A note on mercury and organochlorine accumulation in the Antarctic fin whale based on JARPAII data

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ABSTRACT

Total mercury (Hg) was determined in 10 liver and 16 muscle samples from fin whales sampled by JARPAII in the period from 2005/2006 to 2010/2011. In addition PCBs, DDTs, HCHs, HCB and CHLs were determined in two blubber samples from fin whales sampled in 2010/2011. Mean concentrations of total Hg in liver and muscle samples were 0.052 and 0.021 (ppm wet wt.), respectively. Mean concentrations of PCBs, DDTs, HCHs, HCB and CHLs were 6.5, 13, 0.65, 39 and 4.5 (ng/g fat wt.), respectively. Hg levels in liver and muscle samples from fin and Antarctic minke whales from the Antarctic Ocean were similar and these were one order of magnitude lower than those of fin whales from the western North Atlantic Ocean. Hg accumulation level in whales is affected by age, Hg levels in their prey items, and prey consumption. Hg levels in their prey items, such as fish and zooplankton, increase with trophic level. The 'background' levels of Hg in open oceans are comparatively similar around the world. Therefore, geographical differences of Hg levels among the same species could be caused by food habitats and/or age. Levels of OCs, except for HCB, in fin whales from the Antarctic Ocean were similar to those in the Antarctic minke whales. These levels were extremely lower than those in fin whales from the middle latitude of the northern hemisphere nearby human activity, and those in killer whales from the Antarctic Ocean. These results suggest that the OCs levels in whales could mainly be affected by prey position in the food chain and area. OCs levels in fin and Antarctic minke whales in the Antarctic Ocean could be the lowest among whale species in the world. HCB levels in large whales would be affected by trophic levels of its preys rather than the spatial differences.

KEYWORDS: FIN WHALE; MERCURY; ORGANOCHLORINES; ANTARCTIC; POLLUTANTS

INTRODUCTION

The persistent organochlorine compounds (OCs) and total mercury (Hg) are released into the environment due to their highly persistent character. The systematic monitoring programmes of the OCs and Hg are needed to monitor and predict the behavior and fate of the pollutants in the global environment. The Antarctic Ocean is one of important areas for environmental monitoring of the OCs, because it is at the end of their global transportation. Therefore, the monitoring in this area could provide information on the global dynamics of these pollutants.

For this reason, monitoring of pollutants in baleen whales and the ecosystem were added to a part of the first objective of the JARPAII survey (Pastene *et al.*, 2014). Fin whales (*Balaenoptera physalus*) are comparatively large in size and are abundant in the Antarctic ecosystem. However, there is little information about pollutants in fin whales in Antarctic Ocean.

The objective of the pollution study in the JARPAII is to monitor levels and fate of Hg and OCs, such as polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethanes and metabolites (DDTs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB) and chlordane compounds (CHLs), in fin whales. However, most of the samples in this study since 2005/2006 were lost after the 2011 earthquake and tsunami (see IWC, 2012). Therefore, the limited number of samples not affected by the disaster was compared with samples from other baleen whales in the previous studies.

MATERIALS AND METHODS

Ten samples of liver from 4 males and 6 females and 16 muscle samples from 8 males and 8 females of fin whales taken form Area V in 2010/2011 were measured in the Hg analysis, and PCBs, DDTs, HCHs, HCB and CHLs were measured in two blubber samples from 2 males (Table 1). All cryopreserved samples were stored in polyethylene bags at -20°C until analysis.

The liver and muscle samples were sent to the Japan Food Research Laboratories (Tokyo, Japan) for Hg analyses. Analyses were performed according to the public analytical method of Japan (Japan Ministry of Welfare, 1973).

In the laboratory, OCs were determined by a GC-ECD (Hewlett Packard 5890 Series) and by GC-MS (JEOL Ltd., JMS-700; JMS-SX102A). Chemical analysis of the OCs was carried out using the standard method described by Environmental Agency of Japan, with some modifications (Japan Environmental Agency, 1998). Concentrations of OCs were expressed on a fat weight basis. Accuracy and precision of the methods were confirmed using 'Organics in cod liver oil' (NIST 1588a). Chemical analyses were performed by the Miura Institute of Environmental Science.

RESULTS AND DISCUSSION

Mean concentrations of total Hg in livers and muscles were 0.052 and 0.021 (ppm wet wt.), respectively (Table 2). And mean concentrations of PCBs, DDTs, HCHs, HCB and CHLs were 6.5, 13, 0.65, 39 and 4.5 (ng/g fat wt.), respectively (Table 2).

