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Mercury, DDT and PCB in the Atlantic Walrus (*Odobenus rosmarus rosmarus*) from the Thule District, North Greenland

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ABSTRACT. Tissue samples of 69 Atlantic walruses (*Odobenus rosmarus rosmarus*) were collected in the Thule district, North Greenland, in May-July 1975 and 1977. The mean concentration of total mercury in liver was 1.78 mg kg^{-1} (SD = 1.54; N = 46), wet weight basis, with the mean percentage of methyl mercury being 5.5%. The mean concentration in muscle was 0.08 mg kg^{-1} (SD = 0.05; N = 58; mean age = 10.9 years; range: 1-26 years; neonates excluded). In neonates (N = 9) the mean concentration of total mercury was 0.31 mg kg^{-1} (SD = 0.45) in liver (19.9% methyl mercury) and 0.06 mg kg^{-1} (SD = 0.03) in muscle.

Mean Σ DDT and PCB concentrations in blubber of 28 walruses (mean age = 7.4 years; range: 0-19 years) were 0.063 mg kg^{-1} (SD = 0.080) and 0.221 mg kg^{-1} (SD = 0.207), respectively. In males the concentration of ΣDDT and PCB increased with age. In females there was no correlation between the concentration of ΣDDT and age, while there was a negative correlation between the concentration of PCB and age.

The values of mercury concentrations are low compared with values for seals in Greenland and the eastern Canadian Arctic, and the values of organochlorine concentrations are the lowest reported for pinnipeds.

Key words: Mercury, DDT, PCB, Atlantic walrus, *Odobenus rosmarus rosmarus*, North Greenland

RÉSUMÉ. Des échantilons de tissu ont été prélevés de 69 morses de l'Atlantique (*Odobenus rosmarus rosmarus*) dans le district de Thule, dans le nord du Groënland, entre mai et juillet, en 1975 et en 1977.

La concentration moyenne de mercure total dans le foie était de 178 mg kg^{-1} (DS = 1.54; N = 46), basé sur le poids humide, avec un pourcentage moyen de mercure de méthyle de 5.5%. La concentration moyenne dans les muscles était de 0.08 mg kg^{-1} (DS = 0.05; N = 58; âge moyen = 1.09 ans; portée: 1-26 ans; nouveaux-nés exclus). Pour les nouveaux-nés (N = 9), la concentration moyenne de mercure total était de 0.31 mg kg^{-1} (DS = 0.45) dans le foie (19.9% de mercure de méthyle) et 0.06 mg kg^{-1} (DS = 0.03) dans les muscles.

Les concentrations moyennes de ΣDDT et de PCB dans le blanc de 28 morses (age moyen = 7.4 ans; portée: 0-19 ans) était 0.063 mg kg^{-1} (DS = 0.080) et 0.221 mg kg^{-1} (DS = 0.207), respectivement. Chez les mâles, la concentration de DDT et de PCB augmentait avec l'âge. Chez les femmelles, aucune corrélation n'existait entre le ΣDDT et l'âge, tandis qu'il y avait une corrélation négative entre la concentration de PCB et l'âge.

Les valeurs des concentrations de mercure sont peu élevées par rapport à celles ayant trait aux phoques du Groënland et de l'est de l'Arctique canadien, et les valeurs des concentrations en organochlorures sont les moins élevées des valeurs signalées pour les pinnipédes.

Mots clés: Mercure, DDT, PCB, morse de l'Atlantique, *Odobenus rosmarus rosmarus*, nord du Groënland

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INTRODUCTION

Occurrences of such environmental contaminants as mercury (Hg), organochlorine pesticides (DDT and its metabolites) and industrially used polychlorinated biphenyls (PCB) in the tissues of arctic marine mammals have been reported in recent years (e.g. Addison *et al.*, 1973; Bowes and Jonkel, 1975; Clausen *et al.*, 1974; Clausen and Berg, 1975; Galster, 1971; Galster and Burns, 1972; Holden, 1972, 1975, 1978; Jones *et al.*, 1976; Johansen *et al.*, 1980; Smith and Armstrong, 1975, 1978).

The Atlantic walrus (*Odobenus rosmarus rosmarus*) provides a substantial proportion of the meat diet of the Inuit in the Thule district, North Greenland. The average annual catch in the district is 215 walruses, which amounts to about 80 tons of meat, blubber and hide (own observation).

