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ECOTOXICOLOGY OF ORGANOCHLORINE RESIDUES IN MARINE ECOSYSTEMS.

K. DELBEKE, C. JOIRIS
Laboratory for Ecotoxicology
Vrije Universiteit Brussel
B-1050 Brussels, Belgium

62265

ABSTRACT

Organochlorine residues were determined in particulate matter, sediments, zooplankton, fish and seabirds. Samples were collected at different sites of the North Sea and in different periods of the year. Comparison of contamination levels, on a dry weight base, lipid weight base and volume base (per m^3 water) contributes to the understanding of transfer mechanisms of organochlorine residues in the North Sea. The results show the stability of the contamination of particulate matter by PCB's, when expressed per water volume. The expression of PCB levels on a lipid base is shown to be important for all compartments studied: particulate matter, zooplankton, fish and seabird. The importance of the indirect contamination (through the food) is clearly noted for zooplankton and seabirds; for fish, arguments are favouring the direct and indirect ways of contamination: a definitive conclusion is depending on new laboratory experiments.

1. INTRODUCTION

The mechanisms governing transfer and accumulation of organochlorine residues in marine ecosystems are still subject to much controversy and discussion. We therefore tried to elucidate some of these mechanisms in the North Sea ecosystem.

The problem was studied in three steps :

(1) a general study of the contamination levels of the main compartments (particulate matter, zooplankton, fish, seabirds , sediments), on a dry weight, fat weight basis and per volume unit (m^3) (Bouquegneau, Joiris and Delbeke, this volume).

(2) comparison of contamination levels between different periods and zones of the North Sea, on dry weight basis, fat weight basis and per volume

(3) comparison between the results obtained on the field and laboratory experiments as taken from the literature.

2. MATERIAL AND METHODS

The biological material consists of (1) particulate matter(mainly phytoplankton), collected by continuous centrifugation and in sediment traps; (2)sediment cores;(3) 215µm net samples : zooplankton (sometimes containing Phaeocystis) (4) small fish provided by the bycatch; (5) seabirds found dead.

Lipids were extracted with hexane (Soxhlet extraction for 10 hours) and the organochlorine residues determined by Gas-liquid chromatochraphy as described in Joiris et al. 1979.

3. RESULTS AND DISCUSSION

PCB compounds similar to Arochlor 1254, were detected in all samples (detection limit : 10 $ng.g^{-1}$ dry weight).
No other organochlorine residues (DDT or its metabolites, aldrin, dieldrin, endrin, heptachlore, heptachlore epoxide, lindane, HCB) were present in measurable amounts in particulte matter, sediments nor zooplankton. In fish, pp'DDE and dieldrin were found; in seabirds pp'DDE, dieldrin, heptachlore epoxide, lindane and heptachlore (in order of decreasing concentrations) were present.

3.1. Particulate matter (POM) and sediments.

The association between the PCB and fat content of POM and sediments (consisting of fall-out from POM, plus sand or clay) can be taken from figures 1 and 2.

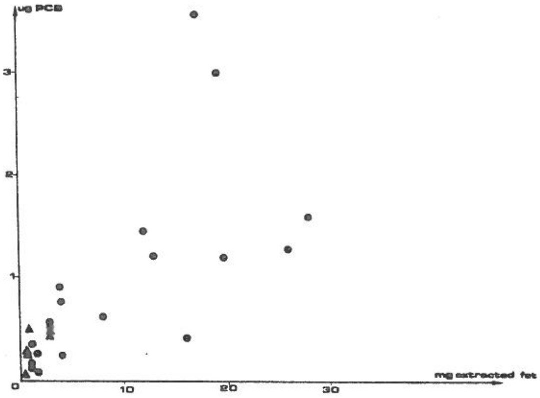

Fig. 1. Relation between PCB levels and fat levels of particulate matter (both on a dry weight basis) collected in the Belgian coastal zone of the North Sea.
● collected trough centrifugation
▲ collected in sediment traps

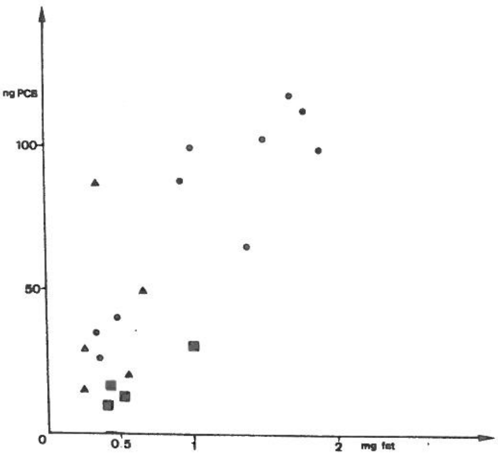

Fig. 2. Relation between PCB levels and fat levels of sediment samples (both on a dry weight basis) collected in the Belgian coastal zone of the North Sea.

● a station close to Zeebrugge containing many clay particles
■ and ▲ stations close to Ostend, containing many sand particles.

