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Organochlorines and heavy metals in pregnant women from the Disko Bay area in Greenland

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Abstract

Recent studies from Greenland and the Canadian Arctic have shown high concentrations of heavy metals, such as mercury, and organochlorines in the blood and fatty tissue of the Inuit. This is attributed in particular to their high consumption of the meat and blubber of marine mammals. In the present study, 180 pregnant women and 178 newborn babies were studied, amounting to 36% of the total number of births in the Disko Bay area during 1994–1996. The pesticides found in the highest concentrations in maternal blood were DDE (4.8 μg/l wet wt.), *trans*-nonachlor (1.6 μg/l) and hexachlorobenzene (1.2 μg/l) while the total concentration of PCB (Aroclor 1260) was 19.1 μg/l. Calculated on a lipid basis, concentrations were slightly higher in maternal than in cord blood. The mercury concentrations were 16.8 μg/l in maternal blood and 35.6 μg/l in cord blood. In a linear regression analysis, the concentrations of organochlorines, mercury and selenium increased with maternal age. Concentrations of mercury and cadmium increased with the consumption of marine mammals, and cadmium was associated with smoking. The contaminants are potentially toxic for several organ systems but the high concentrations of pollutants have so far not been shown to influence health in Greenland.

Keywords: Greenland; Mercury; Lead; Cadmium; PCB; Pesticides; Diet; Marine mammals; Smoking

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1. Introduction

Before the Arctic Monitoring and Assessment Program (AMAP) there were few studies of persistent organic pollutants (POPs) in humans in Greenland but results from investigations on humans in the eastern Canadian Arctic and on the Greenlandic fauna made it probable that concentrations were high. Studies from the late 1970s on fat biopsies from Greenlanders showed higher DDT and DDE levels in Greenlanders than in the population of Denmark but lower DDE levels than in the United States, eastern Europe and India (Clausen and Berg, 1975; Jensen and Clausen, 1979). Concentrations of Lindane, aldrin-like residue, dieldrin, heptachlor-like residue, heptachlor epoxide, and PCBs were similar in Greenlanders and Danes. A recent study of POPs in fat biopsies from autopsies showed very high levels in Greenland compared with Canada, Finland and the USA. PCB mean concentrations were 15 800 μg/kg, DDT concentrations 4450 μg/kg, and HCB 752 μg/kg (Dewailly et al., 1995).

The concentration and distribution of mercury in humans in Greenland have been thoroughly studied over the last 15 years. Surveys have been performed in adults, pregnant women and newborn babies in most parts of Greenland including both the central-west coast, where the majority of the population lives, and the sparsely populated hunting districts in north-western, northern and eastern Greenland. In all regions studied, the determining factor for mercury exposure was found to be the daily intake of meat from marine mammals. At a regional level, the median blood mercury concentrations are directly proportional to the registered mean number of seals caught which suggests that on a population basis, blood mercury relates to the level of seal consumption (Hansen, 1990). In adults, median as well as maximum whole blood concentrations of mercury were lowest in the south-west, higher in the north-west and on the east coast and very high in north Greenland. In north Greenland, 16% of the investigated adult population exceeded 200 μg/l which WHO regards as the minimum toxic blood concentration in adults (Hansen and Pedersen, 1986).

Lead has been studied together with mercury and cadmium in four representative areas of Greenland and compared with Greenlanders living in Denmark. The differences among the four areas were relatively small and no difference was found between Greenlanders and Danes living in Greenland (Hansen et al., 1984; Hansen and Pedersen, 1986). Umbilical cord blood lead levels were a little lower than those of the mothers. The temporal trend of blood lead in Greenlanders is decreasing parallel to blood levels in Europe and North America, which again parallels the decreased addition of lead to gasoline. It has, furthermore, been demonstrated by analyses of stable isotopes of lead which occur in different proportions in gasoline used in Europe and North America, that the decrease in blood lead in Greenland is caused by decreased exposure from both Europe and North America. It is thus, well substantiated that the surprisingly high lead exposure in Greenland is caused by long range atmospheric transport of lead from urbanised centres at lower latitudes (Hansen et al., 1990; Boutron et al., 1995).

