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Contamination by Persistent Organochlorines in Small Cetaceans from Hong Kong Coastal Waters

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Blubber samples of 2 cetacean species, the Indo-Pacific hump-backed dolphin (*Sousa chinensis*) ($n = 11$) and finless porpoise (*Neophocaena phocaenoides*) ($n = 9$), collected from Hong Kong coastal waters were analysed for persistent organochlorines. Mean concentration in the blubber of DDTs was ranked first (46 μg/g wet wt.), followed by PCBs (24 μg/g wet wt.), HCHs (0.76 μg/g wet wt.), chlordane compounds (0.38 μg/g wet wt.) and HCB (0.07 μg/g wet wt.). The present cetacean species may potentially be faced with high risk due to the elevated level of DDTs and PCBs. Relatively high concentrations of PCBs and DDTs can be attributed to the continuous environmental input of these compounds in the Far East region including Hong Kong. Highly chlorinated PCBs such as IUPAC Nos. 138, 153, 180 were the prominent congeners, accounting for 39% of the total PCBs. Mean concentrations of 6 non- and mono-*ortho* coplanar congeners were 2.1 and 2.8 μg/g wet wt. in the hump-backed dolphin and finless porpoise, respectively. Among highly toxic coplanar PCBs, mono-*ortho* congener IUPAC No. 118 and non-*ortho* congener IUPAC No. 126 were estimated to have the greatest toxicity contribution. *Tris*(4-chlorophenyl) methane (TCPMe) and *tris*(4-chlorophenyl) methanol (TCPMeOH), which have been the most recently identified microcontaminants, were also detected with the highest concentration of 290 and 300 ng/g (wet wt. basis), respectively. The concentrations of TCPMe relative to TCPMeOH in cetaceans from Hong Kong coastal waters were significantly higher than those found in various seals collected from other parts of the world, suggesting the different metabolic system of these two compounds between seals and cetaceans. Correlations between the concentrations of *tris*-chlorophenyl compounds with other persistent organochlorines such as HCHs, CHLs, DDTs and PCBs were significant, suggesting their accumulation nature similar to these organochlorines.

Introduction

The Far East region, a rapidly industrialized area in the world, has attracted numerous research interests during the last decade. Particularly, the marine ecosystem in the Far East is under pressure due to expanding industrial activities (Phillips, 1989). Hong Kong is one of the target areas in the Far East region with regard to environmental pollution arising from high urbanization and industrialization. Several investigations dealing with contamination by persistent organochlorines (OCs) in Hong Kong demonstrated considerable exposure by populations (Ip and Phillips, 1989) and the marine ecosystem (Phillips, 1985, Phillips, 1989). Furthermore, a number of studies conducted in our laboratory also indicated notable contamination by polychlorinated biphenyls (PCBs), particularly toxic coplanar PCBs in various environmental compartments such as sediments (Kannan *et al.*, 1989) and mussels from Hong Kong (Tanabe *et al.*, 1987; Kannan *et al.*, 1989). A recent investigation based on the fugacity model has shown that persistent OCs may pose significant risks to marine ecosystems in Hong Kong (Connell *et al.*, 1998). These findings lend credence to the serious environmental situation in Hong Kong, which is believed to be a consequence of recent growth in urbanisation and industrialisation. Nevertheless, only few data dealing with OC contamination in higher trophic animals in the Hong Kong coastal area are available so far. The actual exposures of OC in marine mammals, which have been considered as the most vulnerable organisms with regard to long-term toxicity of hazardous man-made chemicals, are still scarce. Studies on the accumulation of OC in marine mammals are therefore necessary to elucidate contamination status and environmental impacts in the Hong Kong coastal waters. The only previous work was the study done by Parsons and Chan (in press).

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In this study, an effort was made to provide a better understanding about OC pollution in Hong Kong coasts by analysing two species of cetaceans, the Indo-Pacific hump-backed dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*), found stranded along the Hong Kong coasts during 1993–1997. Residue levels and accumulation characteristics of OCs such as DDTs, PCBs, HCHs (hexachlorocyclohexane isomers), HCB (hexachlorobenzene) and CHLs (chlordanes compounds) in these two cetaceans were discussed. Highly toxic coplanar PCBs were also analysed and possible toxicological impacts were assessed. In addition, the residues of two newly identified microcontaminants, such as *tris*-(4-chlorophenyl)methane (TCPMe) and *tris*(4-chlorophenyl)methanol (TCPMeOH), were examined in this study. Metabolic capacity of cetaceans to these chemicals was also evaluated.

Materials and Methods

Indo-Pacific hump-backed dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*) specimens used in the present study were found dead in several locations in Hong Kong from 1993 to 1997 (Fig. 1). Blubber samples were collected from these cetaceans and stored at −20°C until analysis. This work were conducted as part of a larger study on population biology of dolphins in Hong Kong (see Jefferson, 1998).

The analytical method for OCs consisting of Soxhlet extraction, clean-up, fractionation and lipid content determination was described elsewhere (Tanabe *et al*., 1994a). Briefly, about 5 g samples were homogenized with anhydrous Na_2SO_4 and extracted by Soxhlet apparatus for 8 h with a mixture of diethylether:hexane (3:1) (v/v). Samples were then passed through a dry florisil column for removing fat. After eluting OCs from the dry column with a mixture of acetonitrile and water and partitioning in a separatory funnel, hexane extracts were concentrated.

For the identification and quantification of TCPMe and TCPMeOH, aliquots of hexane extract after partitioning were not treated with sulfuric acid to avoid decomposition (de Boer *et al*., 1996) and were directly passed through an 8 g florisil-packed glass column for fractionation. The first fraction eluted with hexane contained HCB, PCBs, *p,p′*-DDE, and *trans*-nonachlor while the second fraction eluted with 20% dichloromethane in hexane contained chlordane compounds (oxychlordane, *trans*-chlordane, *cis*-chlordane, *cis*-nonachlor), *p,p′*-DDD, *p,p′*-DDT, HCHs and TCPMe. The third fraction was collected with 50% dichloromethane in hexane for TCPMeOH separation. Each fraction was concentrated and injected into GC and GC/MS for quantification.

