Chapter 5

Biological Monitoring: Human Tissue Levels of Environmental Contaminants

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Summary

Levels of environmental contaminants in blood samples from humans living in the Arctic regions of the eight circumpolar countries confirm that levels of certain persistent organic pollutants (POPs) and mercury (Hg) are generally higher in the Arctic people who consume certain (mainly marine based) traditional/country foods (e.g., the Inuit of Greenland and Arctic Canada). For Greenland Inuit in particular, the levels of polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), total chlordanes, and Hg found in maternal blood samples are higher than those found in samples from other circumpolar countries, and are likely to reflect the higher consumption of marine mammals by this group.

Other key findings include higher levels of total DDT in a non-indigenous population from Arkhangelsk (Russia) than in any other region, indicating possible continuing use of this pesticide locally or in Russian agricultural regions from which food is transported to the Arkhangelsk region. For β-HCH, the highest levels were also seen in Arctic Russia among non-indigenous groups, but elevated levels were also observed in Iceland and among the 'Others' group (i.e., non-Caucasian, non-Dene/Métis, non-Inuit) in the Canadian Arctic.

Recent data for the Faroe Islands indicate that, due to public health advice for mothers to restrict their consumption of pilot whale, there has been a significant decrease in maternal Hg levels, although very little change in PCB levels. The different response of these two contaminants is probably due to the short half-life of Hg in the body compared to that of PCBs. It is difficult to determine time trends in environmental contaminants of concern in other Arctic human populations since only one or two sequential datasets exist. Most monitoring of human contaminant levels in the Arctic has taken place over only the last five to ten years, and although this has permitted a reasonably good assessment of the spatial variation in contaminant levels in humans, it is too short a period to reliably determine temporal trends. For Hg, the discovery of ancient Greenland mummies, together with some supporting data on biota from their clothing, offers evidence that there has been a significant increase in the concentration of Hg in the Arctic environment over the past 500 years and in people who consume large amounts of marine mammals.

5.1. Introduction

This chapter reports new data obtained since the first AMAP assessment (AMAP, 1998). The data presented for Canada and Greenland do however include findings from the circumpolar maternal blood contaminant study reported in the first AMAP assessment, as this allows a better spatial/regional assessment of contaminant levels in the circumpolar north. For the other circumpolar countries, with the exception of Sweden for which there are no new maternal blood data, only new data have been used. Overall, the combination of the earlier and newer data allows for a greater range of regions/communities to be evaluated than would otherwise have been possible. The locations of the various studies included in the present assessment are presented in Figure 5·1 (see next page).

The results presented in this assessment report focus primarily on maternal blood levels of various POPs (several organochlorine (OC) pesticides and PCBs) and metals (e.g., Hg, cadmium (Cd), and selenium (Se)). A number of these contaminants have been implicated in negative impacts on the developing fetus or young children and are under investigation in various epidemiological studies in the Arctic (see chapters 6 and 9). Data from studies on some adult male populations are provided for comparison. The POPs data are summarized in Tables 5·1 to 5·8 and those for metals in Table 5·12. As there are no new Swedish maternal blood contaminant data, the 1995–96 data presented in the previous AMAP assessment report (AMAP, 1998) are included in Table 5·8. Additional data, on levels of PCBs in breast milk, are presented in Tables 5·9, 5·10, and 5·11.

Blood contaminant levels are discussed within a national and regional context, and then in terms of international comparisons, which includes comparisons between non-indigenous and indigenous populations.

5.1.1. Comparisons of data

Owing to varying national confidentiality requirements for the release or sharing of human data it has not been possible to obtain sufficient raw data to enable statistical comparisons between ethnic peoples or regions. However, comparisons of the population means and ranges for all the circumpolar peoples do permit general patterns of contaminant levels and their spatial relationships to be discerned. The QA/QC activity that has been completed for AMAP Phase II implies an inter-laboratory variability of the order of 20% to 30% for some of the more common analytes of concern (see section 5.5). To ensure that conclusions regarding spatial trends are not simply the result of analytical variability, this assessment is restricted to a consideration of differences of approximately two- to ten-fold between the various comparison groups, which are unlikely to be due to analytical variability.

Data presented in this chapter are on a wet weight basis unless otherwise stated; as these were the values reported by most circumpolar studies. Some data were also made available on a lipid weight basis, and these are tabulated in Annex 5A (Tables 5A·1 to 5A·5) for possible

Figure 5·1. Sampling locations in the AMAP Phase II circumpolar blood monitoring study.

future use. Again, unless otherwise stated, comparisons are made using geometric mean values as most contributors were able to supply these values and geometric means are less affected by extreme values than arithmetic means.

Recruitment of subjects for the various circumpolar studies was usually based on the mother's interest in participating, and on residence in the catchment area of a specific birthing center. Any groups that were recruited based on known or probable increased exposure are identified in the text. When comparing the contaminant levels of different population groups, it is useful to have a description of age, parity, breast feeding history, and diet as these are important determinants of contaminant levels. For mothers, age is not a particularly significant factor as most mothers are fairly similar in age (18 to 35 years). Parity and breast feeding history were not available in many circumpolar studies. For men, age is reported, as levels of POPs increase with age and the possible age class is much wider (18 to 90 years). Diet is an important determinant of contaminant levels. Although it was not possible to implement AMAP dietary surveys in parallel with the maternal blood contaminant surveys in all Arctic countries, such surveys have been performed or are underway in several regions. Chapter 7 reviews the most recent dietary information available for the Arctic populations concerned.

Comparisons between the data reported in this chapter and blood guideline values are made in chapter 9. These comparisons permit a useful assessment of the levels found in various circumpolar populations and place these within the context of ongoing human health effects research within the Arctic and worldwide.

5.2. Persistent organic pollutants

5.2.1. National and regional data

Since the first AMAP assessment (AMAP, 1998), new national data on the levels of OC pesticides and PCBs in maternal blood have been provided for all the circumpolar countries except Sweden. Also available are intra-country regional data on specific OC pesticides (e.g., for Canada, Greenland, Alaska (United States), Russia, and Iceland) and data on differences in contaminant levels between ethnic groups (i.e., indigenous vs non-indigenous peoples) in Canada and Russia.

5.2.1.1. Canada

The sampling of maternal and cord blood in Arctic Canada between 1994 and 1999 has allowed a baseline assessment of environmental contaminants in most regions and ethnic groups of the Canadian north (with the exception of the Yukon). Some of the Canadian data were available for the first AMAP assessment; namely data for the Inuit from the Kitikmeot region. A number of additional Inuit groups have now participated in monitoring programmes, as have Dene/Métis and 'Others' (non-indigenous Canadian residents, mainly of African and East Asian ancestry) groups. Since there were no significant differences in contaminant levels in samples collected in 1994 to 1995 and

Table 5·1. Organochlorine contaminants in maternal blood from Canada, by region and ethnic group (geometric mean (range), µg/L plasma).

				Inuit 1994–2000				
	Caucasian[1] 1994–99 (n=134)	Dene/Métis[1] 1994–99 (n=93)	Other[1] 1995 (n=13)	Baffin 1996 (n=30)	Inuvik 1998–1999 (n=31)	Kitikmeot[1] 1994–95 (n=63)	Kivalliq[1] 1996–97 (n=17)	Nunavik[2] 1995–2000 (n=199)
Oxychlordane	0.05 (nd–0.22)	0.04 (nd–0.23	0.04 (nd–0.21)	0.58 (0.09–2.4)	0.15 (0.03–1.1)	0.29 (nd–2.9)	0.36 (nd–6.2)	0.30 (0.01–3.9)
Trans–nonachlor	0.06 (0.02–0.26)	0.06 (nd–0.37)	0.07 (0.02–0.30)	0.64 (0.16–2.5)	0.28 (0.05–1.8)	0.31 (nd–3.0)	0.44 (0.03–3.7)	0.46 (0.01–4.6)
p,p'-DDT	0.05 (nd–0.19)	0.03 (nd–0.13)	0.22 (nd–3.2)	0.14 (0.04–0.47)	0.07 (nd–0.45)	0.08 (nd–0.33)	0.09 (nd–0.35)	0.09 (0.02–1.1)
p,p'-DDE	0.91 (0.22–11.2)	0.69 (0.15–5.3)	4.0 (0.51–34)	2.1 (0.55–6.0)	1.1 (0.40–3.8)	1.3 (0.12–7.8)	1.7 (0.21–7.2)	2.2 (0.14–18)
DDE:DDT ratio	18 (nd–75)	18 (nd–89)	15 (nd–31)	15 (7.1–43)	13 (nd–51)	15 (nd–53)	19 (nd–52)	23 (2.8–209)
HCB	0.12 (0.04–0.61)	0.18 (0.02–1.7)	0.11 (0.02–0.40)	0.53 (0.14–1.5)	0.31 (0.06–1.2)	0.56 (0.05–4.5)	0.46 (0.07–1.8)	0.31 (0.05–2.8)
β-HCH	0.09 (nd–0.55)	0.04 (nd–0.13)	0.48 (0.04–39)	0.11 (nd–0.44)	0.08 (nd–0.25)	0.09 (nd–0.44)	0.09 (nd–0.30)	0.04 (0.02–0.25)
Mirex	0.02 (nd–0.14)	0.02 (nd–0.21)	0.01 (nd–0.07)	0.06 (nd–0.19)	0.03 (nd–0.11)	0.05 (nd–0.38)	0.06 (nd–0.80)	0.07 (0.01–0.60)
Total Toxaphene	0.05[3] (nd–0.50)	0.07[4] (nd–0.81)	na	0.59 (nd–6.4)	0.43 (nd–3.6)	0.68[5]	0.74 (nd–5.2)	na
Parlar 26	0.01[3] (nd–0.04)	0.01[4] (nd–0.06)	na	0.10 (0.02–0.57)	0.05 (nd–0.36)	0.09[5]	0.08 (nd–0.43)	na
Parlar 50	0.01[3] (nd–0.05)	0.01[4] (nd–0.07)	na	0.13 (0.03–0.66)	0.06 (nd–0.43)	0.14[5]	0.10 (nd–0.57)	na
PCBs (>70% detected)								
Aroclor 1260[6]	1.3 (0.24–5.7)	1.3 (0.26–14)	1.1 (0.31–3.7)	8.0 (2.0–27)	2.4 (0.62 7.9)	4.5 (0.20–27)	5.6 (0.41–60)	6.0 (0.10–48)
CB118	0.04 (nd–0.27)	0.04 (nd–0.26)	0.03 (nd–0.09)	0.14 (0.03–0.50)	0.07 (0.02–0.32)	0.09 (nd–0.40)	0.09 (nd–0.66)	0.10 (0.01–0.84)
CB138	0.11 (0.02–0.48)	0.10 (0.02–0.98)	0.10 (0.03–0.29)	0.51 (0.12–1.5)	0.19 (0.05–0.67)	0.30 (0.02–1.6)	0.37 (0.03–3.3)	0.42 (0.01–3.1)
CB153	0.14 (0.03–0.61)	0.16 (0.03–1.8)	0.12 (0.03–0.41)	1.0 (0.12–1.5)	0.26 (0.06–0.88)	0.56 (0.02–3.6)	0.70 0.75 (0.05–8.3)	(0.03–6.1)
CB180	0.09 (nd–0.50)	0.08 (nd–1.2)	0.07 (0.02–0.29)	0.40 (0.07–1.8)	0.08 (0.02–0.30)	0.27 (0.02–1.7)	0.28 (0.03–4.2)	0.32 (0.02–2.3)
ΣPCB_{14}[7]	0.52 (0.11–2.2)	0.52 (0.12–5.5)	0.43 (0.13–1.4)	2.7 (0.70–9.4)	0.82 (0.23–2.7)	1.6 (0.12–9.4)	1.9 (0.17–22)	2.3 (0.17–16)

nd: not detected; na: not available.

[1]Walker *et al.* (2001); [2]Muckle, pers. comm. (2000), Muckle *et al.* (2001b); [3]n=25; [4]n=42; [5]composite value based on four composite sub-samples (n=12, 12, 12 and 14) (Inuit); [6]Aroclor 1260 quantified as 5.2 (CB138 + CB153), Weber, pers. comm. (2002); [7]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

1998 to 1999 in the Canadian Arctic for Caucasians, Dene/Métis, or Others, the data for these time periods were combined.

Table 5·1 presents regional data on mean levels of various OC pesticides and PCBs in maternal plasma from Canada (Muckle, pers. comm., 2000; Muckle *et al.*, 2001b; Walker *et al.*, 2001).

Table 5·1 indicates that the Inuit in the Arctic regions of the Northwest Territories (NWT) and Nunavut (Walker *et al.*, 2001) and Nunavik in northern Quebec (Muckle, pers. comm., 2000; Muckle *et al.*, 2001b) have levels of oxychlordane and *trans*-nonachlor that are 4 to 15 times higher than those in the other population groups within the NWT/Nunavut region, i.e., Caucasians, Dene/Métis, or Others. When Inuit groups from Nunavik and the four subregions of the NWT/Nunavut region (Baffin, Inuvik, Kitikmeot, and Kivalliq) are examined, the Baffin Inuit are seen to have the highest levels of *trans*-nonachlor (0.64 µg/L) and oxychlordane (0.58 µg/L), while the Kivalliq Inuit have the highest levels of total toxaphene (0.74 µg/L). Among Inuit, levels of mirex and *p,p'*-DDE are highest in Nunavik Inuit. Higher levels of many POPs in Inuit populations from the eastern Arctic regions (i.e., Nunavik, Baffin, and Kivalliq) are due to the greater consumption of marine mammals by these groups relative to other regions.

In contrast, the patterns shown by β-HCH and DDE are quite different. Levels of β-HCH are 5 to 12 times higher in the Others group than among Inuit, Caucasians, or Dene/Métis (0.48 vs 0.04 to 0.11 µg/L). The levels of DDE in the Others group are also roughly two to six times higher than levels observed in Inuit, Caucasians, or Dene/Métis. The Others group comprises people of African, Caribbean and East Asian ancestry, and their exposure to these contaminants may have taken place in these areas of the world or via the consumption of food imported from regions where these compounds are still widely used. For example, Sharma and Bhatnagar (1996) report markedly higher levels of these compounds in the plasma of mothers from India.

The Inuit have higher levels of PCBs estimated as Aroclor 1260 (2.4 to 8.0 µg/L) than Caucasians, Dene/

Table 5·2. Organochlorine contaminants in blood of pregnant women and women of child-bearing age from Greenland, by region (geometric mean (range), µg/L plasma).