Cadmium has been studied together with mercury and lead in the same four regions of Greenland but was only determined in the adult population (Hansen, 1981, 1990). The median blood cadmium concentration in east and north Greenland was at the same level as in Greenlanders living in Denmark, and lower than in west Greenland. The major determinant of blood cadmium concentration was smoking habits and only in non-smokers an effect of dietary habits could be observed.

Selenium has been studied together with the heavy metals in pregnant women and cord blood (Hansen et al., 1984). Selenium levels were found to be high in Greenlanders, in particular from North Greenland (Hansen and Pedersen, 1986). Like mercury, selenium concentrations were closely related to the amount of marine mammals eaten. Selenium levels were also high in umbilical cord blood but somewhat lower than in maternal blood indicating that selenium does not pass the placental barrier as readily as mercury does.

The aim of the present study was to update and complement the information on environmental contaminants in a representative sample of pregnant Greenlandic (Inuit) women and to create a baseline for future monitoring.

2. Material and methods

Pregnant women from the five municipalities of the Disko Bay area in western Greenland were invited to participate in the study which took place from June, 1994, to June, 1996 (Fig. 1). All pregnant women were eligible for the study and enrolment depended on the workload in the antenatal clinics. When the permanent staff were not present, e.g. during summer vacations, enrolment did not take place. The pregnant women were asked to fill in a short questionnaire on demographic variables, living conditions and lifestyle. Dietary habits were assessed by a food frequency question on the most commonly eaten traditional food items.

Towards the end of pregnancy, samples of venous blood were collected from the pregnant women while cord blood samples were collected at birth. Metal analyses were carried out by atomic absorption spectrometry at NERI, Department of Arctic Environment. Full details of the methods and quality procedures used are given in Asmund and Cleemann (2000). Detection limits are: mercury 0.0002 mg/kg, lead 0.004 mg/kg, selenium 0.001 mg/kg and cadmium 0.003 mg/kg. For organochlorine analyses, samples were taken in EDTA vials, separated, transferred to vials washed with hexane, and frozen at −20°C. The quantitation of PCBs and organochlorinated pesticides was performed using the method E-347 developed by the laboratory of the Centre de Toxicologie, Université Laval, Québec, Canada: 2 ml of blood plasma are extracted, cleaned-up on Florisil columns, taken to a final volume of 100 μl and analysed on a HP-5890 series II gas chromatograph with dual-capillary columns and dual Ni-63 electron-capture detectors. Peaks are identified by their relative retention times obtained on the two columns, using a computer program developed in-house. Quantitation is mainly done on the Ultra-1 column. Detection limits, based on three times the average standard deviation of noise are: 0.02 μg/l for PCB congeners and chlorinated pesticides; 0.08 μg/l for heptachlorepoxide and dieldrin; 0.04 for p,p'-DDT and β-BHC. The laboratory is accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL) Inc. Furthermore, the laboratory participates in QA/QC programs with