Being a top carnivore of a food chain with only a few links, the walrus feeds almost exclusively on the feet and siphons of various bottom-dwelling bivalves (Vibe, 1950).

Freuchen (1921) and Vibe (1950) proposed that the walrus occurring in the Thule district is part of a widely-distributed population which makes perennial migrations in Baffin Bay. The existence of this large-scale cycle has been questioned by Mansfield (1958), and recent information from the walrus hunters in the Thule district indicates that the walrus occurring in the northern parts of Baffin Bay may be a local and more or less isolated subpopulation.

While mercury results from industrial activities and also occurs as a natural decompositional product of various rocks, the organochlorines derive from areas of industrial activity and are spread to the Arctic by winds (Harvey and Steinhauer, 1974) or are dissolved in North Atlantic water (Harvey *et al.*, 1973) and carried by ocean currents such as the Gulf Stream. Water of Atlantic origin enters Smith Sound and Kane Basin, which separate the Thule district from Ellesmere Island (Tooma, 1978).

MATERIAL AND METHODS.

During the period May-July in 1975 and 1977, samples from 69 walruses were obtained from the subsistence catch in the Thule district, Smith Sound region (76° 25′N, 78° 30′N). Samples of liver, somatic muscles and blubber

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were kept frozen until analyzed at the Royal Veterinary and Agricultural University in Copenhagen. The ages of 49 walruses caught in 1977 were determined from cement layers in the lower molariform teeth by a method similar to that described by Mansfield (1958). No teeth for age determination were obtained from the 20 walruses in 1975. A minimum age has been determined for the 1975 animals by comparison of 1) individual measures of nose-tail length and 2) tusk length and circumference, with growth curves established on measurement results of walruses of known age collected in Thule in 1977 and 1978.

The content of PCB, the persistent organochlorinated compound DDT, and its fat-soluble metabolites DDE and DDD, was determined by gas chromatography as described by Kraul and Karlog (1976).

Total mercury was determined by a modification of Skare's (1972) method. The methodological basis is digestion of the organic tissue with concentrated sulphuric acid at 60°C, in the presence of potassium permanganate. The excess permanganate is reduced with hydroxylammonium chloride. Finally the mercury is reduced to metallic mercury with stannous chloride, and the vapours are pumped through an absorption cell in a flameless atomic absorption spectrophotometer (Coleman Model MAS-50 Mercury Analyzer).

The analyses of methyl mercury were carried out with gas-chromatographic detection using Newsome's method (1971). [Gas-chromatograph: Varian 1400 fitted with a ^{63}Ni-ec-detector and an all-glass column (6′ x ⅛″) packed with 10% Carbowax 20 M on Chromosorb W (aw, DMCS, 60/80 Mesh)].

RESULTS

Mercury (Hg). Values of total Hg in muscle and liver and the percentage of methyl mercury in liver from the Atlantic walrus are presented in Table 1 (all values in the table are given on a wet weight basis). Values from similar studies on other pinnipeds from different arctic areas are included in the table for comparative purposes. The geographic variation is summarized by Holden (1978) and Roberts *et al.* (1976). The highest concentrations of total Hg (225-765 mg kg^{-1}) are reported in the liver of the harbour seal (*Phoca vitulina*) off the Dutch coast.

In the walrus (neonates excluded) from Thule district the average concentration of total Hg in liver was 22.3 times the concentration found in muscle. In neonates, the average concentration of total Hg in liver was 5.2 times the concentration found in muscle (Table 2).

There was an increase with age in the concentration of total Hg in liver ($Y = 0.098X + 0.647$; $S^2 = 1.932$; $t = 3.421$; $P < 0.01$; $r = 0.425$; d.f. = 53; ages: 0-26 years; mean age: 0.09 years; SD = 6.61).

A negative correlation existed between the percentage of methyl Hg and total Hg in liver ($Y = (-1.466X) + 8.095$; $S^2 = 1.282$; $t = 13.477$; $P < 0.01$; $r = -0.660$; d.f. = 46; ages: 1-26 years). The values range from 16.6% methyl Hg on a total Hg concentration of 0.34 mg kg^{-1} to 0.32% methyl Hg on a total Hg concentration of 6.6 mg kg^{-1}.

