CHLORINATED AND BROMINATED ORGANIC COMPOUNDS IN CETACEANS FROM KOREAN COASTAL WATERS

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Abstract
The liver and blubber of minke whale and common dolphin found entangled in fishing nets along the Korean coasts in 2006 were analyzed for the levels and accumulation profiles of PCBs, OCPs and PBDEs. The concentrations of PCBs and DDTs were high in all of the samples and their concentrations were one or two orders of magnitude higher than the concentrations of CHLs, HCHs and HCB. The concentrations of PBDEs were lower than those of PCBs and DDTs. The overall contamination by PCBs, OCPs and PBDEs in cetaceans from Korean coastal waters was relatively lower or similar to the levels of these contaminants measured from other locations worldwide. The concentrations of PCBs, DDTs, CHLs and PBDEs in the livers and blubbers of common dolphin were significantly higher than those measured in minke whale, while CHLs and HCHs did not show significant difference. The predominant compounds of PCBs, OCPs and PBDEs in both cetacean species were PCB 153, *p, p'*-DDE and BDE 47, respectively. The concentrations of PCBs and DDTs in cetaceans have reached the levels that would adversely affect the health of marine mammals.

Introduction
Environmental contamination by persistent organic pollutants (POPs) is a global concern because these compounds are bioaccumulative and amplify through the food web. Several POPs can cause adverse health effects such as development toxicity, cancer and endocrine disruption[1]. Although the use of PCBs and OCPs has been banned or restricted in Korea, these contaminants are still present in the coastal environment. Polybrominated diphenyl ethers (PBDEs) have been widely used as brominated flame retardants (BFRs) in many products, such as TV, computers and textiles. Marine mammals such as cetaceans are at the higher trophic level in the food chain and possess relatively low metabolic activities; thus, marine mammals accumulate some of highest levels of POPs and related compounds[2,3]. Bioaccumulation and long-term exposure to these contaminants may pose a threat to the health and reproductive potential of cetaceans in marine ecosystems[3,4]. Limited data are available on the concentrations and accumulations of organochlorines (OCs) and PBDEs in marine biota from Korean coastal waters[5,6,7]. In fact, prior to this study, there has been no data concerning POPs in marine mammals from Korean coastal environment. The objective of this study was to investigate the concentrations and accumulation profiles of chlorinated and brominated organic compounds in cetaceans from Korea.

Materials and Methods
Liver and blubber samples were obtained from two cetacean species, minke whale (*B. acutorostrata*) and common dolphin (*Delphinus* spp.) entangled in fishing gear such as seine net along the Korean coasts in 2006. After biometric measurement, the specimens were dissected and immediately transported to the laboratory. Twenty-two PCB congeners, 13 organochlorine pesticides and 23 PBDE congeners were analyzed in the livers and blubbers. Analytical procedure and instrumental analyses of PCBs, OCPs and PBDEs were similar to the methods described elsewhere[5,7], with some modifications.

Results and Discussion
Concentrations of PCBs, OCPs and PBDEs
Concentrations of PCBs, OCPs and PBDEs in the liver and blubber samples of two cetacean species from Korean coastal waters are summarized in Table 1. OCs and PBDEs were detected in all of the cetacean samples. Among the OCs analyzed, the concentrations of PCBs and DDTs were the highest in all of the liver and blubber

samples[8]. The concentrations of CHLs, HCHs and HCB were one or two orders of magnitude lower than concentrations of PCBs and DDTs. This contamination pattern is similar to those reported for cetaceans from other countries including Asian coastal waters[9,10,11,12]. The concentrations of PCBs and OCPs in cetacean samples were higher than those in fish and shellfish from Korean coastal waters[6,7,13], suggesting biomagnification of these contaminants in marine food web. The concentrations of PBDEs in liver and blubber samples were lower than those of PCBs and DDTs. A variety of cetacean species from other countries or locations showed wide ranges of the concentrations of OCs and PBDEs. The overall contamination by organohalogen compounds in cetaceans seems to be relatively lower or similar to the concentrations reported from other countries. This is consistent with the pattern of contamination by OCs and PBDEs in environmental compartments such as air, sediments and biota from Korean coastal waters[5,6,7,13,14].

