POLYCHLORINATED BIPHENYLS IN ARCTIC AND ANTARCTIC ORGANISMS: POLAR BEAR, KRILL, FISH, WEDDELL SEAL AND SKUA

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Introduction

Global contamination by persistent chlorinated hydrocarbons (CHC) such as polychlorinated biphenyls (PCBs) and organochlorine pesticides has been well documented [1]. Oceans are a major sink for persistent pollutants, which are transported from continental areas by atmosphere and oceanic currents [2,3]. Global distillation or fractionation by condensation in cold polar waters has been proposed as a mechanism whereby the polar regions may become sinks for some CHCs [4]. The Arctic and the Antarctic are both remote polar regions, but the former is a perennial frozen sea surrounded by continents, and the latter is a snow covered continent surrounded by ocean. This means that, even if they have the extreme climate, ecosystems of these two regions are different. Apart from geographical features, several factors such as proximity to sources and physicochemical properties of CHCs may determine their occurrence in these polar regions. The Southern Ocean isolates Antarctica from the other oceans. Therefore volatile contaminants can reach Antarctica only via the transport of air mass. Furthermore, the southern hemisphere is mainly occupied by oceans and land is relatively less populated than the northern hemisphere. It is then expected that Arctic and Antarctic organisms show a different pattern of CHC contamination. The aim of this study was to evaluate the accumulation pattern and concentrations of some organochlorine compounds, such as PCBs, *p,p'*-DDE and hexachlorobenzene (HCB) in organisms from polar regions. Polar bear (*Ursus maritimus)*) from Alaska (Arctic), and krill (*Euphausia superba*), fish (*Trematomus pennelli, Chionodraco hamatus, Pleuragramma antarcticum*), South Polar skua (*Catharacta maccormicki*) and Weddell seal (*Leptonichotes weddelli*) from the Ross Sea in Antarctica were analyzed. In addition, polychlorinated naphthalenes (PCNs), which are recently measured in the Arctic air [5], were analyzed in the tissues of organisms from the polar regions.

Materials and Methods

Samples of livers of polar bear were collected from the tissues archived by the U.S. Fish and Wildlife Service, Anchorage, Alaska. All bears were adult males. Details of polar bear samples are given in Table 1. Antarctic organisms – krill, silver fish, skua and Weddell seal- were collected during the X (1994/95) and XI (1995/96) Expeditions in Terra Nova Bay in Antarctica, in the framework of the Italian National Program of Researches in Antarctica (PNRA). Samples were collected during the months of October to February 1994-1996. Livers of polar bear, whole body of krill and fishes and liver or muscle or fat of Weddell seal or skua were analyzed following the method described elsewhere [6]. Homogenized tissues were Soxhlet extracted with methylene chloride and hexane. Clean up and lipid removal was accomplished by multi-layer (acidic) silica gel column chromatography and sulfuric acid treatment. A portion of the

Table 1. Concentrations of PCBs, *p,p'*-DDE and HCB (ng/g, wet wt) in the livers of polar bear from Alaska.

Sample	Location	Date of collection	lip.cont. (%)	HCB	*p,p'*-DDE	PCBs
Polar bear	Point Lay, AK	Feb 28,98	11.2	1.08	2.89	2680
Polar bear	Gambell, AK	May 21,99	14.9	2.43	9.01	520
Polar bear	Barrow, AK	Dec 6, 97	12.3	50.4	28	5130
Polar bear	Savoonga, AK	May 2, 99	7.8	11.7	8.8	1340
Polar bear	Gambell, AK	Jun 15, 99	10.6	15.2	15.6	880
	Mean		11.4	16.2	12.9	2110
	S.D.		2.6	20.1	9.6	1870
	Min		7.8	1.08	2.89	520
	Max		14.9	50.4	28	5130

All polar bears are adult males.

Table 2. Concentrations of PCBs, *p,p'*-DDE and HCB (ng/g, wet wt) in krill, fish, skua and weddell seal tissues from the Antarctic.

