Bull. Environ. Contam. Toxicol. (1997) 58:885-892

Environmental Contamination and Toxicology

Polychlorinated Biphenyls in Barents and Greenland Seas Fish

I. B. Ali, C. R. Joiris, L. Holsbeek

Laboratory for Ecotoxicology and Polar Ecology, Free University of Brussels (VUB), Pleinlaan 2, B-1050 Brussels, Belgium

Received: 4 September 1996/Accepted: 5 February 1997

PCBs are widespread, persistent organochlorines which have the potential for harmful biological effects. The number of possible congeners is 209, but few only are both prevalent and toxic. Commercially-produced PCBs (e.g. Aroclors) consist of mixtures containing between 50 and 90 congeners. According to the classification of PCBs based on potential toxicity, environmental prevalence and relative abundance in animal tissues, the number of environmentally threatening PCB congeners reduces to about 36, of which 25 account for 50 to 75% of the total PCBs in biological compartments (McFarland and Clarke 1989). Their dispersion and accumulation through the ecosystem is reflected by their presence in air, snow, ice, fish, birds and mammals in the polar regions, in the surface and sub-surface water of oceans, in the atmosphere, and in a wide range of plankton, fish, and marine and terrestrial mammals including humans (Safe 1984; Waid 1987). It has been estimated that about 3 1% of the 1.2 million tons of PCBs that have been produced are still present in the environment (Borlakoglu and Haegele 1991).

Seven major fish species collected in the Barents and Greenland seas have been studied in an attempt to answer the question raised by Ottar (1981): "is the Arctic marine environment, as a result of its cold climate, a sink for semi-volatile organics, such as PCBs, PCDD/PCDFs, organochlorine pesticides, polyaromatic hydrocarbons (PAHs) and metals, such as mercury, emitted in the mid-latitudes?".

This work is part of a broader ecotoxicological study on stable residues in European Arctic seas (Joiris *et al.* 1995a, b; 1997).

MATERIALS AND METHODS

Fish samples were collected in the Barents and Greenland seas in the summer of 1991 and 1992 during the ARK VIII (= EPOS II) cruise of RV Polarstern, the MMBI/VUB ARCTIC cruise of RV Dalnie Zelentsy and Polarstern cruise ARK IX/l with otter and Aggaziz trawls: haddock *Melanogrammus aeglefinus*, long rough dab *Hippoglossoides platessoides*, redfish *Sebastes sp. (marinus* and/ or *mentella)*, Atlantic cod *Gadus morrhua*, Greenland halibut *Reinhardtius hippoglossoides*, capelin *Mallotus villosus* and halibut *Hippoglossus hippoglossus*. Sampling stations were already described (Joiris *et al.* 1995a; 1997). Fish samples were immediately deep-frozen, and PCB concentration was determined later in the

Correspondence to: C. R. Joiris

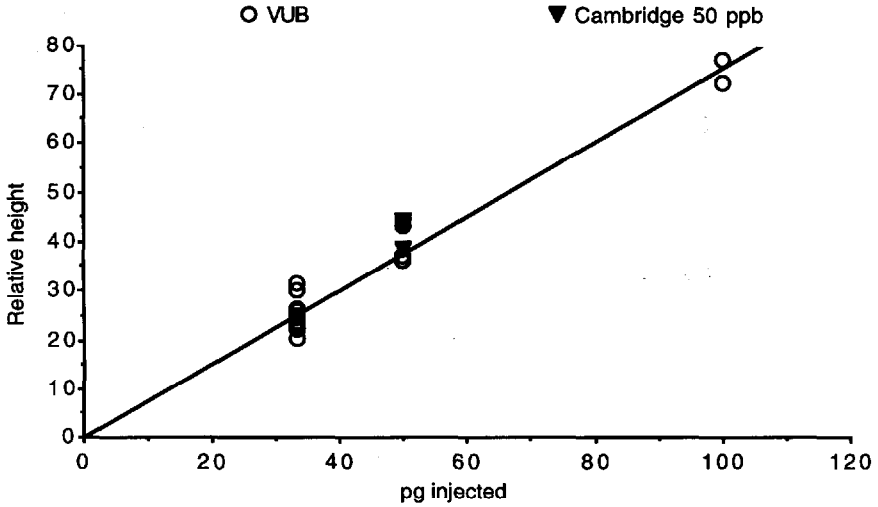

Figure 1. Example of own standard curve for congener 52 (circles) and certified solution of congener 52 (EC-143 1, Cambridge: black triangles); peak height (artificial units) as a function of injected amount (pg)