Table 1. Concentrations (average ± standard deviation; ng/g lipid weight) of chlorinated and brominated organic pollutants in liver and blubber samples of cetaceans from Korean coastal waters

	Liver samples		Blubber samples	
	Minke whale	Common dolphin	Minke whale	Common dolphin
PCBs	760 ± 980	3700 ± 2000	1980 ± 1600	15000 ± 7500
DDTs	320 ± 340	1230 ± 620	2600 ± 2550	13500 ± 6500
CHLs	40 ± 40	90 ± 50	300 ± 210	1100 ± 530
HCHs	170 ± 90	150 ± 50	530 ± 500	340 ± 130
HCB	40 ± 30	40 ± 20	120 ± 90	110 ± 50
PBDEs	20 ± 20	180 ± 90	160 ± 130	1650 ± 720

Species and gender differences

We compared the concentrations of PCBs, OCPs and PBDEs in the livers and blubbers between minke whale and common dolphin (Figure 1). The concentrations of PCBs, DDTs, CHLs and PBDEs in common dolphin were significantly ($p < 0.05$) higher than those measured in minke whale. This can be explained by the difference in habitat and diet (trophic level). The common dolphin is a near-shore species feeding in coastal waters, whereas minke whale migrates both through the near-shore and the off-shore waters. The major diets of common dolphin are long-lived and larger predatory fish with high lipid content such as herring and mackerel. The diet of minke whale is primarily plankton, krill and small fish such as anchovy. The result indicates that habitat and diet can be important factors governing bioaccumulation of POPs and PBDEs in marine ecosystems. Although the overall concentrations of HCHs and HCB in the livers and blubbers of common dolphin were higher than those of minke whale, the gender difference was not significant.

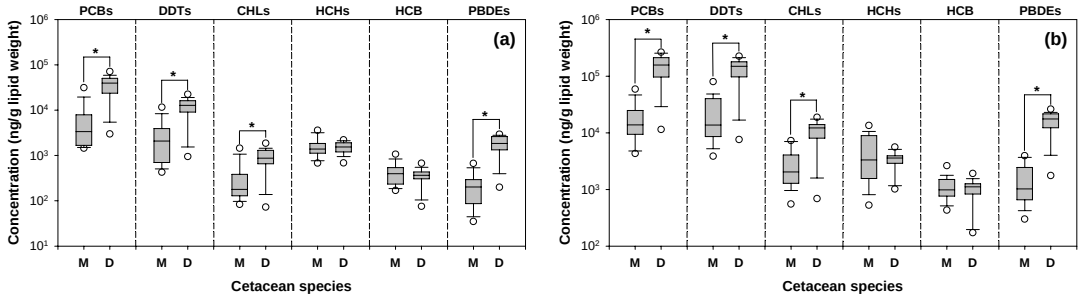

Figure 1. Comparison of the concentrations of PCBs, OCPs and PBDEs in the (a) liver and (b) blubber of minke whales and common dolphins collected from Korean coastal waters. M represents minke whale and D represents common dolphin. The symbol of * indicates the significance at the level of $p < 0.05$ by Student *t*-test between two cetacean species.

The gender-specific differences in the concentrations of PCBs, OCPs and PBDEs for the two cetacean species were investigated (Figure 2). Although the average concentrations of PCBs, OCPs and PBDEs in male

specimens were higher than those of female specimens, only DDTs and HCHs in the livers and HCHs in the blubbers of minke whale showed significant gender differences. No gender difference was found for contaminants in common dolphins. In general, the lactation and reproduction have been known to reduce body burdens of POPs from female bodies[15,16]. Due to the limited sample size and other confounding variables, we did not find a gender difference in PCBs, OCPs and PBDEs as it was found in other studies. Further investigation is needed on this topic.

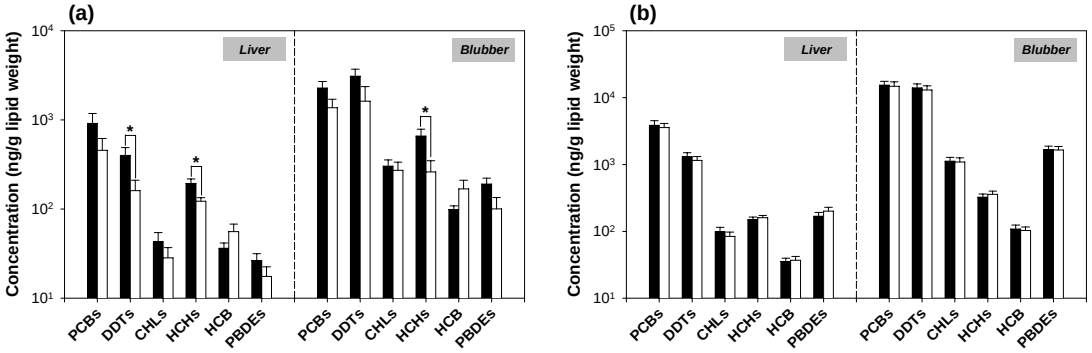

Figure 2. Comparison of concentrations of PCBs, OCPs and PBDEs in the livers and blubbers of male and female (a) minke whale and (b) common dolphin collected from Korean coastal waters. Whiskers on the bars represent the standard error for individual contaminants. The symbol of * indicates the significance at the level of $p < 0.05$ by Student *t*-test between males and females of both cetaceans.

