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A note on POPs and Hg accumulation in sperm whale based on JARPNII samples collected during 2001-2013

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ABSTRACT

Total Hg was determined in 13 liver and 33 muscle samples of sperm whales (*Physeter macrocephalus*) obtained from the western North Pacific by JARPNII in the period 2001-2013. In addition PCBs, DDTs, HCHs, HCB and CHLs were determined in three blubber samples from sperm whales sampled in 2012. Mean concentrations of total Hg in muscle of sperm whales in the periods 2001-2005 and 2011-2013 were 1.9 and 1.5 (ppm wet wt.), respectively. No significant difference was observed in their Hg levels between the two periods. Mean concentrations of PCBs, DDTs, HCHs, HCB and CHLs in blubber samples in 2012 were 1.9, 0.74, 0.040, 0.077 and 0.65 (μg/g fat wt.), respectively. Levels of Hg in muscle samples of sperm whales in the present study were slightly lower than those from Ayukawa, Japan in 1978 and 1979, and from the southern North Sea in 1994 and 1995. Levels of organochlorines, except for CHLs, in sperm whales from the western North Pacific were similar or lower than those in sperm whales from the middle latitudes of the northern hemisphere nearby human activity. In addition, there is no evidence that levels of total Hg in muscle of sperm whales increased in the period of 1970s to 2000s.

KEYWORDS: SPERM WHALE; MERCURY; ORGANOCHLORINES; NORTH PACIFIC; POLLUTANTS; PCB; DDT

INTRODUCTION

Mercury and organochlorine compounds (OCs) released into the environment remain in the marine ecosystem due to their highly persistent character. Systematic monitoring programs of the Hg and OCs are needed to monitor and predict the behavior and fate of these pollutants in the global environment. The North Pacific, a mid-latitude sea area in the northern hemisphere is important for environmental monitoring of the Hg and OCs, because of its vicinity to high human activity land regions. Therefore, continued monitoring in this area could provide valuable information on the global dynamics of these pollutants.

For this reason, monitoring of pollutants in large whales and the ecosystem were added to a part of the second objective of the JARPNII survey. Sperm whales (*Physeter macrocephalus*) are comparatively large in size and are abundant in the North Pacific ecosystem. However, there is little information about pollutants in sperm whales in the western North Pacific.

The one of the objectives of pollutant studies in the JARPNII is to monitor levels and fate of Hg and OCs, such as polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethanes and its metabolites (DDTs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB) and chlordane compounds (CHLs), in sperm whales. However, most of the samples that had been taken for this study since 2008 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 sperm whales in previous studies.

MATERIALS AND METHODS

13 liver and 33 muscle samples of sperm whales taken form the western North Pacific were analyzed for the total Hg, and PCBs, DDTs, HCHs, HCB and CHLs were measured in 3 blubber samples (Tables 1, 2). All samples were cryopreserved in polyethylene bags at -20°C until analysis.

Total Hg analyses of the liver and muscle samples were performed in the Institute of Cetacean Research and the Japan Food Research Laboratories (Tokyo, Japan) 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.

Difference of Hg concentrations in the muscle of sperm whales in the periods 2001-2005 and 2011-2013 was assessed by Mann-Whitney U test. A p value of less than 0.05 was used as the criterion of statistical significance. These statistical analyses were executed with PASW Statics 17.0 for Windows (SPSS Co. Ltd.).

RESULTS AND DISCUSSION

Mean concentrations of total Hg in muscle of female sperm whales in the periods 2001-2005 and 2011-2013 were 1.9 and 1.5 (ppm wet wt.), respectively. No significant difference was observed in their Hg levels between the two periods ($p < 0.05$). Mean concentrations of PCBs, DDTs, HCHs, HCB and CHLs in blubber samples in 2012 were 1.9, 0.74, 0.040, 0.077 and 0.65 (μg/g fat wt.), respectively.

Hg

Mean concentrations of Hg in liver and muscle of sperm whales from the western North Pacific in this study were two or three times higher than those of sperm whales from the southern North Sea (Table 3, Holsbeek *et al.*, 2015), whereas they were slightly lower than those of sperm whales from Ayukawa, Japan in 1978-1979 (Taguchi *et al.*, 1981). Hg accumulation level in whales is affected by age, Hg levels in their prey items, prey consumption, etc. And, Hg levels in their prey items, 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 mainly caused by food habitat and/or age.

Organochlorines

Mean concentrations of PCBs in blubber of sperm whales from the western North Pacific in this study were one order of magnitude lower than those of sperm whales from the North western Mediterranean Sea (Table 3, Pinzone *et al.*, 2015), whereas they were similar to those of sperm whales from Tasmania, Australia (Table 3, Evans *et al.*, 2003) and southern North Sea (Table 3, Holsbeek *et al.*, 2015).

Mean concentrations of DDTs in blubber of sperm whales from the western North Pacific in this study were one or two orders of magnitude lower than those of sperm whales from Tasmania Australia, North western Mediterranean Sea and southern North Sea (Table 3, Evans *et al.*, 2003; Pinzone *et al.*, 2015; Holsbeek *et al.*, 2015).