medio-dorsal part of the fish muscle. PCBs were determined by ECD gas liquid chromatography (Shimadzu GC-14A) with capillary column after extraction of lipids with a hexane/acetone solution (90-10%). They were recognized and quantified as standard mixture Aroclor 1254 ("total" PCBs), as 11 individual congeners (IUPAC n°28+31, 52, 101, 118, 138, 153, 156, 170, 180, and 194) and as "sum congeners". The recovery for the individual congeners was 89 % (± 4.2%). Figure 1 shows an example of standard curve, as well as the determination of a certified solution; similar data are available for congeners 28, 52, 118, 153, 180 and 194. Lipid content was determined by extraction with an hexane/ aceton solution (90/ 10%) and, thus, corresponds to extractable, polar lipids.

Remark: the results did not show a normal distribution; this is why median values are presented.

RESULTS AND DISCUSSION

The PCB pattern in fish was much closer to the standard mixture 1254 than 1260 (Table l), especially for those congeners presenting a clear difference in both standard mixtures: 101,180, 170 and 194. A similar conclusion was drawn already for the PCB pattern in particulate organic matter from the same region (Joiris et al. 1995b). This qualitative difference - in the North Sea, PCB pattern is much closer to 1260 (Joiris *et al.* in prep.) - might be due to the origin of the residues, their age in the environment, and/ or to differences in metabolization in a cold climate. Table 2 lists the median concentrations of PCB congeners quantified in the fish samples expressed as individual congeners, their relative median contribution (expressed in % of "sum congeners"), "sum congeners" and "total" PCB (Aroclor 1254). Clear differences appear when comparing median PCB values in the different species, from 6 ng sum congeners/ g dw in haddock to 113 in halibut. These differences correspond to differences in lipid content, and all species showed a similar

Table 1. Relative mean contribution of 11 individual congeners (as % of "sum congeners") in the standard mixtures Aroclor 1254 and 1260, and in fish from the Barents and Greenland seas; n = number of samples

	Congener>	28	52	101	118	153	138	156	180	170	194
	n	+ 31									
1254	*13*	1	4	20	33	16	18	5	3	2	1
1260	*20*	1	3	8	15	19	15	3	21	10	6
Fish	*168*	4	9	21	17	16	18	7	7	2	1

contamination when expressed on a lipid weight base: between 200 and 300 ng/ g lw, with the exception of capelin (120) and Atlantic cod (500) (Fig. 2, Table 2); these two exceptions might be due to differences in lipid composition, or to migratory movements causing contamination in other water masses.

Phillips (1980) reported that the concentration of the PCB residues in biological tissue is positively correlated with the extractable lipid. Jensen *et al* (1972) noted that PCB concentrations in herring was higher than that of cod and attributed this to the greater lipid content of herring than cod. An extensive study of freshwater fish from a Finnish lake by Hattula *et al.* (1987) confirmed this observation. Other work and similar conclusions concerning PCBs in fish have been made by Barber and Warlen (1979) and Stout (1980). So that differences in PCB load among fish species can be explained by differences in lipid content.

Within species, a strong correlation between lipid content and PCBs concentration was detected as well (Figs. 3 - 7 for haddock, redfish, Atlantic cod, Greenland halibut and capelin, respectively). The conclusion is that uptake of PCBs by fish is

Table 2. PCBs in fish: concentrations of individual congeners, sum congeners and "total" PCBs (as Aroclor 1254) (ng/ g dw); lipid content (g/ g dw); sum congeners (ng/ g lw); median values; n = number of samples; nd = not detected

Species >	Haddock	Long rough dab	Redfish	Atlantic cod	Greenland halibut	Capelin	Halibut
n>	*1 0*	*16*	*55*	*10*	*9*	*65*	*3*
Congener (IUPAC n°)							
28 + 31	0.8	nd	0.8	1.8	nd	1.6	nd
52	0.1	3.4	1.5	8.2	6.0	3.7	6.1
101	0.5	4.2	3.2	18.1	12.8	6.4	42.4
118	0.8	1.3	3.6	0.3	11.6	8.0	16.1
153	0.2	1.6	4.6	21.8	8.6	8.9	17.6
138	1.3	1.6	3.8	19.4	6.9	7.4	28.8
156	0.2	1.0	0.5	3.0	7.9	1.4	12.2
180	0.7	0.7	2.0	6.8	3.1	2.3	2.6
170	0.1	0.3	0.6	2.2	0.4	1.2	0.9
194	nd	0.1	0.3	0.5	0.1	0.2	nd
sum congeners (dw)	6.0	16	21	102	48	42	113
"total" PCBs (dw)	16	79	74	461	249	170	585
lipid weight (g/ g dw)	0.03	0.05	0.07	0.21	0.34	0.41	0.60
sum congeners (lw)	194	329	283	496	267	121	286
total body size (cm)	19	23	11	45	45	14	26