Chemical profiles

Chemical profiles of PCBs, OCPs and PBDEs in liver and blubber of both cetacean species from Korean coastal waters are shown in Figure 3. The profiles of PCBs and PBDEs in the livers and blubbers were similar to each other. The predominant congener of PCBs was PCB 153, followed by PCB 138, PCB 118, PCB 180 and PCB 101, which is consistent with reports for fish[7] and human serum[17] in Korea. The predominant PBDE congener was BDE 47, followed by BDE 154, BDE 99 and BDE 100. Deca-BDE (BDE 209) was detected in some liver and blubber samples of cetaceans from Korean coastal waters, which seems to be associated with high consumption of deca-BDE in Korea[5]. Although the accumulation patterns of OCPs in both cetaceans were different, the predominant OCP was *p,p'*-DDE in all of the liver and blubber samples.

Ecotoxicological concerns

Some studies have reported that reproductive impairments and declining populations of marine mammals are related to high burdens of persistent organic pollutants. In the present study, the concentrations of PCBs and DDTs in the blubbers of cetaceans were compared with the levels of PCBs and DDTs reported for other marine mammals, which showed adverse effects, such as immunosuppression, tumors, decreased fecundity, mass mortality, abortions and premature parturition[18,19,20,21,22,23,24]. The concentrations of PCBs and DDTs from Korean cetaceans have almost reached the levels reported for marine mammals with adverse health effects. Therefore, continuous monitoring and ecotoxicological studies are needed to understand the status of organic contamination as well as health effects of anthropogenic chemicals on this population of cetaceans.

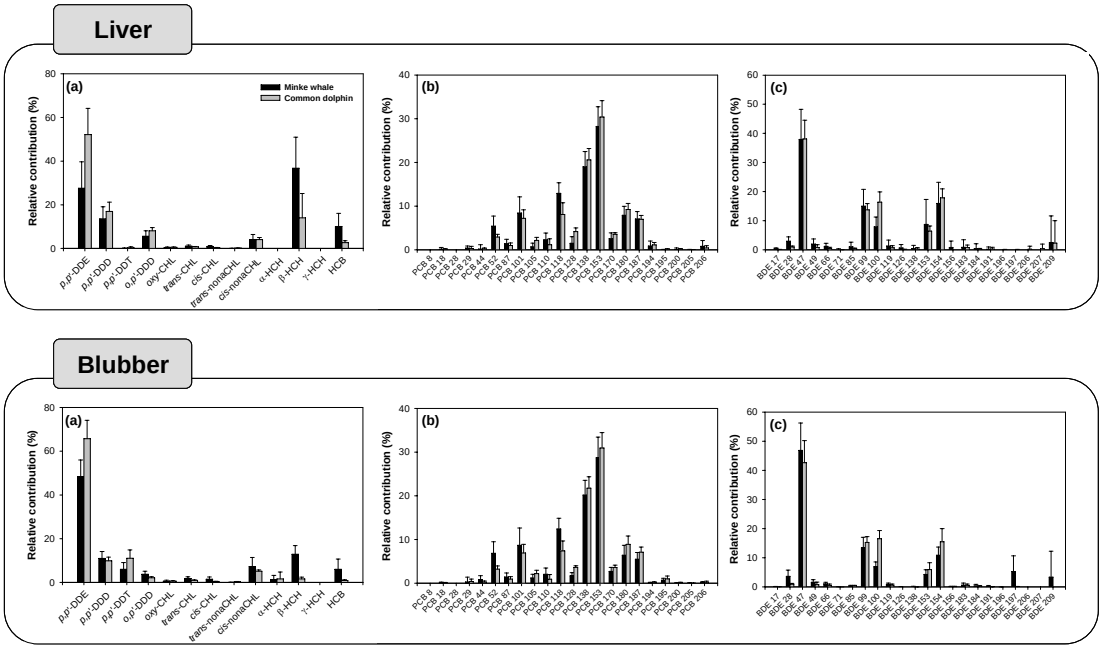

Figure 3. Relative contribution of (a) OCPs, (b) PCBs and (c) PBDEs to the total concentrations of individual chemical group in the liver and blubber of minke whale and common dolphin collected from Korean coastal waters. Whiskers on the bars represent the standard deviation for respective contribution of each chemical group.

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