Organochlorines in the first and second fractions (except TCPMe) were quantified by GC–ECD (Hewlett Packard 5890 II Series) equipped with a moving needle-type injected port. The GC column employed was DB-1 (J & W Scientific Inc., USA) fused silica capillary column (0.25 mm × 30 m) coated with 100% dimethyl polysiloxane at 0.25 μm film thickness. The column oven temperature was programmed from 60°C to 160°C held for 19 min and then increased to 260°C at a rate of 2°C/min and held for 30 min. Injector and detector temperatures were set at 260°C and 280°C, respectively. Helium and nitrogen were used as carrier and make up gases, respectively. Organochlorine concentrations were calculated from the peak area of the sample to the corresponding external standard. The PCB standard used for quantification was an equivalent of the Kanechlor mixture (KC-300, KC-400, KC-500, KC-600) with known PCB composition and content. Concentrations

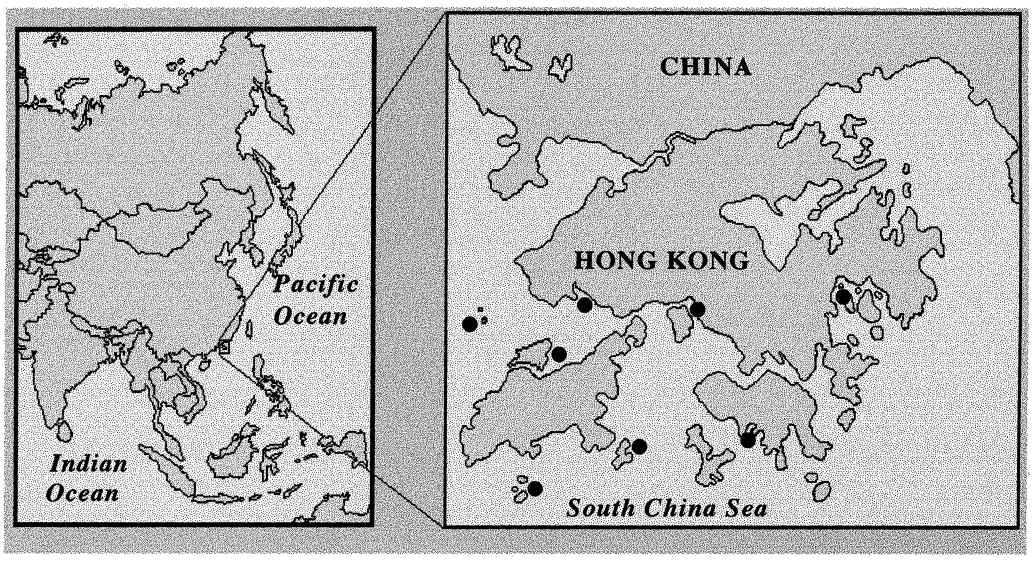

Fig. 1 Map showing the locations of stranded cetaceans found in Hong Kong coastal waters, which were used for chemical analysis.

of individually resolved peaks of PCB isomers and congeners were summed to obtain total PCB concentration. For TCPMe and TCPMeOH quantification, a GC/MS (Hewlett-Packard 5890 in coupled with 5970 mass selective detector) was employed. Data acquisition was carried out by HP 5970C Data system, in which cluster ions were monitored at m/z 139, 253, 251, 362, 364 for TCPMeOH and 311, 313, 346, 348 for TCPMe.

Isomer-specific analysis of PCBs including coplanar congeners was conducted following the alkaline-alcohol digestion method (Wakimoto *et al*., 1971; Tanabe *et al*., 1987). Quantification was carried out using a GC–MS (Hewlett Packard 5890 II Series in coupled with 5970 mass selective detector). Hewlet Packard 5970 data system was used for quantification, in which cluster ions were monitored at m/z 256, 292, 326, 360, 394 and 430 for tri-, tetra-, penta-, hexa-, hepta- and octa-chlorobiphenyls, respectively.

Recoveries of OC through analytical procedure ranged from 88% to 104% for OC pesticides, 90–110% for TCPMe and TCPMeOH and 89–103% for PCB isomers including toxic coplanar PCBs. Concentrations were not corrected for recovery percentages.

Results and Discussion

Concentrations of OC including TCPMe and TCPMeOH in the blubber of Indo-Pacific hump-backed dolphins and finless porpoises from Hong Kong coastal waters are shown in Table 1. Residue levels of DDTs (sum of p,p'-DDE, p,p'-DDD, p,p'-DDT) were predominant, followed by PCBs, HCHs, chlordane compounds (CHLs), HCB, TCPMe and TCPMeOH. This pattern is similar to that found in cetaceans from several locations in the North Pacific. This is explained by their high persistency, less biodegradability and strong affinity to lipid-rich tissues, and therefore DDTs and PCBs are retained in the body of animals for a long period of time (Tanabe *et al*., 1994a,b). It was also noted that extremely high concentrations of DDT (>100 μg/g wet wt.) and PCB (up to 50 μg/g wet wt.) were observed in some specimens. It was suggested that total PCBs concentration of >50 μg/g (wet wt.) in the blubber may cause a health risk to cetaceans (Wagemann and Muir, 1984). On this basis, residue levels of PCBs in some cetaceans from Hong Kong may be enough to cause a health risk and affect populations of these animals. Moreover, additional toxic effects on these species may be suggested due to the elevated DDTs concentrations.

The concentrations of DDT were found in males ranging from 31 to 80 μg/g and 26 to 160 μg/g (wet wt. basis) for hump-backed dolphins and finless porpoises, respectively. Generally, there was no significant difference in the concentrations between the two species. As seen in Table 2, DDTs concentrations in cetaceans from Hong Kong coastal waters were comparable to those found in the Asian region (Prudente *et al*., 1997). Similarly, DDT concentrations were comparable to those reported in harbour porpoises from the Black Sea (Tanabe *et al*., 1997a), but higher than those reported from the west coast of South Africa (deKock *et al*., 1994) and the coastal areas of eastern and northern European countries (Law *et al*., 1997; Granby and Kinze, 1994). However, DDT levels found in the present study were still lower than some highly polluted areas in the Mediterranean Sea, such as Spanish (Kannan *et al*., 1993) and Italian coastal waters (Corsolini *et al*., 1995).

Among DDT metabolites, p,p'-DDE accounted for the highest composition, 48% in finless porpoise and 63% in the hump-backed dolphin (Fig. 2). Aguilar (1984) suggested a ratio of p,p'-DDE-DDTs of 0.6 in the marine mammals is indicative of fresh input of DDT. The present results suggest the recent input of DDTs in Hong Kong ecosystem (see also Parsons and Chan, in press). Further, Hong *et al*. (1995) reported that sediment in Xiamen Harbour contained very high composition of p,p'-DDT (up to 85%). This finding supports the recent inputs of DDT in southern China, as has been suggested from our study with marine mammals.