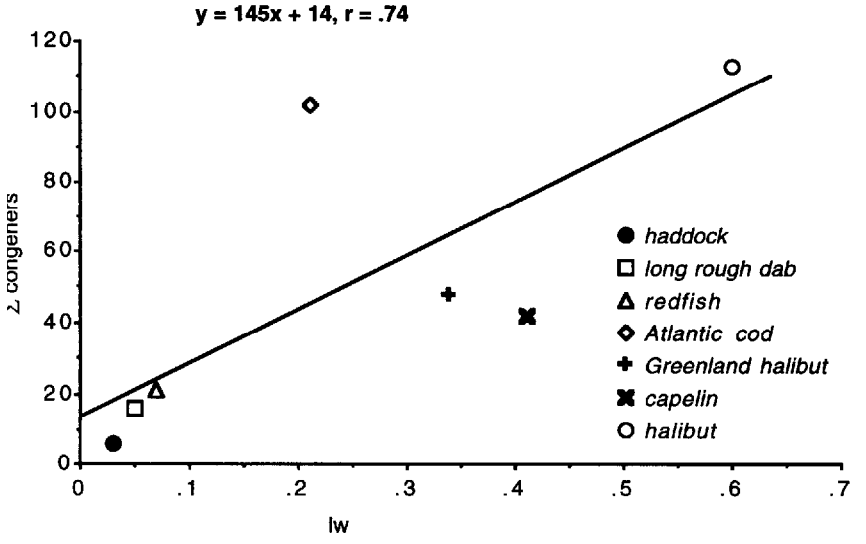

Figure 2. Correlation between the sum of 11 PCB congeners ("Σ congeners") ng/g dw) and lipid content (g/g dw) in the different fish species; median values

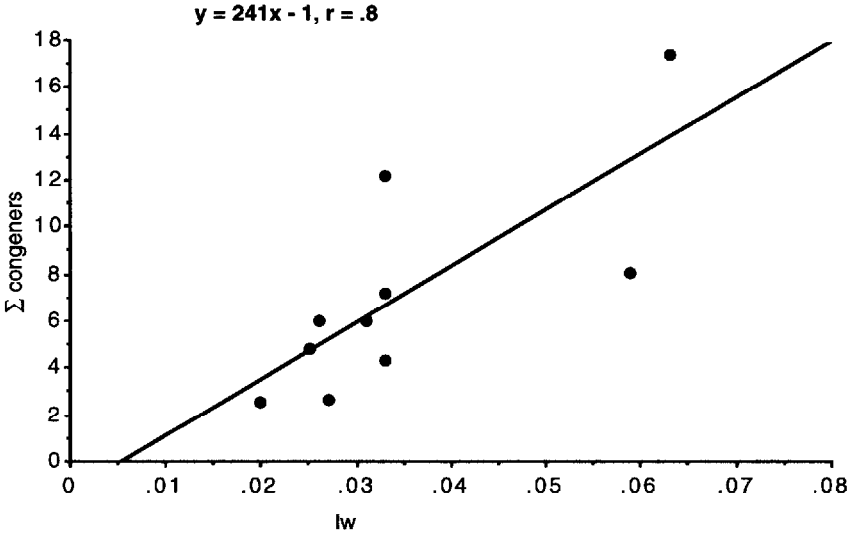

Figure 3. Correlation between Σ congeners and lipid content in haddock, *Melanogrammus aeglefinus*

mainly direct (from water), without significant influence of diet nor age, for both pelagic and demersal fish.