	Disko Bay[1,2,3] 1997–98 (n=95)	Ilullissat[1,2,3] 1999–2000 (n=29)	Nuuk[3,4] 1999 (n=32)	Ittoqqortoormiit[1,2,3] 1999–2000 (n=8)	Tassiilaq[1,2,5] 1997 (n=10)
Oxychlordane	0.54 (0.02–3.9)	0.26 (0.01–1.1)	0.17 (0.02–0.75)	1.5 (0.41–4.8)	1.2 (0.28–4.1)
Trans-nonachlor	1.1 (0.03–8.4)	0.49 (0.01–2.3)	0.40 (0.04–2.1)	1.3 (0.61–4.5)	2.2 (0.63–5.5)
p,p'-DDT	0.11 (0.01–13)	0.04 (0.01–0.37)	0.05 (0.02–0.34)	0.26 (0.14–1.3)	0.31 (0.16–0.73)
p,p'-DDE	3.6 (0.56–17)	1.7 (0.39–6.0)	2.0 (0.63–7.8)	5.2 (2.7–18)	6.9 (2.6–24)
DDE:DDT ratio	33 (0.06–300)	48 (13–432)	40 (9.3–136)	20 (14–38)	22 (10–59)
HCB	0.80 (0.14–4.0)	0.39 (0.10–1.6)	0.38 (0.14–1.2)	0.78 (0.37–2.0)	1.0 (0.30–2.7)
β-HCH	0.15 (0.03–0.50)	0.07 (0.01–0.18)	0.11 (0.05–0.26)	0.24 (0.12–0.61)	0.20 (0.04–0.48)
Mirex	0.08 (0.01–1.9)	0.04 (0.01–0.19)	0.03 (0.01–0.15)	0.18 (0.05–0.88)	0.25 (0.06–0.85)
Sum of Toxaphene[6]	0.81 (nd–4.7)	0.24 (0.05–1.1)	0.27 (0.05–1.4)	0.61 (0.37–1.2)	1.2 (0.48–2.4)
Parlar 26	0.26 (0.01–2.1)	0.08 (0.01–0.40)	0.09 (0.01–0.57)	0.24 (0.12–0.47)	0.56 (0.23–1.1)
Parlar 50	0.33 (0.01–2.6)	0.11 (0.01–0.63)	0.14 (0.01–0.83)	0.31 (0.16–0.72)	0.67 (0.25–1.3)
PCBs (>70% detected)					
Aroclor 1260[7]	15 (3–60)	6.4 (2.0–22)	7.9 (2.6–28)	36 (14–125)	33 (12–82)
CB118	0.32 (0.05–1.3)	0.13 (0.03–0.47)	0.15 (0.05–0.83)	0.53 (0.25–1.6)	0.57 (0.18–1.6)
CB138	1.1 (0.22–4.5)	0.47 (0.14–1.8)	0.59 (0.20–2.2)	2.3 (1.1–7.7)	2.4 (0.84–5.9)
CB153	1.8 (0.36–7.0)	0.76 (0.23–2.6)	0.92 (0.30–3.2)	4.7 (1.6–16)	3.9 (1.5–9.9)
CB180	0.72 (0.16–2.9)	0.32 (0.10–1.0)	0.39 (0.14–1.2)	2.4 (0.66–10.1)	2.2 (0.58–5.5)
ΣPCB_{14}[8]	5.5 (1.1–21)	2.5 (0.72–8.1)	3.1 (0.97–10.2)	14.5 (6.1–49)	12.4 (4.9–30)

[1]Deutch, pers. comm. (2001); [2]Deutch and Hansen (2000); [3]pregnant women; [4]Bjerregaard, pers. comm. (2001); [5]women of child-bearing age; [6]parlars 26 + 50; [7]Aroclor 1260 quantified as 5.2 (CB138+CB153); Weber, pers. comm. (2002); [8]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

Métis or Others (1.3, 1.3 and 1.1 µg/L, respectively). When the Inuit data for the NWT/Nunavut (Walker *et al.*, 2001) and Nunavik (Muckle, pers. comm., 2000; Muckle *et al.*, 2001b) areas are separated regionally, it is evident that the Baffin Inuit have the highest levels of PCBs as Aroclor 1260, although levels in Nunavik, Kivaliq and Kitikmeot Inuit are only slightly lower.

When PCBs are examined on a congener-specific basis, CB138 and CB153 are present at the highest levels exhibiting a pattern corresponding to that for PCBs as Aroclor 1260.

Most of the dietary assessments undertaken in connection with the maternal and cord blood sampling programme in the Canadian Arctic were relatively basic, but a consistent pattern relating increased consumption of marine mammal tissues among Inuit populations to increased body burdens of PCBs and a number of pesticides (chlordane derivatives, toxaphene, and mirex) was noted. A more detailed assessment of more specific components of the traditional diet is underway and the results should be available shortly.

5.2.1.2. **Greenland**

Contaminant levels in women of child-bearing age are currently available for the Disko Bay, Ilullissat, Nuuk, Ittoqqortoormiit and Tassiilaq regions of Greenland (Table 5·2) (Deutch, in prep; Deutch and Hansen, 2000).

Contaminant concentrations in the blood plasma of women from Ittoqqortoormiit and Tassiilaq were two to three times higher than in women from Disko Bay, i.e., oxychlordane: 1.5 and 1.2 vs 0.54 µg/L; *p,p*'-DDE: 5.2 and 6.9 vs 3.6 µg/L. The OC levels in women from Ilullissat and Nuuk are even lower, often only 50% of those found in the Disko Bay women (Table 5·2). The concentrations of toxaphene measured as Parlars 26 and 50 are at least two-fold higher in women from the east coast community of Tassiilaq compared to the other populations sampled.

Blood levels of CB118, CB138, CB153 and CB180 were also consistently higher in the Tassiilaq and Ittoqqortoormiit women compared to pregnant women from Disko Bay (Table 5·2). Levels of PCBs estimated as Aroclor 1260 followed the same pattern, and were about

Table 5·3. Organochlorine contaminants in blood of men from Greenland, by District, 1997 (geometric mean (range), μg/L plasma).

	Ittoqqortoormiit (n=15)	Nanortalik (n=5)	Nuuk (n=15)	Ilullissat (n=16)	Upernavik (n=11)
Mean age	38 (19–60)	36.6 (23–52)	28.5 (19–36)	42 (23–59)	31.6 (25–38)
Oxychlordane[1]	3.9 (0.49–15)	2.4 (0.93–5.1)	0.75 (0.13–3.0)	2.0 (0.25–7.2)	1.0 (0.35–6.6)
Trans-nonachlor[1]	3.0 (0.32–50)	4.5 (1.8–8.0)	1.5 (0.23–7.0)	3.9 (0.46–14)	1.8 (0.73–7.5)
p,p'-DDT[1]	0.17 (0.04–0.98)	0.79 (0.29–2.2)	0.11 (0.03–0.37)	0.14 (0.03–0.76)	0.10 (0.04–0.24)
p,p'-DDE[1]	11 (1.6–32)	15 (7.1–27)	5.2 (1.3–16)	8.0 (1.9–25)	4.7 (2.2–17)
DDE:DDT ratio	63 (29–220)	19 (12–32)	48 (23–122)	58 (15–357)	46 (23–101)
HCB[2]	1.5 (0.40–3.9)	1.2 (0.4–2.6)	1.1 (0.22–5.1)	2.4 (0.38–8.4)	0.90 (0.25–2.7)
β-HCH[2]	0.56[3] (0.17–1.8)	0.20 (0.08–3.0)	0.18 (0.06–0.66)	0.31 (0.07–0.85)	0.18 (0.10–0.42)
Mirex[2]	0.52 (0.02–2.2)	0.61 (0.29–1.4)	0.16 (0.06–0.51)	0.26[1] (0.07–0.64)	0.16 (0.05–1.0)
Sum of Toxaphene[2,4]	0.71 (0.18–2.1)	1.6 (0.50–3.7)	0.78 (0.07–5.2)	1.9 (0.19–7.0)	0.79 (0.29–3.1)
Parlar 26[1]	0.34 (0.09–1.0)	0.67 (0.21–1.6)	0.38 (0.03–2.1)	0.74 (0.09–3.2)	0.37 (0.14–1.4)
Parlar 50[1]	0.37 (0.09–1.1)	0.89 (0.28–2.1)	0.45 (0.04–3.1)	0.93 (0.10–3.8)	0.41 (0.15–1.7)
PCBs					
Aroclor 1260[1,5]	107 (18–331)	63 (29–113)	21 (7–71)	39 (8–87)	18 (10–81)
CB118[1]	1.0 (0.18–4.3)	0.48 (0.17–1.0)	0.29 (0.06–1.6)	0.57 (0.08–2.0)	0.31 (0.13–0.86)
CB138[1]	6.0 (1.0–19)	4.3 (1.8–8.4)	1.6 (0.50–5.5)	2.6 (0.56–6.5)	1.3 (0.72–5.0)
CB153[1]	14 (2.4–44)	7.7 (3.8–13)	2.6 (0.81–8.2)	4.4 (0.94–10)	2.2 (1.3–11)
CB180[1]	9.6 (1.4–31)	3.5 (1.6–6.7)	1.2 (0.35–4.0)	2.0 (0.47–4.6)	1.1 (0.51–4.4)
ΣPCB_{14}[2,6]	41 (6.6–127)	21 (9.6–40)	7.6 (2.4–27)	14 (2.8–29)	6.6 (3.9–27)

[1]Deutch, pers. comm. (2001); [2]Deutch and Hansen (2000); [3]n=14; [4]parlars 26 and 50; [5]Aroclor 1260 quantified as 5.2 (CB138 + CB153); Weber, pers. comm. (2002); [6]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

twice as high in women from the Tassiilaq and Ittoqqortoormiit regions as in Disko Bay women; even lower levels were seen in women from Ilullissat and Nuuk. There are some age differences in these populations, with slightly older average ages in Tassiilaq, but when these data are sorted by age group the same regional patterns emerge (Deutch, in prep).

Table 5·3 outlines mean blood plasma levels of OC pesticides and four PCB congeners in men from five districts of Greenland (Deutch, in prep; Deutch and Hansen, 2000). The regional pattern of OCs in men is very similar to that for women. Levels of oxychlordane were highest in men from Ittoqqortoormiit (3.9 μg/L). Levels of oxychlordane in men from Nanortalik (2.4 μg/L) and Ilullissat (2.0 μg/L) were also relatively high – more than twice those found in men from Nuuk and Upernavik. The levels of DDT (0.79 μg/L) and DDE (15 μg/L) in men from Nanortalik were roughly 5 to 8 times and 1.5 to 3 times higher, respectively, than those from any other region. Nanortalik men also had the highest mean level of mirex. The highest mean level of HCB was found in men from Ilullissat (2.4 μg/L), and that of β-HCH in men from Ittoqqortoormiit (0.56 μg/L). Ittoqqortoormiit men also showed the highest concentrations of the four PCB congeners listed in Table 5·3. Men from Nuuk and Uppernavik had lower levels of many of these contaminants but are on average five to thirteen years younger than men from the other three communities.

It is clear from these data that there are strong regional differences in the levels of POPs in blood plasma throughout Greenland. These differences are related mainly to different intakes of traditional/country foods (e.g., marine mammals such as seals), which have very high POP levels along the east coast of Greenland, which includes the Tassiilaq and Ittoqqortoormiit regions (Deutch and Hansen, 2000).

Strong correlations were found between POP concentrations in the blood plasma of mothers and newborns. The association between reported monthly food intake and POP concentrations was relatively weak, but the POP levels were strongly correlated with plasma and erythrocyte n-3/n-6 fatty acid ratios as biomarkers of

Table 5·4. Organochlorine pesticides and total PCBs in serum[1] samples from Aleutian and Pribilof villages in Alaska (median or arithmetic mean (range), µg/L serum). Source: Middaugh, pers. comm. (2001).

	Akutan (n=11)		Atka (n=30)		Nikolski (n=10)		St. George (n=19)		St. Paul (n=96)		Total (n=166)	
	median	am	median	am	median	am	median	am	median	am	median	am
Oxychlordane	0.65	0.84	0.63	1.3	0.41	0.39	0.51	0.59	0.28	0.49	0.37	0.66 (nd–4.2)
Trans-nonachlor	0.69	1.3	1.8	3.2	0.82	0.80	0.96	1.3	0.67	1.3	0.82[2]	1.6 (nd–12.4)
p,p'-DDT	nd	0.05	nd	0.15	nd	0.07	nd	0.01	nd0.02		nd	0.05 (nd–0.58)
p,p'-DDE	9.7	12.3	9.8	16.9	11.3	10.4	7.8	11.7	6.5	14.0	7.5	13.9 (nd–158)
DDE:DDT ratio	na		na		na		na		na		na	
HCB	na		na		na		na		na		na	
β-HCH	0.26	0.35	0.30	0.53	0.25	0.24	0.23	0.39	0.15	0.30	0.19	0.35 (nd–2.6)
Mirex	nd	0.04	0.18	0.22	nd	0.07	0.10	0.12	nd	0.06	nd	0.10[3] (nd–0.80)
Total Toxaphene	na		na		na		na		na		na	
Heptachlor Epoxide	0.12	0.15	0.06	0.19	nd	0.06	nd	0.08	nd	0.10	nd	0.11 (nd–1.6)
Dieldrin	nd	0.04	nd	0.10	nd	0.01	nd	0.02	nd	0.04	nd	0.05 (nd–0.53)
ΣPCB_{36}[4]	5.5	8.4 (2.8–18)	8.0	15 (nd–54)	5.7	6.0 (0.9–13)	6.6	7.1 (nd–30)	3.4	5.7 (nd–42)	4.8	7.7 (nd–54)

am: arithmetic mean; nd: not detected; na: not available.

[1]The serum samples were from a group of 166 individuals consisting of 83 females and 83 males, with an age range of 18–91 years. A further age–sex breakdown by village and by contaminant was not available; [2]n=160; [3]n=162; [4]CB8, CB20, CB44, CB49, CB52, CB66, CB74, CB87, CB99, CB101, CB105, CB110, CB118, CB128, CB138 + CB158, CB146, CB149, CB151, CB153, CB156, CB157, CB167, CB170, CB172, CB177, CB178, CB180, CB183, CB187, CB189, CB194, CB195, CB196 + CB203, CB201, CB206, and CB209.

marine food intake (Deutch and Hansen, 2000). Marine mammal meat and organs are consumed by the Greenland Inuit to such an extent that it results in a relatively high exposure to environmental contaminants such as POPs. In the northern and eastern regions, consumption of seal meat is higher than for any other food item, while fish consumption predominates on the south and east coasts (AMAP, 1998).

There was also a strong positive correlation between smoking and POP plasma levels, after correction for age, alcohol intake, marine food, plasma lipids, and n-3/n-6 fatty acid ratios (Deutch and Hansen, 2000). This implies that the most important determinants of high plasma POP levels in Greenlanders are age, high plasma n-3 fatty acid levels (which indicate the consumption of marine foods), residence in the east coast region, and heavy smoking (Deutch and Hansen, 2000).

