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Concentrations and Metabolism of PCBs in Eggs of Waterbirds on the German North Sea Coast

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Among environmental chemicals found in top predators the polychlorinated biphenyls (PCB) often occur at high concentrations and are of toxicological relevance (DFG 1988, Elliott et al. 1990). Not only concentrations but also the composition of the PCB mixtures, which consist of many congeners of different degrees of chlorination, vary among species and sites (Heidmann & Beyerbach 1989, Heidmann et al. 1990).

In this paper we show the interspecific variation in PCB concentrations and in the degree of metabolism of the PCB mixtures in eggs of 11 waterbird species breeding on the highly polluted German Wadden Sea coast (Becker 1989), where the PCB contamination of birds has been increasing during the last decade (Becker et al. 1991).

MATERIALS AND METHODS

In 1987 we collected eggs of 11 coastal bird species (Table 1) from five breeding sites at the Jade, German Wadden Sea. Ten fresh eggs per species were collected after completion of a clutch; one egg per clutch was taken. All eggs of one species originate from the same site. Eggs from different species from different sites are comparable as at the Jade no intersite differences in contamination with PCBs were found within common terns and oystercatchers (Becker et al. 1991). All samples were frozen to -18°C prior to further treatment.

The preparation of the samples and the determination of 45 PCB congeners have been described by Heidmann (1986). Concentrations are given as mg/kg fresh weight egg without shell. The detection limit was 0.001 mg/kg per congener.
To characterize the PCB mixtures the following parameters were used:

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Sum of PCB: concentrations of the individual congeners are added, the unit is mg/kg (ppm).
Degree of metabolism: difference between the mean weighted degree of chlorination of the environmental samples and the mean weighted degree of chlorination of a standard PCB-mixture (Clophen a 60/Arochlor 1254 1:1) (Heidmann & Beyerbach 1989). The standard PCB mixture is expected to be similar to these PCBs set free into the environment and is used because the real composition of the technical PCB-mixture, which is released into the environment, is not known and varies with time and location (Heidmann 1986).

The mean weighted degree of chlorination is calculated by the sum of the products of the number of chlorines of each congener and of the molar concentration of this congener in the PCB mixture. With this formula a mean weighted degree of chlorination of 5.54 was found for the standard PCB mixture and of 5.7 - 6.0 for the waterbirdeggs. During metabolism of PCBs the lower chlorinated PCBs are more readily metabolized so that the degree of chlorination increases. Thus the difference between environmental samples and standard mixture is assumed to represent the degree of metabolism.
The results were evaluated with a oneway analysis of variance; the means were compared with Tukey`s w-procedure.

RESULTS AND DISCUSSION

The terns and the shelduck were the species contaminated most with PCBs followed by the oystercatcher (Table 1). Intermediate levels were found in gulls, common eider and avocet. The least contaminated species were ringed plover and redshank.

Regarding the degree of metabolism another order was found. The patterns of the PCB mixtures of the highly contaminated terns` eggs result in a low degree of metabolism with values as low as the ringed plover and the redshank (Table 1). Higher metabolized PCB mixtures were found in shelduck, common gull, oystercatcher, avocet and herring gull, whereas common tern, black-headed gull and common eider were in an intermediate position.

The high contamination of the terns is explainable with their high position in the food-chain (Table 2), consuming fish, a highly contaminated food (Becker et al. 1991, Focardi et al. 1988). Terns arrive in the Wadden Sea some weeks before egg laying. Accordingly considerable amounts of lipids and proteins must be mobilized within a short time to produce the eggs.

Table 1 : PCB concentration (mg/kg) and degree of metabolism in eggs (n=10) of 11 waterbird species

Species	ΣPCB	Degr. of Met.
Sandwich Tern (Sterna sandvicensis)	5.14 ± 1.11	0.17 ± 0.05
Common Tern (Sterna hirundo)	3.85 ± 1.34	0.33 ± 0.08
Shelduck (Tadorna tadorna)	3.80 ± 1.51	0.48 ± 0.07
Oystercatcher (Haematopus ostralegus)	3.03 ± 0.95	0.41 ± 0.02
Common Gull (Larus canus)	1.87 ± 1.43	0.42 ± 0.08
Common Eider (Somateria mollissima)	1.76 ± 0.64	0.35 ± 0.07
Herring Gull (Larus argentatus)	1.45 ± 0.58	0.40 ± 0.11
Avocet (Recurvirostra avosetta)	1.34 ± 0.82	0.41 ± 0.15
Black-headed Gull (Larus ridibundus)	1.15 ± 0.77	0.34 ± 0.11
Ringed Plover (Charadrius hiaticula)	1.10 ± 0.56	0.28 ± 0.05
Redshank (Tringa totanus)	0.93 ± 0.33	0.21 ± 0.12
highly significant difference	1.49	0.13

Means that differ more than the highly significant difference (Tukey's w-procedure) from each other, are significantly different at the level of $p \leq 0.05$.