De Voogt *et al.* (1990) suggested that fish tissue from relatively uncontaminated waters, e.g., capelin from Icelandic waters, may contain as little as 10 ng/ g dw of total PCBs. Our results on capelin ranged from 25 to 450 ng/ g dw, with a median value of 120. Muir *et al.* (1992) made a comprehensive study on PCBs in the Arctic marine ecosystems and reported PCB concentrations in fish far below what was

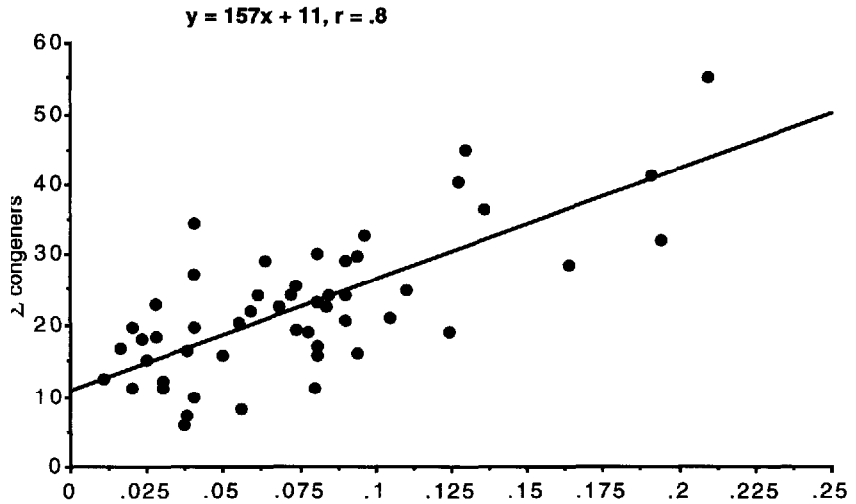

Figure 4. Correlation between Σ congeners and lipid content in redfish, *Sebastes s p*

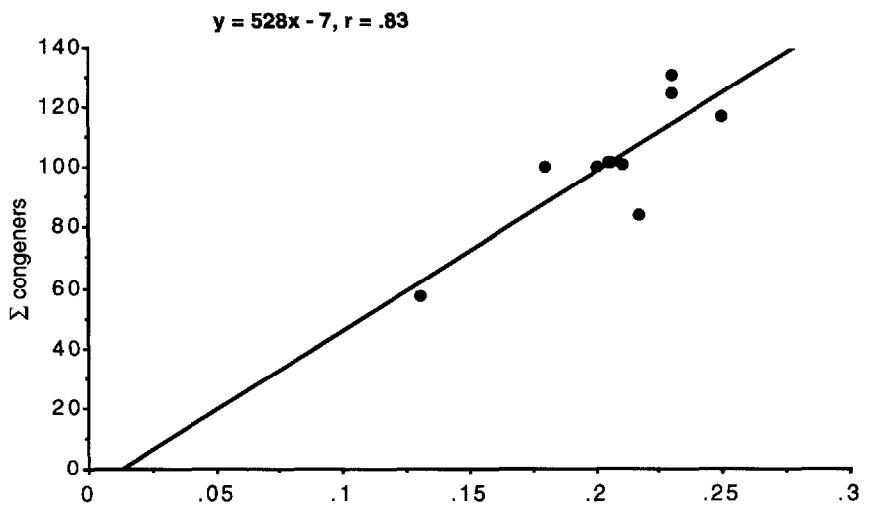

Figure 5. Correlation between Σ congeners and lipid content in Atlantic cod, *Gadus morhua.*

detected in our work, except for the samples from North of Finland which were very high compared to what we measured. Hargrave *et al* (1992) also reported high PCB concentrations in abyssal fish liver in the Canadian Arctic (1.3 µg ΣPCB/ g dw): this concentration was far higher than the ones reported here.

Among the 10 highly toxic coplanar PCBs that are able to produce dioxin-like toxic effects, 4 (118, 156, 138 and 170) were quantified in our samples. Each contributed between 22 and 56% of the sum congeners. These figures were