Organism	Tissue/species	Weight/ details	lip.cont. (%)	HCB	*p,p'*-DDE	PCBs
Krill	Fresh, whole	Whole	1.45	0.17	0.04	1.93
Krill	CRM	Whole	44	1.4	0.12	86.2
Krill	CRM	Whole	40.5	1.1	0.19	115
Fish	*Trematomus pennelli*	Body wt 81 g	2.15	7.8	2.9	176
Fish	*Trematomus pennelli*	Body wt 61 g	1.60	3.9	3.8	110
Fish	*Chionodraco hamatus*	Body wt 299 g	1.38	0.38	0.27	4.2
Fish	*Chionodraco hamatus*	Body wt 270 g	3.88	0.64	0.40	12.6
Fish	*Pleuragramma antarcticum*	Pool of 3	9.36	4.4	0.30	138
Weddell seal	Liver	Female	2.71	0.13	1.2	34
Weddell seal	Fat	Female	100	0.82	17	395
Skua	Muscle		1.65	168	130	2630
Skua	Liver		42.1	345	300	10370

CRM: Certified reference material of krill from the Antarctic.

final extract was used for the determination of PCBs other than coplanar congeners, *p,p'*-DDE and HCB. Remaining extracts were subjected to activated carbon impregnated silica gel column chromatography fractionation to separate *ortho*-substituted PCB congeners from *non-ortho* coplanar PCBs and PCNs. Concentrations of individual PCB congeners were measured against the corresponding PCB congener standards. Gas chromatograph with electron capture detector (GC-ECD) or mass spectrometer (GC-MS) was used.

Results and Discussion

Concentrations of HCB, *p,p'*-DDE and PCBs were greatest in the livers of polar bears from the Arctic compared those of the samples (except skua) from the Antarctic (Tables 1 and 2). Concentration ranges of HCB, *p,p'*-DDE and PCBs in polar bears were 1-50, 2.9-28, 520-5130, ng/g wet wt, respectively (Table 1). The wide ranges in concentrations suggest the influence of sources and biological parameters such as age. To minimize the effect of age, only adult male animals were analyzed. On a lipid weight basis, PCB concentrations ranged from 3500 to 42000 ng/g, lipid wt. These values are within the ranges of values reported in the adipose fat of polar bears in the Arctic region [7].

HCB concentrations in fish and krill from the Antarctic were in the ranges of 0.17 – 7.8 ng/g, wet wt (Table 2). Skua contained the greatest HCB concentrations of 168-345 ng/g, wet wt, which were 2 to 3-orders of magnitude greater than that in Weddell seal tissues. Presence of noticeably high concentrations of HCB in Antarctic samples can be attributed to its sources originating from Australia [8]. South polar skuas spend only about 4-5 months in Antarctica, then migrate through the Southern Ocean and are not uncommon in the northern Pacific and northern Atlantic during the southern winter [9]. Therefore, great concentrations of HCB and PCBs in skua may suggest exposure in wintering grounds. Similarly, *p,p'*-DDE concentrations were the highest in skua liver. PCB concentrations in skua liver and muscle were 10,370 and 2,630 ng/g wet wt, respectively, while in the other Antarctic organisms it varied from 1.93 ng/g wet wt in fresh krill to 395 ng/g wet wt in the Weddell seal fat. Concentration of PCBs in Weddell seal fat was slightly less than those reported earlier by Focardi et al. (9) (585 ng/g, wet wt) whereas that in skua liver was much greater than those reported earlier.

Profiles of PCB congeners in polar bear liver and in skua liver are shown in Figure 1. Hexachlorobiphenyl congener 153 (2,2',4,4',5,5') was the most abundant in the liver. Several other congeners were also found. Earlier studies have reported the occurrence of only a few congeners such as IUPAC Nos. 99, 138, 153, 170 and 180 in the adipose fat of polar bears (7). Relatively large number of congeners in the liver suggests recent exposures and tissue-specific retention. Liver of skua also contained several PCB congeners. Pentachlorobiphenyl congener 99 (2,2',4,4',5) and hexachlorobiphenyl 153 were the most abundant ones. While fat tissues contain relatively a few congeners [10], livers tend to contain several congeners, some of which are lower chlorinated ones, possible arising from the dechlorination or metabolism of higher chlorinated congeners.

Polychlorinated naphthalenes were also detected in polar bear and skua livers at concentrations in the range of a few parts-per-billion on a wet weight basis. These results indicate that PCNs can be found in marine organisms from remote locations.

