Recent contamination of persistent chlorinated endocrine disrupters in cetaceans from the North Pacific and Asian coastal waters

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Abstract To elucidate the global distribution and toxicological impacts of persistent organochlorines (OCs) on cetaceans, the present study determined the concentrations of organochlorine pesticides such as DDT and its metabolites (DDTs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB), chlordane compounds (CHLs) and PCBs including toxic coplanar congeners in the blubber of 10 species of adult male odontoceti cetaceans collected from several locations in the North Pacific Ocean and coastal waters of Japan, Hong Kong, Philippines and India during 1985–1997. Concentrations of *tris*(4-chlorophenyl)methane (TCPMe) and *tris*(4-chlorophenyl)methanol (TCPMOH), which are among the newly identified contaminants, were also determined. Residue pattern was in the order of DDTs≥PCBs>CHLs>HCHs>HCB>TCPMOH> TCPMe. Greater DDT concentrations were found in cetaceans from the Japan Sea, coastal waters of Hong Kong and India, indicating serious marine pollution in industrialized Asian nations and current usage of DDTs in tropical regions. In general, cetaceans inhabiting cold and temperate waters contained relatively higher concentrations of PCBs, HCHs, CHLs and HCB as compared with those from tropical regions, reflecting atmospheric transport from the tropical sources to the northern sinks. Latitudinal distribution of TCPMe and TCPMOH in cetaceans from the North Pacific Ocean and Asian coastal waters was similar to that of DDTs, suggesting the less transportable nature of TCPMe and TCPMOH in the marine environment. Penta- and hexa-chlorobiphenyls were the predominant PCB congeners, accounting for about 70% of the total PCBs. 2,3,7,8-tetrachlorodibenzo-*p*-dioxin equivalents (TEQs) of non- and mono-*ortho* coplanar PCBs in the blubber of cetaceans ranged from 36 (in spinner dolphin from Philippines) to 510 pg/g wet wt (in hump-backed dolphin from Hong Kong). Toxic evaluation of coplanar PCBs using TEQ concept indicates an increasing impact on cetaceans from mid-latitudes. Mono-*ortho* congener IUPAC 118 or non-*ortho* congener IUPAC 126 was estimated to have the greatest toxicity contribution. The estimated TEQ concentrations in the blubber of some cetacean species exceeded the level associated with immunosuppresion in harbour seals.

Keywords Cetaceans; coplanar PCBs; persistent organochlorines; *tris*(4-chlorophenyl)methane; *tris*(4-chlorophenyl)methanol; 2,3,7,8-tetrachlorodibenzo-*p*-dioxin equivalents

Introduction

Organochlorine compounds (OCs) such as DDT compounds (DDTs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB), chlordane compounds (CHLs) and polychlorinated biphenyls (PCBs) have been produced in huge quantities in order to meet the increasing demand of agriculture and public heath. These man-made chemicals have received considerable attention due to their adverse effects on human health and

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environmental quality over the world. In recent years, there has been a growing concern that some synthetic chemicals including persistent organochlorines such as DDTs and PCBs may cause a variety of unexpected health effects in both human and wildlife populations due to their ability to mimic or block the action of the natural hormone estrogens and androgens, and consequently, impact the function of the endocrine system (Colborn *et al.*, 1993). Industrial chemicals such as PCBs have been produced in large quantities in developed nations until the 1970s and due to the persistent and highly bioaccumulative nature, their contamination has extended worldwide and resulted in severe environmental problems and human health hazards. On the other hand, organochlorine pesticides are still being used in some developing countries for vector control as well as for public health purposes (Dave, 1996).

Beside numerous studies on global contamination and toxic effects of classic chemicals, over the last few years, the discovery of some new environmental contaminants has also been given particular attention. *Tris*(4-chlorophenyl)methane (TCPMe) and *tris*(4-chlorophenyl)methanol (TCPMOH) with similar structures to pesticides DDT and dicofol, respectively, are among the most recently identified micro-contaminants in environmental samples. Although the point sources of these compounds are still unknown, their occurrence in the marine environment is widespread (Jarman *et al.*, 1992). TCPMOH has also been suggested to induce hepatic enzymes (Poon *et al.*, 1997) and pose an anti-androgenic effect (Korner *et al.*, 1997).