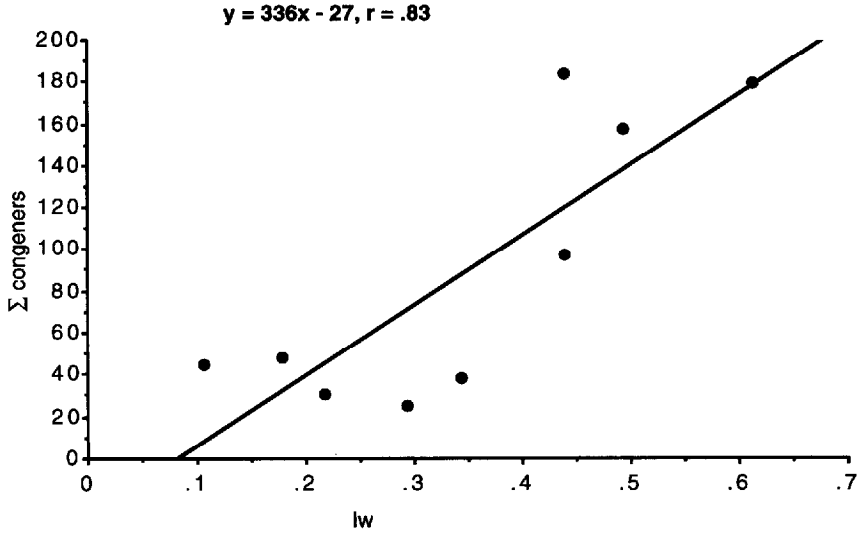

Figure 6. Correlation between Σcongeners and lipid content in Greenland halibut, *Reinhardtius hippoglossoides*

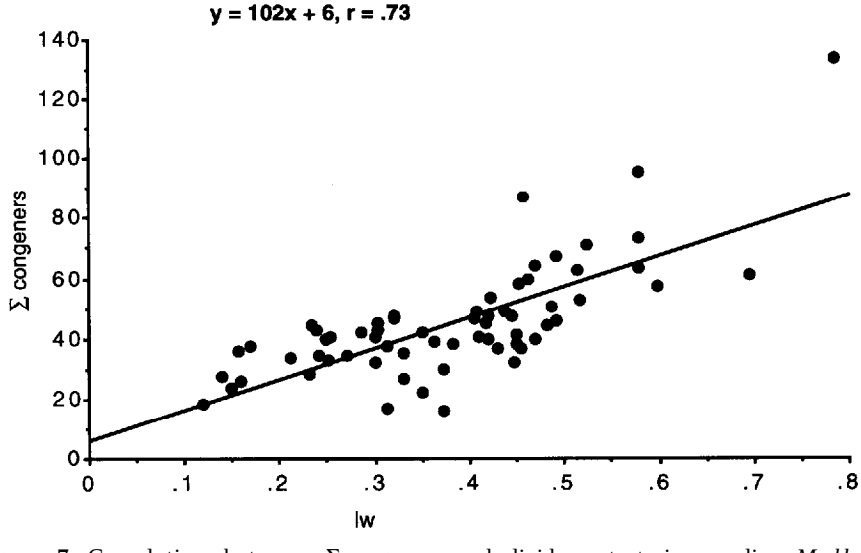

Figure 7. Correlation between Σcongeners and lipid content in capelin, *Mallotus villosus*

alarming hence their toxic equivalents (TEQs) were calculated to see if these components of PCBs pose a significant toxic threat. This was done by computing theoretical aryl hydrogen hydroxylase (AHH) and ethoxy resorufin O-deethylase (EROD) concentrations (Table 3)(TEQs were adapted from Smith *et al.* 1990). The sum of the concentrations of these four were found to be in the range of 2.4 to 50 rig/g dw and the sum of their TCDD TEQs were 0.07 to 0.90 pg/g dw for AHH and from 0.1 to 1.5 pg/g dw for EROD. Among them, 170 represented less than

Table 3. Calculated 2,3,7,8, TCDD toxic equivalents for coplanar PCB congeners in fish (10^{-6} ng/g dw); AHH = aryl hydrogen hydroxylase; EROD = ethoxy resorfurin 0-deethylase

	AHH					EROD				
Congener >	118	156	138	170	sum	118	156	138	170	sum
Conversion factor >	*8.3*	*46.0*	*7.2*	*1.6*		*9.1*	*89.0*	*8.9*	*6.6*	
Species										
haddock	7	60	1	nd	68	7	116	7	1	131
long rough dab	11	46	12	1	69	12	89	14	2	117
redfish	30	23	27	1	81	33	45	34	4	116
Atlantic cod	168	138	140	4	450	185	267	173	15	640
Greenland halibut	96	363	50	1	510	106	703	61	3	873
capelin	66	66	53	2	187	73	125	66	8	272
halibut	134	207	561	1	903	147	256	1086	6	1495

4% of the total TEQ values, which makes it an insignificant toxic threat. The remaining three congeners contributed about 35% each of the total TEQ values in all the fish, except in haddock, long rough dab, halibut and Greenland halibut where congeners 156 and 138 contributed between 62 and 90% of the total TEQ values, which may impart a significant toxic threat.