References

1. Barrie, L.A., Gregor, D., Hargrave, B., Lake, R., Muir, D.C.G., Shearer, R., Tracey, B. and Bidleman, T. (1992). Sci. Total. Environ. 122, 1-74.

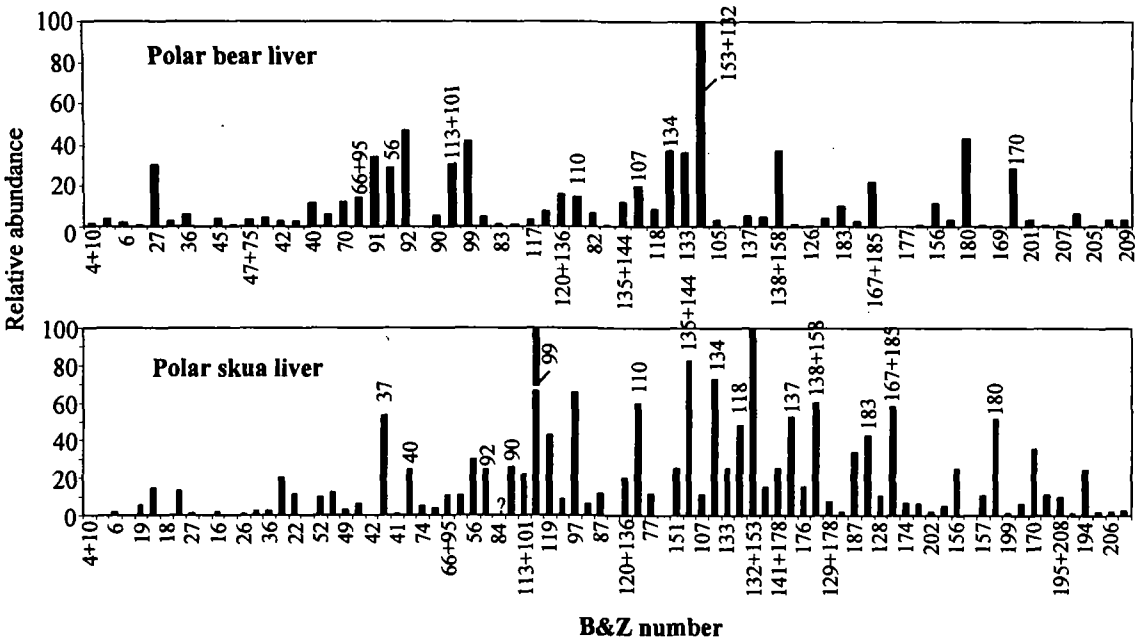

Figure 1. Relative abundance of PCB isomers and congeners in the livers of polar bear and polar skua from Alaska and Terra Nova Bay, Antarctica, respectively. Concentrations were normalized to PCB 153.

2. Loganathan, B.G. and Kannan, K. (1991). Mar. Pollut. Bull., 22, 582-584.
3. Loganathan, B.G. and Kannan, K. (1994). Ambio, 23, 187-191.
4. Wania, F. and Mackay, D. (1993). Ambio 22, 10-18.
5. Harner, T., Kylin, H., Bidleman, T.F., Halsall, C., Strachan, W.M.J., Barrie, L.A. and Felin, P. (1998). Environ. Sci. Technol. 32, 3257-3265.
6. Kannan, K., Yamashita, N., Imagawa, T., Decoen, W., Khim, J.S., Day, R.M., Summer, C.L. and Giesy, J.P. (2000). Environ. Sci. Technol., 34, 566-572.
7. Norstrom, R.J., Belikov, S.E., Born, E.W., Garner, G.W., Malone, B., Olpinski, S., Ramsay, M.A., Schliebe, S., Stirling, I., Stishov, M.S., Taylor, M.K. and Wiig, .. (1998). Arch. Environ. Contam. Toxicol., 35, 354-367.
8. Kannan, K., Tanabe, S., Williams, R.J. and Tatsukawa, R. 91994). Sci. total Environ., 153, 29-49.
9. Focardi, S., Bargagli, R. and Corsolini, S. (1995). Antarctic Sci., 7, 31-35.
10. Senthilkumar, S., Watanabe, S., Kannan, K., Subramanian, A. and Tanabe, S. (1999). Toxicol. Environ. Chem., 71, 221-239.