5.2.1.3. **Alaska**

Table 5·4 shows the mean and median concentrations of OC pesticides in serum samples from 166 individuals (83 men and 83 women) from five Aleutian and Pribilof villages in Alaska (Middaugh *et al.*, 2001). The mean and median levels of all pesticides measured in samples from St. Paul Island and St. George Island are generally similar to or lower than the levels found in Atka, Akutan, and Nikolski. Mean and median levels in samples from all five villages were strongly associated with age; the highest levels were found in individuals over 50 years old (Middaugh *et al.*, 2001).

Included in the 115 samples from the Pribilof Island villages of St. Paul and St. George were 29 women of child-bearing age. Mean pesticide levels among these women were lower than those in the eleven such women from the Aleutian Island villages of Atka, Akutan, and Nikolski. The age range for the women of child-bearing age was 15 to 45 years and there were no known pregnant women in the sample (Middaugh *et al.*, 2001).

Recently data have become available for contaminants in maternal blood from Yup'ik mothers from the Yukon–Kuskokwim river delta or from villages on the Bering Sea (these mothers all delivered in Bethel) and Iñupiat mothers living in the villages on the northern Arctic coast (these mothers all delivered in Barrow) (Berner, pers. comm., 2001).

Data received to date for these mothers are presented in Table 5·5. Care must be taken in comparing the contaminant levels in women of child-bearing age from the Aleutian/Pribilof Islands with those of mothers from Yup'ik or Iñupiat mothers since the Aleutian/Pribilof women were specifically selected for high traditional food consumption and therefore possible higher contaminant exposure. This may explain the higher levels of DDE in the Aleutian/Pribilof women compared to the Iñupiat and Yup'ik mothers (4.1 vs 0.65 and 1.3 µg/L, respectively). It is also interesting to note that the ratio of DDE to DDT is very different for the Bethel and Barrow mothers (16 and 8.6) compared to the women of child-bearing age from the Aleutian and Pribilof Islands (a ratio of 203, based on population means). This indi-

Table 5·5. Organochlorine contaminants in maternal blood and blood of women of child-bearing age from Alaska (geometric mean, median, or arithmetic mean, (range), g/L serum).

	Yupik (Bethel)[1] 2000 (n=23) gm	Inupiat (Barrow)[1] 2000 (n=22) gm	Aleutian–Pribilof women of child-bearing age[2] 1999 (n=40)[3] median	am
Oxychlordane	na	na	0.18	0.26
Trans-nonachlor	na	na	0.3	0.62
Total DDT	0.08[4] (0.04–1.4)	0.08[4] (0.05–0.19)	nd	0.03
p,p'-DDE	1.3 (0.17–6.1)	0.65 (0.11–1.5)	4.1	6.1
DDE:total DDT ratio [5]	16	8.6	203[6]	
HCB	na	na	na	
β-HCH	na	na	nd	0.12
Mirex	na	na	nd	0.02
Total Toxaphene	na	na	na	
Parlar 26	na	na	na	
Parlar 50	na	na	na	
PCBs				
Aroclor 1260[7]	na	na	na	
CB118	0.07 (0.01–0.15)	0.03 (0.01–0.15)	na	
CB138	na	na	na	
CB153	0.33 (0.06–1.7)	0.09 (0.01–0.58)	na	
CB180	0.12 (0.03–0.92)	0.04 (0.01–0.21)	na	
ΣPCB_{36}[8]	na	na	2.0 (nd–15)	2.9

gm: geometric mean; am: arithmetic mean; na: not available; nd not determined.

[1]Berner, pers. comm. (2001); [2]Middaugh, pers. comm. (2001); [3]n=40: 29 from St. Paul and St. George, and 11 from Atka, Akutan, and Nikolski; [4]values are for total DDT; [5]the DDT value in this ratio is for total DDT. The *o,p*'-DDT values were very low relative to *p,p*'-DDT values; thus, total DDT values are approximately equal to *p,p*'-DDT values; [6]this DDE:total DDT ratio is based on population means; [7]Aroclor 1260 quantified as 5.2 (CB138 + CB153); Weber, pers. comm. (2002); [8]CB18, CB20, CB44, CB49, CB52, CB66, CB74, CB87, CB99, CB101, CB105, CB110, CB118, CB128, CB138 + CB158, CB146, CB149, CB151, CB153, CB156, CB157, CB167, CB170, CB172, CB177, CB178, CB180, CB183, CB187, CB189, CB194, CB195, CB196 + CB203, CB201, CB206, and CB209.

cates that there is likely to be a different source of exposure for these population groups, as is also reflected in the higher levels of the parent compound (DDT) in the Bethel and Barrow mothers.

Dietary differences might explain the marked difference in DDT/DDE exposure between the Aleutian/Pribilof and Bethel/Barrow cohorts. Although there is no dietary information available for any of the Aleutian/Pribilof cohort, they reside in an isolated region with a high dependence on subsistence foods. Although speculative, it is clear that DDE levels increase with age, and there were a fair number of older people in the sample. Older people eat a lot of fish and seals, all of which feed in the North Pacific Ocean, in the currents that sweep up the Asian coast, so it could well represent biomagnification combined with decades of DDT use in Asia. Women from the Yukon–Kuskokwim river delta eat considerably more salmon and pike, and seals, while the Arctic coast women eat more bowhead whale (*Balaena mysticetus*) and terrestrial animals (Berner, pers. comm., 2001).

Limited PCB data are available for Alaska. Of the three congeners for which data are available, CB153 occurred at the highest concentrations, with the mothers from Bethel having higher concentrations than those from Barrow (0.33 vs 0.09 μg/L). Similar patterns were seen for CB118 and CB180. Data have recently become available for the sum of 36 PCB congeners in the blood of Aleutian/Pribilof women of child-bearing age (2.9 μg/L, arithmetic mean) but these data are not directly comparable with any other data collected in AMAP programme.

In conclusion, the recent findings for OC pesticide levels in blood confirm earlier reports from the Alaska Department of Health and Social Services. For women of child-bearing age in particular, the low levels of OC pesticides strongly support current recommendations by

Table 5·6. Organochlorine contaminants in maternal blood from Russia, by region and indigenous status (geometric mean (range), μg/L plasma).

	Non-indigenous regions			Indigenous regions		Non-indigenous
	Norilsk[1] 1995–96 (n=49)	Salekhard[2] 1996–98 (n=31)	Dudinka[1] 1995–96 (n=27)	Taymir[1] 1995–96 (n=18)	Yamal[2] 1996–98 (n=12)	Arkhangelsk[3] 1999 (n=30)
Oxychlordane	na	na	na	na	na	0.18[4] (nd–0.67)
Trans-nonachlor	0.10 (0.05–0.25)	0.12 (0.07–0.24)	0.15 (0.07–0.34)	0.09 (0.04–0.15)	0.10 (0.04–0.23)	0.12[4] (nd–0.66)
p,p'-DDT	0.21 (0.08–0.57)	0.16 (0.03–0.75)	0.14 (0.05–0.33)	0.07 (0.04–0.13)	0.05 (0.03–0.08)	0.83[5] (0.28–5.1)
p,p'-DDE	1.8 (0.62–4.0)	1.5 (0.35–4.4)	1.3 (0.45–3.6)	1.1 (0.39–2.0)	0.72 (0.32–1.4)	4.5[6] (1.7–13.1)
DDE:DDT ratio	8.0 (5.1–14)	8.8 (5.4–14)	9.3 (5.9–13)	15 (7.8–21)	14 (6.4–21)	5.5 (na)
HCB	0.21 (0.05–0.52)	0.26 (0.15–0.59)	0.30 (0.06–0.09)	0.20 (0.02–0.71)	0.18 (0.05–0.42)	0.47[4] (0.18–1.4)
β-HCH	1.1 (0.40–3.7)	0.45 (0.09–3.4)	0.31 (0.04–1.6)	0.35 (0.02–0.76)	0.45 (0.18–0.94)	3.1[4] (1.3–11.6)
Mirex	0.01 (nd–0.04)	0.01 (nd–0.03)	0.01 (nd–0.02)	0.01 (nd–0.02)	0.01 (nd–0.02)	0.20[4] (0.14–0.51)
Toxaphene	na	na	na	na	na	na
Parlar 26	na	na	na	na	na	0.05 (nd–0.10)
Parlar 50	na	na	na	na	na	0.06 (0.02–0.70)
PCBs		(n=5)				
Aroclor 1260[7]	3.8[8] (1.2–9.1)	4.3[8] (2.3–9.2)	3.3[8] (2.0–5.5)	1.5[8] (0.5–4.2)	3.0[8] (1.7–4.6)	4.2[7,9] (1.2–16.9)
CB118	na	0.33 (0.24–0.45)	na	na	na	0.29[9] (0.10–1.0)
CB138	na	0.43 (0.20–0.89)	na	na	na	0.42[9] (0.12–1.5)
CB153	na	0.45 (0.30–0.57)	na	na	na	0.39[9] (0.11–1.7)
CB180	na	0.20 (0.06–0.47)	na	na	na	0.13[9] (0.04–1.0)
ΣPCB_{14}[10]	na	2.1 (1.0–3.2)	na	na	na	1.7[9, 11] (0.6–6.8)

na: not available.

[1]Klopov *et al.* (1998); [2]Klopov (2000), Klopov and Shepovalnikov (2000), Klopov and Tchachchine (2001); [3]Odland, pers. comm. (2000);[4]n=24; [5]n=16; [6]n=26; [7]Aroclor 1260 quantified as 5.2 (CB138 + CB153), Weber, pers. comm. (2002); [8]calculated using method of Sergei Vlasov, Vlasov, pers. comm. (2001); [9]n=27; [10]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187; [11]does not include CB28.

Alaskan public health officials for continued unrestricted consumption of traditional foods (Middaugh *et al.*, 2001).

5.2.1.4. **Russia**

Generally, the major source of exposure to environmental contaminants in Russia is via food consumption. For example, freshwater fish consumption is a key source of contaminant exposure in Salekhard and Norilsk (AMAP, 1998).

From Table 5·6, it is evident that the mean maternal blood plasma levels for all the OC pesticides are higher in the non-indigenous population from the Arkhangelsk region (Odland, pers. comm., 2000) than in any other areas of Russia for which new data are available (Klopov, 2000). In particular, the levels of *p,p'*-DDT (0.83 μg/L) and *p,p'*-DDE (4.5 μg/L) are much higher in the Arkhangelsk region than in the other Russian regions studied. Arkhangelsk women also had the highest blood levels of β-HCH (3.1 μg/L) and HCB (0.47 μg/L).

When earlier data (AMAP, 1998) from the industrial area of Nikel on the Kola Peninsula are included in the analysis, it is evident that this region also has high levels of OC pesticides with concentrations only slightly lower than those in Arkhangelsk; for example, *trans*-nonachlor (0.09 μg/L), DDT (0.34 μg/L), DDE, (3.0 μg/L), β-HCH (1.7 μg/L), and HCB (0.47 μg/L).

The levels of *trans*-nonachlor are similar within the non-indigenous and indigenous populations of Arctic Russia. DDT levels show a different pattern with concentrations two to four times higher in non-indigenous populations, Norilsk having the highest levels. DDE levels are also slightly to moderately elevated in non-indigenous populations. These DDE and DDT levels result in lower DDE: DDT ratios in non-indigenous regions of Siberia, suggesting a current exposure to DDT due to its use within the local environment or within commercial food production.

Table 5·7. Organochlorine contaminants in blood from Iceland, 1999 (geometric mean (range), µg/L plasma). Source: Olafsdottir, pers. comm. (2001).

		Pregnant mothers (n=33)				
	Males (n=27)	Reykjavik (n=8)	Vestmannaeyjar (n=8)	Olafsvik (n=8)	Sauðarkrokur (n=9)	Total (n=33)
Oxychlordane	0.05 (0.01–0.12)	0.03 (nd–0.07)	0.05 (0.03–0.17)	0.02 (nd–0.06)	0.05 (0.03–0.12)	0.04 (nd–0.17)
Trans-nonachlor	0.13 (0.04–0.49)	0.11 (0.06–0.17)	0.13 (0.07–0.37)	0.10 (0.05–0.15)	0.14 (0.08–0.31)	0.12 (0.05–0.37)
p,p'-DDT[1]	0.07 (<0.03–0.41)[1]	0.04 (0.02–0.09)	0.02 (nd–0.13)	0.03 (nd–0.22)	0.07 (nd–0.22)	0.04 (nd–0.22)
p,p'-DDE	1.2 0.30–4.6)	0.76 (0.41–1.7)	0.76 (0.30–1.8)	0.64 (0.26–1.4)	0.99 (0.40–2.4)	0.78 (0.26–2.4)
DDE:DDT ratio	18 (6.5–98)	16 (7.6–33)	15 (7.5–23)	12 (6.5–23)	14 (9.4–30)	14.5 (6.5–33)
HCB	0.39 (0.18–0.93)	0.38 (0.18–0.54)	0.38 (0.25–0.76)	0.35 (0.21–0.68)	0.44 (0.31–0.71)	0.39 (0.18–0.76)
β-HCH	0.21 (0.07–0.73)	0.18 (0.08–0.37)	0.16 (0.09–0.35)	0.19 (0.09–0.56)	0.21 (0.11–0.49)	0.19 (0.08–0.56)
Mirex	na	na	na	na	na	na
Total Toxaphene	na	na	na	na	na	na
Parlar 26[2]	(nd–0.14)[2]	(nd–0.03)	(nd–0.05)	nd	(nd–0.09)	(nd–0.09)
Parlar 50	0.05 (nd–0.23)	0.06 (0.04–0.09)	0.05 (0.03–0.08)	0.04 (0.03–0.06)	0.07 (nd–0.20)	0.05 (nd–0.20)
PCBs						
Aroclor 1260[3]	6.2 (3.0–6.2)	4.4 (2.9–7.4)	4.4 (2.1–9.6)	3.4 (1.7–6.8)	4.2 (2.4–8.2)	4.1 (1.7–9.6)
CB118	0.14 (0.04–0.52)	0.10 (0.06–0.19)	0.11 (0.03–0.30)	0.12 (0.07–0.22)	0.12 (0.06–0.24)	0.11 (0.03–0.30)
CB138	0.49 (0.21–1.3)	0.35 (0.21–0.56)	0.33 (0.17–0.71)	0.26 (0.13–0.50)	0.32 (0.18–0.61)	0.31 (0.13–0.71)
CB153	0.75 (0.36–1.7)	0.50 (0.32–0.86)	0.52 (0.23–1.1)	0.39 (0.19–0.83)	0.49 (0.28 0.96)	0.47 (0.19–1.1)
CB180	0.48 (0.28–0.91)	0.26 (0.13–0.51)	0.32 (0.15–0.77)	0.23 (0.11–0.55)	0.30 (0.16–0.57)	0.28 (0.11–0.77)
ΣPCB_{14}[4]	2.6 (1.4–5.5)	1.7 (1.2–3.0)	1.8 (0.89–3.9)	1.5 (0.76–2.7)	1.7 (0.98–3.2)	1.7 (0.76–3.9)

nd: not detected; na: not available.