Hg

Mean concentrations of Hg in liver and muscle of fin whales from the Antarctic Ocean in this study (Table 2) were one order of magnitude lower than those of fin whales from the western North Atlantic Ocean (Table 3, Sanpera *et al.*, 1993), whereas they were similar to those of Antarctic minke whales from the Antarctic Ocean (Table 3, Yasunaga *et al.*, 2014a). Hg accumulation level in whales is affected by age, Hg levels in their prey items, prey consumption. And, Hg levels in their prey items, such as fish and zooplankton, increase with trophic level (Konovalov, 2000), and background levels of Hg in open oceans are comparatively similar in the world’s oceans (Sohrin and Issiki, 2005). Therefore, geographical difference of Hg levels among the same species could be caused by food habitat and/or age.

Organochlorines

Mean concentrations of PCBs in blubber of fin whales from the Antarctic Ocean in this study (Table 2) were 3 orders of magnitude lower than those of fin whales from the North Atlantic Ocean (Table 4, Aguilar and Borrell, 1988; Hobbs *et al.*, 2001; Gauthier *et al.*, 1997) and those of killer whales from the Antarctic Ocean (Table 4, Krahn *et al.*, 2008), whereas they were one order of magnitude lower than those of Antarctic minke whales from the Antarctic Ocean (Table 4, Yasunaga *et al.*, 2014a).

Mean concentrations of DDTs in blubber of fin whales from the Antarctic Ocean in this study (Table 2) were 2-3 orders of magnitude lower than those of fin whales from the North Atlantic Ocean (Table 4, Aguilar and Borrell, 1988; Hobbs *et al.*, 2001; Gauthier *et al.*, 1997) and those of killer whales from the Antarctic Ocean (Table 4, Krahn *et al.*, 2008), whereas they were one order of magnitude lower than those of fin whales (Table 4, Henry and Best, 1983) and Antarctic minke whales (Table 4, Yasunaga *et al.*, 2014a) from the Antarctic Ocean.

Mean concentrations of HCHs in blubber of fin whales from the Antarctic Ocean in this study (Table 2) were 3 orders of magnitude lower than those of fin whales from the North Atlantic Ocean (Table 4, Hobbs *et al.*, 2001; Gauthier *et al.*, 1997), whereas they were similar to those of Antarctic minke whales from the Antarctic Ocean (Table 4, Yasunaga *et al.*, 2014a).

Mean concentrations of HCB in blubber of fin whales from the Antarctic Ocean in this study (Table 2) were 2-7 times lower than those of fin whales from the North Atlantic Ocean (Table 4, Hobbs *et al.*, 2001; Gauthier *et al.*, 1997) and Antarctic minke whales from the Antarctic Ocean (Table 4, Yasunaga *et al.*, 2014a), whereas they were about 20 times lower than those of killer whales from the Antarctic Ocean (Table 4, Krahn *et al.*, 2008).

Mean concentrations of CHLs in blubber of fin whales from the Antarctic Ocean in this study (Table 2) were 2-3 orders of magnitude lower than those of fin whales from the North Atlantic Ocean (Table 4, Hobbs *et al.*, 2001; Gauthier *et al.*, 1997) and those of killer whales from the Antarctic Ocean (Table 4, Krahn *et al.*, 2008), whereas they were one order of magnitude lower than those of Antarctic minke whales (Table 4, Yasunaga *et al.*, 2014a) from the Antarctic Ocean.

Levels of OCs, except for HCB, in fin whales from Antarctic Ocean were similar to those in Antarctic minke whales, whereas were extremely lower than those in fin whales from the middle latitude of the northern hemisphere nearby human activity and in killer whales, a top predator, from the Antarctic Ocean. On the other hand, the HCB levels in fin whales in the Antarctic were extremely lower than those of killer whales, whereas the differences of HCB levels among fin whales in both hemispheres were comparatively smaller than those of other OCs. Zhang and Lohmann (2010) reported that the HCB levels (0.4-0.8 pg/m^3) in Oceans of the southern hemisphere were slightly lower than those of northern hemisphere (0.4-1.6 pg/m^3). Therefore HCB levels in large whales would be affected by the trophic levels of its preys rather than the spatial differences.

