which disturb the breeding of the species. Since also other factors such as hunting and ice conditions may influence the success of breeding of seals, the exact effect of poisons on the decline of seal populations is still unclear.

6. SUMMARY AND CONCLUSIONS

Although hardly a decade has passed since the first discoveries of mercury, DDT and PCBs in the Baltic animals were made, the investigations have already produced several generalizations, some of which have been presented in the abstract of this paper. One of the main results obtained is the discovery of relatively high levels of, especially, DDT in the animals of the central southern Baltic compared with those found in the same or closely related species inhabiting the west coast of Sweden or the Norwegian waters. The exact reasons for these differences are somewhat unclear, but several authors cited in this paper consider that the high level of contamination of the Baltic animals by pesticides is at least partly dependent on the small water volume, low primary production and limited exchange of water of that sea. It is also possible that the airborne fallout of organochlorines in the Baltic area where southwesterly winds dominate is larger than in areas west of Scandinavia and Denmark. The local differences found in the contamination levels of animals within the Baltic area seem to be closely related to agricultural and industrial activities; thus DDT levels are highest near effectively cultivated regions, while mercury and PCB contents are usually highest near industrial centres. Birds and some fish deviate somewhat from this general pattern, having high levels of pesticides even in uncontaminated areas, but it is possible that they obtain most of the contaminants during their migrations.

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