In the neonates the average methyl Hg percentage of total Hg is high (19.8%; SD = 12.1; range: 4.0-45.0%; N = 9) compared with the whole group (neonates excluded) of 5.5% (N = 46), but the actual methyl Hg concentration in

TABLE 1. Mercury concentrations in pinnipeds from different arctic locations

		Total Hg (mg kg^{-1})								% Methyl Hg					
		LIVER				MUSCLE				LIVER				Mean age in years	
Species	Area	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N		Source
Atlantic walrus Greenland	Thule district	1.78	1.54	0.12-7.3	46	0.08	0.05	0.03-0.13	58	5.5	3.4	0.32-26.7	56	10.9*	Present study
	Herchell I.	9.8	-	-	1	-	-	-	-	-	-	-	-	-	
Atlantic walrus Canada	Holman I.	3.92	-	-	1	-	-	-	-	-	-	-	-	-	Eaton
		17.0	-	-	1	-	-	-	-	-	-	-	-	-	(Pers. comm.)
	Pond Inlet	10.6	-	-	1	-	-	-	-	-	-	-	-	-	
Pacific walrus Alaska	St. Lawrence I. St. Mathew I.	0.49	0.10	-	7	0.02	0.00	-	6	-	-	-	-	-	Galster (Pers. comm.)
Bearded seal Alaska	Point Barrow St. Mathew I.	1.91	1.20	-	4	0.20	0.15	-	7	-	-	-	-	-	Galster (pers. comm.)
Bearded seal Canada	W. Victoria I.	143	170	-	6	0.53	0.35	-	3	0.39	0.32	-	6	8.5	Smith and Armstrong, 1978
	Belcher I.	26.18	26.13	-	56	0.09	0.04	-	55	0.58	0.71	-	10	4.9a 5.4b	
Ringed seal Canada	W. Victoria I.	27.50	30.10	-	83	0.72	0.33	-	83	5.84	12.29	-	42	12.8a 14.3b	Smith and Armstrong, 1978
	Pond Inlet	3.76	3.42	-	33	0.31	0.17	-	33	13.30	6.38	-	8	5.2	
Ringed seal Greenland	Upernavik														
	1973	2.4	-	0.32-4.9	10	0.23	-	<0.05-0.51	10	15	-	1.3-22.9	7	-	Johansen *et al.*, 1980
	1974	0.34	-	<0.05-1.2	7	0.09	-	0.05-0.12	7	27	-	1.7-64.7	7	-	
	1976	2.1	-	0.14-11.9	31	-	-	-	-	-	-	-	-	-	
	Daneborg	2.9	-	1.4-8.1	7	0.42	-	0.25-0.68	7	20	-	10.6 -33.1	7	-	

a = mean age of liver and muscle sample (Total Hg)
b = mean age of liver sample (% Methyl Hg)
All concentrations on wet weight basis

*: ages: 1-26 years (newborns excluded)
SD = standard deviation

TABLE 2. Concentrations of mercury in mother/calf walrus pairs from North Greenland

Age		LIVER			MUSCLE	KIDNEY	
		Total Hg	Methyl Hg	% Methyl Hg	Total Hg	Total Hg	% Methyl Hg
Mothers	Calves	(mg kg^{-1})	(mg kg^{-1})		(mg kg^{-1})	(mg kg^{-1})	
17 years		0.92	0.06	6.5	0.07	-	-
	2 weeks	1.16	0.04	25.5	0.042	0.060	23.5
13 years		0.97	0.05	5.6	0.10	-	-
	2 weeks	0.17	0.05	26.7	0.062	0.074	36.3
11 years		6.6	0.02	0.3	0.08	-	-
	4 weeks	0.28	0.07	23.5	0.066	0.15	-
10-13 years		1.4	0.08	5.8	0.20	-	-
	1 week	0.04	0.02	45.6	0.08	-	-
No data from mothers:							
	3 weeks	1.5	0.06	4.0	0.12	-	-
	3 weeks	0.17	0.03	16.9	0.042	0.063	25.4
	3 weeks	0.16	0.02	14.8	0.029	0.11	8.7
	3 weeks	0.19	0.02	10.5	0.040	0.11	14.0
	3 weeks	0.12	0.01	11.7	0.040	0.09	12.8
Newborns:							
	Mean:	0.31	0.04	19.9	0.057	0.094	21.3
	SD:	0.45	0.02	12.2	0.028	0.032	9.8
	N:	9	9	9	9	7	7

All values on wet weight basis
SD = standard deviation

the neonates is comparable to that of the mothers, even though the concentration of total Hg is much lower (Table 2). There is one exception: the concentration of total Hg in one neonate was about nine times higher than the concentrations in the other neonates, and was comparable to the concentrations and methyl Hg percentages in the older individuals. No specimens were secured from the mother of this newborn.