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Table 1. Samples of fin whales taken from JARPAII surveys used in this study.

Survey year	ID No.	Sex	Body length
2005/2006	2005/2006-F001	M	19.17
	2005/2006-F002	F	20.05
	2005/2006-F003	F	19.47
	2005/2006-F004	M	18.73
	2005/2006-F005	M	19.14
	2005/2006-F006	F	19.15
	2005/2006-F007	F	20.22
	2005/2006-F008	F	18.22
	2005/2006-F009	M	18.3
	2005/2006-F010	F	19.35
2006/2007	2006/2007-F002	M	20.67
	2006/2007-F003	F	21.15
2008/2009	2008/2009-F001	F	14.79
2009/2010	2009/2010-F001	M	17.61
2010/2011	2010/2011-F001	M	19.05
	2010/2011-F002	M	18.99

Table 2. Concentrations of total Hg (ppm wet wt.) in liver and muscle, and PCBs, DDTs, HCHs, HCB and CHLs (ng/g fat wt.) in blubber of fin whales taken from JARPAII surveys.

Survey year	ID No.	Hg		PCBs	DDTs	HCHs	HCB	CHLs	Fat (%)
		Liver	Muscle	Blubber	Blubber	Blubber	Blubber	Blubber	Blubber
2005/2006	2005/2006-F001	0.068	0.035						
	2005/2006-F002	0.046	0.025						
	2005/2006-F003	0.06	0.027						
	2005/2006-F004	0.063	0.014						
	2005/2006-F005	0.046	0.013						
	2005/2006-F006	0.041	0.027						
	2005/2006-F007	0.054	0.017						
	2005/2006-F008	0.022	0.013						
	2005/2006-F009	0.036	0.008						
	2005/2006-F010	0.079	0.027						
2006/2007	2006/2007-F002		0.05						
	2006/2007-F003		0.03						
2008/2009	2008/2009-F001		0.01						
2009/2010	2009/2010-F001		0.02						
2010/2011	2010/2011-F001		0.03	5.2	10	0.35	42	3.6	67.7
	2010/2011-F002		0.03	7.8	15	0.94	35	5.4	72.4
Average		0.052	0.021	6.5	13	0.65	39	4.5	70.1
min		0.022	0.008						
max		0.079	0.035						
n		10	17	2	2	2	2	2	2

Table 3. Mean concentrations of total mercury (ppm wet wt.) in liver and muscle of baleen whales reported from different parts of the world.

species	Location	Survey year	*n* (sex)	Age or Maturity	Hg (ppm wet wt.)		References
					Liver	Muscle	
fin whale	NW Atlantic Ocean (Factory in Spain)	1983, 1984	11 (11M)	4-49	0.55	0.13	Sanpera *et al.* (1993)
fin whale	NW Atlantic Ocean (Factory in Iceland)	1986	5 (5M)	12-26	0.55	0.20	Sanpera *et al.* (1993)
Antarctic minke whale	Antarctic Ocean (Area V)	2010/2011	51 (51M)	1-42	0.081		Yasunaga *et al.* (2014a)

Table 4. Mean concentrations (ng/g fat wt.) of organochlorines in blubber of baleen whales reported from different parts of the world.

species	Location	Survey year	*n* (sex)	Age or Maturity	PCBs	DDTs	HCHs	HCB	CHLs	References
fin whale	Antarctic Ocean (Landed at Durban)	1974	6 (3M3F)		<500	140				Henry and Best (1983)
fin whale	NE Atlantic (factory of NW Spain)	1982-1984	27 (27)	8-15	1537	1165				Aguilar and Borrell (1988)
fin whale	NW Atlantic (Newfoundland)	1971-1972	12 (6M6F)		1470	4350	241	288	579	Hobbs *et al.* (2001)
fin whale	NW Atlantic (Nova Scotia)	1971-1972	5 (4M1F)		5640	23800	166	218	1180	Hobbs *et al.* (2001)
fin whale	NW Atlantic (St Lawrence)	1991	15		2670	3810	215	96.3	619	Gauthier *et al.* (1997)
Antarctic minke whale	Antarctic Ocean (Area V)	2010/2011	5 (5M)	21-25	28	100	0.8	140	25	Yasunaga *et al.* (2014b)
Killer whale	Antarctic Ocean (Ross sea)	2005-2006	7(7M)	Mature	2100	4300	ND	740	1300	Krahn *et al.* (2008)

ND: Not detected