Elevated DDT levels found in Hong Kong cetaceans are related to the DDT utilization in this country until 1989 (Phillips and Tanabe, 1989). Statistical data on the movement of pesticides to and from Hong Kong, as reported by Ip (1990), showed a considerable difference in the quantities of pesticides exported and imported, in which DDT occupied the largest net gain (over 700 metric tons) compared to the others such as HCB (25 metric tons) and lindane (12 metric tons). Although the reported data are more than 5 yr old from the present day, it can be inferred that such a fact could be an explanation for the DDT contamination.

As shown in Table 1, PCB concentrations ranged between 3.3–50 μg/g (wet wt. basis), higher than in the hump-backed dolphin from Bay of Bengal, India (Prudente *et al*., 1997), harbour porpoise from various coastal waters of the western North Atlantic (Westgate *et al*., 1997) but lower than the diseased cetaceans from the Mediterranean Sea (Kannan *et al*., 1993; Corsolini *et al*., 1995). The PCB usage in Hong Kong has been reported by Morton (1989), who noted that over 3300 capacitors are still in use or in storage in Hong Kong. This fact may be a plausible explanation for the elevated levels of PCBs found in cetaceans in Hong Kong waters. Moreover, the presence of PCBs was also found in mussels in various locations in the Hong Kong coastal area at relatively high concentrations (Tanabe *et al*., 1987). This fact could also be realistic evidence for PCB contamination. Fig. 3 shows the pattern of PCB isomer composition. As commonly found in cetaceans, hexa- and hepta-chlorobiphenyls occupied a major composition, in which IUPAC 138, 153 and 180 were the dominant congeners, accounting for 39% of the total PCBs. Apparently similar patterns were observed in both species, reflecting the similar source of exposure of PCBs.

TABLE 1

Concentrations of organochlorines (ng/g wet wt.) in the blubber of small cetaceans collected from Hong Kong coastal waters.

No.	Specimen number	Sex	Body length (cm)	Lipid content (%)	DDTs[a]	PCBs[a]	HCHs	CHLs	HCB	TCPMe	TCPMeOH
	Hump-backed dolphin										
1	SC97-31/05A	M	117	76	80	50	510	510	240	88	220
2	SC93-26/05	M	163	31	59	48	710	250	160	120	270
3	SC94-23/12	M	222	34	31	33	300	580	43	65	170
4	SC95-11/02	M	247	73	49	40	570	550	38	99	66
5	SC94-28/04	M	230	45	53	19	1700	450	60	240	200
6	SC96-29/8	M	102	30	61	13	1400	260	59	43	160
7	SC96-31/8	M	105	32	62	15	2200	410	13	73	170
8	SC96-26/05	F	107	54	5.1	3.3	52	44	30	4.1	12
9	SC97-31/05B	F	235	71	55	30	370	840	77	290	110
10	SC96-9/8	F	107	30	44	13	500	200	31	56	84
11	SC97-27/03	F	u.n[b]	63	6.6	4.4	5.4	76	34	13	12
Mean					46	24	760	380	71	99	134
Range					5.1–80	3.3–50	5.4–2200	44–840	13–240	4.1–290	12–270
	Finless porpoise										
1	NP96-11/01	M	168	75	160	48	1100	720	110	260	300
2	NP96-23/7	M	144	29	26	6.7	54	94	26	67	110
3	NP96-25/04	M	84	87	37	5.9	180	120	86	27	35
4	NP97-26/01	F	150	77	5.4	1.4	20	30	13	14	13
5	NP95-02/11	F	83	76	24	2.6	64	67	49	24	37
6	NP93-22/12	F	71	81	70	27	580	610	240	22	100
7	NP97-23/01	F	157	73	2.6	0.8	27	14	5.6	9.5	7.3
8	NP97-12/04	u.n.	ca. 140	90	14	6.1	46	85	41	42	19
9	NP97-15/08	u.n.	157	81	10	8.1	53	100	71	27	22
Mean					39	12	240	210	71	55	71
Range					2.6–160	0.8–48	20–1100	14–720	5.6–240	9.5–260	7.3–300

[a] concentrations in μg/g wet wt.
[b] $\gg$ 200 cm; u.n.: unknown; M: Male; F: Female.

TABLE 2

Comparison of organochlorine residue levels (μg/g wet wt.) in male cetaceans from Hong Kong waters with those in cetaceans from different locations.

Species	Location	Survey year	PCBs	DDTs	HCHs	CHLs	HCB	References
Finless porpoise	Hong Kong waters	1993–1997	27	93	0.58	0.41	0.068	Present study
Hump-backed dolphin	Hong Kong waters	1993–1997	35	48	0.82	0.46	0.075	Present study
Spinner dolphin	Mindanao Sea, Philippines	1996	7.7	43	0.24	0.93	0.06	Prudente *et al.* (1997)
Hump-backed dolphin	Bay of Bengal, India	1992	4.6	55	0.6	0.1	0.01	Prudente *et al.* (1997)
Spinner dolphin	Bay of Bengal, India	1990–1991	0.1	16	0.1	na	0.01	Tanabe *et al.* (1993)
Dall's porpoise	Northern North Pacific	1987	17	17	1.7	3.8	0.67	Prudente *et al.* (1997)
Dall's porpoise	Japan Sea	1989	27	49	6.5	5.4	1.3	Prudente *et al.* (1997)
Striped dolphin	Western North Pacific	1986	28	37	0.27	na	0.15	Loganathan *et al.* (1990)
Risso's dolphin	Off Taiji, Japan	1991	110	37	0.34	11	0.21	Prudente *et al.* (1997)
Baird's beaked whale	Wadaura, Chiba, Japan	1985–1989	10	10	0.14	0.89	0.33	Prudente *et al.* (1997)
Harbour porpoise	Black Sea	1993	16	70	10	0.8	0.4	Tanabe *et al.* (1997a), Tanabe *et al.*, 1997b
Bottlenose dolphin	Mediterranean Sea	1992	560	190	na[a]	na	na	Corsolini *et al.* (1995)
Harbour porpoise	Danish and Norwegian waters	1987–1991	23	16	0.7	2.1	0.6	Kleivane *et al.* (1995)
Harbour porpoise	Great Britain	1990	22	7.7	1.2	na	0.6	Kuiken *et al.* (1993)
Harbour porpoise	Danish and Greenland waters	1986–1988	13	13	0.43	na	0.71	Granby and Kinze (1994)
Harbour porpoise	West Cost, North America	1986–1989	10	15	0.8	2.4	0.35	Jarman *et al.* (1996)
Harbour porpoise	Newfoundland, Western North Atlantic	1989–1991	5.2	4.1	0.39	na	6.9	Westgate *et al.* (1997)
Harbour porpoise	Gulf St. Lawrence Western North Atlantic	1989–1991	11	7	0.51	na	14	Westgate *et al.* (1997)
Beluga whale	St. Lawrence river estuary, Canada	1987–1990	65	67	0.38	6.9	na	Muir *et al.* (1996)
Bowhead whale	Alaska, USA		0.11	0.44	na	na	na	Varanasi *et al.* (1992)
Killer whale	West Cost, North America	1986–1989	22	32	0.71	3.9	0.45	Jarman *et al.* (1996)
Common dolphin	South Africa	1984–1986	8.4	5.5	na	na	0.1	deKock *et al.* (1994)

[a] na: not analysed.