In the age group 1-26 years no correlation between the concentrations of total Hg in liver and in muscle was found ($r = 0.010$; P = NS; $N = 46$), while in the neonates a positive correlation existed between total Hg concentrations in the muscle and total Hg concentrations in the liver ($r = 0.800$; $Y = 0.050X + 0.042$; $S^2 = 0.0003$; $t = 3.440$; $P < 0.01$; d.f. 7).

DDT and PCB. In Tables 3 and 4 results of analyses of 28 Atlantic walruses (0-19 years old) are presented. All values in the tables are given on a wet weight basis. The mean lipid content in the blubber is 77.8 wet weight. Values from similar studies of other arctic pinnipeds are included in Table 3 for comparative purposes. The table includes only the lowest reported mean concentrations in other pinnipeds as the values for the Atlantic walrus are the lowest reported. The northern fur seal (*Callorhinus ursinus*) from the Bering Sea is an exception as no organochlorines were detected in this species by Anas and Wilson (1970).

In all specimens of the Atlantic walrus from Thule the metabolite DDE was detected, while unmetabolized DDT was not detected (< 0.001 mg kg^{-1}) in 10 individuals, including a 10-13-year-old female with her newborn. The concentration of DDE was higher than the concentration of DDT in all animals except five specimens where the levels of DDE were equal to the levels of DDT.

In Table 4 concentration of DDE and PCB in three lactating females with their calves are shown.

In males the concentration of ΣDDT increased with age ($Y = 0.019X + 0.009$; $S^2 = 0.008$; $r = 0.765$; $t = 2.906$; $P < 0.025$; d.f. = 6; ages: 0-14 years). Similarly, there was an age-dependent increase in the concentration of PCB ($Y = 0.048X + 0.154$; $S^2 = 0.039$; $r = 0.802$; $t = 3.284$; $P < 0.025$; d.f. = 6; ages: 0-14 years).

In the female there was no correlation between the concentration of DDT and age ($Y = 0.005X + 0.049$; $S^2 = 0.003$; $r = 0.051$; $t = 0.218$; $P > 0.10$; d.f. = 18; ages: 0-19 years). There was a negative correlation between the concentration of PCB and age ($Y = (-0.010X) + 0.268$; $S^2 = 0.012$; $r = -0.490$; $t = 2.382$; $P < 0.025$; d.f. = 18; ages: 0-19 years).

There was a significant difference in the mean concentration of PCB between the immature and the mature females ($t = 2.900$; $P < 0.01$; d.f. = 18). The mean concentration in the immatures (ages: 0-4 years, inclusive) was 0.272 mg kg^{-1} PCB (SD = 0.150; range: 0.07-0.530 mg kg^{-1}) and the mean concentration in the matures (ages: 8-19 years, inclusive) was 0.130 mg kg^{-1} (SD = 0.072; range: 0.063-0.255 mg kg^{-1}).

There was no significant difference in the concentration of ΣDDT between the immature and the mature females ($t = 1.520$; $P > 0.10$; d.f. = 18).