[1]Detection limit for the male *p,p'*-DDT data is 0.02–0.03 mg/L. The detection limit for other *p,p*'-DDT values is 0.02 mg/L; [2]detection limit for the male parlar 26 data is 0.02–0.06 mg/L. The detection limit for other parlar 26 values is 0.02 mg/L; [3]Aroclor 1260 quantified as 5.2 (CB138 + CB153), Weber, pers. comm. (2002); [4]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

For indigenous peoples of Russia living in the Taymir and Yamal regions of Siberia, traditional activities include reindeer herding, fishing, and hunting. Siberia's non-indigenous population depends to a much greater extent on the commercial Russian food supply. The non-indigenous populations in Arkhangelsk have consistently higher levels of DDE and β-HCH in maternal blood plasma than the indigenous peoples of the Taymir and Yamal regions (Klopov, 2000) (Table 5·6). This is probably due to the use of these pesticides in commercial Russian food production or within the local environment.

New data on PCB levels in maternal blood are available for Arkhangelsk and Salekhard. Blood levels of CB118, CB138, CB153, and CB180 in Arkhangelsk and Salekhard were very similar to those previously observed in Nikel (AMAP, 1998).

5.2.1.5. **Iceland**

Iceland has a socially and culturally homogenous population, and human levels of environmental contaminants are generally similar to or slightly higher than those reported in other Northern Hemisphere countries. The main source of exposure is via the diet, mainly fish consumption (AMAP, 1998). The mean maternal blood plasma levels of OC pesticides in four regions of Iceland (Olafsdottir, pers. comm., 2001) were similar, although slightly higher in Sauðarkrokur than in Reykjavik, Vestmannaeyjar, and Olafsvik (Table 5·7). The β-HCH levels were relatively high in all four regions (0.16 to 0.21 µg/L), and were similar to the higher Icelandic levels of β-HCH cited in the 1994–1997 AMAP maternal blood study (Van Oostdam *et al.*, in prep). These levels are also much higher than the mean maternal plasma β-HCHlevel of 0.05 µg/L found in Norwegian women (Odland, pers. comm., 2000) (see section 5.2.2.1.). Finally, on a country-wide basis, the levels of *trans*-nonachlor, oxychlordane, DDE, DDT, β-HCH and HCB are similar to those reported in the first AMAP assessment (AMAP, 1998).

The mean maternal plasma levels of PCBs in the four areas studied are similar, and are also similar to those observed in Scandinavian countries (see section 5.2.1.6.). In addition, the aggregate levels of PCBs for all four regions combined are slightly lower than those reported previously (AMAP, 1998) (Table 5·7).

Table 5·8. Organochlorine contaminants in maternal blood from Norway, Finland, Sweden, and the Faroe Islands (geometric mean (range), µg/L plasma).

	Norway[1] (Vestvågøy in Lofoten) 1999 (n=50)	Finland[2] (Lapland Region) 1996–98 (n=13)	Sweden[2] (Kiruna Region) 1995–96 (n=40)	Faroe Islands[3] 2000–2001 (n=148)
Oxychlordane	0.04[4] (0.02–0.11)	0.03 (0.01–0.04)	0.02 (0.01–0.05)	0.12 (0.03–1.4)
Trans-nonachlor	0.11[4] (0.04–0.32)	0.05 (0.03–0.08)	0.04 (0.01–0.10)	0.38 (0.02–4.2)
p,p'-DDT	na	0.02 (0.02–0.04)	0.02 (0.02–0.12)	0.26 (0.10–1.5)
p,p'-DDE	0.95[5] (0.20–5.08)	0.58 (0.19–0.79)	0.84 (0.33–5.5)	3.6 (0.35–39.4)
DDE:DDT ratio	na	26 (13–48)	35 (9–367)	14 (na)
HCB	na	0.19 (0.12–0.31)	0.16 (0.07–0.32)	0.28 (0.05–1.9)
β-HCH	0.05[5] (0.02–0.36)	0.07 (0.02–0.09)	0.09 (0.02–0.28)	0.11 (0.05–0.60)
Mirex	na	0.01 (0.01–0.01)	0.01 (0.01–0.22)	na
Total Toxaphene	na	na	na	0.39
Parlar 26	0.03[6] (nd–0.18)	na	na	0.13 (0.03–1.5)
Parlar 50	0.05[6] (nd–0.62)	na	na	0.16 (0.03–1.6)
PCBs				
Aroclor 1260[7]	6.6[6] (2.2–16.7)	3.8 (1.9–5.3)	6.1 (2.7–15)	14.9 (1.1–129)
CB118	0.11[8] (0.01–0.67)	0.07 (0.04–0.11)	0.11 (0.06–0.40)	0.31 (0.03–2.9)
CB138	0.79[6] (0.24–2.3)	0.30 (0.15–0.40)	0.48 (0.22–1.1)	1.3 (0.11–10.3)
CB153	0.47[6] (0.17–1.23)	0.43 (0.21–0.61)	0.70 (0.31–2.0)	1.6 (0.10–14.5)
CB180	0.40[9] (0.13–0.84)	0.24 (0.15–0.33)	0.34 (0.15–0.91)	1.0 (0.06–7.4)
ΣPCB_{14}[10]	2.3[6,8] (0.8–6.2)	1.5 (0.80–2.0)	2.3 (1.1–5.6)	6.3 (nd–14.5)

na: not available; nd: not detected.

[1]Odland, pers. comm. (2000); [2]Van Oostdam *et al.* (in prep); [3]Weihe, pers. comm. (2001); [4]n=25; [5]n=45; [6]n=47; [7]Aroclor 1260 quantified as 5.2 (CB138 + CB153), Weber, pers. comm. (2002); [8]does not include CB28, CB52, or CB156; [9]n=46; [10]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

5.2.1.6. Norway, Finland, and Sweden

The maternal blood data available for Norway, Finland, and Sweden are more limited than for the other circumpolar countries discussed in the preceding sections. Both Norway and Finland have provided new data, while for Sweden no new maternal blood data are available (although new data on PCBs in breast milk were provided). Consequently, data reported for the Kiruna (Giron) area of Sweden in the previous AMAP assessment (Van Oostdam *et al.*, in prep) are used for comparison (Table 5·8).

Northern (mainland) Norway, which consists of three counties – Nordland, Troms, and Finnmark – has only one significant source of industrial pollution: an iron-producing plant in Kirkenes which closed down in 1996. Exposure to POPs and Hg in the coastal regions is primarily via consumption of marine foods, mainly fish, and to a much lesser extent, marine mammals. This constitutes an important difference in dietary pattern compared to the indigenous populations of Canada and Greenland (AMAP, 1998). The levels of most POPs in human tissues have remained unchanged or have only slightly decreased over the years, and are lower in Norway than in Russia (AMAP, 1998).

A comparison of the new Norwegian data from the Vestvågøy area in Lofoten (Odland, pers. comm., 2000) with the combined earlier data from the Hammerfest and Kirkenes regions of Norway (AMAP, 1998) shows that maternal blood levels of various OC contaminants are still low in Norway but slightly higher in Vestvågøy. Levels of *trans*-nonachlor and DDE are about 2 and 1.6 times higher, respectively, in Vestvågøy relative to those in the Hammerfest/Kirkenes regions (0.11 vs 0.05 µg/L, and 0.95 vs 0.60 µg/L). Regarding PCBs, levels of CB118, CB138, CB153, CB180, and the sum of 14 PCB congeners, are consistently higher in Vestvågøy than in Hammerfest/Kirkenes (0.11, 0.79, 0.47, and 0.40 µg/L vs 0.08, 0.27, 0.41, and 0.20 µg/L, respectively for the individual CB congeners).

The new Norwegian data from Vestvågøy (Odland, pers. comm., 2000) can be compared with those for Finnish Lapland in the most northern and northeastern part of Finland (Soininen, pers. comm., 2001), and with the 1995 Swedish data from the Kiruna (Giron) area, in the northernmost part of Sweden (AMAP, 1998). Table 5·8 shows that maternal blood levels of oxychlordane, *trans*-nonachlor, DDE, and β-HCH are similar in Finland, Norway and Sweden, and that the absolute values are low.

Mean blood levels of CB118, CB138, CB153, and CB180 are lower in Finland than in Norway and Sweden; Swedish levels of all four congeners are approximately 50% higher than those observed in Finland. The Swedish levels are also higher than the earlier Norwegian data from the initial maternal blood study (AMAP, 1998), but lower for CB138 and CB180 when compared to the new Norwegian data. This is probably due to regional differences, as the earlier Norwegian data were from the Hammerfest/Kirkenes regions, while the more recent data were collected from the Vestvågøy area.

5.2.1.7. **Faroe Islands**

Pilot whale blubber is thought to be the main source of exposure to OC contaminants in the Faroe Islands. Dietary surveys in the 1980s indicated that the local population consumed on average 7 grams of pilot whale blubber per day, which resulted in high levels of PCBs in human adipose tissue, breast milk and cord blood. In 1998 pregnant women and women who intended to become pregnant were advised to stop eating pilot whale blubber and meat. A dietary survey and a blood contaminant sampling programme were undertaken in 2000–2001 to assess the success of this advice (Weihe, pers. comm., 2001). These surveys indicated that pilot whale blubber and meat consumption had decreased by a factor of ten. However, they also indicated that PCB levels in Faroese mothers were still two to three times higher than the corresponding levels in other Scandinavian countries (Table 5·8), and had not decreased markedly since the 1980s (Weihe, pers. comm., 2001). This lack of decrease in maternal PCB levels is probably due to the long half-lives of PCBs in the body or to other unknown sources of PCB in the diet. PCB exposures continue to be considered a potential health problem in the Faroese community (see chapter 9 for comparisons with blood guidelines and health effect levels). Quite different findings were obtained for Hg as a result of this dietary intervention; as discussed in section 5.3.1.6.

5.2.2. **International comparisons**

In the present AMAP assessment, sufficient data are available to allow comparisons between countries and regions, and between different ethnic groups (i.e., indigenous and non-indigenous peoples). Comparisons are also made among non-indigenous populations (consumers of commercial foods) from different countries; among indigenous populations (consumers of traditional foods) from different countries; and between indigenous and nonindigenous populations.

5.2.2.1. **Non-indigenous populations**

The non-indigenous populations of Norway (Odland, pers. comm., 2000), Iceland (Olafsdottir, pers. comm., 2000), Finland (Soininen, pers. comm., 2001), and Canada (Walker *et al.*, 2001) have low levels of OC contaminants such as oxychlordane (Figure 5·2) (0.04 to 0.05 μg/L) when compared to the non-indigenous population of the Arkhangelsk region of Russia (0.18 μg/L)

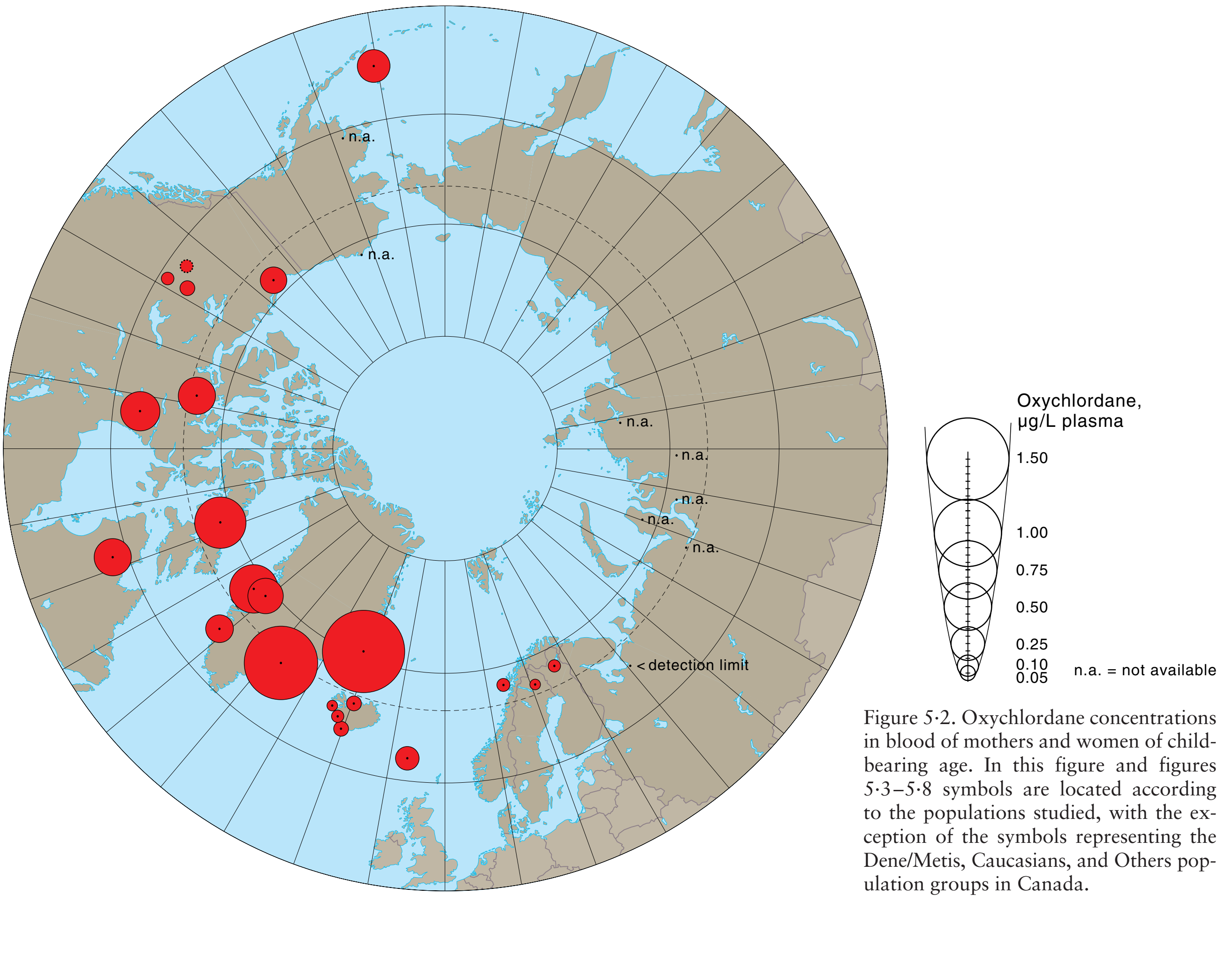


Figure 5·2. Oxychlordane concentrations in blood of mothers and women of childbearing age. In this figure and figures 5·3–5·8 symbols are located according to the populations studied, with the exception of the symbols representing the Dene/Metis, Caucasians, and Others population groups in Canada.