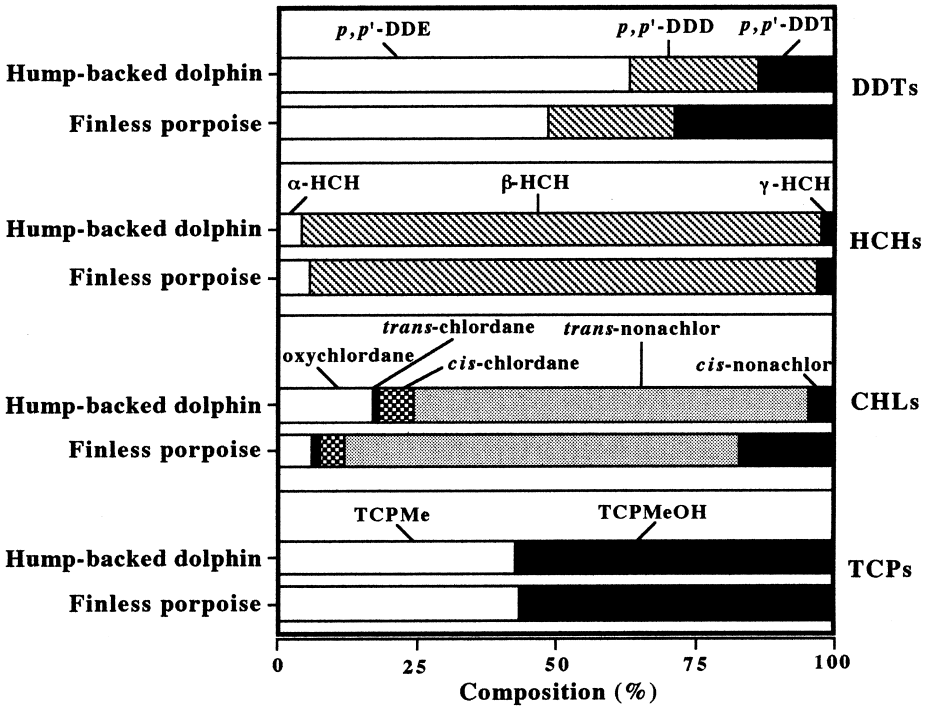

Fig. 2 Percentage compositions of organochlorines in small cetaceans from Hong Kong coastal waters.

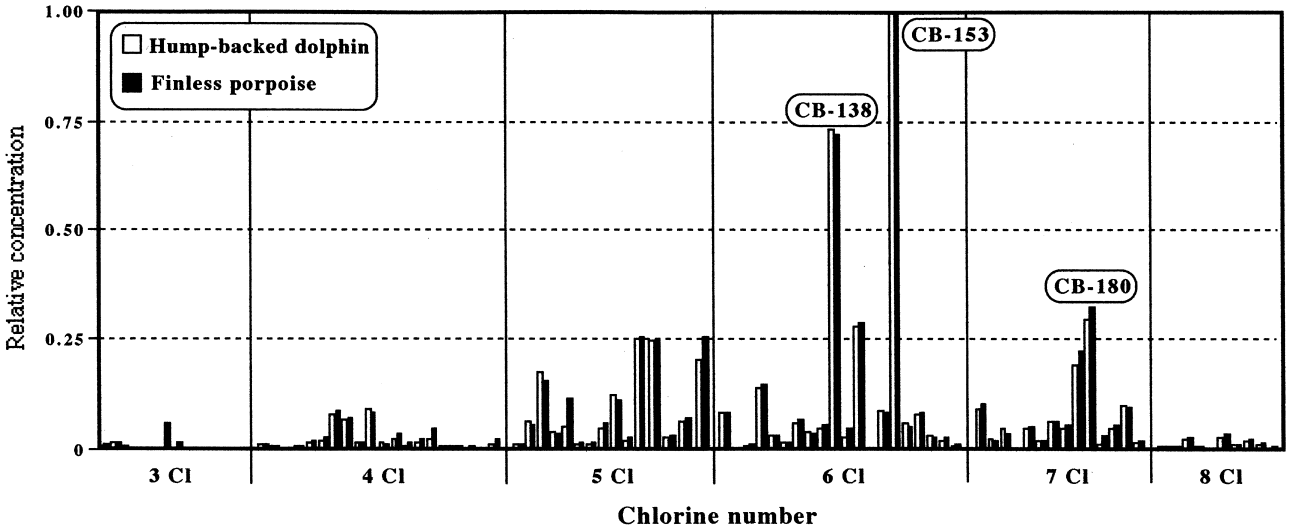

Fig. 3 PCBs isomer and congener compositions in male cetaceans from Hong Kong waters. Vertical bars represent concentrations of individual congeners relative to the most abundance congener (IUPAC No. 153), which was treated as 1.0.

Relatively high concentrations of total PCBs found in Hong Kong small cetaceans prompted us to examine the residue levels of toxic coplanar PCBs. The concentrations of non-, mono- and di-*ortho* congeners in the blubber of male cetaceans are given in Table 3. Among the toxic mono- and non-*ortho* coplanar PCBs, concentrations of mono-*ortho* congeners were about 1–2 orders of magnitude higher than the non-*ortho* ones. Levels of mono- and non-*ortho* congeners were higher than in harbour porpoises in the Black Sea (Tanabe *et al.*, 1997b), but apparently lower than striped dolphins from the western Mediterranean Sea (Kannan *et al.*, 1993) and some odontocetes from Italian coastal waters (Corsolini *et al.*, 1995). As for highly toxic non-*ortho* congeners, the residue pattern was T_4CB (IUPAC 77) > P_5CB (IUPAC 126) > H_6CB (IUPAC 169). The concentration of the more biodegradable congener IUPAC 77 remained at the highest concentration. This result may be explained by the high abundance of CB-77 in technical PCB mixtures, about 3–4 orders of

TABLE 3

Mean and range concentrations of non- and mono-*ortho* coplanar PCBs and their 2,3,7,8-TCDD toxic equivalents (TEQs) in the blubber of male cetaceans from Hong Kong coastal waters.

