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POLYCHLORINATED HYDROCARBONS IN FISHES, BLUE MUSSEL (*MYTILUS EDULIS*), AND BOTTOM SEDIMENTS OF THE SOUTH-WESTERN BALTIC SEA

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Polychlorinated hydrocarbons are convenient indicators of environmental pollution. The aim of this study was to determine the presence of p,p'-DDT and its metabolites (p,p'-DDE and p,p'-DDD) and γ-HCH and PCBs in: the dorsal muscles of 3 most important fish species (cod, herring, and flounder), in blue mussels, and in the bottom sediments off the coast of the south-western Baltic Sea. The analyses were carried out using the method of gas chromatography. The presence of all analysed compounds was detected in the samples studied. The highest concentrations of polychlorinated hydrocarbons in the bottom sediments were stated at the coast of Kiel, while the lowest—in the Świnoujście area. In blue mussels no such significant differences in the content levels of the analysed compounds were observed. The muscles of herring demonstrated the highest content of ΣDDT and PCBs. The present results will constitute a contribution to the knowledge on the presence of polychlorinated hydrocarbons in the marine environment of the south-western Baltic Sea.

Key words: polychlorinated hydrocarbons, fishes, blue mussel, bottom sediments

INTRODUCTION

Polychlorinated hydrocarbons are characterised by their high chemical stability and resistance to atmospheric factors (Fishbein 1972, Södergren and Gelin 1983). Those compounds practically do not dissolve in water, but they dissolve well in organic solvents, fats, and natural oils. In bodies of water those compounds, as lipophilic, are quickly involved in the trophic circle and they are characterised by high bioaccumulation coefficients (Tatsukawa 1973, Harvey et al. 1974, Dexter and Field 1989). In addition to that, they adsorb to the mineral and organic particles of

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suspended matter and precipitate to the bottom (Abdullah et al. 1982, Barker 1984, Delbeke et al. 1990, Barker et al. 1991). The presence of polychlorinated hydrocarbons in water, even at low concentrations, adversely affects the development of many aquatic organisms and may lead to unfavourable qualitative changes in their specific composition (Glooschenko and Glooschenko 1975, Södergren and Gelin 1983, Łukowski and Ligowski 1988, Bystrzejewska et al. 1989, Everartes et al. 1990). Polychlorinated hydrocarbons are characterised by their high toxicity for aquatic organisms and their high bioaccumulation coefficient. Their global production before 1980 has been estimated to range between 1.2 (Tanabe 1988) and 2.0 (Anonymous 1979) million tons. It is estimated that about 60% of that ended up in the seas and oceans. About 30% of the former amount is accumulated in the coastal bottom sediments (Tanabe 1988). The principal source of pollution of water bodies with pesticides has been the runoff from the agricultural land.

Polychlorinated biphenyls (PCBs) reach the marine and inland waters in the form of industrial and communal sewage and solid industrial and municipal waste, stored at landfills from where they get to soil and surface waters. Utilisation of wastes containing PCBs is difficult, because they do not disintegrate, during their incineration in conventional furnaces, but they are carried up into the atmosphere.

All those compounds easily co-distillate with water to the atmosphere and can travel long distances with winds and they are ubiquitous on the earth surface from Antarctic to the North Pole (Popov 1983). Under natural conditions, polychlorinated hydrocarbons—as very stable compounds—undergo biodegradation in a low extent. Because in water bodies that accumulate mainly in the bottom sediments and in living organisms (Lin 1980, Balley et al. 1983, Larsson 1984, 1986, Ciereszko 2001) a number of studies had been initiated on the content of selected polychlorinated hydrocarbons in major pelagic and demersal fish species of the Baltic Sea and in the blue mussel inhabiting the bottom layers of waters and also in the bottom sediments in order to determine the environmental pollution and the pollution levels of selected living organisms constituting a food source.

MATERIAL AND METHODS

The material for the present study were fishes (herring, *Clupea harengus*; Atlantic cod, *Gadus morhua*, and flounder, *Platichthys flesus*) caught in October 1995 in the Pomeranian Bay. The samples of the bottom sediments and blue mussel (*Mytilus edulis*) were collected in March and October 1995 during the cruise of a German research vessel *R/V ALKOR*. The bottom sediments were sampled with a Van Veen sampler while the blue mussels—with a dredge. The samples were collected in the areas of: Kiel, Warnemünde, and Świnoujście (Pomeranian Bay) (Fig. 1).