Comparison of PCB levels per dry weight and per m^3 (table 1) indicates that the amount of PCB's adsorbed on the particulate matter in a volume of seawater is rather constant (5-6.5 $\mu g/m^3$, with the exception of 1 sample in the coastal zone of the Southern Bight in April 1983). The PCB concentration expressed per dry weight, carbon weight, fat weight is thus dependent on the amount of particulate matter present in the watercolumn; this shows how important it is not to express all contamination results on a weight basis only. These findings agree very well with laboratory results obtained by Brown et al.,(1982).

Table 1. PCB levels in particulte matter. Median values (n = number of samples)

Identification	n	PCB $\mu g.g^{-1}$ dry weight	$\mu g.m^{-3}$
Southern Bight, April 1982	5	0.52	5.5
Southern Bight, May 1982	7	1.28	6.1
Southern Bight, October 1982	5	0.15	-
Southern Bight, April 1983	1	0.49	23.9
English Channel, April 1982	2	0.69	6.5
English Channel, May 1982	2	2.40	6.5
English Channel, October 1982	3	0.22	-
English Channel, May 1983	1	0.09	4.8

3.2. Zooplankton

Zooplankton (here mainly copepods) can be contaminated by PCB directly through adsorption from the water (partitioning) or indirectly through feeding. If direct uptake is the major uptake mechanisms for zooplankton than, some relation between the PCB and lipid content should be noted, at least within one region or period.
No such relationship could be observed, wether considering all samples pooled or considering zooplankton from each period or region seperately (Table 2). An indirect uptake of PCB compounds through feeding is therefore more likely as a primary uptake mechanism for PCB compounds than adsorption-partition. An indirect uptake as main mechanisms for PCB accumulation in zooplankton is in contradiction with the findings of Clayton et al, 1977 or Franco et al., 1981 but agrees with laboratory results from Wyman and O'Connor (1980) or Brown et al., (1981).

Table 2. PCB residues in zooplankton. Median values (n = number of samples)

Identification	n	PCB $\mu g.g^{-1}$ dry weight	PCB $\mu g.g^{-1}$ lipid weight
Ostend, June 1982	1	1.20	6.7
West-Hinder, July 1982	6	0.35	4.1
West-Hinder, September 1982	5	0.51	6.5
Belgian coast, June 1983	2	0.86	1.71
Southern bight, September 1983	5	1.84	9.43
English Channel, April 1982	3	0.09	24
N. North Sea, September 1983	11	0.36	1.82

During the cruise of September 1983 (fig. 3) regional contamination differences could be observed for zooplankton.

(1) A higher contamination level exists in the Southern Bight as compared to the northern North Sea. The might reflect the existence of two different water masses : North Sea with lower, and Atlantic with higher salinities (Table 3).

(2) The highest levels are noted on the banks of the Southern Bight.

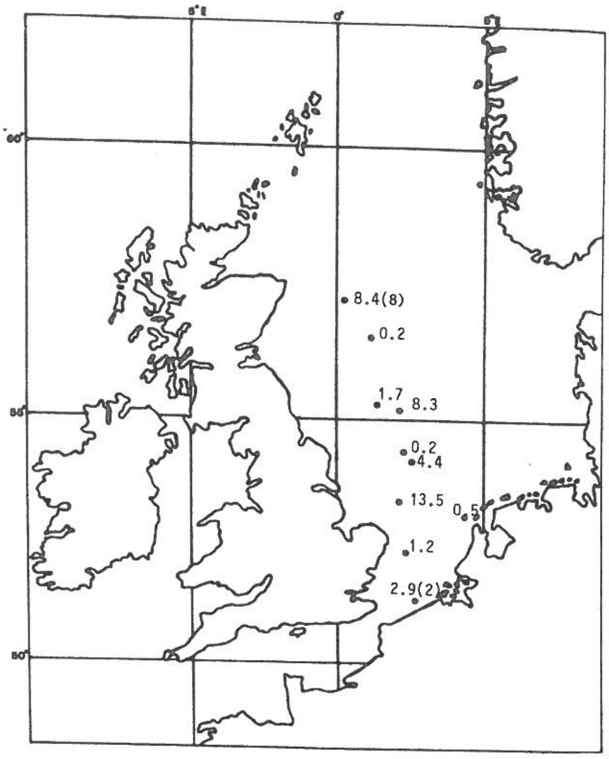

Fig. 3. PCB contamination levels ($\mu g.g^{-1}$ dry weight) of zooplankton sampled in the North Sea.

Table 3. Geographical differences in the PCB levels of zooplankton. September 1983 (n=number of samples, $\bar{m}$ = mean) (a) Picard (pers. com.)