PCB congener (IUPAC No.)	Concentration (ng/g wet wt.)			TEQs (pg/g wet wt.)	
	Hump-backed dolphin ($n = 6$)	Finless porpoise ($n = 2$)	TEF value[a]	Hump-backed dolphin	Finless porpoise
Non-*ortho*					
77	9.1 (3.6–19)[b]	3.3 (0.56–6)	0.0005	4.6 (0.36–1.9)	1.7 (0.056–0.6)
126	2.1 (1.1–2.9)	0.6 (0.27–0.92)	0.1	210 (110–290)	60 (27–92)
169	0.62 (0.19–0.99)	0.36 (0.28–0.43)	0.01	6.2 (1.9–9.9)	3.6 (2.8–4.3)
Mono-*ortho*					
105	440 (290–590)	450 (140–750)	0.0001	44 (29–59)	45 (14–75)
118	1500 (1100–2000)	2200 (510–3800)	0.0001	150 (110–200)	220 (51–380)
156	190 (90–290)	130 (64–190)	0.0005	95 (45–145)	65 (32–95)

[a] Toxic equivalent factor values were obtained from Ahlborg *et al.* (1994).
[b] Values in parentheses indicate the range.

magnitude higher than IUPAC 126 and 169, respectively (Kannan *et al.*, 1993).

The 2,3,7,8-TCDD toxic equivalents (TEQs) approach, using toxic equivalent factors (TEFs) reported by Ahlborg *et al.* (1994), was adopted for the toxicity assessment of mono- and non-*ortho* coplanar PCBs in male cetaceans from Hong Kong waters. The mean and ranges of TEQs for 6 coplanar PCBs were given in Table 3. Generally, mono-*ortho* congeners contributed larger TEQs than non-*ortho* PCBs, with IUPAC-118 showing the highest. Similar results were also observed in other marine mammals (Kannan *et al.*, 1989; Corsolini *et al.*, 1995). However, as shown in Table 3, non-*ortho* congeners IUPAC-126 had the highest percentage in hump-backed dolphins, accounting for 41% of the TEQ contribution. Based on these observations, it can be proposed that the mono-*ortho* congener IUPAC-118 (2,3′,4,4′,5-pentachlorobiphenyl) and non-*ortho* congener IUPAC-126 (3, 3′, 4, 4′, 5-pentachlorobiphenyl) may be potentially hazardous toxicants exerting long-term toxic effects on cetaceans from Hong Kong waters.

As for chlordane compounds, the concentrations ranged between 14 and 840 ng/g (wet wt. basis), lower than those found in various Odontoceti species from the North Pacific and Indian Ocean (Prudente *et al.*, 1997). *Trans*-nonachlor is the dominant compound, followed by oxychlordane, *cis*-chlordane, *cis*-nonachlor and *trans*-chlordane (Fig. 3). This pattern is similar to other previous studies dealing with freshwater and marine mammals (Kannan *et al.*, 1994; Nakata *et al.*, 1995).

Among HCH isomers, β-HCH was the most predominant isomer, followed by α-HCH, while γ-HCH accounted for a relatively small percentage. This is different from the technical HCH mixture with the highest percentage of α-HCH. This fact indicates that cetaceans have the capacity to metabolise α-HCH and also reflects the high persistency of β-HCH towards enzymatic degradation. On a global scale, concentrations of HCHs and HCB were apparently lower than those in other countries in the Far East region and the other parts of the world (Table 2). This finding can be attributed to the evaporation nature of HCHs and HCB, particularly in the tropics (Tanabe *et al.*, 1994b). Dispersion via atmospheric transport and resultant low residue levels in the water phase may be a reason for less residue levels of HCHs and HCB in Hong Kong cetaceans.

The concentrations of TCPMeOH ranged from 12 to 270 and 7.3 to 300 ng/g (wet wt. basis) in the blubber of hump-backed dolphins and finless porpoises, respectively. There was no difference in TCPMeOH concentrations between the two species. The results of this study, nevertheless, due to the limited number of samples analysed and the lack of biological data of sample batch, could not clearly reflect sex and age trends. However, interestingly, the concentrations of TCPMe in the blubber samples (ranged from 4.1 to 290 and 9.5 to 260 ng/g wet wt. in hump-backed dolphins and finless porpoises, respectively) were comparable to those of TCPMeOH. So far, data for TCPMe in environmental samples are limited, because its analytical standard was synthesized only recently (de Boer *et al.*, 1996). As seen in Fig. 4, the concentration ratios of TCPMeOH to TCPMe in cetaceans were apparently lower than those in seals. Similar to this study, Muir *et al.* (1996) found comparable concentrations of these two compounds in beluga whales from the St. Lawrence River (Canada). These findings may suggest that the metabolic capacity is different between cetaceans and seals for TCPMe and TCPMeOH.

Table 4 shows the correlation coefficients and slope values of linear regressions between TCPMe/TCPMeOH and other OC concentrations. Significant correlations were observed with almost all OCs, except HCB, indicating that the bioaccumulative nature of

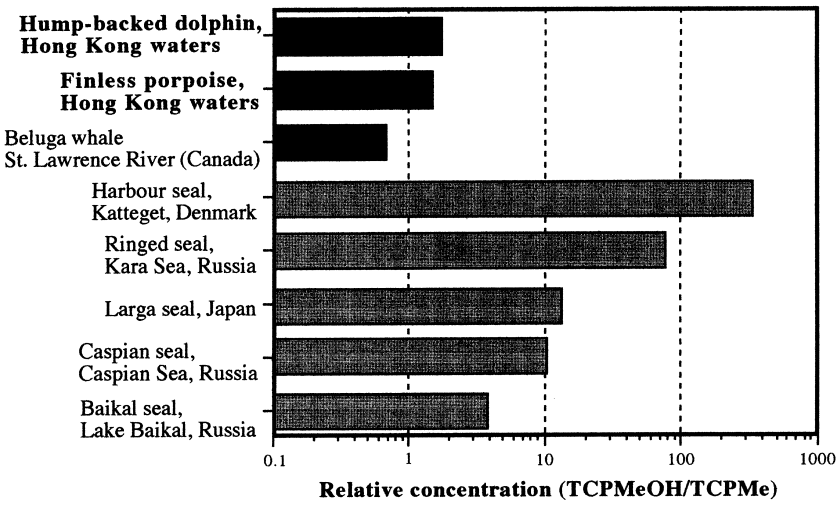

Fig. 4 Comparison of relative concentrations of TCPMeOH to TCPMe in cetaceans from Hong Kong waters with those in marine mammals from various locations. Data on beluga whales were cited from Muir *et al.* (1996); harbour seals from Rahman *et al.* (1993); ringed seals, larga seals, Caspian seals and Baikal seals from Watanabe *et al.*, in press; hump-backed dolphins and finless porpoises from the present study.