This is possible through assimilation of food, through the mobilization of bodylipids or a mixture of both (Hoerschelmann et al. 1979). But parts of the body reserves of lipids have been stored in the Wadden Sea. Because of this, the contamination with pollutants in the breeding area is directly visible in the eggs and the distinct intersite variation of the PCB mixtures in the Wadden Sea could be revealed by the eggs of terns (Becker et al. 1991).

On the other hand the degree of metabolism of the PCB mixtures was low in terns. We explain this fact by their temporary limited presence in the contaminated Wadden Sea. Owing to this the PCB-metabolizing enzymes are induced through ingestion of PCBs during the breeding season in the Wadden Sea (Elliott et al. 1990, Goerke & Weber 1990). For the rest of the year, characterized by very low new uptake of PCBs in the less industrialized winterquarters, a lower metabolism of the PCBs can be expected.

The relatively high PCB contamination of shelduck and oystercatcher is not explained by the type of their food (Table 2) which is in lower position in the food net than the terns` diet. However, both species stay in the Wadden Sea for the whole year permanently taking food contaminated by PCBs.
Therefore, their enzymesystem is continously induced leading to PCB mixtures that have a high degree of metabolism. The three species of gulls investigated are more or less resident in the Wadden Sea and adjacent areas beyond the breeding season. Their broad spectrum of diets results in an intermediate PCB contamination, their presence over the whole year in a high degree of metabolism. In a similar situation, with respect to migration, is the common eider, characterized by an intermediate degree of metabolism, too.

Table 2 : Diets of the investigated waterbird species after Becker et al. (1985)

Species	Food	Parts of Plants	Worms	Mussels/Snails	Crustaceans	Insects	Echinodermata	Fish	other Vertebrates	Waste
Sandwich Tern								1		
Common Tern			3	3	2	3		1		
Shelduck		2	2	2	3	3				
Common Eider			3	1	3	3	3			
Oystercatcher			3	1	2	3				
Common Gull		3	1	2	3	2	3	2	3	3
Herring Gull			2	2	2	3	2	2	3	2
Black-headed Gull		3	1	2	2	1		2	3	2
Avocet			1		1	1				
Ringed Plover			1	3		1				
Redshank			1	1	1	3				

1 = predominant
2 = often
3 = occasional

An exception from the discussed facts was the avocet. Indeed this bird showed a low contamination level dependent on its food, but in contrast to the other studied migratory birds the PCB mixture of the avocet was highly metabolized. There may be two possible explanations for this result.

First, this species may have a modified enzymatic system. Secondly, the avocet winters in France, Portugal and northern Africa down to Senegal. If PCB contamination occurs in these winterquarters, the enzymatic system should be induced, and the PCB mixture could be metabolized.
Further investigations of the PCB mixtures of food animals of the avocet from Germany down to Portugal may give evidence to this interpretation.

High PCB concentrations in eggs of a bird species must not have toxic effects on the birds. Perhaps these high values are in part a consequence of the storage of PCB without any metabolism. In this case there would be no negative effects on the metabolism of the animals. In contrast, however, it may be possible that a species with low PCB contamination could be damaged through the metabolized part of the PCB mixture. It is not clear if the metabolized, but not measurable part, or the stored part of the PCBs is the greater damage for the animal.

The degree of metabolism is an index for the metabolized PCB in the body. The concentrations of persistent xenobiotics in gill-breathing animals are often in a state of equilibrium with the surrounding water (Falkner & Simonis 1982, Larsson 1984, Ernst 1985). Consequently, species with a high degree of metabolism that feed on gill-breathing animals, should be more influenced by PCB than animals with comparable feeding behavior and a low degree of metabolism.

Further investigations are necessary to get information on the PCB levels and mixtures in top predators like birds as well as in their diets to draw conclusions about metabolism and toxicity of PCBs in food chains.

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