Salinity °/°° (a)	T° °C (a)	POSITION N	POSITION E	DATE Day		DATE (hour)	PCB $\mu g.g^{-1}$ dry weight (n)	
North Sea (Southern Bight)								
32.69	17.73	51°25	02°80	09	-	(15)	2.9 (2)	
34.30	16.96	52°38	02°40	10	-	(06)	1.2 (2)	$\bar{m}$ = 1.8
31.00	16.90	53°00	04°70	11	-	(18)	0.5 (1)	
34.09	13.66	55°34	01°34	17	-	(08)	1.7 (1)	
Banks								
34.39	15.19	53°46	02°46	10	-	(13)	13.45 (1)	
34.66	15.73	54°32	02°19	10	-	(19)	0.2 (1)	$\bar{m}$ = 6
34.85	15.91	54°23	02°58	11	-	(07)	4.4 (1)	
Atlantic (Northern North Sea)								
34.54	14.06	55°16	02°03	13	-	(19)	0.3 (1)	
34.71	13.75	56°54	01°23	14	-	(07)	0.2 (1)	$\bar{m}$ = 0.4
35.07	12.02	57°35	00°40	14	-	16	0.4 (8)	

3.3. Fish

Muscles of small fish (bycatch) show the same contamination level (12 $\mu g.g^{-1}$ fat weight), as the fillets of commercial species of the Southern North Sea (9 $\mu g.g^{-1}$fat) (Vandamme and Baeteman 1982, 1984).
A strong correlation (Fig. 4) is noted between the amount of PCB and the amount of fat in the different fish species caught in the North Sea and representing a wide variety of dietary habits and lifestyles.
This is an indication for adsorption-partition as the most important pathway of PCB uptake by fish in the North Sea. Varying contamination levels with age or season (Vandamme and Baeteman 1982, 1984), on the other hand, are an indication of uptake through food, but could also caused by the existence of a stocking mechanism, such as de novo formation of lipid globules.
As not enough information exists on uptake mechanisms of PCB's by marine fish in controlled laboratory conditions, it is difficult to draw conclusions on the main uptake mechanisms of PCB's by marine fish : this has clearly to be solved by laboratory experiments.

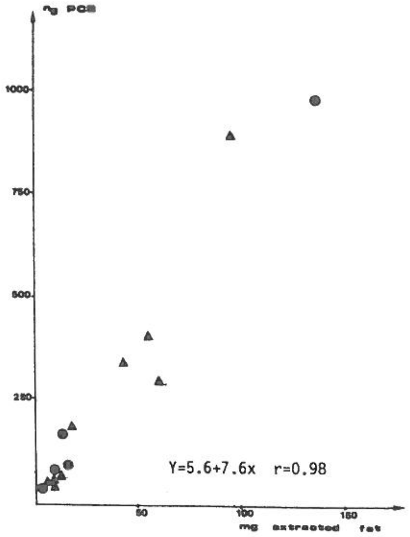

Fig. 4. Relation between mean PCB levels and fat levels for different species of fish (Fish fillets) (fresh weight base)
● this study; ▲ From Vandamme and Baeteman 1982, 1984.

3.4. Seabirds

An important bioaccumulation of organochlorine residues by seabirds is evident (see Bouquegneau, Joiris and Delbeke, this volume).
Contamination differences between muscle and liver are mainly due to differences in fat levels (Table 4).
The PCB/DDE ratio of Larus canus is very close to the ratio (between 2 and 5) observed in terrestrial systems (Joiris and Delbeke, '81,'85)reflecting the more terrestrial feeding habits of the Larus gulls. The much higher values (15 and more) in Guillemots and Fulmars are probably typical for marine systems.

4. CONCLUSION

Transfer mechanisms of organochlorine residues in marine ecosystems can be evaluated by determining contamination levels in the field and comparing them with laboratory experiments.
The results obtained in the field have to be expressed in three systems of units : dry weight (or fresh or carbon), fat weight and per water volume. This approach shows the influence of the variations in the amount of particulate matter on its contamination level, since the PCB levels of POM remains constant per volume of seawater. It also indicates the importance of food in the contamination of zooplankton. Finally, it shows the important bioaccumulation taking place from zooplankton and fish to seabirds.
For fish, the contamination levels could indicate the importance of direct partition but no adequate laboratory experiments are yet available to validate this statement.
A difference in the ratio of surface available for adsorption compared to body volume may be at the root of the difference in PCB uptake between zooplankton and fish : the gills of fish enlarge the adsorption surface, whereas the chitinous corvering of copepods may constitute a barrier to PCB compounds.

Table 4. Organochlorine residues in seabirds ($\mu g.g^{-1}$ fresh weight, median values) (ND = not detected).

Bird species (main diet)	Tissue	n	$\%H_2O$	% fat	PCB	DDE	Dieldrin	Lindane	Heptachlore	Hept.epox	ratio $\frac{PCB}{DDE}$
Guillemot *Uria aalge* (fish)	muscle	19	33	0.73	5.45	0.29	0.03	0.01	0.01	0.04	18.8
	liver	19	39	3.8	71.60	2.40	0.47	0.09	0.03	0.30	29.8
Fulmar *Fulamarus glacialis* (zooplankton,fish)	muscle	4	26	1.0	27.60	1.70	0.02	0.01	ND	0.16	16.2
	liver	5	61	5.7	92.50	5.89	0.05	0.06	ND	0.34	15.7
Common Gull *Larus canus* (offall)	muscle	9	34	6.9	0.55	0.14	0.07	0.04	ND	0.03	3.9
	liver	6	35	3.7	0.44	0.05	0.01	0.01	ND	0.01	8.8