TABLE 4

Slope values (S) and correlation coefficients (R) of the linear regressions ($p < 0.01$) between TCPMe/TCPMeOH and other organochlorine concentrations in the blubber of cetaceans from Hong Kong coastal waters.

	DDTs		PCBs		HCHs		CHLs	
	S	R	S	R	S	R	S	R
TCPMe	0.0014	0.87	0.0033	0.65	0.15	0.76	0.33	0.90
TCPMeOH	0.0023	0.84	0.0044	0.80	0.16	0.75	0.39	0.87

TCPMe and TCPMeOH is similar to other organochlorines, such as PCBs and DDTs. In addition, the slope values of regression lines were not so varied in TCPMe and TCPMeOH, suggesting the similar biochemical and physicochemical nature of these two compounds. A previous investigation (Buser, 1995) suggested that technical DDT preparations might be a possible source of TCPMe and TCPMeOH. Significant correlations of TCPMe and TCPMeOH with DDTs in cetaceans in the present study may support this hypothesis.

Table 5 shows the comparison of TCPMe and TCPMeOH in marine mammals from various locations so far reported. In general, concentrations in cetaceans are apparently higher than in seals. The residue levels of TCPMeOH in hump-backed dolphins and finless porpoises from Hong Kong waters are apparently higher than those found in Caspian seals, Baikal seals (Watanabe *et al.*, in press), harp seals, whales and harbour seals from the St. Lawrence River, Canada (Jarman *et al.*, 1992) and Puget Sound, USA (Walker *et al.*, 1989). With regard to other coastal areas in developed European countries, such as southern North Sea, Dutch Wadden Sea (de Boer *et al.*, 1996), the concentration of TCPMeOH, however, was lower. Relatively high residue levels in Hong Kong are likely to indicate more serious contamination by these compounds in the Far East region. Inferring from such information, it can be suggested that TCPMe and TCPMeOH are widespread contaminants with potential accumulation features. Recent investigations reported that TCPMeOH has phase I and II induction and poses an antiandrogenic effect (Poon *et al.*, 1997; Korner *et al.*, 1997). Considering these toxic observations, further monitoring studies on TCPMe and TCPMeOH in higher trophic animals are necessary for understanding their ecological risk.

In general, the results of this study agree closely with those reported by Parsons and Chan (in press) for the same species in Hong Kong. The high concentration of OCs in some individuals, not to mention the high incidence of newborns among stranded dolphins and porpoises in Hong Kong over the past few years, both raise serious concerns over the effects of environmental contaminants on the populations involved (Jefferson, 1998; Parsons and Chan, in press). Unfortunately, we have very little scientific information on the actual health effects of such contaminants on wild individuals and

TABLE 5

Comparison of residue levels (ng/g lipid wt.) of TCPMe and TCPMeOH in blubber of marine mammals from various regions.

Species	Locations	Survey years	TCPMe	TCPMeOH	References
Harbour seal	Puget Sound, USA	1972–1982	na[a]	170	Walker *et al.* (1989)
Northern fur seal	St. Lawrence River, Canada	1981	na	17	Jarman *et al.* (1992)
Harp seal	St. Lawrence River, Canada	1952	na	2	Jarman *et al.* (1992)
Ringed seal	Baltic Sea	1980–1987	na	900	Zook *et al.* (1992)
Common seal	Dutch Wadden Sea	1990–1992	na	1200	de Boer *et al.* (1996)
Caspian seal	Caspian Sea, Russia	1993	12	120	Watanabe *et al.*, in press
Baikal seal	Lake Baikal, Russia	1995	5.4	20	Watanabe *et al.*, in press
Larga seal	Northwestern Japan	1992–1996	7.7	100	Watanabe *et al.*, in press
Beluga whale	St. Lawrence River, Canada	1987–1990	260	170	Muir *et al.* (1996)
Killer whale	Pacific coast, Japan	1986	na	1600	Watanabe *et al.*, in press
Whitebeaked dolphin	Newfoundland, Canada	1982	na	180	Norstrom and Simon (1988)
Whitebeaked dolphin	Dutch Wadden Sea	1992	na	570	de Boer *et al.* (1996)
Whitebeaked dolphin	Southern North Sea	1990	na	1400	de Boer *et al.* (1996)
Harbour porpoise	Southern North Sea	1990	na	1000	de Boer *et al.* (1996)
Hump-backed dolphin	Hong Kong waters	1993–1997	310	490	Present study
Finless porpoise	Hong Kong waters	1993–1997	290	390	Present study

[a] na: not analysed.

populations of small cetaceans. Over the next few years, we will try to determine if there are definable relations between environmental contaminant levels and pathology and health status of stranded cetaceans in Hong Kong. Such work is critical for us to move to the next stage in protecting these animals from the damaging effects of man-made chemicals on the marine ecosystem.

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Aguilar, A. (1984) Relationship of DDE/ΣDDT in marine mammals to the chronology of DDT input into the ecosystem. *Canadian Journal of Aquatic Fisheries Science* **41**, 840–844.

Ahlborg, U. G., Becking, G. C., Birnbaum, L. S., Brouwer, A., Derks, H. J. G. M., Feeley, M., Golor G., Hanberg, A., Larsen J. C., Liem, A. K. D., Safe, S. H., Schlatter, C., Waern, F., Younes, M. and Yrjanheikki, E. (1994) Toxic equivalency factors for dioxin-like PCBs. *Chemosphere* **28**, 1049–1067.

Buser, H. R. (1995) DDT, a potential source of environmental *tris* (4-chlorophenyl)methane and *tris* (4-chlorophenyl)methanol. *Environmental Science and Technology* **29**, 2133–2139.