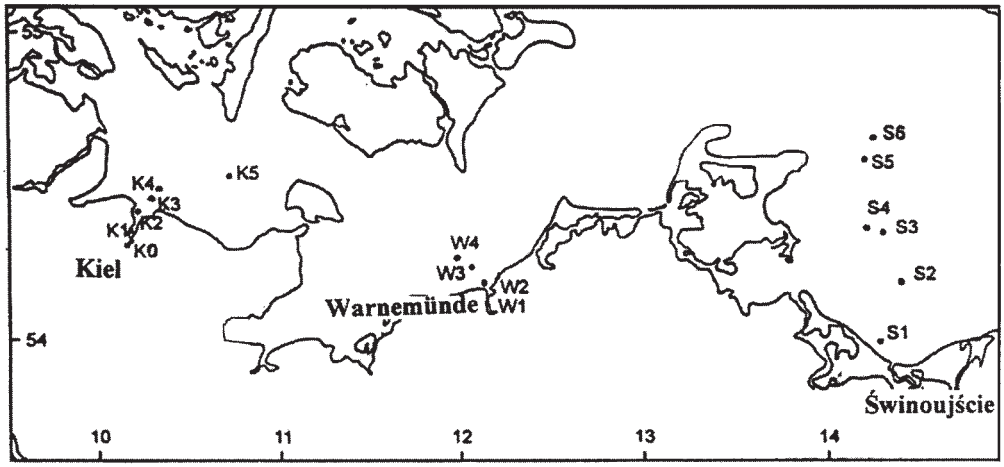

Fig. 1. Location of sampling areas of bottom sediments and blue mussel in south-western Baltic

Preparation of the bottom sediment samples to the analysis consisted in their mixing and preliminary drying at room temperature (18–20°C). Subsequently 100-g samples were grind in a mortar and drained through a sieve (2-mm mesh). Their 10-g sub-samples for analysing the compounds surveyed and 5-g sub-samples for determining dry weight were placed in 100-cm^3 conical flasks with glass stopper. Amounts of 50 cm^3 of n-hexane–ethyl ether mixture (2.5 : 1) and again 50 cm^3 of n-hexane–ethyl ether mixture (9 : 1) were used for extraction. After filtration the merged extracts, placed in a 250-cm^3 conical flask with glass stopper were condensed in a rotary vacuum evaporator down to the volume of 2.0 cm^3 and they were transferred quantitatively to 10-cm^3 calibrated conical test tubes with glass stoppers. The content of those tubes was condensed again in a hot air flow (50°C) to the volume of 1.0 cm^3 and purified with 7% SO_3 in concentrated H_2SO_4 and subsequently in 5% KOH in 96% C_2H_5OH.

To analyse those compounds in blue mussels, samples of soft tissues were taken from 50 specimens. They were subsequently homogenized and 10-g sub-samples were grind in a mortar with anhydrous Na_2SO_4 until they assumed the form of loose homogeneous mass. Extraction and purification was as described above.

The content of the analysed substances in fishes was determined in the dorsal muscles from below the dorsal fin. Samples from 10 specimens of each fish were homogenised and 10-g sub-samples were taken for analysis. They were grind with anhydrous Na_2SO_4 and transferred quantitatively to 250-cm^3 conical flasks. Extraction and purification was as described above.

The compounds studied were determined quantitatively and qualitatively with the method of gas chromatography, using Chromatron GCHF 18.3 with ECD trite detector, under the following conditions:

– 3-m glass column, 3-mm diameter, filled with Chromosorb Q 100-120 mesh, with 3% V-101 liquid phase,
– carrier gas: nitrogen, 30 $cm^3 \cdot min^{-1}$ flow,
– column- and detector temperature: 200°C, feeder temperature: 240°C.

The analyses were done in triplicate.

RESULTS AND DISCUSSION

The presence of the compounds surveyed was detected in all analysed samples of fish muscles, blue mussels, and the bottom sediments (Tables 1, 2).