In view of these facts, comprehensive surveys on global contamination by persistent OCs have been extensively carried out in our laboratory and reports have revealed that large quantities of OCs used in the tropical regions are released into the atmosphere and redistributed via long-range atmospheric transport on a global scale (Iwata *et al.*, 1993; Tanabe *et al.*, 1994). In this context, it was also indicated that the open ocean may serve as a final sink for such chemicals and therefore, toxic threat by persistent OCs to marine organisms is a matter of great concern. Being top predator of the marine food chain, marine mammals particularly cetaceans, are considered to be the most vulnerable animals to the long term toxic effects by persistent OCs (Tanabe and Tatsukawa, 1992; Colborn and Smolen, 1996). Elevated concentrations of PCBs including highly toxic coplanar congeners have been reported in tissues of marine mammals and these levels have been suspected to be linked to a series of mass mortalities of marine mammals that occurred during the last decade (Martineau *et al.*, 1987; Storr-Hansen and Spliid, 1993; Kannan *et al.*, 1993; Aguilar and Borrell, 1994). To our knowledge, despite a number of studies that were conducted to make clear contamination status and toxic evaluation of organochlorine pesticides and PCBs, their distribution, behavior as well as toxicological impacts in global terms are scarce.

In this study, concentrations of organochlorine pesticides, individual PCB congeners including toxic coplanar ones as well as TCPMe and TCPMOH were determined in 10 species of adult male odontoceti cetaceans collected from various locations in the North Pacific Ocean and coastal waters of Japan, Hong Kong, Philippines and India. An attempt is made to elucidate the global distribution by these OCs and to understand the transport and behavior of TCPMe and TCPMOH on a global scale. In addition, possible toxicological impacts of highly toxic coplanar biphenyls on these cetacean species were also evaluated.

Materials and methods

Blubber samples were taken from 10 species of adult male odontoceti cetaceans collected from different locations in the North Pacific Ocean and coastal waters of Japan, Hong Kong, Philippines and India during 1985–1997. Geographical locations for collecting cetacean samples are shown in Figure 1. Blubber samples were obtained from three

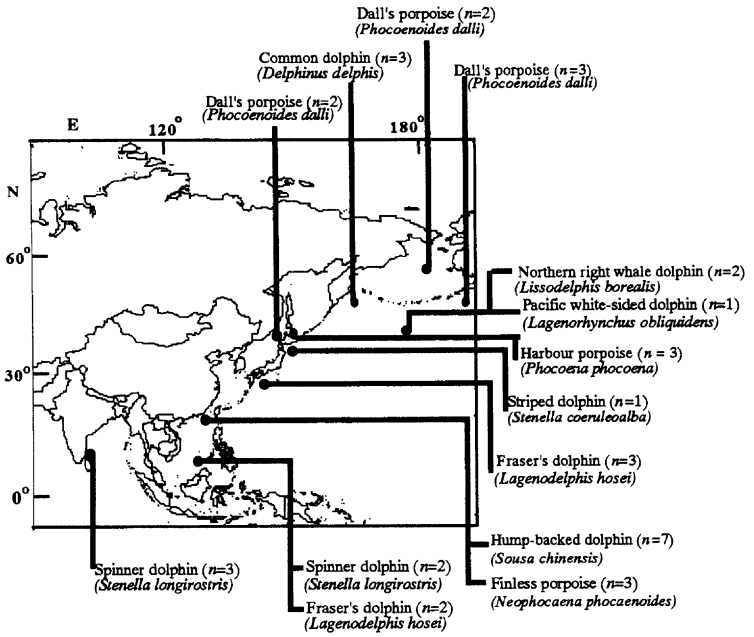

Figure 1 Map showing geographaphical sampling locations of cetaceans from the North Pacific and Asian coastal waters. Values in parentheses indicate number of samples analyzed

sources: (i) fresh strandings along the coastlines, (ii) accidental catches by fishermen and (iii) specimens collected by Whaling for Commercial and Scientific Purposes that were accepted by the International Convention for the Regulation of Whaling. In the framework for our research, only those species with large population sizes were collected and endangered species were ruled out. Blubber samples were taken from adult male individuals and immediately after dissection, samples were frozen in clean plastic bags, transported to the laboratory and stored at –20°C until analysis.