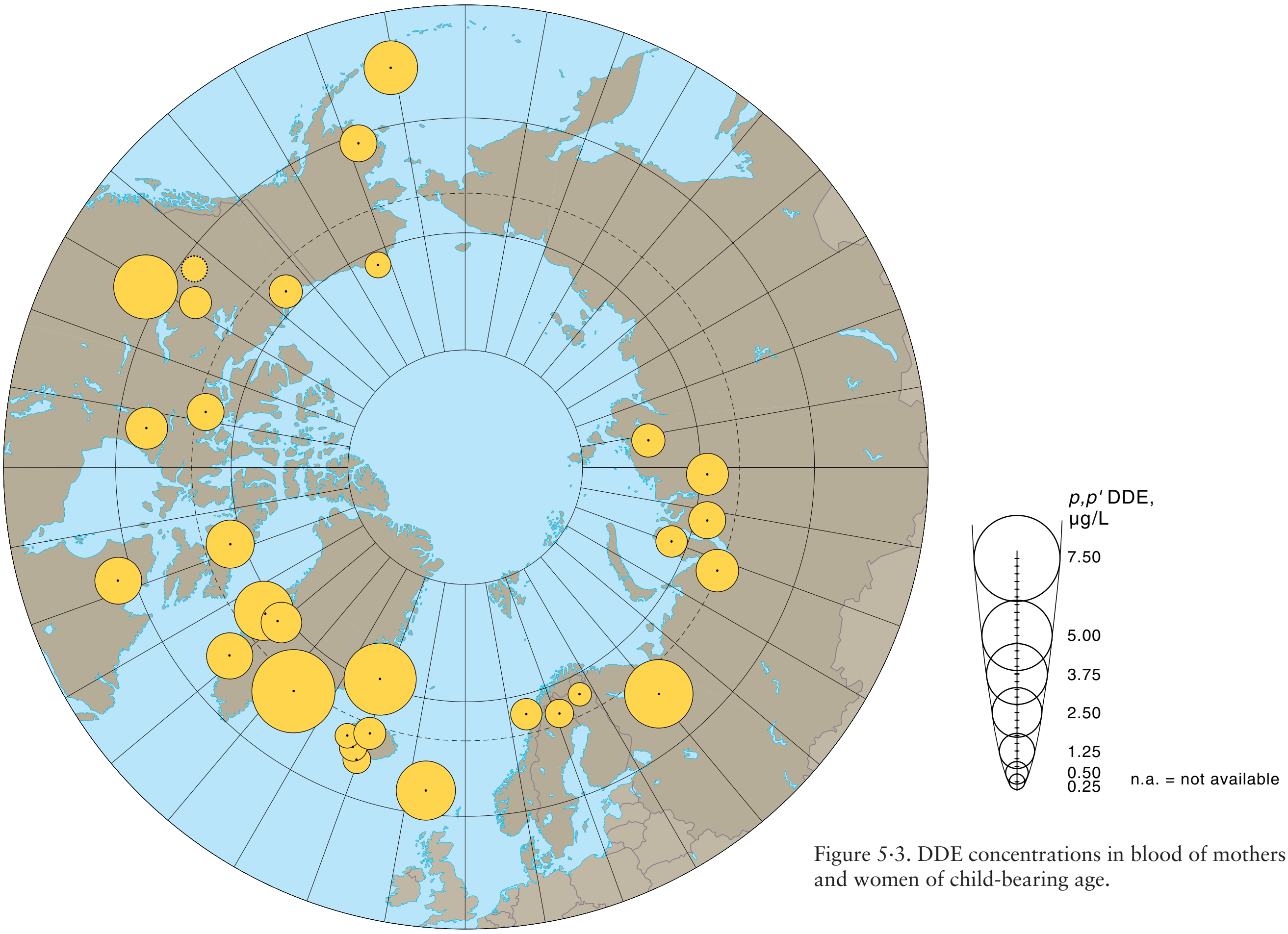


Figure 5·3. DDE concentrations in blood of mothers and women of child-bearing age.

(Odland, pers. comm., 2000). This may indicate that chlordane is being used in the Arkhangelsk region or in commercial Russian food production.

A similar pattern is observed for DDE (Figure 5·3), where lower levels are seen in Finland (0.47 µg/L), Norway (0.95 µg/L), Iceland (0.78 µg/L), and Canadian Caucasians (0.9 µg/L); and higher levels in non-indigenous peoples in Arctic Russia (1.3 to 1.8 µg/L) (Klopov, 2000) and in Arkhangelsk (4.5 µg/L) (Odland, pers. comm., 2000). Levels of β-HCH (Figure 5·4) also follow a similar pattern. These differences also indicate the probable use of these pesticides within commercial Russian food production or for controlling insects in the local environment.

DDE and β-HCH levels are also higher in maternal samples from the Others group in Canada (4.0 and 0.48 µg/L, respectively) than in those from Norway, Iceland, or Caucasians in Canada (Figures 5·3 and 5·4). As noted in section 5.2.1.1., if the mothers included in the Others group are of African or East Asian ancestry, regions where these pesticides are still being used, their higher exposure to these contaminants may have occurred there or through foods imported from these regions. However, whether these individuals were exposed to DDT and β-HCH in Africa or East Asia was unspecified and remains unclear.

The levels of OC contaminants in the Norwegian, Icelandic, and (1995) Swedish samples are very similar and virtually indistinguishable from values found at lower latitudes (AMAP, 1998). This is probably because, with the exception of the Saami people in northern Norway and Sweden, these three countries all have Caucasian (i.e., non-indigenous) populations, whose main source of exposure to environmental contaminants is via the consumption of foods that are common to these and other western countries (in contrast to the traditional foods consumed by some indigenous peoples).

It is useful to compare the Norwegian data with the Icelandic data, since both countries (like Sweden) have mainly Caucasian populations and some similarity in diet. The maternal blood plasma levels of OC contaminants in Norway are similar to those in Iceland, except for the level of β-HCH, which is three to four times higher in Iceland (0.16 to 0.21 vs 0.05 µg/L for Norway) (Figure 5·4). The higher β-HCH levels in the Icelandic mothers are consistent with results of earlier studies in circumpolar countries (AMAP, 1998). However, increased levels of β-HCH have not been found in the Icelandic marine environment. The use of γ-HCH has been banned since 1994 and the use of technical HCH has never been registered in Iceland (Olafsdottir, pers. comm., 2001).

The levels of PCBs (estimated as Aroclor 1260) in maternal samples for indigenous and non-indigenous women are presented in Figure 5·5. Among the non-indigenous populations, Caucasians of Arctic Canada have the lowest PCB levels, estimated as Aroclor 1260, the sum of PCB congeners, or as individual congeners (Tables 5·1 to 5·8). Intermediate levels of PCBs are found in mothers from Iceland and Finland, and higher levels in mothers from Norway, Sweden and Russia.

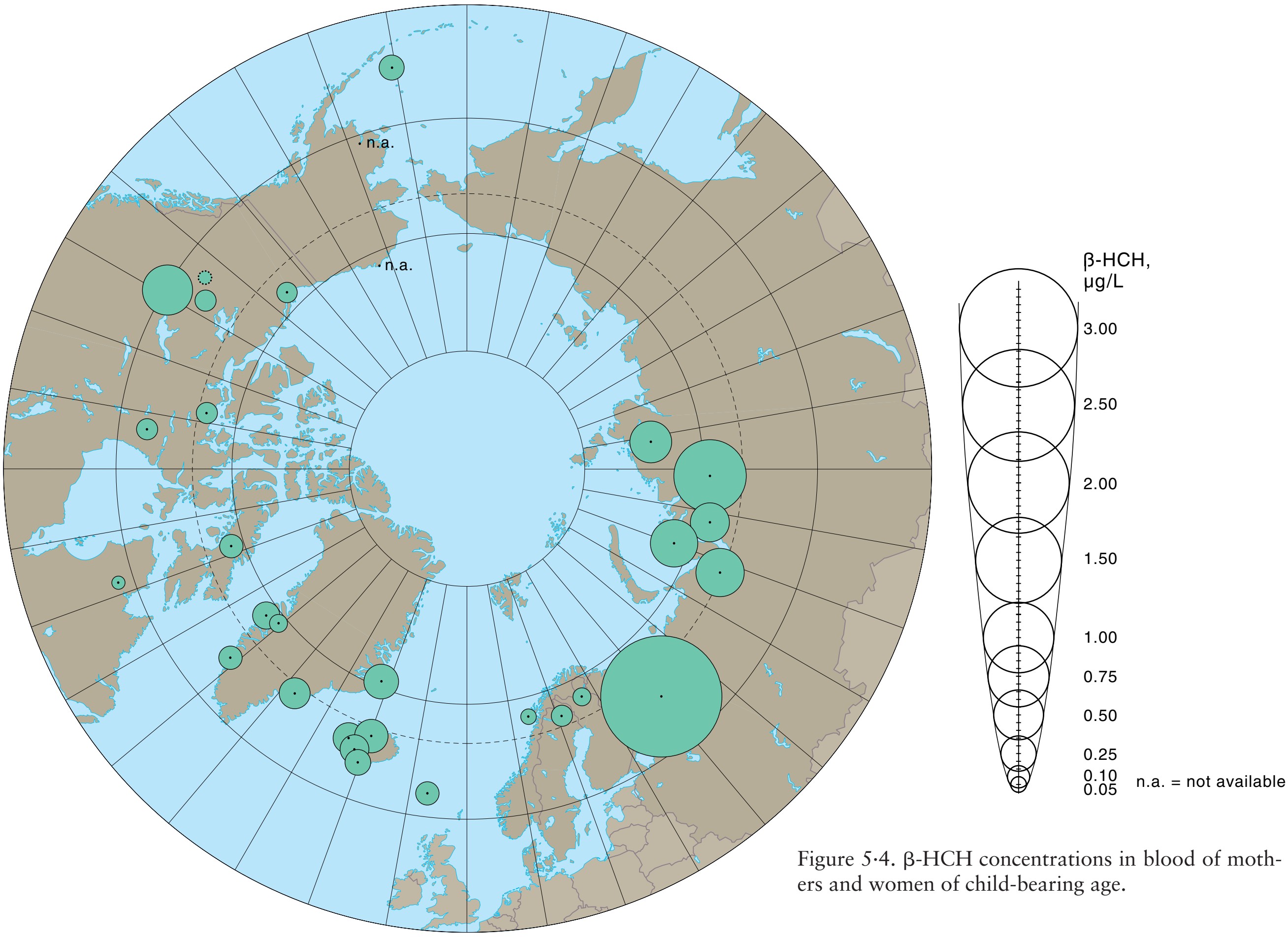


Figure 5·4. β-HCH concentrations in blood of mothers and women of child-bearing age.

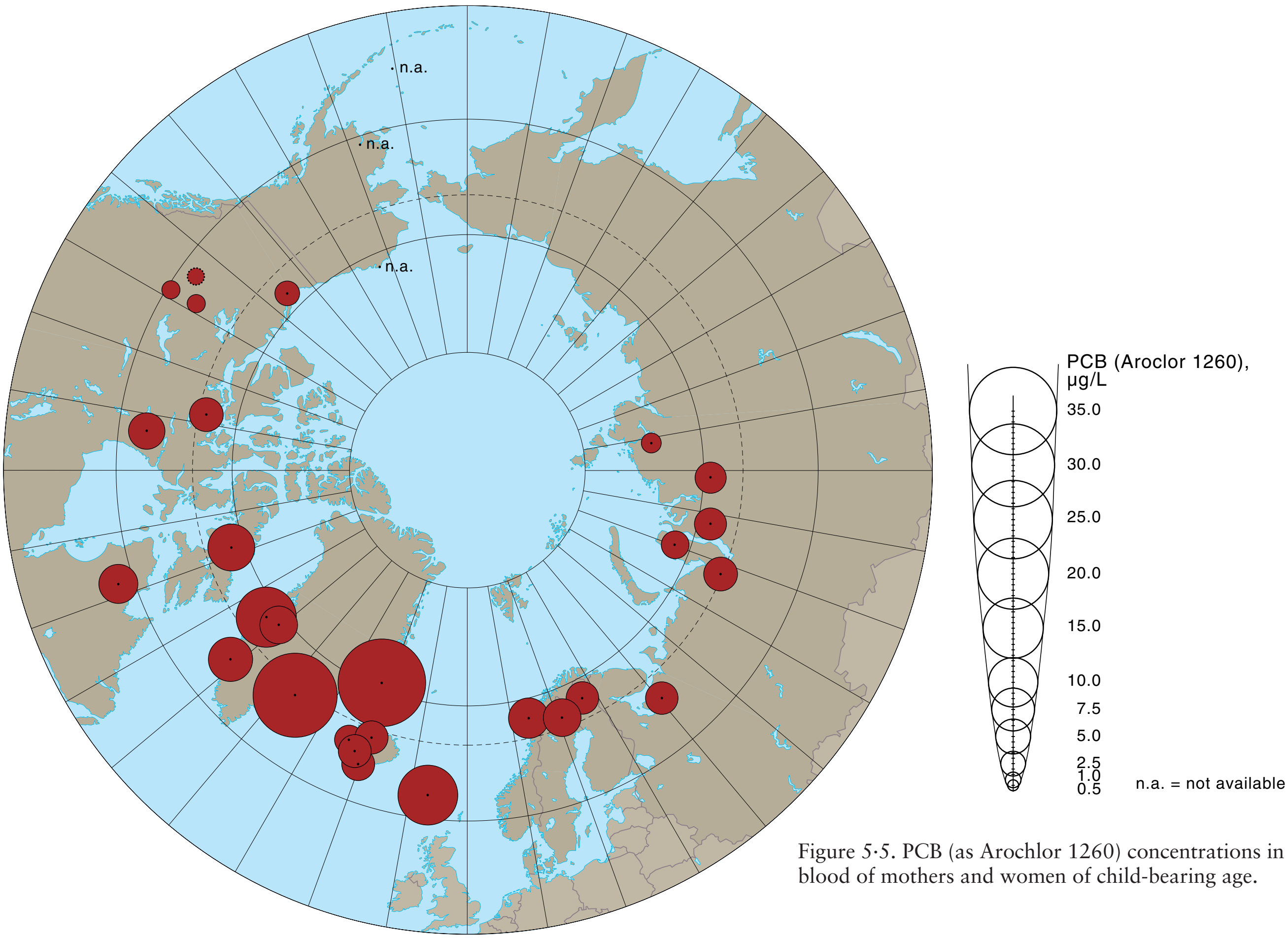
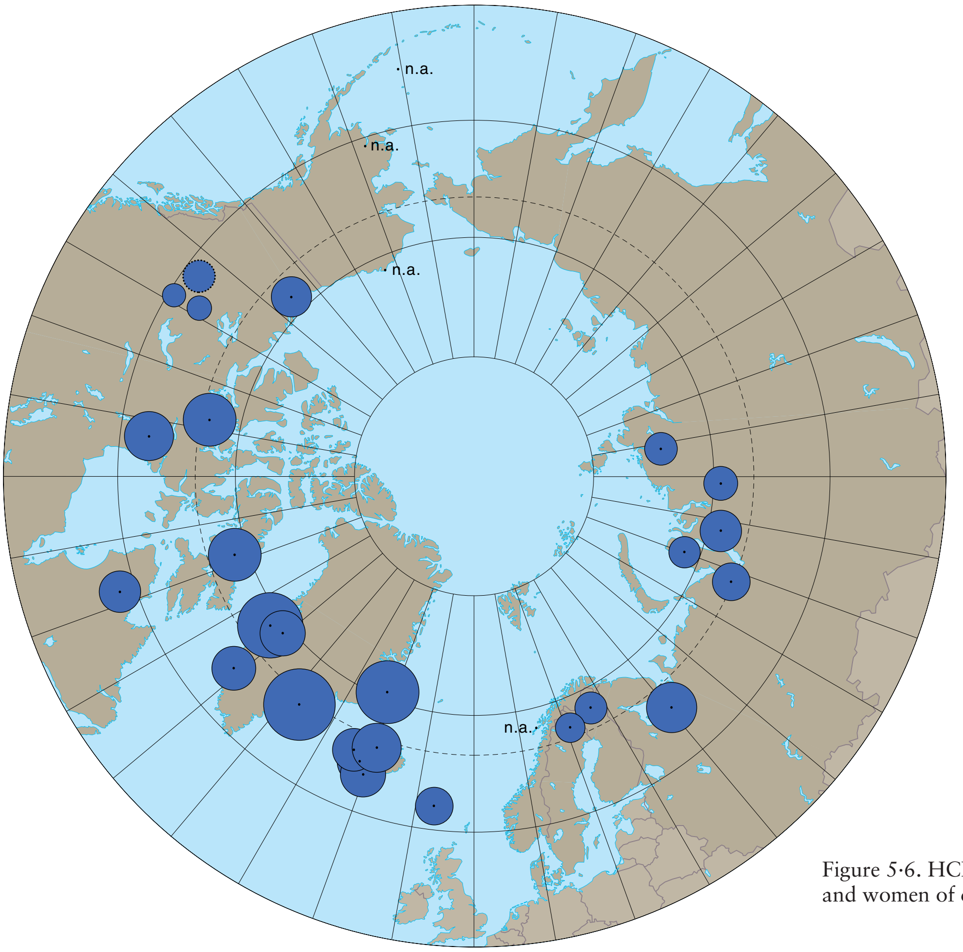


