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PERSISTENT ORGANIC POLLUTANTS IN SELECTED ORGANISMS OF AN ANTARCTIC BENTHIC COMMUNITY

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Introduction

The presence of persistent organic pollutants (POPs) in the Antarctic environment has been documented since the 1960s[1, 2]. The Southern Ocean isolates Antarctica from the other oceans, thus volatile contaminants can reach Antarctica mainly via air mass transport through the so-called grasshopper effects. It has been described as a global distillation process[3]. Among POPs, polychlorobiphenyls (PCBs), hexachlorobenzene (HCB), dichlorodiphenyl-dichloro ethane (*pp'*-DDE), polychlorodibenzodioxins (PCDDs) and polychlorodibenzofurans (PCDFs) are known to elicit acute or toxic responses in organisms, including humans. Dioxin-like compound toxic potential was calculated by using the Toxic Equivalency Factor (TEF) approach[4]. POPs were determined in various Antarctic benthic species, including the red algae *Iridaea cordata*, echinoderms (sea cucumbers, the sea star *Odontaster validus*, the sea urchin *Sterechinus neumayeri*), mollusks (the Antarctic scallop *Adamussium colbecki*, the Antarctic whelk *Neobuccinum eatoni*, the Antarctic yoldia *Yoldia eightsi*) and fish (the emerald rockcod *Trematomus bernacchii*) from Terra Nova Bay (Ross Sea). These organisms belong to the same benthic commmunity and are linked between them by prey-predator relationships.

An important factor that might affect the POP accumulation in Antarctic organisms is their low metabolic rate, due to the low temperatures. This means that they may have a longer time to bioaccumulate chemicals. Antarctic bivalves show a very slow growing rate, if compared to species living in temperate areas (10% slower)[5]. Juvenile *A. colbecki* may live attached to the adult valve for 4-5 years; they become adult when they leave the parent bivalve. During this phase, the young scallops increase their gonad and muscle weight[6]. Even *O. validus* shows a slow growing rate, taking nine years to weigh 30 g[7]. *S. neumayeri* needs forty years to reach its maximum diameter (70 mm)[8]; the oogenesis is very long too (2 years). The *T. bernacchii* female may be 21 years old and the male 16 years old[9]. Prey-predator relationships and other ecological features can give interesting information on the POP accumulation in a benthic community and they have been taken into account when discussing the results.

Materials and Methods

Sampling was carried out in the framework of the Italian National Program for Research in Antarctica (PNRA) during 1999/2000 season; samples were collected at Terra Nova Bay (74°40'S, 164°10'E). Samples were kept at –30°C until laboratory analyses. They were analyzed following the method described elsewhere[2, 10]. Briefly, homogenised tissues were Soxhlet extracted. Multi-layer silica gel column and activated carbon impregnated silica gel column chromatography were used to clean the extract up and separate dioxin-like compounds. Gas chromatography (GC-ECD) and GCQ plus ion trap mass spectrometry were used to identify and quantify all compounds.

Results and Discussion

Results are shown in Table 1. Higher POP levels were found in emerald rockcod liver samples (6.4±6.2 ng/g wet wt HCB, 0.42±0.1 ng/g wet wt *pp'*-DDE, 22.7±18.6 ng/g wet wt PCBs); this species is considered to be at a high level of the trophic web we analyzed. HCB and *pp'*-DDE lower levels were detected in Antarctic yoldia (0.035 ng/g wet wt and 0.016 ng/g wet wt, respectively). Concentrations varied between individuals, likely in relation to several biological and ecological features (sex, age, breeding season, etc.). Many Antarctic organisms (e.g. the sea star) accumulate lipids during the breeding season and to overwinter[11]; it may pose a major risk to accumulate POPs for them with respect to organisms that accumulate glycogen to overwinter[11]. PCB concentrations in emerald rockcod were higher than in the sea urchin, Antarctic scallop and Antarctic whelk, all predated by the fish (Figure 1). Interestingly, the Antarctic whelk accumulated slightly less than its prey, the Antarctic scallop. The feeding habits may be responsible for that: the scallop is filter feeding[12]. In general, a filter feeding organism accumulates more POPs than what is expected in relation to its trophic position in the food web. Most samples showed the following pattern: PCB > HCB > *pp'*-DDE, which is different from that expected in samples from other areas (PCBs > *pp'*-DDE > HCB). The POP transport pathway to Antarctica may be responsible for this pattern: due the global fractionation, highly volatile POPs (e.g. HCB) reach the polar regions rather rapidly with respect to heavier molecules. Fish from the Antarctic Peninsula[13] and krill and fish from the Ross Sea[2] showed the same pattern.

