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PCBs in Lake Geneva (Lake Leman) Fish

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Lake Leman is one of the largest lakes in western Europe ; 2/3 of the lake belongs to Switzerland and the other third to France. The families of more than 50 professional fishermen live off fishing along the French coast. For several years the economically important species (Chars, Coregonines) have been decreasing in number due in part to an ever increasing pollution of the lake.
Recently, fish have shown high levels of contamination by organochlorine residues (pesticides and PCB) and unfortunately the entire "Leman ecosystem" has been affected (MOWRER et al. 1982). We determined the PCB levels of 4 fish species which were collected in the French part of the lake. The factors of intra-and extra-species variations of contamination and the risks in reproduction were studied. These results are included in a more general study of lake Leman contamination by organochlorines residues.

MATERIALS AND METHODS

Fish collection : Fish species were selected according to their trophic level and plentifulness : Chars (*Salvelinus alpinus*) a predator species ; Perches (*Perca fluviatilis*) less predator, Roaches (*Rutilus rutilus*) primarily omnivorous and Coregonines (*Coregonus* species) strictly planktivorous.
Professional fishermen caught the fish during the period of reproduction. The fish were then wrapped in aluminium foil and frozen at -18° C until they were analysed.

Sample treatment : Afterwards the frozen fish were weighed, measured and examined. Organs taken for analysis were : gills, kidney, liver, gonads, muscle and abdominal fat. According to species, we took the scales, otolithes or vertebra in order to determine the age of the fish.

Analytical method : 1 to 10 g of sample was pounded in hexane. After centrifugation the hexanic phase was poured into a distillation flask previously weighed. This step was carried out 3 times. The hexanic extract was then evaporated, and the flask weighed to determine the sample lipid content. 10 ml of hexane was added and about 5 ml was purified with 1 to 2 ml of concentrated sulfuric acid. pp'-DDE, pp'-DDD and pp'-DDT (ΣDDT) which have nearly the same gas chromatographic retention times as several major PCB homologues in the samples, were converted to dichlorobenzophenone (DCBP) according to methods developed by JENSEN and coworkers

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(JENSEN et al. 1972-1974). The final hexanic extract was analyzed with electron capture detector. Quantification was performed with regard to DP_6 (a French product similar to Aroclor 1260) because the PCB detected in all samples most closely resembled DP_6 although PCB lighter than those most abundant in DP_6 were also present. The recovery of the method was 97 % and the results are given with an error less than 5 %.

RESULTS AND DISCUSSION

PCB concentrations expressed in terms of fresh weight and lipid weight are presented in table 1 and 2.

TABLES 1 and 2 : PCB levels (ppm) of the 4 fish species studied (in parentheses : number of fishes analysed)

(1) males

Species		Chars (5)	Coregonines (6)	Roaches (5)	Perches (23)
Age (years)		3 to 6	3	3 to 6	1 to 3
Gills	/f.w.	0.12 to 0.24	0.05	0.20 to 0.24	0.28 to 0.32
	/l.w.	4.8 to 24	2.8	6.9 to 14	12 to 18
Muscle	/f.w.	0.31 to 1.30	0.04	0.04 to 0.29	0.04 to 0.08
	/l.w.	22 to 41	2.4	5.7 to 15	10 to 12
Kidney	/f.w.	0.18 to 0.47	0.28	0.48 to 1.3	0.34 to 0.47
	/l.w.	12 to 29	3.9	7.6 to 13	6.8 to 8.9
Liver	/f.w.	1.1 to 2.7	0.12	0.21 to 1.25	0.21 to 0.29
	/l.w.	15 to 38	3.8	5.3 to 21	13 to 17
Milt	/f.w.	0.39 to 0.58	0.06	0.04 to 0.33	0.20
	/l.w.	14 to 16	3.9	4.4 to 17	10 to 12
Abdominal	/f.w.	5.2 to 13	4.2	6.3 to 18	6.0 to 20
fat	/l.w.	25 to 40	4.8	9.7 to 23	8.3 to 26