Chemical analyses of TCPMe and TCPMOH and other OCs were followed by the method previously described (Watanabe *et al.*, 1989). The method consists of Soxhlet extraction, fat removal, fractionation and quantification. Organochlorines (except TCPMe and TCPMOH) were quantified by a GC-ECD (Hewlett Packard 5890 Series II) equipped with a moving needle-type injection port. The PCB standard used for quantification was an equivalent mixture of Kanechlor preparations (KC-300, KC-400, KC-500, KC-600) with known PCB composition and content. For the quantification of TCPMe and TCPMOH, a GC-MSD (Hewlett-Packard 5890 series II GC coupled with 5972 mass selective detector) was employed. Recoveries of this analytical method were 95±1.1% for TCPMe, 100±2.1% for TCPMOH, 99±2.0% for PCBs, 95±7.5% for DDTs, 96±7.7% for HCHs, 100±4.7% for CHLs, 94±5.9% for HCB. Concentrations were not corrected for recovery rates. Isomer-specific analysis, including non-*ortho* coplanar congeners (IUPAC Nos. 77, 126, 169) was conducted following the method previously described (Wakimoto *et al.*, 1971; Tanabe *et al.*, 1987a). The method consists of Soxhlet extraction, alkaline digestion, clean up, acid treatment, fractionation of non-*ortho* congeners by carbon column and quantification. Quantification of PCB congeners was carried out by a GC-MSD which is similarly described above. Recoveries of total PCBs and non-*ortho* coplanar congeners were examined by spiking 3.0 μg of Kanechlor standard and 90.2, 91.0, and 30.4 ng of IUPAC Nos. 77, 126 and 169 standards, to corn oil. The recoveries ranged from 100–105% for total PCBs, 93±6.5% for IUPAC 77, 96±7.0% for IUPAC 126 and 93±0.7% for IUPAC 169. PCB congeners are referred to by their IUPAC numbers throughout the manuscript.

Results and discussion

Status of organochlorine pesticides, *tris*(4-chlorophenyl)methane and *tris*(4-chlorophenyl)methanol contamination

In general, residue pattern of persistent organochlorines was in the order of DDTs ≥ PCBs > CHLs > HCHs > HCB > TCPMOH > TCPMe. DDT concentrations were found to be the highest in the northern right whale dolphins from northern North Pacific and hump-backed dolphins and finless porpoises from Hong Kong (Figure 2). On the other hand, relatively high concentrations were also observed in spinner dolphins from India. This result indicates serious marine pollution in industrialized Asian nations and current usage of DDT in tropical region. Apparently greater DDT residues in surface seawater from tropical and sub-tropical coastal waters were also reported in our previous investigation (Iwata *et al.*, 1993). An interesting pattern was observed for HCHs, showing higher residue levels in cetaceans from the high latitude region. HCH isomers, with high vapor pressures, tend to be transported long distances, primarily towards the polar regions. However, greater residue levels of HCHs found in cetaceans from Hong Kong may suggest the usage of these compounds in southern China in recent years. Distribution patterns of CHLs and HCB revealed somewhat similar to that observed for HCHs (data were not shown), showing higher residues in cold and temperate cetaceans from high latitudes than those in tropical regions. As a whole, the present results in distribution pattern of OCs likewise conform with the migration processes suggested by Wania and Mackay (1996). In this context, it is generally observed that magnitude of contamination by persistent semivolatile chemicals was influenced by the global redistribution phenomenon, which is mainly characterized by their temperature dependent physico-chemical properties.