The PCB isomer class composition was hexa-CBs > penta-CBs > hepta-CBs > tri-CBs > tetra-CBs > octa-CBs > nona-CBs (Figure 2). Tri- to penta-CBs were 35-65% of the total PCB residue in all organisms, confirming a peculiar class of isomer pattern in Antarctic organisms: lower chlorinated congeners often show higher concentrations than higher chlorinated ones. Fingerprints showed different patterns, likely depending on species, sex, age and breeding activity. Fish and invertebrates show low detoxifying activity to metabolize PCB138, 153 and 180[14]; their concentrations were lower in the prey respect to the predator (sea urchin, Antarctic scallop, Antarctic whelk < emerald rockcod; Antarctic scallop < sea star; Antarctic scallop < sea urchin; algae < sea urchin; sea urchin, Antarctic scallop < sea star).

Among the dioxin-like POPs, PCDDs and PCDFs were below the detection limit (<0.001 ng/g wet wt) in all the analyzed samples (Table 1). Non-*ortho* PCB concentrations were very low in all the samples (Σnon-*ortho* PCBs ranged from <0.001-0.198 ng/g wet wt) and their pattern was PCB126 > PCB77 > PCB169. PCB77 might be partially eliminated by gill exchange or detoxifying activity (less probable), due to its moderate lipoaffinity. Most of the toxicity, expressed as TEQs, was due to PCB126 in Antarctic yoldia and *N. eatoni* (59% and 84%, respectively), to PCB118 in the sea star and fish liver samples (60% ca. both) and to PCB105 in the Antarctic scallop and fish muscle samples (60% ca. both).

In general, POP and TEQ concentrations in Antarctic organisms were low compared to those reported for marine species from lower latitudes[15] and they are among the lowest in the world[3]. The extreme weather conditions largely affect the physiology and ecology of organisms; feeding habits, lipid accumulation (strongly linked to food availability during Summer months) and long-life span may be considered factors of risk. Unusually high concentrations in invertebrates may be of concern not only for organism themselves, but even for top predators (due to biomagnification).

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References

1. Risebrough R.W., Rieche P., Peakall D.B., Herman S.G., Kirven M.N. (1968) Nature 220, 1098
2. Corsolini S., Kannan K., Imagawa T., Focardi S., Giesy J.P. (2002) Env Sci Technol. 36, 3490
3. Wania F., Mackay D. (1993) Ambio. 22, 10.
4. Van den Berg M., Birnbaum L., Bosveld A.T.C., Brunstom B., Cook P., Feeley M., Giesy J.P., Hanberg A., Hasegawa R., Kennedy S.W., Kubiak T., Larsen J.C., van Leeuwen F.X.R., Djien Liem A.K., Nolt C., Peterson R.E., Poellinger L., Safe S., Schrenk D., Tillit D., Tysklind M., Younes M., Waern F., Zacharewski T. (1998) Environ. Health Persp. 106, 775
5. Peck L.S., Bullough L.W. (1993). Mar Biol. 117, 235.
6. Chiantore M., Cattaneo-Vietti R., Povero P., Albertelli G. (2000) in: Ross Sea Ecology Italiantarctic Expeditions (1987-1995) (Faranda, F.M., Guglielmo, L., Ianora, A. Ed.), Springer Verlag Berlin Heidelberg New York, ISBN 3-540-65372-4
7. McClintock J.B., Pearse J.S., Bosch I. (1988) Mar Biol. 99, 235
8. Brey T., Pearse J., Basch L., McClintock J., Slattery M. (1995) Mar Biol. 124, 279
9. Vacchi M., La Mesa M., Greco S. (2000) in: Ross Sea Ecology Italiantarctic Expeditions (1987-1995) (Faranda, F.M., Guglielmo, L., Ianora, A. Ed.), Springer Verlag Berlin Heidelberg New York, ISBN 3-540-65372-4
10. March R. E. (1997) J Mass Spectrometry. 32, 351
11. Clarke A. (1983) Oceanogr Biol Ann Rev. 21, 341
12. Berkman P.A., Nigro M. (1992) Mar Pollut Bull. 24, 322
13. Weber K., Goerke H. (1996) Chemosphere. 33, 377
14. Bright D.A., Grundy S.L., Reimer K.L. (1995) Env Sci Technol. 29, 2504
15. Kannan, K., Yamashita, N., Imagawa, T., Decoen, W., Khim, J.S. (2000) Env Sci Technol. 34, 566