The concentrations of those compounds in the muscle tissue of fishes from the Pomeranian Bay were many times lower than those in blue mussels, which are typical benthic organisms. The content of polychlorinated biphenyls and hydrocarbons in the muscles of cod and flounder did not differ significantly in the respect of the amounts of ΣDDT and PCBs. The concentrations stated in the muscles of herring were slightly higher than those determined in the muscles of cod and flounder. It may be explained by the higher lipid content in the muscles of herring (8.2%) than in flounder (1.8%) and cod (1.1%).

Wet weight content of γ-HCH in the samples of the soft tissues of blue mussel, irrespectively of the sampling site, were similar and their average value was 2.8 ±0.6 $\mu g \cdot kg^{-1}$. The highest concentrations of p,p'-DDT and ΣDDT, in the organisms surveyed, were found the area of Kiel, at sampling site W_3 in the area of Warnemünde (March), at W_2 (October), and at S_1 (March). The average ΣDDT content (wet weight) in blue mussels from Kiel was 59.1 $\mu g \cdot kg^{-1}$, from Warnemünde it amounted to 43.8 $\mu g \cdot kg^{-1}$, while from Świnoujście it was 35.9 $\mu g \cdot kg^{-1}$. Higher concentrations of p,p'-DDE and p,p'-DDD were found in blue mussels acquired in October at site K_2 near Kiel, while the lowest—near Świnoujście. The highest PCB concentrations were detected in soft tissues of blue mussels collected at sites K_2 and W_2 in October. In the remaining samples the relevant concentrations were lower and they did not differ significantly (Table 1).

The highest values of γ-HCH content (dry weight) in sediments were detected in the area of Kiel in March at sites K_4 and K_5 and in October at K_0, K_4, and K_5. At all sampling sites, in the areas of Warnemünde and Świnoujście, the concentrations of this compound oscillated around a similar level, with slightly higher value in October.

Table 1

Content of selected polychlorinated hydrocarbons in fishes and blue mussels from the south-western Baltic Sea ($\bar{x}$ ±s.d.)

Area of study	Month	Fishes and sampling site	Content (µg·kg^{-1}, wet weight)					
			γ-HCH	p,p'-DDT	p,p'-DDE	p,p'-DDD	ΣDDT	PCBs
			Fishes					
Pomeranian Bay	October	Cod	1.4 ±0.5	1.2 ±0.5	1.6 ±0.2	0.8 ±0.1	3.6 ±1.8	4.5 ±1.8
		Herring	1.4 ±0.5	3.0 ±0.2	4.2 ±2.2	2.4 ±1.0	9.6 ±2.2	6.5 ±2.2
		Flounder	0.9 ±0.1	1.6 ±0.5	0.9 ±0.7	1.0 ±0.6	3.5 ±1.7	5.2 ±0.7
			Blue mussel					
Kiel	March	K_1	2.2 ±0.6	51.4 ±9.7	1.5 ±1.1	4.9 ±2.1	57.8 ±14.2	26.2 ±4.6
		K_2	2.6 ±0.9	37.5 ±4.6	1.6 ±0.9	2.5 ±1.2	41.6 ±9.6	34.8 ±6.6
	October	K_0	3.1 ±1.0	55.1 ±8.9	3.1 ±1.6	4.3 ±1.8	62.5 ±11.8	35.0 ±7.2
		K_2	2.0 ±0.4	49.0 ±6.3	11.6 ±3.8	13.9 ±5.8	74.5 ±15.3	62.7 ±12.7
Warnemünde	March	W_1	3.4 ±0.9	27.1 ±3.4	3.1 ±2.1	2.1 ±0.8	32.3 ±5.8	30.1 ±9.6
		W_2	3.5 ±1.0	27.8 ±4.1	2.9 ±1.9	3.5 ±1.4	34.2 ±6.1	28.5 ±7.2
		W_3	3.6 ±0.8	43.5 ±6.2	4.4 ±2.3	4.8 ±2.3	52.7 ±9.0	38.6 ±10.2
	October	W_2	3.1 ±0.8	44.0 ±8.1	2.3 ±1.7	8.1 ±3.7	54.4 ±11.0	61.4 ±13.4
		W_3	2.1 ±0.6	34.5 ±5.7	4.2 ±1.8	6.9 ±1.9	45.6 ±8.1	30.6 ±8.2
Świnoujście	March	S_1	3.2 ±0.9	82.3 ±11.3	2.9 ±1.1	1.7 ±0.8	87.4 ±17.3	25.8 ±4.4
		S_2	2.4 ±0.4	19.5 ±1.6	1.8 ±0.9	1.8 ±1.1	23.1 ±7.1	27.0 ±5.2
		S_3	2.8 ±0.6	18.8 ±2.1	1.1 ±1.1	1.1 ±0.6	21.0 ±4.8	24.2 ±3.8
		S_5	3.5 ±0.9	16.6 ±1.4	2.2 ±0.9	2.2 ±1.3	21.0 ±3.9	34.6 ±5.5
		S_6	2.8 ±0.7	30.5 ±7.6	3.3 ±2.1	3.3 ±1.6	37.1 ±7.4	37.3 ±6.1
	October	S_2	3.3 ±0.8	32.7 ±6.8	2.1 ±0.8	2.1 ±1.4	36.9 ±6.6	32.8 ±5.7
		S_3	2.5 ±0.4	34.0 ±6.6	1.4 ±0.8	2.6 ±1.4	38.0 ±8.2	36.2 ±5.8
		S_4	1.9 ±0.5	20.1 ±1.7	1.1 ±0.4	1.7 ±0.8	22.9 ±2.6	26.4 ±4.2