Connell, D. W., Wu, R. S. S., Richardson, B. J., Leung, K., Lam, P. S. K. and Connell, P. A. (1998) Fate and risk evaluation of persistent organic contaminants and related compounds in Victoria harbour, Hong Kong. *Chemosphere* **36**, 2019–2030.

Corsolini, S., Focardi, S., Kannan, K., Tanabe, S., Borrell, A. and Tatsukawa, R. (1995) Congener profile and toxicity assessment of polychlorinated biphenyls in dolphin, sharks and tuna collected from Italian coastal waters. *Marine Environmental Research* **40**, 33–53.

de Kock, A. C., Best, P. B., Cockcroft, V. and Bosma, C. (1994) Persistent organochlorine residues in small cetaceans from the east and west coasts of Southern Africa. *Science Total Environment* **154**, 153–162.

de Boer, J., Wester, P. G., Evers, E. H. G. and Brinkman, U. A. T. (1996) Determination of *tris* (4-chlorophenyl)methanol and *tris* (4-chlorophenyl)methane in fish, marine mammals and sediment. *Environmental Pollution* **93**, 39–47.

Granby, K. Kinze, C. C. (1991) Organochlorines in Danish and West Greenland harbour porpoise. *Marine Pollution Bulletin* **22**, 458–462.

Hong, H., Xu, L., Zang, L., Chen, J. C., Wong, Y. S. and Wan, T. S. M. (1995) Environmental fate and chemistry of organic pollutants in the sediment of Xiamen and Victoria Harbours. *Marine Pollution Bulletin* **31**, 229–236.

Ip, H. M. H. and Phillips, D. J. H. (1989) Organochlorine chemicals in human breast milk in Hong Kong. *Archieves of Environmental and Contamination Toxicology* **18**, 490–494.

Ip, H. M. H. (1990) Chlorinated pesticides in foodstuffs in Hong Kong. *Archieves of Environmental and Contamination Toxicology* **19**, 291–296.

Jarman, W. M., Simon, M., Nostrom, R. J., Bruns, S. A., Bacon, C. A., Simaret, B. R. T. and Riseborough, R. W. (1992) Global distribution of *tris*(4-chlorophenyl)methanol in high trophic level birds and mammals. *Environmental Science and Technology* **26**, 1770–1774.

Jarman, W. M., Norstrom, R. J., Muir, D. C. G., Rosenberg, B., Simon, M. and Baird, R. W. (1996) Level of organochlorine compounds, including PCDDs and PCDFs, in the blubber of cetaceans from the West Coast of North America. *Marine Pollution Bulletin* **32**, 426–436.

Jefferson, T. A. (1998) Population biology of the Indo-Pacific hump-backed dolphin (*Sousa chinensis* Osbeck, 1765) in Hong Kong waters: final report. Report to the Agriculture and Fisheries Department of the Hong Kong SAR Government, p. 128.

Kannan, N., Tanabe, S., Tatsukawa, R. and Phillips, D. H. J. (1989a) Persistency of highly toxic coplanar PCBs in aquatic ecosystem: uptake and release kinetics of coplanar PCBs in green-lipped mussels (*Perna viridis linnaeus*). *Environmental Polllution* **56**, 65–76.

Kannan, N., Tanabe, S., Okamoto, T., Tatsukawa, R. and Phillips, D. J. H. (1989b) Polychlorinated biphenyls (PCBs) in sediments in Hong Kong: a congener-specific approach to the study of coplanar PCBs in aquatic ecosystem.*Environmental Pollution* **62**, 223–235.

Kannan, N., Tanabe, S., Ono, M. and Tatsukawa, R. (1989c) Critical evaluation of polychlorinated biphenyls toxicity in terrestrial and marine mammals: increasing impact of non-*ortho* and mono-*ortho* coplanar polychlorinated biphenyls from land to ocean. *Archieves of Environmental and Contamination Toxicology* **18**, 850–857.

Kannan, K., Tanabe, S., Borrell, A., Aguilar, A., Focardi, S. and Tatsukawa, R. (1993) Isomer-specific analysis and toxic evaluation of polychlorinated biphenyls in stripped dolphin affected by an epizootic in the western Mediterranean Sea. *Archieves of Environmental and Toxicology* **25**. 227–233.

Kannan, K., Tanabe, S. and Tatsukawa, R. (1994) Biodegradation capacity and residue pattern of organochlorines in Ganges River dolphin from India. *Toxicology and Environmental Chemistry* **42**, 249–261.

Kleivane, L., Skare, J. U., Bjorge, A., Ruiter, E. and Reijnder, P. J. H (1995) Organochlorine pesticide residue and PCBs in harbour porpoise (*Phocoena phocoena*) incidentally caught in Scandinivian waters. *Environmental Pollution* **89**, 137–146.

Korner, W., Hanf, V., Oettling, G., Schuller, W. and Hangenmaier, H. (1997) Effects of *tris* (4-chlorophenyl)methanol on proliferation of human breast cancer cells. *Organohalogen Compounds* **34**, 364–369.

Kuiken, T., Hofle, U., Bennett, P. M., Allchin, C. R., Kirkwood, J. K., Baker, J. R., Appleby, E. C., Lockyer, C. H., Walton, M. L. and Sheldrick, M. C. (1993) Adrenocortical hyperplasia, disease and chlorinated hydrocarbons in the harbour porpoises (*Phocoena phocoena*). *Marine Pollution Bulletin* **26**, 440–446.

Law, R. J., Allchin, C. R., Jones, B. R., Jepson, P. D., Baker, J. R. and Spurrier, C. J. H. (1997) Metals and organochlorines in tissues of Blainville's beaked whale (*Mesoplodon densirostris*) and killer whale (*Orcinus orca*) stranded in the United Kingdom. *Marine Pollution Bulletin* **34**, 208–212.

Loganathan, B. G., Tanabe, S., Tanaka, H., Watanabe, S., Miyazaki, N., Amano, M. and Tatsukawa, R. (1990) Comparison of organochlorine residue levels in the stripped dolphin from Western North Pacific, 1978–1979 and 1986. *Marine Pollution Bulletin* **21**, 435–439.

Morton, B. S. (1989) Pollution of the coastal waters of Hong Kong. *Marine Pollution Bulletin* **20**, 310–318.