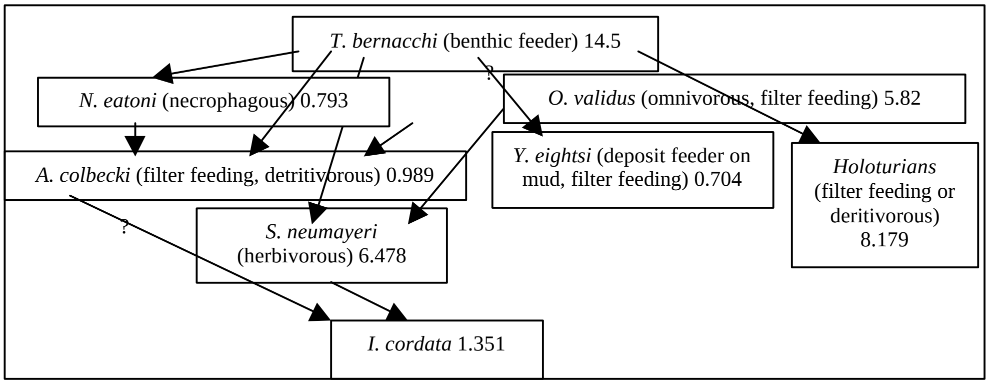

Figure 1: PCB concentrations (ng/g wet wt) in relation to the position of organisms in the trophic web (schematic).

Table 1: Concentration of HCB, *pp'*-DDE, ΣPCBs (ng/g wet wt) and non-*ortho* PCB77, 126, 169, ΣPCDDs, ΣPCDFs (pg/g wet wt) in the benthic organisms (S.D. in brackets).

	algae	seacocumber	seaurchin	scallop	yoldia	whelk	seastar	fish m[a]	fish l[b]
n	1	9	6	4	1*	2	6	8	3
HCB	0.178	0.269	0.495	0.059	0.035	<0.001	0.282	2.596	6.435
		(0.659)	(0.800)	(0.076)		(0.001)	(0.331)	(3.516)	(6.286)
pp'-DDE	0.024	0.343	0.065	0.045	0.016	0.034	0.178	0.159	0.428
		(0.420)	(0.062)	(0.005)		(0.047)	(0.098)	(0.095)	(0.162)
ΣPCBs	1.351	8.179	6.478	0.989	0.704	0.793	6.061	6.350	22.711
		(13.003)	(9.275)	(1.369)		(0.969)	(6.163)	(4.799)	(18.633)
PCB77	<0.001	0.014	0.034	<0.001	0.012	0.004	0.035	0.046	0.049
		(0.035)	(0.033)	(0.001)		(0.005)	(0.051)	(0.077)	(0.006)
PCB126	<0.001	0.082	0.002	0.001	0.053	0.130	0.147	0.060	0.021
		(0.108)	(0.002)	(0.001)		(0.165)	(0.190)	(0.100)	(0.012)
PCB169	<0.001	0.007	0.005	<0.001	0.019	0.017	0.016	0.014	0.082
		(0.011)	(0.007)	(0.001)		(0.003)	(0.015)	(0.022)	(0.093)
Σnon-*ortho*	<0.001	0.103	0.041	0.001	0.083	0.151	0.198	0.120	0.153
		(0.138)	(0.040)	(0.001)		(0.163)	(0.222)	(0.196)	(0.102)
ΣPCDD	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ΣPCDF	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ΣTEQ$_{PCBs}$ (pg/g wet wt)									
mono-*o*	0.0003	0.001	0.002	0.0002	0.0002	0.0001	0.002	0.014	0.003
non-*o*	-	0.0004	<0.0001	<0.0001	0.0003	0.001	0.001	0.0003	0.0001

*pool of 4 individuals; [a]m = muscle; [b]l = liver

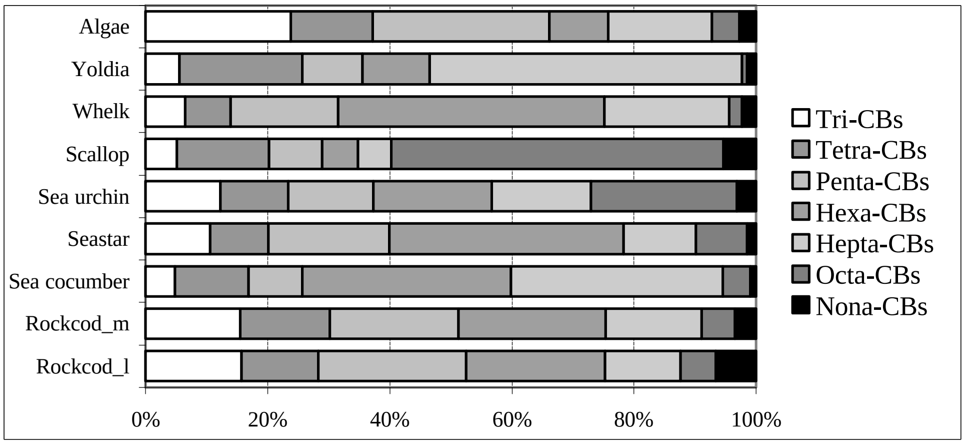

Figure 2: PCB class of isomer composition in the organisms.