Some organochlorine pesticides concentrations were also determined in the same samples: they were generally low (Table 4).

Table 4. Organochlorine pesticides in fish (ng/ g dw)

Species >	Haddock	Long rough dab	Redfish	Atlantic cod	Greenland halibut	Capelin	Halibut
Pesticide n >	*10*	*16*	*55*	*10*	*9*	*65*	*3*
heptachlor	0.4	0.7	0.3	0.8	0.8	0.3	0.7
aldrin	0.5	0.7	0.4	0.3	0.7	0.3	1.1
op & pp'DDE	1.2	1.4	3.2	13.9	6.4	5.7	65
pp'DDT	0.1	0.3	0.2	1.3	1.0	0.2	11

Acknowledgements. Barents Sea fish were collected in summer of 1991 during the ARK VIII/2 cruise of RV Polarstern by CJ, and MMBI/VUB cruise of RV Dalnie Zeientsy by LH, J Tahon, and D Vangeluwe. Greenland Sea fish collected during Polarstern cruise ARK IX/l (1992), were provided by C von Dorrien. Study partially funded by the Belgian National Science Foundation, and proposed to the European Commission (DGXI) but classified C "without scientific value".

REFERENCES

Barber RT, Warlen SM (1979) Organochlorine insecticide residues in deep sea fish from 2500 m in the Atlantic Ocean. Environ Sci Technol 13:1146

Borlakoglu JT, Haegele KD (1991) Comparative aspect on the bioaccumulation, metabolism and toxicity with PCBs. Comp Biochem Physiol 100C:327-338

De Voogt P, Wells DE, Reutergardh L, Brinkman UATh (1990) Biological activity, determination and occurrence of planar, mono- and di- ortho PCBs- a review. Intern J Environ Anal Chem 40:l-46

Hattula M, Janatuinen J, Sarkka J, Passivirta J (1978) A five-year monitoring study of the chlorinated hydrocarbons in the fish of a Finnish Lake ecosystem. Environ Pollut 15:121

Hargrave BT, Harding GC, Vass WP, Erickson PE, Fowler BR, Scott V (1992) Organochlorine pesticides and polychlorinated biphenyls in the Arctic Ocean food web. Arch Environ Contam Toxicol 22:4l-45

Jensen S, Jonnels AG, Olsson M, Otterlind G (1972) DDT and PCB in herring and cod from the Baltic, the Kattegat and the Skagerrak. Ambio Spec. Rep. No. 1:71

Joiris CR, Ali BI, Holsbeek L, Bossicart M, Tapia G (1995a) Total and organic mercury in Barents Sea pelagic fish. Bull Environ Contam Toxicol 55:674-681

Joiris CR, Moatemri LN, Holsbeek L (1995b) Mercury and polychlorinated biphenyls in suspended particulate matter from the European Arctic seas. Bull Environ Contam Toxicol 55:893-900

Joiris CR, Ali BI, Holsbeek L, Kanuya - Kinoti M, Teleke - Michael Y (1997) Total and organic mercury in Greenland and Barents seas demersal fish. Bull Environ Contam Toxicol 58:101-107

McFarland VA, Clarke JU (1989) Environment occurrence, abundance, and potential toxicity of polychlorinated biphenyl congeners: considerations for a congener-specific analysis. Environ Health Persp 81:225-239

Muir DCG, Wagemann R, Hargrave BT, Thomas DJ, Peakall DB, Norstrom RJ (1992) Arctic marine ecosystem contamination. Sci Tot Environ 122:75-134

Ottar B (1981) The transfer of airborne pollutants to the Arctic Region. Atmos Environ 15:1439-1445

Phillips DJH (1980) Quantitative aquatic biological indicators: their use to monitor trace metal and organochlorine pollution. London Appl Sc Ltd.

Safe S (1984) Polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs): biochemistry, toxicology and mechanism of action. CRC Crit Rev Toxicol 13:319-395

Smith LM, Schwartz TR, Feltz K, Kubiak TJ (1990) Determination and significance in environmental samples of the most toxic PCB congeners. Chemosphere 21: 1063-1085

Stout VF (1980) Organochlorine residues in fish from the Northwest Atlantic Ocean and Gulf of Mexico. Fish Bull US 78:51

Waid JS (1987) PCBs and the environment, Vols. I-III. CRC Press, Boca Raton, Fl