TCPMe and TCPMOH are newly detected micro-contaminants and their physico-chemical properties were mainly unknown. To understand the transport and behavior of these compounds on a global scale, we compared their distribution patterns with those of other classic OCs such as DDTs, PCBs and HCHs, which were characterized to have low, moderate and high potential to migrate around the globe, respectively (Iwata *et al.*, 1993; Wania and Mackay, 1996) (Figure 2). Interestingly, the distribution pattern of TCPMe and TCPMOH was similar to that of DDTs, which showed an increasing trend in the mid-latitude region and decreasing trend towards the tropical region as in Philippines and in India. The highest concentrations of TCPMe, TCPMOH and DDTs were found in northern right whale dolphins from the northern North Pacific and hump-backed dolphins and finless porpoises from Hong Kong, while the lowest concentrations were observed in colder regions. Considering these observations, it can be suggested that similar to DDTs, TCPMe and TCPMOH may have less mobility to migrate through long-range atmospheric transport.

From a global view point, average DDT concentrations in cetaceans from the Asia-Pacific region (mean: 22 μg/g wet wt) were higher than those reported in harbour porpoises from Great Britain (Kuiken *et al.*, 1993) and Danish waters (Kleivane *et al.*, 1995),

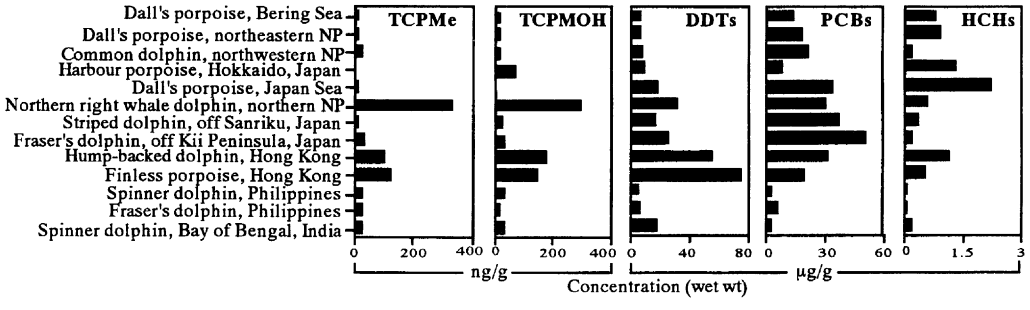

Figure 2 Latitudinal distribution of some OCs in cetaceans from the North Pacific (NP) and Asian coastal waters

Table 1 Comparison of total PCB concentrations and TEQs (wet wt) of non- and mono-ortho coplanar PCBs in cetaceans from various regions*

Species	Location	Survey year	Total PCBs (μg/g)	Total TEQs (μg/g)	Reference
Dall's porpoise	Bering Sea	1985	13	82	present study
Dall's porpoise	North-eastern North Pacific	1987	19	150	present study
Common dolphin	North-western North Pacific	1987	22	110	present study
Harbour porpoise	Hokkaido, Japan	1993	8.0	100	present study
Dall's porpoise	Japan Sea	1989	34	290	present study
Northern right whale dolphin	Northern North Pacific	1991	30	190	present study
Pacific white-sided dolphin	Northern North Pacific	1991	27	240	present study
Striped dolphin	off Sanriku, Japan	1992	37	280	present study
Fraser's dolphin	off Kii Peninsula, Japan	1991	51	400	present study
Hump-backed dolphin	Hong Kong	1993–1997	31	510	present study
Finless porpoise	Hong Kong	1993–1997	20	400	present study
Spinner dolphin	Mindanao Sea, Philippines	1996	2.5	36	present study
Fraser's dolphin	Mindanao Sea, Philippines	1996	6.2	45	present study
Spinner dolphin	Bay of Bengal, India	1990	2.2	69	present study
Dall's porpoise	Northern North Pacific	1980–1985	8.6	61	Kannan *et al.*,1989a
Finless porpoise	Seto Inland Sea, Japan	1985	320	1400	Kannan *et al.*,1989a
Baird's beaked whale	Pacific coast of Japan	1985	2.3	55	Kannan *et al.*,1989a
Killer whale	Pacific coast of Japan	1986	370	2800	Kannan *et al.*,1989a
Harbour porpoise	Black Sea	1993	22	170	Tanabe *et al.*,1997
Striped dolphin	Western Mediterranean Sea	1990	390	3300	Kannan *et al.*,1993
Bottlenose dolphin	Italian coastal waters	1992	590	2500	Corsolini *et al.*,1995
Risso's dolphin	Italian coastal waters	1992	320	3100	Corsolini *et al.*,1995
Common porpoise	Puck Bay, Baltic Sea	1989–1990	31	160	Falandysz *et al.*,1994
Beluga whale	St. Lawrence river	1987–1990	160	890	Muir *et al.*,1996
Killer whale	British Columbia coast	1986–1989	22	380**	Jarman *et al.*,1996
False killer whale	British Columbia coast	1987–1989	40	360**	Jarman *et al.*,1996
Risso's dolphin	British Columbia coast	1988	1.7	77**	Jarman *et al.*,1996
Dall's porpoise	British Columbia coast	1987–1988	4.5	380**	Jarman *et al.*,1996
Harbour porpoise	British Columbia coast	1987–1989	8.4	290**	Jarman *et al.*,1996