Table 2

Content of selected polychlorinated hydrocarbons in bottom sediments from the south-western Baltic Sea ($\bar{x}$ ±s.d.)

Area of study	Month	Sampling site	Content (μg·kg^{-1}, dry weight)					
			γ -HCH	p,p'-DDT	p,p'-DDE	p,p'-DDD	ΣDDT	PCBs
Kiel	March	K_1	4.0 ±1.1	662.3 ±61.8	26.7 ±3.1	101.1 ±11.7	790.1 ±103.8	192.4 ±21.3
		K_2	5.0 ±0.9	58.2 ±6.1	1.8 ±1.7	8.7 ±1.8	68.7 ±7.1	16.3 ±2.1
		K_3	5.0 ±1.3	119.4 ±17.9	27.8 ±4.8	13.5 ±1.4	160.7 ±19.3	41.8 ±3.7
		K_4	7.1 ±2.1	79.8 ±8.1	2.4 ±1.2	13.5 ±1.7	95.7 ±10.2	42.6 ±4.2
		K_5	6.8 ±1.7	15.4 ±2.2	1.7 ±0.3	2.3 ±1.1	19.4 ±4.1	15.0 ±1.8
	October	K_0	8.1 ±2.7	701.3 ±57.2	32.3 ±4.2	121.3 ±8.7	854.9 ±87.4	201.2 ±19.7
		K_1	6.8 ±2.4	671.3 ±11.3	2.3 ±0.7	1.9 ±1.1	675.5 ±37.9	224.7 ±21.3
		K_2	5.8 ±1.9	123.1 ±15.3	10.3 ±1.9	15.2 ±4.2	148.6 ±27.3	21.4 ±4.9
		K_3	5.7 ±2.0	132.7 ±16.3	33.3 ±6.2	14.3 ±3.7	180.3 ±26.4	53.4 ±3.9
		K_4	8.2 ±1.2	83.2 ±9.2	3.7 ±2.8	2.4 ±0.9	89.3 ±15.8	49.7 ±4.1
		K_5	7.2 ±2.1	21.7 ±6.4	2.1 ±0.8	1.9 ±1.1	25.7 ±7.6	17.8 ±2.1
Warnemünde	March	W_1	3.6 ±0.8	5.9 ±0.9	1.3 ±0.8	1.8 ±1.2	9.0 ±2.4	8.7 ±3.3
		W_2	2.8 ±1.0	6.2 ±1.7	1.3 ±1.1	1.8 ±0.6	9.3 ±2.2	3.0 ±1.7
		W_3	3.9 ±0.9	4.3 ±1.1	1.4 ±0.8	1.9 ±1.0	7.6 ±1.9	10.5 ±3.7
		W_4	3.5 ±1.2	17.5 ±3.1	1.9 ±1.2	1.3 ±0.8	20.7 ±3.7	12.8 ±2.9
	October	W_2	4.1 ±0.9	7.1 ±1.2	1.9 ±0.7	1.6 ±0.4	10.6 ±1.7	10.4 ±3.8
		W_3	4.2 ±1.8	7.7 ±1.4	1.8 ±0.8	2.1 ±0.9	11.6 ±2.1	5.7 ±1.4
		W_4	4.1 ±1.3	21.4 ±5.6	2.3 ±1.1	1.7 ±1.1	25.4 ±6.8	17.5 ±3.3
Świnoujście	March	S_1	3.3 ±0.7	4.0 ±1.2	0.4 ±0.7	0.6 ±0.4	5.0 ±1.7	3.9 ±1.7
		S_2	3.6 ±0.8	4.6 ±1.1	0.9 ±0.9	1.2 ±0.5	6.7 ±1.8	4.3 ±1.9
		S_3	3.0 ±1.1	7.9 ±2.0	0.8 ±1.0	1.5 ±0.7	10.2 ±2.5	5.8 ±1.9
		S_5	3.2 ±1.0	7.2 ±1.6	2.3 ±1.4	2.1 ±1.1	11.6 ±1.9	10.5 ±2.7
		S_6	3.0 ±0.8	7.0 ±1.4	1.8 ±1.1	1.9 ±1.3	10.7 ±1.9	9.9 ±2.4