Figure 5·5. PCB (as Arochlor 1260) concentrations in blood of mothers and women of child-bearing age.



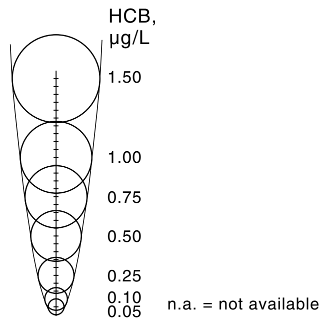
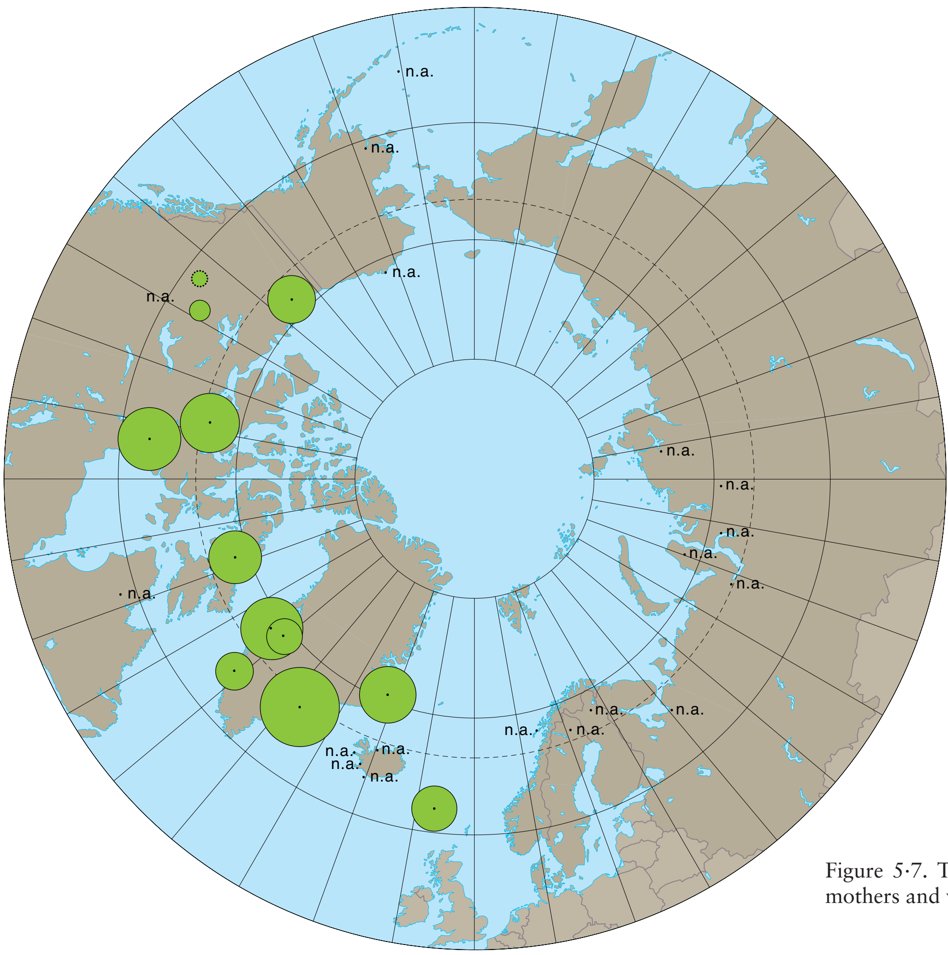


Figure 5·6. HCB concentrations in blood of mothers and women of child-bearing age.



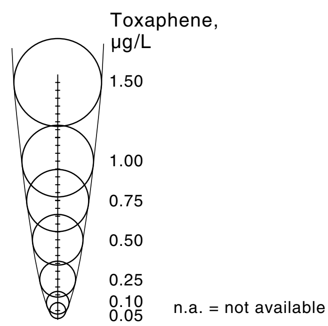


Figure 5·7. Toxaphene concentrations in blood of mothers and women of child-bearing age.

Table 5·9. Organochlorine contaminants in breast milk from Canada, and selected PCB congeners in breast milk from Sweden (geometric mean (range), µg/kg lipid).

	Nunavik, Canada[1] 1996–2000 (n=116) mean age: 24.6 ± 5.7[3]	Kiruna, Sweden[2] 1995 (n=11) mean age: 28 ± 5
Oxychlordane	81 (11–642)	na
Trans-nonachlor	113 (15–547)	na
p,p'-DDT	30 (1.0–161)	na
p,p'-DDE	420 (86–2295)	na
DDE:DDT ratio	na	na
HCB	50 (7.6–226)	na
β-HCH	11 (1.3–60)	na
Mirex	5.8 (0.4–35)	na
Toxaphene	na	na
Parlar 26	na	na
Parlar 50	na	na
PCBs		
Aroclor 1260[4]	na	na
CB118	19 (3.7–108)	13[5] (3.3–28)
CB138	78 (14–409)	81[5] (37–124)
CB153	132 (22–728)	98[5] (44–140)
CB180	48 (11–214)	44[5] (19–70)
ΣPCB_{14}[6]	386 (76–1916)	309[5]

na: not available.

[1]Muckle, pers. comm. (2000), Muckle *et al.* (2001b); [2]Lejon (1996); [3](n=175); [4]Aroclor 1260 quantified as 5.2 (CB138 + CB153), Weber, pers. comm. (2002); [5]arithmetic mean; [6]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

Similar general patterns are found in the data for HCB (Figure 5·6) and toxaphene (Figure 5·7).

5.2.2.2. Indigenous populations

In comparing the Inuit populations of Greenland and Canada it is clear that much higher levels of total PCBs (estimated as Aroclor 1260, Figure 5·5) are found in mothers from Greenland (6.4 to 36 µg/L) (Deutch, in prep; Deutch and Hansen, 2000), than in Canadian Inuit mothers (2.4 to 8.0 µg/L) (Muckle, pers. comm., 2000; Muckle *et al.* 2001b; Walker *et al.*, 2001). A similar pattern is found for DDT. This difference is probably due to the higher consumption of marine mammals by Greenland Inuit. The Dene/Métis of Canada, and the indigenous peoples of Russia (Klopov, 2000), have much lower levels of many contaminants than the Inuit populations, as observed in the maternal data from these countries. The differences in contaminant levels are probably explained by diet; i.e., the Dene/Métis of Canada consume large amounts of fish and terrestrial mammals that have markedly lower levels of POPs than the marine mammals consumed by the Inuit.

5.2.2.3. Comparisons of indigenous and non-indigenous peoples or regions

As stated in the previous sections, Inuit mothers of the circumpolar north, particularly in Greenland, have higher levels of many contaminants (e.g., oxychlordane, Figure 5·2; HCB; and PCBs, Figure 5·5) than other northern indigenous populations (e.g., Dene/Métis in Canada; and indigenous people in the Taymir and Yamal regions of Arctic Russia). They also have higher levels of these contaminants than non-indigenous peoples from Canada, Norway, and Iceland (AMAP, 1998). Levels in the Dene/Métis of Canada and the indigenous peoples of Russia are either similar to or lower than those in many of the non-indigenous populations. The Dene/Métis of Canada depend on terrestrial mammals such as caribou or moose and on freshwater fish, which have relatively low levels of POPs. Many of the indigenous peoples of Arctic Russia surveyed to date also consume mainly fish and terrestrial mammals.

Few data on contaminant levels in men were available for the circumpolar north. Samples were, however, available for men from Greenland and Iceland, and these show a very similar pattern to that found in mothers. Three to twenty times higher levels of PCBs, DDE and chlordane derivatives were observed in Greenlandic Inuit men compared to Icelandic men (Tables 5·3 and 5·7).

5.2.2.4. Comparison of breast milk levels of contaminants

Data from Sweden on the mean levels of PCBs in breast milk (on a lipid weight basis) (Lejon, 1996) can be compared to levels in Inuit from Nunavik (Muckle *et al.*, 2001b), to highlight both geographic and ethnic differences. Table 5·9 shows that the breast milk levels of four PCB congeners, as well as of the sum of 14 congeners, in Nunavik Inuit women were consistently higher than those in women from the Kiruna (Giron) area of Sweden (386 vs 309 µg/kg lipid, respectively, for ΣPCB_{14}). The Kiruna area is one of the two main industrial areas in the Swedish Arctic. However, the main source of exposure to environmental contaminants there and in other parts of Sweden is through the consumption of commercial foods (e.g., marine fish, and terrestrial mammals such as sheep, cattle, and pigs; AMAP, 1998), similar to the situation in other western countries. The higher levels of PCBs in Inuit breast milk are due to the consumption of traditional/country foods which have higher levels of POPs such as PCBs.

In Sweden, nine of the 11 women sampled were breast feeding their first baby. The PCB levels in the breast milk of the remaining two women, who had breast fed four and three children, respectively, were approximately 40% lower than in the breast milk of the other nine (Lejon, 1996). This emphasizes the importance of birth order in PCB exposure through breast milk.

Some data have recently become available for a limited number of contaminants in breast milk of women

Table 5·10. Organochlorine contaminants in breast milk from indigenous and non-indigenous regions of Siberian Russia (geometric mean (range), µg/kg lipid).

	Non-indigenous regions			Indigenous regions	
	Norilsk[1] 1995–96 (n=49)	Salekhard[2] 1996–98 (n=31)	Dudinka[1] 1995–96 (n=27)	Taymir[1] 1995–96 (n=18)	Yamal[2] 1996–98 (n=12)
Oxychlordane	na	na	na	na	na
Trans-nonachlor	17 (8–31)	19 (8–36)	16 (7–36)	14 (5–45)	18 (7–44)
p,p'-DDT	49 (19–212)	56 (17–198)	49 (16–188)	24 (8–57)	28 (8–67)
p,p'-DDE	399 (191–1292)	425 (105–1502)	435 (166–1283)	314 (176–747)	375 (143–1262)
DDE:DDT ratio	8.8 (5.1–14)	8.7 (4.8–14)	9.3 (5.9–13)	16 (9.6–21)	14 (6.4–21)
HCB	123 (29–387)	70 (25–195)	73 (19–188)	111 (65–210)	78 (22–166)
β-HCH	142 (49–582)	59 (10–447)	40 (8–203)	46 (3–124)	59 (21–171)
Mirex	1.2 (0.4–5.1)	1.9 (0.4–3.7)	1.6 (0.4–2.9)	0.8 (0.1–2.2)	1.6 (0.4–3.1)
Total Toxaphene	na	na	na	na	na
Parlar 26	na	na	na	na	na
Parlar 50	na	na	na	na	na

na: not available.

[1]Klopov *et al.* (1998); [2]Klopov (2000), Klopov and Shepovalnikov (2000), Klopov and Tchachchine (2001).

Table 5·11. Organochlorine contaminants in breast milk from four regions of northern Russia (arithmetic mean (range), µg/kg lipid). Source: Polder *et al.* (2002a).

	Kargopol		Severodvinsk		Arkhangelsk		Naryan–Mar	
	Primipara (n=10)	Multipara (n=9)	Primipara (n=37)	Multipara (n=13)	Primipara (n=40)	Multipara (n=11)	Primipara (n=11)	Multipara (n=9)
Mean age (SD)	21.6 (1.7)	25.3 (3.5)	22.6 (4.3)	28.9 (4.8)	22.0 (2.8)	28.4 (5)	25.1 (6.1)	25.9 (4.4)
Oxychlordane	6 (4–11)	8 (4–19)	9 (4–13)	10 (3–17)	9 (<1–19)	12 (4–22)	13 (5–28)	15 (4–28)
Trans-nonachlor	14 (5–23)	17 (10–37)	20 (7–49)	22 (7–45)	22 (<1–60)	32 (13–52)	21 (12–39)	21 (3–47)
p,p'-DDT	108 (51–174)	115 (50–262)	147 (28–415)	79 (33–176)	194 (3–691)	136 (44–281)	171 (58–389)	118 (25–293)
p,p'-DDE	869 (352–1454)	944 (186–2587)	979 (416–2395)	724 (120–1296)	1192 (352–3824)	947 (594–1664)	923 (150–2143)	632 (70–1729)
DDE:DDT ratio	6.25 (2.5->10)	5.88 (3.33->10)	6.25 (2.5->10)	7.69 (3.33->10)	6.25 (2.5->10)	7.14 (5.0->10)	5.0 (2.5->10)	4.54 (2.0->10)
HCB	79 (47–127)	77 (40–192)	87 (41–240)	80 (31–157)	77 (20–188)	82 (43–119)	129 (49–472)	120 (46–248)
β-HCH	304 (114–932)	187 (104–429)	376 (171–736)	292 (123–519)	401 (14–1202)	317 (105–586)	183 (57–524)	120 (49–253)
Mirex	na	na	na	na	na	na	na	na
Total Toxaphene	na	na	na	na	na	na	na	na
Parlar 26[1]	2.3		2.9		4.3		3.4	
Parlar 50[1]	3.7		4.8		4.8		5.8	
PCBs								
Aroclor 1260[2]	na	na	na	na	na	na	na	na
CB118	29 (11–52)	34 (17–64)	46 (16–96)	45 (15–115)	41 (18–110)	42 (22–63)	36 (17–96)	35 (12–76)
CB138	45 (14–66)	52 (26–124)	69 (25–158)	59 (22–96)	67 (21–192)	79 (36–109)	73 (35–189)	69 (25–122)
CB153	52 (19–86)	60 (36–163)	72 (29–210)	73 (30–121)	73 (28–213)	105 (43–143)	98 (41–321)	99 (36–222)
CB180	24 (9–48)	31 (20–88)	31 (10–100)	34 (14–57)	36 (13–85)	48 (23–80)	52 (26–150)	70 (20–143)
ΣPCB_{14}[3]	na	na	na	na	na	na	na	na

na: not available.