Muir, D. C. G., Ford, C. A., Rosenberg, B., Norstrom, R. J., Simon, M. and Beland, P. (1996) Persistent organochlorines in beluga whales (*Delphinapterus leucas*) from the St. Lawrence River estuary – I. Concentrations and patterns of specific PCBs, chlorinated pesticides and polychlorinated dibenzo-*p*-dioxins and dibenzofurans. *Environmental Pollution* **93**, 219–234.

Nakata, H., Tanabe, S., Tatsukawa, R., Amano, M., Miyazaki, N. and Petrov, E. A. (1995) Persistent organochlorine residues and their accumulation kinetics in Baikal seal (*Phoca sibirica*) from lake Baikal, Russia. *Environmental Science andTechnology* **29**, 2877–2885.

Norstrom, R. and Simon, M. (1988) Presence of *tris*(4-chlorophenyl)methanol in Canadian environmental tissue samples. Rep CRD-88-7. Canadian Wildlife Service, Chemistry Research Division, Hull, Quebec, Canada.

Parsons, E. C. M. and Chan, H. M. (in press) Organochlorines in Indo-Pacific hump-backed dolphin (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) from Hong Kong. In *The Marine Biology of the Sounth China Sea*, ed. B. Morton. Hong Kong University Press, Hong Kong.

Phillips, D. J. H (1985) Organochlorines and trace metals in green-lipped mussel *Perna viridis* from Hong Kong waters: a test of indicator ability. *Marine Ecology and Progressive Series* **21**, 251–258.

Phillips, D. J. H. and Tanabe, S. (1989) Aquatic pollution in the Far East. *Marine Pollution Bulletin* **20**, 297–303.

Phillips, D. J. H. (1989) Trace metals and organochlorines in the coastal waters of Hong Kong. *Marine Pollution Bulletin* **20**, 319–327.

Poon, R., Lecavalier, P., Bergman, A., Yaminas, A., Chu, I. and Valli, V. E. (1997) Effect of *tris*(4-chlorophenyl)methanol on the rat following shot-term oral exposure. *Chemosphere* **34**, 1–12.

Prudente, M., Tanabe, S., Watanabe, M., Subramanian, A., Miyazaki, N., Suarez, P. and Tatsukawa, R. (1997) Organochlorine contamination in some odontoceti species from the North Pacific and Indian Ocean. *Marine Environmental Research* **44**, 415–427.

Rahman, M. S., Montanarella, L., Johansson, B. and Larsen, B.R. (1993) Trace levels of *tris*(4-chlorophenyl)methanol and methane in human milk. *Chemosphere* **27**, 1487–1497.

Tanabe, S., Tatsukawa, R. and Phillips, D. J. H. (1987) Mussel as bioindicators of PCBs pollution: a case study on uptake and release of PCB isomers and congeners in green-lipped mussels (*perna viridis*) in Hong Kong waters. *Environmental Pollution* **47**, 41–62.

Tanabe, S., Subramanian, A. N., Ramesh, A., Kumaran, P. L., Miyazaki, N. and Tatsukawa, R. (1993) Persistent organochlorine residues in dolphins from the Bay of Bengal, South India. *Marine Pollution Bulletin* **26**, 311–316.

Tanabe, S., Sung, J, Choi, D., Baba, N., Kiyota, M. Yoshida, K. and Tatsukawa, R. (1994a) Persistent organochlorine residues in northern fur seal from the Pacific coast of Japan since 1971. *Environmental Pollution* **85**, 305–314.

Tanabe, S., Iwata, H. and Tatsukawa, R. (1994b) Global contamination by persistent organochlorines and their ecotoxicological impact on marine mammals. *Science Total Environment* **154**, 163–177.

Tanabe, S., Madhusree, B., Ozturk, A. A., Tatsukawa, R., Miyazaki, N., Ozdamar, E., Orhan, A., Samsun, O. and Ozturk, B. (1997a) Persistent organochlorine residues in harbour porpoise (*Phocoena phocoena*) from the Black Sea. *Marine Pollution Bulletin* **34**, 338–347.

Tanabe, S., Madhusree, B., Ozturk, A. A., Tatsukawa, R., Miyazaki, N., Ozdamar, E., Orhan, A., Samsun, O. and Ozturk, B. (1997b) Isomer-specific analysis of polychlorinated biphenyls in harbour porpoise (*Phocoena phocoena*) from the Black Sea. *Marine Pollution Bulletin* **34**, 712–720.

Varanasi, U., Stein, J. E., Tilbury, K. L., Brown, D. W., Meador, J.P., Krahn, M. M. and Chan, S. L. (1993) Contaminant monitoring for NMFS Marine mammals health and stranding response program. In *Coastal Zone 93: Proceedings of the Eighth Symposium on coastal and ocean management*, eds. O. T. Magoon, W. S. Wilson, H. Converse and L. T. Tobin, pp. 2517–2530. American Society of Civil Engineers, New York.

Wagemann, R. and Muir, D. C. G. (1984) Concentrations of heavy metals and organochlorines in marine mammals of northern waters: overview and evaluation. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1279, Western Region, Department of Fisheries and Oceans, Canada.

Wakimoto, T., Tatsukawa, R. and Ogawa, T. (1971) Analytical method of PCBs. *Journal of Environmental Pollution Control* **7**, 517–522.

Walker, W., Riseborough, R. W., Jarman, W. M., Lappe, B. W., Lappe, J. A., Tefft, J. A. and de Long, R. L. (1989) Identification of *tris* (4-chlorophenyl)methanol in blubber of harbour seals from Puget Sound. *Chemosphere* **18**, 1799–1804.

Watanabe, M., Tanabe, S., Amano, M., Miyazaki, N., Petrov, E. A. and Jarman, W. M. (in press) Contamination of *tris*(4-chlorophenyl)methane and *tris*(4-chlorophenyl)methanol in marine mammals from Russia and Japan: body distribution, bioaccumulation and contamination status. *Marine Pollution Bulletin*.

Westgate, A., Muir, D. C. G., Gaskin, D. and Kingsley, M. C. S. (1997) Concentration and accumulation patterns of organochlorine contaminants in the blubber of harbour porpoise, *Phocoena phocoena*, from the coast of Newfoundland, the Gulf of St. Lawrence and the Bay of Fundy/gulf of Maine. *Environmental Pollution* **95**, 105–119.

Zook, D. R., Buser, H. R., Bergqvist, P. A., Rappe, C. and Olsson, M. (1992) Detection of *tris*(4-chlorophenyl)methane and *tris*(4-chlorophenyl)methanol in ringed seal (*Phoca hispida*) from the Baltic Sea. *Ambio* **21**, 557–560.