*TEQs were calculated using TEF values cited from Van den Berg *et al.* (1998).

**TEQs were calculated for non-ortho coplanar congeners only

Newfoundland and Gulf of St. Lawrence, Canada (Westgate *et al.*, 1997). These levels, however, are significantly lower than those in diseased striped dolphins, bottlenose and Risso's dolphins from the western Mediterranean Sea (Kannan *et al.*, 1993; Corsolini *et al.*, 1995) as well as in beluga whales from the St. Lawrence River, Canada (Muir *et al.*, 1996). HCHs residues were higher than those beluga whales from the St. Lawrence River, Canada, but comparable to lower than those in cetaceans from northwestern European region (Kuiken *et al.*, 1993; Kleivane *et al.*, 1995).

Environmental occurrences of TCPMe and TCPMOH in marine mammals were relatively scarce as compared to other classic OCs. The highest residues found in northern right whale dolphins in this study (mean concentrations of TCPMe and TCPMOH were 330 and 300 ng/g wet wt, respectively), greater than those reported in harbour porpoises from the Baltic Sea (Falandysz *et al.*, 1999), whitebeaked dolphin from the Dutch Wadden Sea (de Boer *et al.*, 1996). Nevertheless, cetaceans from highly industrialized areas such as the St. Lawrence River, Canada (Muir *et al.*, 1996) and the North Sea (de Boer *et al.*, 1996) contained apparently higher TCPMe and TCPMOH concentrations as compared to those observed in the present study.

PCB pollution and their toxicological impacts

PCB residue levels ranged from 2.2 (in spinner dolphins from India) to 51 μg/g wet wt (in Fraser's dolphins off Kii Peninsula, Japan) (Table 1). Generally, cetaceans inhabiting

temperate and cold waters accumulated relatively higher concentrations than the species from tropical waters. The highest residue levels were found in Fraser's dolphins off Kii Peninsula, Japan (mean: 51 μg/g wet wt), reflecting serious PCB contamination in heavily industrialized areas among the locations studied. Elevated accumulation of PCBs was also previously reported in several cetacean species collected from Japanese coastal waters (Kannan *et al.*, 1989a; Tanabe *et al.*, 1988). Moreover, high concentrations were also observed in individual open ocean species such as northern right whale dolphin (30 μg/g wet wt) and Pacific white-sided dolphin (27 μg/g wet wt), which may be attributable to the wide migration and distribution of these species including highly polluted areas such as coastal California (Carvadine, 1995). Fraser's dolphins and spinner dolphins from Philippines and India showed the lowest concentrations.