[1]Concentrations in pooled milk samples; [2]Aroclor 1260 quantified as 5.2 (CB138 + CB153), Weber, pers. comm. (2002); [3]CB28, CB52, CB99, CB101, CB105, CB118, CB128, CB138, CB153, CB156, CB170, CB180, CB183, and CB187.

Table 5·12. Metal concentrations in maternal blood from circumpolar countries (geometric mean (range), µg/L whole blood).

Country/Ethnic Group/Region	n	Mercury (total)	Mercury (organic)	Selenium	Lead	Cadmium
Canada						
Caucasian[1] (1994–99)	134	0.9 (nd–4.2)	0.69 (nd–3.6)	123 (80–184)	21 (2.1–58)	0.43 (nd–8.5)
Métis/Dene[1] (1994–99)	92	1.4 (nd–6.0)	0.80 (nd–4.0)	117 (67–160)	31 (5.0–112)	0.65 (nd–5.9)
Other[1] (1995)	13	1.3 (0.20–3.4)	1.2 (nd–3.0)	128 (97–156)	22 (5.0–44)	0.36 (nd–3.2)
Inuit						
Baffin[1] (1996)	31	6.7 (nd–34)	6.0 (nd–29)	118 (99–152)	42 (5.0–120)	1.7 (0.03–6.2)
Inuvik[1] (1998–99)	31	2.1 (0.60–24)	1.8 (nd–21)	118 (88–151)	19 (2.1–102)	1.0 (nd–7.1)
Kitikmeot[1] (1994–95)	63	3.4 (nd–13)	2.9 (nd–11)	122 (86–171)	36 (6.2–178)	1.9 (0.01–7.8)
Kivalliq[1] (1996–97)	17	3.7 (0.60–12)	2.7 (0.40–9.7)	106 (77–156)	29 (12–64)	1.4 (0.11–7.7)
Nunavik[2] (1995–2000)	162	9.8 (1.6–44)	na	318 (150–1232)	50 (5.2–259)	na
Greenland						
Disko Bay[3] (1997)	94	na	na	140[4]	na	na
Thule[3] (1997)	4	50[4]	na	409[4]	na	na
Ilullissat[3] (1999–2000)	29	12.4	na	158	50	1.2
Nuuk[5] (1999)	34	3.6	na	142 (n=38)	37	0.68
Ittoqqortoormiit[3] (1999–2000)	8	10.5	na	133	31	0.96
Alaska						
Bethel[6] (2000)	23	5.5 (1.6–14.3)	na	na	33[4] (nd–91)	0.3[4] (nd–1.6)
Barrow[6] (2000)	23	1.3[4] (nd–4.5)	na	na	11 (7.0–27)	0.2[4] (nd–0.9)
Siberian Russia						
Non-indigenous						
Norilsk[7] (1995–96)[7]	49	1.4 (1–5)	na	90 (62–134)	32 (12–44)	0.29 (0.1–1.5)
Salekhard[7] (1996–98)	31	1.5 (1–5)	na	91 (64–130)	24 (12–40)	0.40 (0.1–1.4)
Dudinka[7] (1995–96)	27	1.6 (1–5)	na	85 (56–122)	21 (14–42)	0.38 (0.1–1.4)
Indigenous						
Taymir[7] (1995–96)	18	2.7 (2–8)	na	89 (58–126)	29 (12–48)	0.33 (0.1–1.0)
Yamal[7] (1996–98)	12	2.9 (2–7)	na	80 (60–122)	24 (12–40)	0.20 (0.1–0.8)
Finland[8] (1996–98)	130	1.4 (0.2–6.0)	na	74 (51–122) (n=148)	11 (5–58)	0.13 (0.1–2.2)
Faroe Islands[9] (2000–2001)	124	1.2 (nd–7.5)	na	105 (54–169)	21 (13–100)	0.21 (0.2–2.9)

nd: not detected; na: not available.

[1]Walker *et al.* (2001); [2]Muckle *et al.* (2001b); [3]Deutch, pers. comm. (2001); [4]arithmetic mean; [5]Bjerregaard, pers. comm. (2001); [6]Berner, pers. comm. (2001); [7]Klopov (2000), Klopov and Tchachchine (2001); [8]Soininen, pers. comm. (2001), Soininen *et al.* (2000); [9]Weihe, pers. comm. (2001).

from Arctic Russia (Table 5·10). The breast milk samples from non-indigenous regions do not show the same pattern as that seen in the maternal blood samples, i.e., higher levels of β-HCH and DDE in the non-indigenous mothers. Only non-indigenous mothers from Norilsk had higher levels of β-HCH in their breast milk compared to indigenous mothers (142 vs 46 or 59 µg/kg lipid). The Inuit mothers from Nunavik (Canada) had markedly higher levels of mirex and *trans*-nonachlor compared to those in the Russian Arctic. Breast milk from both indigenous and non-indigenous mothers in Russia had four to ten times higher levels of β-HCH than found in Nunavik Inuit (40 to 142 vs 11 µg/kg lipid, respectively). This indicates the use of β-HCH in commercial Russian food production or in the local environment, as was concluded in the evaluation of the Russian maternal blood data. Additional data have been supplied for northern Russia by Polder *et al.* (2002a), see Table 5·11.

5.3. Metals

New data are currently available on maternal blood levels of a number of priority metals, i.e., mercury (Hg), lead (Pb), cadmium (Cd), and selenium (Se). These data are available for six countries within the circumpolar area – Canada, Finland, Greenland, the Faroe Islands, Arctic Russia, and United States (Alaska).

5.3.1. National and regional data

5.3.1.1. Canada

Mercury has long been a contaminant of concern in traditional foods in the Arctic. In Canada, in NWT/Nunavut and Nunavik, significantly higher levels of total Hg were found in maternal blood from Inuit compared to Caucasian, Dene/Métis or Others (2.1 to 9.8 vs 0.9 to 1.4 µg/L) (Muckle, pers. comm., 2000; Muckle *et al.*, 2001b; Walker *et al.*, 2001) (Table 5·12). Markedly higher levels of Hg (2 to 5 times) were seen in Inuit from the Baffin region of Nunavut (6.7 µg/L) and Nunavik (9.8 µg/L). The Canadian dataset contains both total and organic Hg levels. On the basis of the mean values presented in Table 5·12, 57 to 92% of Hg in blood occurs as organic Hg, but there does not appear to be a relationship with ethnic origin or Hg concentration. Se levels in maternal serum were very similar among Caucasian, Dene/Métis, Others, and Inuit (Baffin, Inuvik, Kitikmeot, Kivalliq) peoples from the NWT/Nunavut. Only among the Nunavik Inuit, who also had the highest levels of Hg, were Se levels elevated (318 µg/L). High concentrations of Se are generally found in the traditional foods of the Inuit in Greenland and Canada, particularly in foods derived from marine mammals (e.g., muktuk). Se is a component of glutathione peroxidases and may act as an antagonist to methylmercury (MeHg), thereby offering some protection against potential adverse health effects from MeHg exposure (AMAP, 1998).

Lead levels are moderately elevated among some of the Inuit and the Dene/Métis (50 to 31 µg/L), while levels are lower among Caucasians, Others and some Inuit (19 to 22 µg/L). Pb isotope signatures indicate that these elevations in blood Pb levels are probably due to the presence of Pb shot in consumed game (Dewailly *et al.*, 2000b).

The highest Cd levels were observed in Inuit mothers (1.0 to 1.9 µg/L), while lower levels were seen in Caucasian, Dene/Métis and Others mothers (0.36 to 0.65 µg/L). This difference is probably due to the high rate of smoking among Inuit mothers and the high Cd content of Canadian tobacco. Benedetti *et al.* (1994) found that non-smoking Canadian Inuit had markedly lower levels of blood Cd (0.27 µg/L) compared to Inuit who smoked (5.3 µg/L).

5.3.1.2. **Greenland**

Mercury levels are extremely variable among Greenland Inuit peoples (Table 5·12), ranging from a maximum of 50.4 µg/L among a small sample of Inuit mothers from the Thule region (Deutch, in prep) to a more moderate 3.6 µg/L in mothers from Nuuk. Intermediate but still somewhat high levels of Hg are seen in the women from Ilullissat and Ittoqqortoormiit (Table 5·12). Along with these higher levels of Hg, many of these populations have moderately to highly elevated levels of Se (133 to 409 µg/L). As noted in section 5.3.1.1., high Se concentrations are generally found in the traditional diet of the Inuit in Greenland and Canada, particularly in foods derived from marine mammals (e.g., muktuk).

Lead levels among Greenland Inuit mothers are similar (31 to 50 µg/L) to the moderately increased levels among some of the Canadian Inuit and Dene/Métis. Analyses of seabirds in Greenland have shown that Pb shot in game is a significant contributor to human Pb exposure (Johansen *et al.*, 2001).

Cadmium levels are higher in the Greenland Inuit than in the Canadian Arctic Caucasians and Others groups, but lower than levels seen in Canadian Inuit. The increased Cd levels among Greenland Inuit are also likely to be due to increased rates of smoking relative to other population groups, such as Danes living in Greenland. However, based on blood samples from non-smokers, diet is also a significant source of Cd (Hansen, 1990).

5.3.1.3. **Alaska**

Mercury levels in the Iñupiat mothers from the Barrow region are on average 75% lower than concentrations in Yup'ik mothers from the Bethel region (1.3 vs 5.5 µg/L) (Table 5·12). Concentrations in the Yup'ik mothers are of a similar magnitude to those in Canadian Inuit (5.5 vs 2.1 to 9.8 µg/L). Both the Iñupiat and the Yup'ik peoples are considered Inuit, but the differences in their blood contaminant levels indicate significant dietary differences. The Yup'ik mothers consume significant amounts of freshwater fish and some marine mammals that may have elevated levels of Hg; while the Iñupiat mothers consume terrestrial mammals and bowhead whales (*Balaena mysticetus*) that have lower levels of Hg. Without dietary surveys, numeric dietary comparisons cannot be made. To date there are no data available on Se levels in Alaskan mothers, but the maternal blood levels of Pb and Cd are low and similar to those in many of the non-indigenous population groups.

5.3.1.4. **Russia**

Levels of metals in maternal tissues are a concern in parts of the Russian Arctic, in particular due to the presence of large non-ferrous metal smelters in Norilsk and Nikel. The data in Table 5·12 indicate that non-indigenous Russians from Norilsk, Salekhard, and Dudinka have lower levels of Hg than the indigenous peoples of Taymir and Yamal, but very similar levels to those in the non-indigenous (Caucasian and Others) Arctic Canadians. Indigenous Russians from Taymir and the Yamal regions have intermediate levels of Hg (2.7 and 2.9 µg/L) which are similar to those in Canadian Inuit from Inuvik (2.1 µg/L) but markedly lower than levels in Inuit from Greenland or the Baffin and Nunavik regions of Canada (Table 5·12). This may indicate exposure to Hg through consumption of local fish. Se levels among all Russian ethnic groups (80 to 91 µg/L) are approximately 30% lower than those in Caucasians or Dene/Métis in Arctic Canada, and up to 80% lower than levels among Canadian and Greenland Inuit who have high levels of both Se and Hg.

Lead and Cd levels are similar among indigenous and non-indigenous women of Arctic Russia (21 to 32 µg/L and 0.20 to 0.40 µg/L, respectively) and the mean values are similar to or lower than those in Arctic Canada or Greenland. The data presented here do not indicate that these women are exposed to higher levels of Pb or Cd, supporting the view that the effects of point sources such as the smelters in Norilsk remain local.

5.3.1.5. **Finland**

Exposure to metals is a major concern in the northern parts of Finnish Lapland. There is no major domestic source of pollution in this area, but metals originating from the smelters on the Kola Peninsula (Russia) are a significant concern. Also, Hg is known to accumulate in freshwater fish, which is one of the most important components of the diet in Lapland (AMAP, 1998). The mean blood level of Hg in pregnant women from the most northern and northeastern parts of Finnish Lapland (Soininen *et al.*, 2000) is much lower than the levels found in Canadian Inuit and Greenlandic Inuit women (1.4 µg/L vs 2.1 to 9.8 and 3.6 to 50 µg/L, respectively) (Table 5·12). The Finnish value is similar to corresponding values found in previous studies in Arkhangelsk (Russia), and in Sweden (Soininen *et al.*, 2000). Se levels in the Finnish mothers are the lowest of those observed in the Arctic populations studied (74 vs 117 to 318 µg/L in Canada, and 133 to 409 µg/L in Greenland).

Lead levels in the Finnish mothers tend to be lower than those in the other Arctic populations reported here. Cd levels are also lower than in the other Arctic populations sampled. The data presented here do not indicate that the smelters on the Kola Peninsula contribute to increased levels of Pb or Cd in mothers from northern Finland.

5.3.1.6. Faroe Islands

The consumption of pilot whale meat is thought to be the main source of Hg in the Faroe Islands population, and dietary surveys in the 1980s indicated that the local population consumed on average 12 grams of whale meat per day. As stated in section 5.2.1.7., in 1998 pregnant women and women who intended to become pregnant were advised to stop eating pilot whale blubber and meat. A dietary survey and blood contaminant sampling programme were undertaken in 2000–2001 to assess the effect of this advice (Weihe, pers. comm., 2001). These surveys indicated that pilot whale blubber and meat consumption had decreased by a factor of ten in the target groups. Hg levels in maternal blood had also decreased markedly since the 1980s (12.1 vs 1.3 µg/L), and there appears to have been a very positive response to the dietary advice (Grandjean *et al.*, 1992; Weihe, pers. comm., 2001), which is very specific and aimed particularly at pregnant women and women intending to become pregnant. Hg levels are now quite low in the Faroese population and similar to levels found in Finland, in indigenous peoples from Barrow (Alaska), and in non-indigenous populations in Russia and Canada (Table 5·12). Additional monitoring is needed to validate these very marked trends.