(2) females

Species		Chars (4)	Coregonines (7)	Roaches (10)	Perches (4)
Age (years)		3 to 6	2	3 to 6	2
Gills	/f.w.	0.19 to 0.25	0.06	0.08 to 0.18	0.14
	/l.w.	11 to 22	2.5	5.8 to 8.0	3.5
Muscle	/f.w.	0.34 to 2.5	0.07	0.07 to 0.23	0.05
	/l.w.	13 to 22	4.4	7.0 to 11	17
Kidney	/f.w.	0.28 to 0.37	0.41	0.40 to 0.61	0.64
	/l.w.	11 to 15	5.3	6.0 to 12	8.5
Liver	/f.w.	0.29 to 0.72	0.01	0.20 to 0.70	-
	/l.w.	9.4 to 17	0.56	9.1 to 12	-
Eggs	/f.w.	0.17 to 0.22	0.19	0.04 to 0.11	0.09
	/l.w.	14 to 22	3.0	9.7 to 20	6.4
Abdominal	/f.w.	2.7 to 8.4	4.9	3.7 to 5.8	9.9
fat	/l.w.	16 to 22	6.3	4.5 to 9.8	15

Contamination levels : In many studies, PCB levels are expressed on a whole body basis, nevertheless we shall try to compare these with our results.
The levels that we measured are within the same range as those found by other workers on fishes in lake Leman (MOWRER et al. 1982).
Fish are rather highly contaminated since PCB levels are higher than those found in the same species living in Northern European lakes : in lake Païjanne (Finland) Coregonines contained 0,07 ppm PCB, Roaches 0,07 ppm also and Perches 0,05 ppm (levels expressed on a whole body basis) (HATTULA et al. 1978). In Sweden, Roaches of lake Roxen had 10 ppm PCB (on a lipid basis) in muscle (OLSSON et al. 1978) and those of lake Havgärd were contaminated with 0,6 ppm PCB and Perches with less than 4 ppm (on a lipid basis) (SODERGREN 1973).
In North America, Coregonines of lake Superior seemed to be yet more contaminated than those of the Leman : 0,7 ppm (VEITH et al. 1977) and 1.2 to 2.3 ppm (PASSINO and KRAMER 1980) on a whole body basis. Nevertheless, Perches of the American Fall Reservoir (Idaho) did not contain detectable PCB residues (KENT and JOHNSON 1979). We are not aware of other results on Chars

but in the Leman their contamination level is within the same range of magnitude as those of lake trout in the western part of lake Superior : 0.3 to 5.6 ppm on a whole body basis (VEITH et al. 1977). The Cayuga lake trout of the same age than the Leman Char were more contaminated (BACHE et al. 1972), but the latter had PCB levels much higher than the lake trout captured in Labrador (Canada) : 0.3 to 0.7 ppm in mesentery fat (MUSIAL et al. 1979).

Variation of contamination : We studied intraspecies and interspecies factors of variation.

As far as the intraspecies factor is concerned the lipid content is of great importance. Indeed, there is a good correlation (P : 0.05) between PCB levels in different organs and their lipid contents when the fish studied are of the same species, age and sex. The same results were obtained by other workers (REINERT and BERGMAN 1974) and (HAMELINK et al. 1971).

Therefore, nature of the organ is not very important because differences between organ PCB levels, which are large when expressed on a fresh weight basis, are rather minimized when expressed on a lipid weight basis (table 1 and 2). The different PCB contents in organs are mainly explained by differences in lipid content.

For the two species in wich several classes of age are present (Char and Roach), older fish are more contaminated if PCB levels are expressed on freshweight or lipid weight basis. Two PCB properties explain bioaccumulation : little biodegradability and little elimination by contaminated organisms. Variation in food diet is also possible : older fish more carnivorous would show a tendancy to eat more contaminated diet than the young which are essentially planktivorous (PHILLIPS 1980).

The influence of age is more important in male than in female fish (table 1 and 2). Indeed, in the spwaning period, the females eliminate more PCB than the males because the quantity of eggs is much larger than the milt quantity (ANDERSON and FEDERSON 1970). Females accumulate PCB less rapidly than males and this would explain the larger contamination of males compared to females in older individuals (table 1 and 2). We do not believe that other sexual determinisms exist. If this would be the case, the differences between males and females would probably exist in young individuals. We did not observe such results.

In order to properly study interspecies factors of PCB level variation it was necessary to minimize intraspecies factors, so we worked with individuals of the same age and sex and we expressed PCB levels on a lipid weight basis.

Figure 1 shows that Chars and Perches are more contaminated than Roaches and Coregonines.