There was a positive correlation between the corresponding concentrations of DDT and PCB in the blubber of the walrus (Males: $r = 0.963$; $Y = 0.393X - 0.052$; $S^2 = 0.001$; $t = 8.757$; $P < 0.001$; d.f. = 6. Females: $r = 0.394$;

TABLE 3. Lowest reported organochlorine concentrations in pinnipeds from different arctic localities

		Organochlorines in blubber (mg kg^{-1})																
		DDE				DDT				ΣDDT				PCB				
Species	Area	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N	Source
Atlantic walrus Greenland	Thule district																	
	Females	0.034	0.042	0.005-0.19	20	0.016	0.012	ND-0.043	14	0.053	0.054	0.007-0.255	20	0.180	0.123	0.063-0.53	20	Present
	Males	0.055	0.091	0.009-0.28	8	0.031	0.030	ND-0.083	5	0.089	0.126	0.031-0.400	8	0.358	0.309	0.159-1.1	8	study
Pacific walrus	Alaska	-	-	-	-	-	-	-	-	0.08	-	-	4	1.78	-	-	4	Galster and Burns. 1972
Bearded seal	Alaska	-	-	-	-	-	-	-	-	0.33	-	-	-	1.78	-	-	-	"
Bearded seal	SW Greenland	0.466	0.263	0.20-0.80	5	-	-	-	-	-	-	-	-	1.80	0.99	0.6-3.0	5	Clausen and Berg, 1975
Ringed seal	Alaska	-	-	-	-	-	-	-	-	0.28	-	-	-	1.78	-	-	-	Galster and Burns, 1972
Ringed seal	SW Greenland	0.154	0.096	0.025-0.20	5	-	-	-	-	-	-	-	-	0.900	0.274	0.6-1.3	5	Clausen and Berg, 1975
Ringed seal Canada	Grise Fjord Sachs Harbour	0.459	0.421	0.060-1.55	7	-	-	-	-	1.056	0.889	0.555-2.919	7	0.801	0.692	0.05-1.93	7	Bowes and Jonkel, 1975
Ringed seal Canada	Holman I.																	
	Males	0.76	-	0.22-1.34	15	0.55	-	0.17-1.11	15	1.31	-	-	15	4.1	-	1-6	15	Addison
	Females	0.29	-	0.14-0.46	13	0.32	-	0.03-0.62	13	0.06	-	-	13	2.0	-	1-4	13	and Smith, 1974
Ringed seal NW Greenland	Upernavik																	
	1974	0.54	-	-	9	0.53	-	-	9	1.2	-	0.43-2.0	9	1.2	-	0.62-1.9	9	Johansen
	1975	0.36	-	-	31	0.34	-	-	31	0.76	-	0.35-6.2	31	0.99	-	0.28-3.6	17	*et al.*,
	1976	0.78	-	-	17	0.47	-	-	17	1.4	-	0.35-6.2	17	0.99	-	0.28-3.6	17	1980
	Daneborg NE Greenland																	
	1974	1.4	-	-	7	1.4	-	-	7	3.1	-	1.1-7.2	7	3.2	-	1.9-5.8	7	

All values on wet weight basis.
ND = concentrations below the detection limit, SD = standard deviation.

TABLE 4. Concentrations of organochlorines in mother/calf walrus pairs from North Greenland

Age		Organochlorines in blubber (mg kg^{-1})						
Mothers	Calves	DDE	DDD	DDT	ΣDDT	% DDT	PCB	% Fat
10-13 years		0.012	ND	ND	0.013	ND	0.16	73.7
	1 week, F	0.006	0.001	ND	0.007	ND	0.070	73.1
10 years		0.058	0.008	0.033	0.11	30	0.29	85.6
	1 week, F	0.058	0.007	0.029	0.10	13	0.28	63.5
8-9 years		0.013	ND	0.006	0.020	30	0.13	60.8
	1 year, F	0.016	0.010	0.021	0.050	42	0.33	79.3
No data from mothers								
	3 weeks, M	0.024	0.006	ND	0.033	ND	0.237	64.5
	3 weeks, M	0.012	0.015	0.018	0.048	38	0.200	76.0
	3 weeks, M	0.037	ND	ND	0.041	ND	0.249	86.7
Newborns								
	Mean	0.027	0.007	0.024	0.046	25.5	0.207	72.6
	SD	0.021	0.005	0.008	0.034	17.7	0.082	9.4
	N	5	4	2	5	2	5	5

ND = Not detected. SD = standard deviation.
All values on wet weight basis.

$Y = 0.172 + 0.022$; $S^2 = 0.003$; $t = 6.281$; $P < 0.001$; d.f. = 18). A similar correlation between the concentrations of ΣDDT and PCB was reported for the harbour seal (*Phoca vitulina*) by Drescher *et al.* (1977) and has been found in other seals (Holden, 1972).