5.3.2. International comparisons

5.3.2.1. Comparisons of indigenous and non-indigenous peoples

The highest maternal blood Hg levels occur in the Inuit of Canada and Greenland and in the Yup'ik Inuit from the Bethel region of Alaska (5.5 to 50 µg/L) (Figure 5·8). These high blood levels in the Inuit are associated with consumption of muscle and fatty skin (muktuk) from marine mammals, both of which have high levels of Hg and Se. Intermediate levels of Hg (1.3 to 2.9 µg/L) occur in the Dene/Métis and in some Inuit populations from Canada, and in the indigenous peoples of the Taymir and Yamal regions of Arctic Russia. Lower levels of Hg were observed in all non-indigenous populations from Canada, Finland, and Russia. The lowest levels of Se occur in mothers from Finland and northern Russia, and only some of the Inuit populations with elevated Hg levels also have markedly higher levels of Se (318 and 409 µg/L in Nunavik and Thule, respectively).

Lead levels are moderately increased (30 to 50 µg/L) among some Inuit mothers from Canada and Greenland compared to other Arctic regions. This increase is probably related to the use of Pb shot in the hunting of traditional foods. Cd is also elevated in the Dene/Métis and Inuit mothers from Arctic Canada and in Inuit mothers from Greenland. This increase in Cd is thought to be related to increased cigarette smoking among indigenous peoples (Benedetti *et al.*, 1994) and also, in some areas, to the consumption of marine mammals.

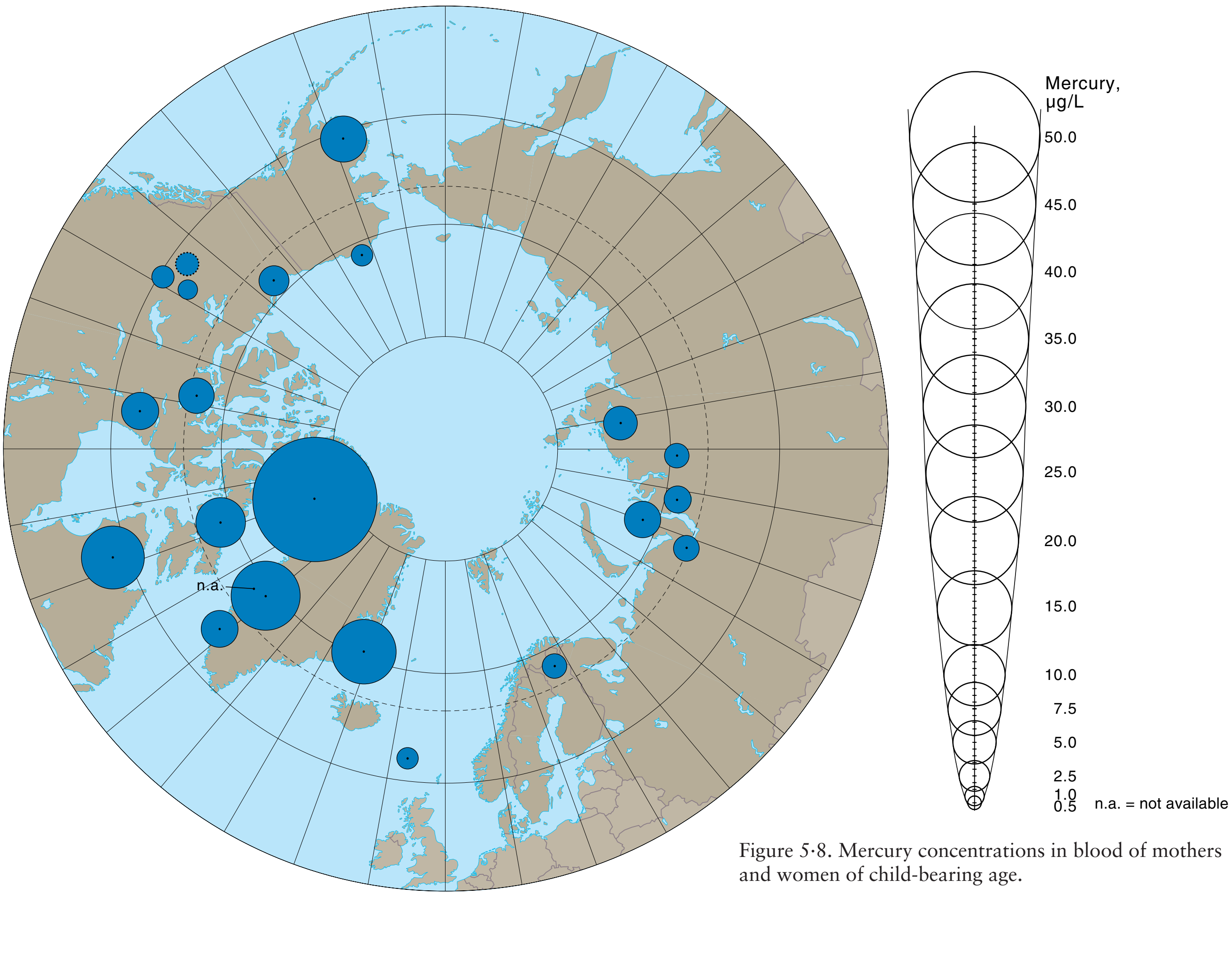


Figure 5·8. Mercury concentrations in blood of mothers and women of child-bearing age.

Lead and Cd levels are not markedly elevated among non-indigenous mothers from northern Russia and Finland. This indicates that these mothers are not being exposed to significant amounts of these metals from local point sources such as the smelters on the Kola Peninsula and in Norilsk.

5.4. Temporal trends

Sampling human blood for contaminant analyses is relatively new in the Arctic. Data for AMAP human health assessments were obtained from blood or breast milk samples collected during the period 1994 to 1999. This is a very short period on which to base estimates of temporal trends in contaminant levels in human tissues. There are often only one or two sampling points from specific countries, ethnic groups, or regions, for example, for Sweden maternal blood data were available for the first AMAP assessment report (AMAP, 1998), but not since then. In other cases (e.g., Alaska, Russia, and Norway), data were obtained during the late-1990s from regions for which they had not previously been reported. For some other countries (e.g., Canada) limited data from the initial circumpolar maternal blood contaminants studies were combined with newer data to produce more robust datasets, after confirming that there were no major temporal differences in contaminant levels between the two datasets. Overall, the data presented in the present assessment report provide a more reliable basis for assessing spatial variation in human contaminant levels in the circumpolar Arctic, but are insufficient for temporal trend analyses.

There are some data for Greenland, from preserved mummies and their clothing, that provide an indication of possible trends in Hg levels over the past 500 years. Figure 5·9 shows concentrations of Hg in hair of Inuit and animals from Greenland for samples representing the fifteenth, sixteenth, and twentieth centuries (Hansen, pers. comm., 2001; Hansen *et al.*, 1989). It is evident that Hg levels are three- to seven-fold higher in the twentieth century Inuit hair samples than in the fifteenth- and sixteenth-century samples. The concentrations of Hg in

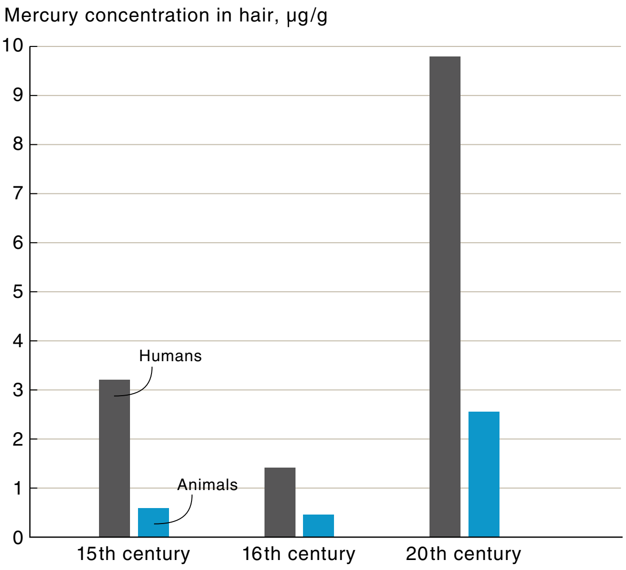


Figure 5·9. Changes in mercury concentration in human and animal hair from Greenland.

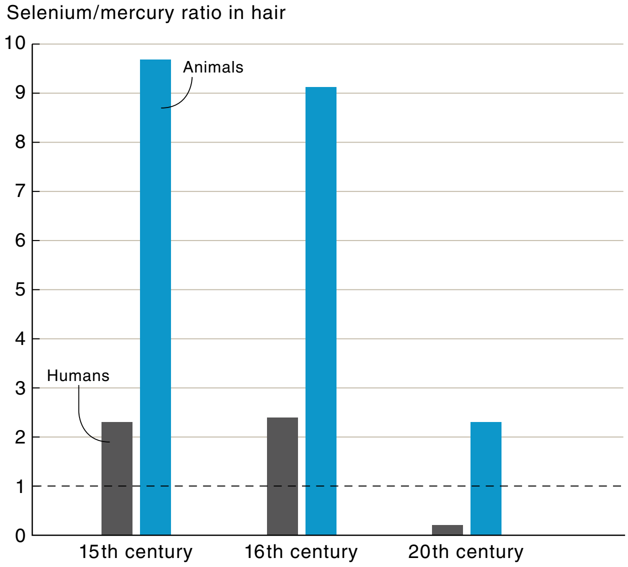


Figure 5·10. Changes in selenium/mercury ratios in human and animal hair from Greenland.

animal hair (seal and reindeer) from Greenland are also four- to six-fold higher in the twentieth century samples (Figure 5·9). These markedly higher concentrations in the Greenland Inuit and their traditional foods may indicate substantially higher exposure to Hg in the twentieth century.

This study also determined Se levels in these samples, and Figure 5·10 presents the associated Se:Hg ratios (Hansen, pers. comm., 2001; Hansen *et al.*, 1989). The Se:Hg ratio has decreased ten-fold in humans and four-fold in animals over the 500-year period. Most of this change is due to the increasing Hg concentrations in the hair of animals and humans as well as to the decreasing concentration of Se in twentieth century human hair (Hansen, pers. comm., 2001; Hansen *et al.*, 1989). With lower levels of Se in relation to Hg, the mitigating effect that Se is thought to have on Hg toxicity may be reduced, and Hg may be having impacts on human health and biota that were not previously occurring. A number of studies are underway in the Arctic which address the possible impacts of Hg and other contaminants on human health (see chapter 9).

5.5. Quality assurance/quality control

The AMAP circumpolar blood monitoring programme was initiated under AMAP Phase I. This took the form of a single circumpolar maternal blood contaminant study in which a single laboratory conducted all the analyses. This programme has been expanded and further developed under AMAP Phase II. In its present form sample analyses are performed by several laboratories in different countries (Table 5·13).

In order to ensure the comparability of the data from the different laboratories, a QA/QC activity was established specifically to support the AMAP Human Health Monitoring Programme. The various laboratories may use similar, but slightly different methods to measure the contaminant concentrations, and the QA/QC programme provides information about the level of comparability of the results. The QA/QC activity addresses both sampling and analytical issues. AMAP human

Table 5·13. Laboratories participating in AMAP Human Tissue Analyses.

Laboratory	Origin of samples
Blood	
L'Institute Nationale de Santé Publique du Québec, Sainte-Foy, QC, Canada	Greenland, Canada, Finland, Sweden
Dept. Pharmacology and Toxicology, Univ. Iceland, Reykjavik, Iceland	Iceland
National Center for Environmental Health of the Centers for Disease Control for Disease Control and Prevention in Atlanta, Georgia, USA	Alaskan mainland and Aleutian and Pribilof Islands
Norwegian Institute of Air Research (NILU), Polar Environmental Centre, Tromsø, Norway	Norway, Archangelsk
Regional Centre Monitoring of the Arctic (RCMA), St. Petersburg, Russia	Siberian Russia
Institute and Out-Patient Clinic for Occupational, Social and Environmental Medicine, Univ. Erlangen, Nuremberg, Germany	Faroe Islands
Breast milk	
L'Institute Nationale de Santé Publique du Québec, Sainte-Foy, QC, Canada	Canada
Regional Centre Monitoring of the Arctic (RCMA), St. Petersburg, Russia	Siberian Russia
Laboratory for Environmental Toxicology at the Norwegian School of Veterinary Science, Oslo, Norway	Kargopol, Severodvinsk, Archangelsk, Naryan Mar
Dept. Environmental Chemistry, Umea Univ., Umea, Sweden	Sweden

health laboratories are currently participating in a series of ring-tests, currently coordinated by the Institute Nationale de Santé Publique du Québec. These ring-tests are also open to other (non-AMAP) laboratories. Two such ring-tests, for PCBs and organic pesticides (i.e., DDTs and mirex), were completed prior to the preparation of this assessment. Metals have not been included in the AMAP ring-tests to date. Results indicate that most of the laboratories involved in the AMAP Human Health Monitoring Programme produce results for PCBs that are within 30% of expected values; and within 20% for DDTs. Results for mirex are, however, less comparable.

5.6. Conclusions

It is apparent that the levels of certain POPs and Hg are generally higher in the maternal blood samples of Arctic peoples who consume traditional foods (e.g., the Inuit of Greenland and Arctic Canada). For the Greenland Inuit, in particular, blood levels of several environmental contaminants (e.g., PCBs, HCB, total chlordanes, and Hg) are higher than those in maternal blood samples from Canada and other circumpolar countries, and this probably reflects a higher consumption of marine mammals. Levels of total DDT are higher in the non-indigenous population from Arkhangelsk (Russia) than in any other region, indicating possible continuing use of DDTs in Russian agriculture or local pesticide use. For β-HCH, the highest levels were also found in Arctic Russia among the non-indigenous population groups, but elevated levels were also seen in Iceland and among the Others group in the Canadian Arctic.

Recent data for the Faroe Island population indicate that, due to public health advice to restrict pilot whale consumption, particularly in the case of pregnant women and nursing mothers, there has been a significant decrease in maternal blood Hg levels, but very little change in PCB levels. The different response of these two contaminants is probably due to the short half-life of Hg in the body compared to that of PCBs. For other Arctic populations, for which there are generally only one or two sequential datasets covering mainly the 1990s, it is very difficult to determine any time trends for the contaminants of concern. Most human health related monitoring in the Arctic has taken place only over the last five to ten years, and although this has provided a much better basis for assessment of the spatial variation in contaminant levels, this period is too short to reliably identify any temporal trends. For Hg, the discovery of ancient Greenland mummies, together with supporting data on biota from their clothing, offers evidence that there has been a significant increase in the concentration of Hg in the Greenland Arctic environment and in peoples who consume large amounts of marine mammals (Hansen *et al.*, 1989; Hansen, pers. comm., 2001).