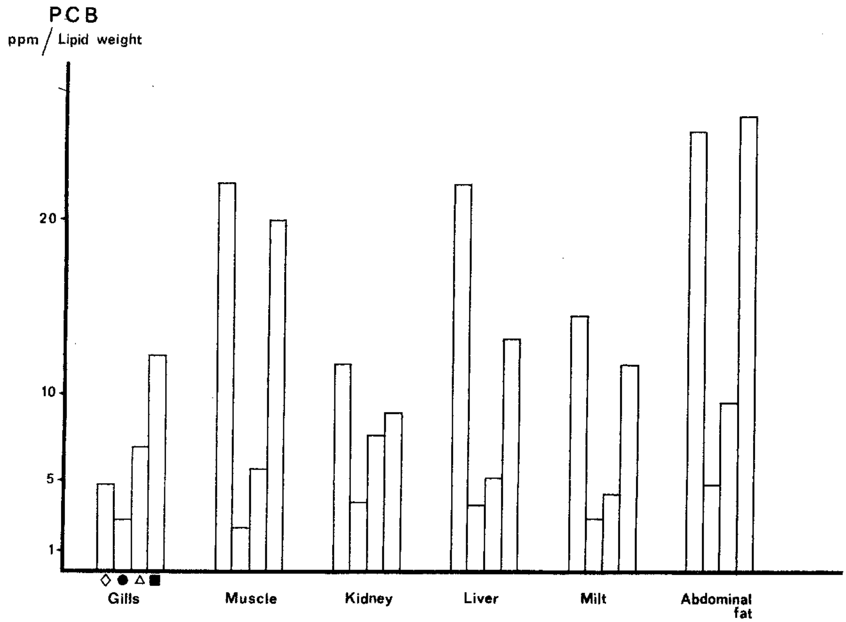

Figure 1 : PCB levels in organs of male fish 3 years old
(◇: Chars ; ●: Coregonines ; △: Roaches ; ■: Perches

It is thus possible to conclude that the total PCB burden (µg in the whole body) in Chars is larger than in Perches because 3 year old Chars (average lenght : 35 cm, average weight : 400 g) are larger than the same age Perches (average lenght : 23 cm, average weight : 100 g). In similar fashion although PCB concentration is larger in Roaches than in Coregonines, the whole body PCB burden may not be very different in those 2 species because Coregonines grow more quickly than Roaches. Therefore, growth time must be taken into account to compare contamination levels of different species.

Among factors likely to explain the differences between species, the geographic factor is not of significance, as the fish studied are ubiquitous.

Different PCB levels (expressed on a lipid basis) between species may be mainly explained on diet basis. PCBs are concentrated by food web (SODERGREN 1973) (KENT and JOHNSON 1979) (MUSIAL et al. 1979) (NIIMI 1981) (THOMANN 1981). Our results are consistent with biomagnification : indeed, those species studied have very different diet, Coregonines are strickly planktivorous whereas other species have a carnivorous diet: in increasing order these are : Roaches, Perches, Chars. PCB levels increase in the same order. Nevertheless, the PCB burden may be partly obtained directly from water by the partitioning of PCB between lake water and fish lipids (HAMELINK et al. 1971), but this is not sufficient to explain PCB levels in the four species because this mechanism should not lead to such differencies in PCB concentrations (on a lipid basis) as those observed in our study.

Among the long term effects of PCB, those affecting the reproduction process must be seriously taken into account (JOHANSSON et al. 1970) (NEBEKER et al. 1974) (FREEMAN and IDLER 1975) (HOGAN and BRAUHN 1975) (BENGTSSON 1980). In our study Char eggs contained PCB levels between 14 to 22 ppm on a lipid basis (0.17 to 0.22 ppm on a fresh weight basis). Now JOHANSSON et al. (1970) found 12 % mortality in Atlantic Salmon eggs containing 9.2 ppm PCB on a lipid weight basis (0.4 ppm versus fresh weight) and 100 % mortality in eggs containing 34 ppm on a lipid weight basis (1.9 ppm versus fresh weight). The very high sensitivity of the Char is a good argument to explain the degree of mortality in Char eggs related to PCB content.

PCB levels in lake Leman fish are comparatively high and therefore, the contamination of the ecosystem is certainly not negligible. For that reason the following studies are under investigation : contamination in other trophic levels ; the fate of PCB in the ecosystem ; sources ; risks for Char reproduction.

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