In general, higher p,p'-DDT contents were recorded in samples of bottom sediments from the area of Kiel. The highest values were stated in March at site K_1 and in October at K_0 and K_1, while the lowest—at K_5. In the sediments from the areas of Warnemünde and Świnoujście the concentrations of this compound were on the similar level and they were significantly lower than those at the coast of Kiel. Concentrations of p,p'-DDE, p,p'-DDD, and ΣDDT were the highest in the sediments from the area of Kiel at the same points as p,p'-DDT, and in the area of Warnemünde and Świnoujście they were substantially higher and they oscillated around a similar level at individual sampling sites. Similar concentrations of polychlorinated biphenyls in the bottom sediments in March and October were higher in the area of Kiel, particularly at sampling sites K_0 and K_1, than at the coasts of Warnemünde and Świnoujście. Lower PCB concentrations in the bottom sediments were recorded at all sampling sites in the areas of Warnemünde and Świnoujście, particularly at sites W_2 and S_1. Concentration levels of the compounds studied in the areas of Warnemünde and Świnoujście are consistent with the results of Strandberg et al. (1998) from north-western Baltic Sea and only the present data from the Kiel coast were much higher.

No differences in ΣDDT concentration levels in the bottom sediments and in blue mussels were observed between individual areas. Particularly high ΣDDT concentrations in the bottom sediments in the area of Kiel (on the average 282.6 $\mu g \cdot kg^{-1}$ dry weight) did not translate into proportionally high its concentrations in the soft tissues of blue mussels. The latter value was by about 26 percentage points higher than that in blue mussels from the area of Warnemünde, despite that the bottom sediments from the latter locality contained 20 times less ΣDDT than the bottom sediments near Kiel. There was, on the other hand, a close correlation between ΣDDT content in the Baltic bottom sediments in the areas of Warnemünde and Świnoujście and the content of those compounds in blue mussels. Elevated SDDT content in the sediments was reflected in its elevated contents in blue mussels.

CONCLUSIONS

1. The compounds surveyed were present in all samples examined.
2. Herring muscles contained more ΣDDT and PCB than the muscles of flounder and cod.
3. Blue mussels from the area of Kiel contained the highest amounts of ΣDDT reaching 59.1 $\mu g \cdot kg^{-1}$. Those from Warnemünde contained 43.8 $\mu g \cdot kg^{-1}$, while those from Świnoujście contained 35.9 $\mu g \cdot kg^{-1}$ of dry weight.
4. The highest values of ΣDDT and PCB in the bottom sediments were recorded near the coast of Kiel where the average value was 282.5 $\mu g \cdot kg^{-1}$ (of dry weight). The lower values were observed in Warnemünde (13.5 $\mu g \cdot kg^{-1}$) and Świnoujście (9.9 $\mu g \cdot kg^{-1}$).
5. The differences in the content of the compounds studied were not as high in blue mussels from different areas as they were in the bottom sediments.

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