Comparing the contamination status in other parts of the world (Table 1), average PCB concentration in cetaceans from the North Pacific and Asian coastal waters (21 μg/g wet wt) was greater than that reported in killer whales, Risso's dolphins, Dall's porpoises and harbour porpoises from British Columbia coasts (Jarman *et al.*, 1996) and comparable to that found in harbour porpoises from the Black Sea (Tanabe *et al.*, 1997) and common dolphins from Puck Bay, Poland (Falandysz *et al.*, 1994). However, these levels were still significantly lower than those reported in the blubber of striped dolphins, which were victims of an epizootic in the western Mediterranean Sea and bottlenose dolphins and Risso's dolphins found dead along Italian coastal waters (Kannan *et al.*, 1993, Corsolini *et al.*, 1995) as well as in beluga whales from the St. Lawrence River, Canada (Muir *et al.*, 1996). Nevertheless, in some species from Japanese coastal waters such as Fraser's dolphin collected off Kii Peninsula, PCB concentrations in the blubber approached the level associated with health risk of cetaceans as suggested by Wagemann and Muir (1984).

Isomer-specific analysis of PCBs in the blubber of cetaceans revealed the presence of 61 individual congeners (data were not shown). Penta- and hexa-chlorobiphenyls were the most predominant congeners, accounting for about 70% of the total PCBs. Hexachlorobiphenyl IUPAC No. 153 was the most prevalent congener, followed by IUPAC Nos. 138 and 180. Mean concentrations (wet wt) of 3 non-*ortho* congeners IUPAC Nos. 77, 126 and 169 ranged from 0.75 ng/g (in spinner dolphins from Philippines) to 6.6 ng/g (in Fraser's dolphins off Kii Peninsula, Japan). In general, concentrations of IUPAC 77 were the highest among non-*ortho* congeners. Similar results were also observed in various aquatic mammals (Kannan *et al.*, 1993; Jarman *et al.*, 1996; Muir *et al.*, 1996; Tanabe *et al.*, 1997), which may be attributable to its predominant existence in technical PCB preparations (Kannan *et al.*, 1993). Concentrations of mono-*ortho* congeners were about 2 to 3 orders of magnitude greater than those of non-*ortho* congeners (ranged from 120 to 2900 ng/g wet wt).

Mammal-specific 2,3,7,8-TCDD toxic equivalency factors (TEF) recently proposed by the World Health Organization (WHO) (Van den Berg *et al.*, 1998) were used to estimate the toxic equivalents (TEQs) of non- and mono-*ortho* PCB congeners detected in the blubber of cetaceans. Mean concentrations of TEQs (wet wt) were considerably high in humpbacked dolphins (510 pg/g), finless porpoises (390 pg/g) from Hong Kong coastal waters and Fraser's dolphins off Kii Peninsula, Japan (400 pg/g), while lower levels were observed from species in higher (Bering Sea and the North Pacific) and lower latitude regions (Philippines and India). As shown in Figure 3, the TEQs in cetaceans from different locations indicated an increasing toxicological impact of coplanar PCBs in the mid-latitude region (Japan and Hong Kong), where industrial and human activities are very high and point sources of pollution are also conspicuous. Our earlier studies likewise showed the elevated contamination by persistent OCs in various environmental compartments from Japan and Hong Kong (Kannan *et al.*, 1989b; Tanabe *et al.*, 1987b, 1988).

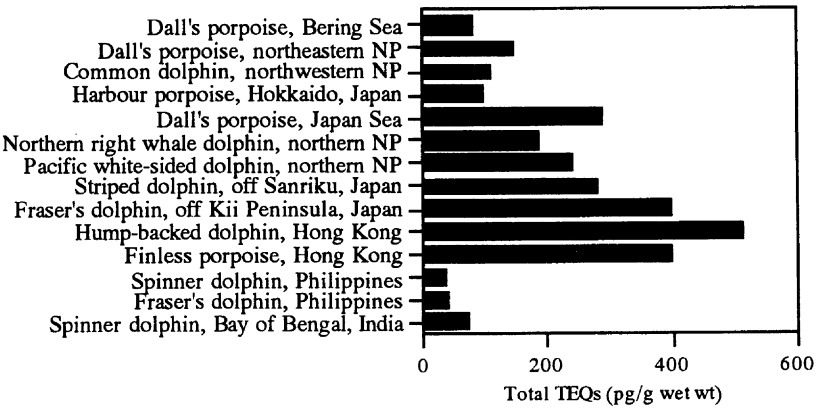

Figure 3 Total 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents (TEQs) of non- and mono-*ortho* coplanar congeners in the blubber of cetaceans from the North Pacific (NP) and Asian coastal waters