The mean ratio of PCB and DDT is 5.4:1 for all walrus specimens.

DISCUSSION

Mercury. Our results show that total mercury is present in the livers of newborn Atlantic walrus at concentrations about 15 times lower than in their mothers, while the concentrations of methyl mercury in newborns' livers are comparable to those in the mothers. This indicates an early transfer of methyl mercury from the mother to the calf, either through the placenta or in the milk. No analyses of mercury concentrations in fetuses or in milk were done in our study, but the concentrations of methyl mercury in the livers of four newborns accompanied by data from the mothers indicate an increase in the methyl mercury burden in the first four weeks post partum, due to transfer in the milk. Furthermore, the high percentage of methyl mercury in the newborns compared to the older walruses indicates a delay in the onset of the demethylating mechanishm in the livers of the calves. Freeman and Horne (1973) concluded that in the harp seal (*Pagophilus groenlandicus*) methyl mercury was passed from the mother to the pup in milk, and not through the placental barrier. Jones *et al.* (1976) concluded from their study of harp seals that only small amounts of methyl mercury were passed from mothers to pups in milk, but that this form of mercury was capable of passing through the placenta. Kim *et al.* (1975) also concluded that a transfer of methyl mercury through the placenta could take place in the northern fur seal (*Callorhinus ursinus*).

Freeman and Horne (1973) and Sergeant and Armstrong (1973) showed that variations in mercury concentrations in different seal species could be related to differences in feeding habits and migrational patterns. The walrus feeds mainly on bottom-dwelling bivalves (Vibe, 1950; Mansfield, 1958). Bivalves concentrate mercury in the methylated form; however, the more toxic methyl mercury is lower relative to the total mercury burden (Windom and Kendall, 1979). Compared to other seals the walruses utilize a narrow selection of food sources, which may explain the low concentrations of mercury found in the walrus. However, the concentrations of total mercury found in three of four Atlantic walruses from Canada (Table 1) are higher than the highest concentrations found in our study, even in old walruses. This indicates a regional difference in the mercury burden of the Atlantic walrus and emphasizes the sedentary habits of this subspecies of the walrus. Similar regional differences were reported by Sergeant and Armstrong (1973) for the relatively sedentary bearded seal (*Erignathus barbatus*) in Canada.

DDT and PCB. Holden (1972) found a correlation between levels of organochlorines in seals and in different nutrient sources, the concentrations being generally lower in invertebrates than fish. The feeding patterns of the walrus may explain the low organochlorine concentrations found in our study. Marine phytoplankton adsorb organochlorines (Cox, 1970) and these are transferred to the suspension-feeding bivalves. The organochlorines are accumulated in the fat of the bivalves that have a lipid content of 1.1 to 2.2% (wet weight: 22.7% dry matter; analyzed at the National Food Institute of Denmark) compared with, for example, a lipid content of 6.6% in herring (Brawn *et al.*, 1968). However, regional differences in the organochlorine concentrations in the walrus are indicated. Galster and Burns (1972) report ΣDDT concentrations for the Pacific walrus in the Bering Strait that are comparable to those in the Atlantic walrus in the Thule district, while the concentrations of PCB are lower in our study than in the Pacific walrus (op. cit.). Johansen *et al.* (1980) report organochlorine concentrations in the ringed seal (*Phoca hispida*) that are lower in the Upernavik district, situated close to the Thule district, compared with the concentrations found in ringed seals from the Greenland east coast.

In the male Atlantic walrus the concentrations of ΣDDT and PCB increased with age; this finding corresponds to that by Addison *et al.* (1973) for the harp seal. A similar correlation was found for ΣDDT and a less pronounced one for PCB in the male ringed seal, while no correlation was found for females in the Canadian Arctic (Addison and Smith, 1974). In the female Atlantic walrus there was no correlation between the concentrations of ΣDDT and age, while the concentrations of PCB were significantly lower in sexually mature females than in immature females. Apparently, the female walrus reduces her organochlorine burden either during pregnancy or during lactation. Addison and Brodie (1977) found that the grey seal (*Halichoerus grypus*) mother may reduce her organochlorine burden by 30% during lactation. Jones *et al.* (1976) suggested that organochlorines are capable of crossing the placental barrier and being transferred from mother to pup in the harp seal.

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