Mean concentrations of HCHs in blubber of sperm whales from the western North Pacific in this study were similar to those of sperm whales from Tasmania Australia (Table 3, Evans *et al.*, 2003) and southern North Sea (Table 3, Holsbeek *et al.*, 2015), and those of males of sperm whales from North western Mediterranean Sea (Table 3, Pinzone *et al.*, 2015) were one order of magnitude lower than those of females of sperm whales from North western Mediterranean Sea (Table 3, Pinzone *et al.*, 2015).

Mean concentrations of HCB in blubber of sperm whales in this study were about 5 times lower than those of sperm whales from southern North Sea (Table 3, Holsbeek *et al.*, 2015).

Levels of OCs, except for CHLs, in sperm whales from the western North Pacific were similar or lower than those in sperm whales from the middle latitudes of the northern hemisphere nearby human activity. In addition, there is no evidence that total Hg in muscle of sperm whales increased in the period of 1970s to 2000s.

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Table 1. Sample list of sperm whales taken from JARPNII surveys

Survey year	Sex	*n*	Body length*
2001	male	2	9.59 (8.98-10.20)
	female	6	9.91 (9.14-11.03)
2002	male	2	9.26 (8.42-10.10)
	female	3	9.79 (8.71-10.40)
2003	male	1	7.87
	female	9	10.41 (8.33-11.51)
2005	male	3	10.12 (9.15-10.94)
	female	2	9.09 (8.90-9.28)
2011	female	1	10.15
2012	male	1	8.71
	female	2	10.68 (9.84-11.51)
2013	female	1	7.36

*: Average and ranges in parentheses

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

Year	ID No.	Sex	Hg		PCBs	DDTs	HCHs	HCB	CHLs	Fat (%)
			Liver	Muscle	Blubber	Blubber	Blubber	Blubber	Blubber	Blubber
2001	2001NP-S001	F	250	4.6						
	2001NP-S002	M	17	2.2						
	2001NP-S003	F	100	2.4						
	2001NP-S004	F	110	3.1						
	2001NP-S005	M	7.6	1.4						
	2001NP-S006	F	48	2.5						
	2001NP-S007	F	27	1.9						
	2001NP-S008	F	13	1.7						
2002	2002NP-S001	F	150	2.6						
	2002NP-S002	M	4	0.98						
	2002NP-S003	F	3.2	1.2						
	2002NP-S004	F	150	3.8						
	2002NP-S005	M	27	1.7						
2003	2003NP-S001	F		1.1						
	2003NP-S002	F		1.8						
	2003NP-S003	M		0.75						
	2003NP-S004	F		2.1						
	2003NP-S005	F		2.2						
	2003NP-S006	F		1.4						
	2003NP-S007	F		1.5						
	2003NP-S008	F		0.96						
	2003NP-S009	F		1.2						
	2003NP-S010	F		1.6						
2005	2005NP-S001	M		1.6						
	2005NP-S002	M		2.2						
	2005NP-S003	F		1.9						
	2005NP-S004	M		2.2						
	2005NP-S005	F		1.5						
2001-2005	Males		14	1.6						
	Females		95	2.0						
	Total		70	1.9						
2011	2011NP-S001	F		2.7						
2012	2012NP-S001	M		1.4	2.8	1.0	0.057	0.12	1.0	66.9
	2012NP-S002	F		2.0	1.4	0.51	0.021	0.038	0.38	65.1
	2012NP-S003	F		0.89	1.6	0.71	0.042	0.072	0.57	55.8
2013	2013NP-S001	F		0.55						
2011-2013	Males			1.4	2.8	1.0	0.057	0.12	1.0	66.9
	Females			1.5	1.5	0.61	0.032	0.055	0.48	60.5
	Total			1.5	1.9	0.74	0.040	0.077	0.65	62.6

Table 3. Mean and standard deviation concentrations of total mercury (ppm wet wt.) in liver and muscle and OCs (ppm lipid wt.) in blubber of sperm whales reported from different part of the world

Location	Survey year	*n* (sex)	Age or Maturity	Hg (ppm wet wt.)		PCBs	DDTs	HCHs	HCB	CHLs	DDTs/PCBs	DDE/DDTs	Lipid (%)	References
				Liver	Muscle	Blubber	Blubber	Blubber	Blubber	Blubber	Blubber	Blubber	Blubber	
Tasmania, Australia (stranding samples)	1998	5M	unknown			0.8±0.4	1.7±1.9	0.01±0.1			2.1±1.9	0.6±0.2	41.3±15.6	Evans *et al.* (2003)
		32F				1.3±1.2	3.1±3.6	ND			2.1±1.0	0.7±0.2	50.4±18.1	
North western Mediterranean Sea (biopsy samples)	2006-2013	47M				24.2±17.4	44.2±41.9	0.085±0.092			2.1±2.8	9.6±3.3	10±8	Pinzone *et al.* (2015)*
		14F				16.9±7.2	17.4±11.2	0.21±0.00			0.9±0.2	9.6±3.0	18±8	
Southern North Sea (stranding samples)	1994-1995	6M		18±12	0.82±0.16	5.3±0.9	13±2.8	0.04±0.01	0.45±0.09		2.5±0.3	0.55±0.02		Holsbeek *et al.* (1999)**
Ayukawa, Japan (commercial whaling)	1978-1979	2			2.7									Taguchi *et al.* (1981)

*: Original values (µg/g lipid wt.) were converted to ppm lipid wt.

**: Data of only live standing samples was used. Original values (µg/g dry wt.) were converted to ppm lipid wt. using with lw/dw cofficients.