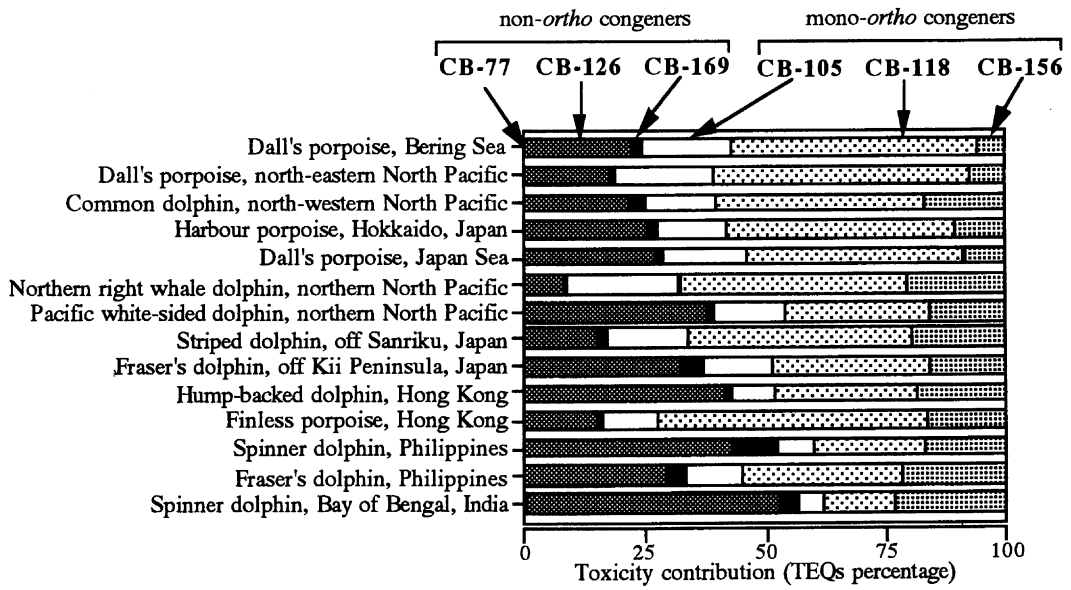

Figure 4 Relative contribution to TEQs by non- and mono-*ortho* coplanar congeners in the blubber of cetaceans from the North Pacific and Asian coastal waters

Comparison of estimated TEQ concentrations in cetaceans from other parts of the world, the highest levels found in this study (in cetaceans from Hong Kong and off Kii Peninsula, Japan) were higher than those estimated for the blubber of harbour porpoises from the Black Sea (Tanabe *et al.*, 1997), common porpoises from Puck Bay, Poland (Falandysz *et al.*, 1994) and comparable to those of killer whales, Risso's dolphins, Dall's porpoises and harbour porpoises from coastal waters of British Columbia and California (Jarman *et al.*, 1996). These levels are, however, apparently lower than those reported in striped dolphins suffered from an epizootic in the western Mediterranean Sea and bottlenose dolphins and Risso's dolphins from Italian coastal waters (Kannan *et al.*, 1993; Corsolini *et al.*, 1995) as well as in beluga whales from the St. Lawrence River, Canada (Muir *et al.*, 1996) (Table 1).

Among 6 coplanar congeners, mono-*ortho* IUPAC 118 or non-*ortho* IUPAC 126 has the greatest contribution to the total TEQs (Figure 4). Contribution of IUPAC 118 was prominent in species from high latitude oceans such as the Bering Sea and the North Pacific, whereas non-*ortho* congener IUPAC 126 accounted for the highest contribution in cetaceans from lower latitude regions such as in Philippines and India. In almost cetacean species, contributions of mono-*ortho* to TEQs were predominant. Similar results were also reported in various cetaceans from other locations (Kannan *et al.*, 1989a, 1993; Corsolini *et al.*, 1995).

Interestingly, an increasing percentage of non-*ortho* coplanar congeners was found in cetacean species from high to low latitudes.

Mono-*ortho* coplanar congeners are metabolized by both 3-methylcholanthrene (MC, mainly cytochrome P450 1A subfamily – CYP1A) and phenobarbital (PB, mainly cytochrome P450 2B subfamily – CYP2B) type enzymes, whereas CYP1A is responsible for metabolism of non-*ortho* coplanar congeners (Boon *et al.*, 1997). In addition, small cetaceans were characterized by relatively low MC-type activities and deficient PB-type enzymes (Tanabe *et al.*, 1988; Watanabe *et al.*, 1989). Due to higher exposures of mono-*ortho* congeners and relatively weak induction of CYP2B enzymes, these congeners accumulate prevalently and contribute greater TEQs as compared to non-*ortho* congeners. However, the increasing pattern of non-*ortho* coplanar congeners in cetaceans from high to low latitude areas may be attributable to a decreasing biotransformation of non-*ortho* coplanar PCBs due to a lower potential for CYP1A induction. Alternatively, behavior of these congeners in global terms can be another explanation for the observed pattern. Non-*ortho* coplanar congeners have relatively low values of Henry Law constants (HLCs). For example, HLC for IUPAC No. 77, 126 and 169 was estimated as 10.4, 8.29 and 6.60 Pa m^3/mol, respectively (Dunnivant and Eizerman, 1992), which are in the range of those reported for DDT compounds (Iwata *et al.*, 1993). Persistent semivolatile organic compounds with low HLCs were characterized by low mobility to migrate around the globe (Iwata *et al.*, 1993). In this case, the less transportable nature of non-*ortho* PCBs through the atmosphere might be a reason for the relative enrichment of these congeners in cetaceans from lower latitudes.

Considering these observations, it can be suggested that some cetaceans from the North Pacific and Asian coastal waters may have a relatively high risk for the impacts of dioxin-like toxicity, because of the high bioaccumulation potential of toxic coplanar PCBs. Recent toxicological studies have suggested the biological effects of toxic coplanar PCBs in marine mammals. A total TEQ concentration of 209 pg/g (lipid wt) in the blubber caused the immunological dysfunctions in harbour seals (*Phoca vitulina*) (Ross *et al.*, 1995). A recent investigation on exposure of beluga whale leukocytes has suggested that certain mixtures of the several most abundant PCB congeners found in the blubber of cetaceans might induce immunosuppression (De Guise *et al.*, 1998). Although no direct evidence is so far available on the relationship between toxic symptoms in cetaceans and persistent organochlorine residues, mean TEQ concentrations of toxic coplanar PCBs in the blubber of some odontoceti cetaceans measured in the present study such as northern right whale dolphin (230 pg/g lipid wt) and Pacific white-sided dolphin (320 pg/g lipid wt) from the northern North Pacific, Dall's porpoise from Japan Sea (330 pg/g lipid wt), striped dolphin off Sanriku (560 pg/g lipid wt) and Fraser's dolphin off Kii Peninsula, Japan (570 pg/g lipid wt), hump-backed dolphin (1100 pg/g lipid wt) and finless porpoise (610 pg/g lipid wt) from Hong Kong exceeded the level associated with immunosuppression in harbour seals as noted by Ross *et al.* (1995).

Conclusions

This study presents the concentrations of persistent OCs, including TCPMe and TCPMOH in the blubber of cetaceans from the Asia-Pacific region. Elevated residues of PCBs and DDTs in some cetaceans from the mid-latitude region (Hong Kong and Japan) suggest these species may be at risk. In general, cetaceans from cold and temperate waters contained higher OC concentrations than those from tropical regions. Latitudinal distribution of TCPMe and TCPMOH was similar to that of DDTs, suggesting the less transportable nature of these compounds in the marine environment. Toxic evaluation of coplanar PCBs using the TEQ concept indicates an increasing impact on cetaceans from the mid-latitude

region. Considering various studies of toxicity caused by organochlorines to marine mammals, and the suspected links between mass mortalities and organochlorine residues, continued monitoring and ecotoxicological studies are needed to understand the status of contamination as well as actual health effects of man-made chemicals on wild individuals and populations of cetaceans.

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