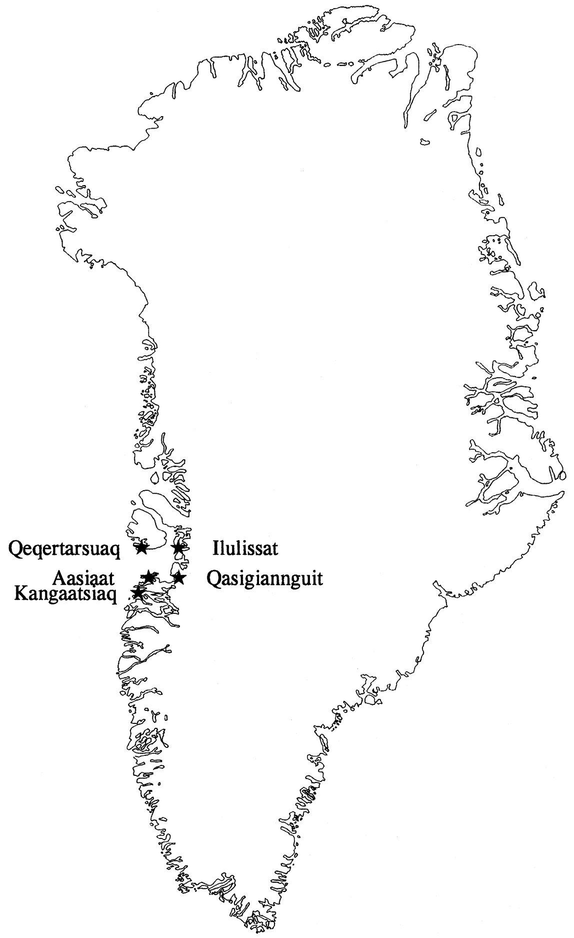

Fig. 1. The five towns in Greenland where data collection was carried out during 1994–1996.

the National Environmental Research Institute (NERI); AMAP (Denmark); the Arctic Strategy Program, Environment Canada; the Canadian Association for Environmental Analytical Laboratories (CAEAL) Inc.; and the Great Lakes Research Program.

For samples below the detection limit, half of the detection limit was used for calculation of means. Concentrations were log-transformed to approach normal distribution for the parametric statistic procedures. Data were entered on the computer, cross-checked and validated in Epi-Info v. 6.0 (Dean et al., 1994) and SPSS/Windows v. 6.1.3 or newer versions (Norusis, 1995). Analyses were performed in SPSS. Statistical tests included bivariate Pearsson correlations, general factorial linear models and linear regression analyses.

3. Results

Information was obtained from 180 mothers and 178 newborn children. This corresponds to 36% of the total number of births during the study period. Information was available on 136 mother–child pairs. Of the 180 mothers, 122 (68%) had filled in the questionnaire, while questionnaire data were available for 120 children (67%). Although the response rate was low relative to the total number of births, selection was not based on properties of the mother or the child, apart from the apparent exclusion of low-birth-weight children. Compared with all births in Greenland, 1990–1992, those in the sample were heavier (3415 g and 3595 g; $P < 0.001$) and there were no children weighing less than 2400 g.

3.1. Persistent organic pollutants

A total of 175 maternal blood samples and 160 cord blood samples were analysed for 14 PCB congeners and 11 pesticides. Table 1 shows the statistics for these compounds in maternal blood. The pesticides found in the highest concentrations were DDE, *trans*-nonachlor and hexachlorobenzene. Most of the compounds were, however, detected in all of the samples. The correlation (R^2) between maternal and cord blood concentrations were high, in the range of 0.72–0.90 for single compounds ($P < 0.001$ for all correlations). In maternal blood of 126 sample pairs, the concentration of PCB (Aroclor 1260)

Table 1
Plasma concentrations (μg/l wet wt.) of PCB and pesticides in pregnant women from the Disko Bay area, Greenland, 1994–1996[a]

	Geometric mean	Arithmetic mean	S.D.	Minimum	Maximum	Percent detected	Mother/child correlation (R^2)
Aroclor 1260	14.2	18.4	14.8	3.0	95.3	100	0.89
Sum of PCB congeners	5.2	6.7	5.3	1.1	34.0	–	0.91
Aldrin	–	–	–	–	–	0	n.a.
β-BHC	0.2	0.2	0.1	0.04	0.8	100	0.73
Total chlordanes	1.8	2.8	2.7	0.05	19.1	–	0.88
α-Chlordane	–	–	–	–	–	0	n.a.
γ-Chlordane	0.01	0.01	0.01	0.01	0.06	19	–
cis-Nonachlor	0.2	0.3	0.3	0.01	2.6	95	0.90
Oxychlordane	0.5	0.9	0.9	0.01	6.3	99	0.87
trans-Nonachlor	1.0	1.6	1.5	0.01	10.8	99	0.88
Total DDT	3.8	5.0	4.1	0.5	30.8	–	0.89
pp'-DDE	3.7	4.8	4.0	0.5	29.9	100	0.89
pp'-DDT	0.1	0.2	0.2	0.02	1.5	100	0.83
Hexachlorobenzene	0.9	1.2	1.0	0.1	7.0	100	0.85
Mirex	0.1	0.1	0.1	0.02	0.7	82	0.72

[a] Half of the detection limit was used for calculations of means in case of no detection.

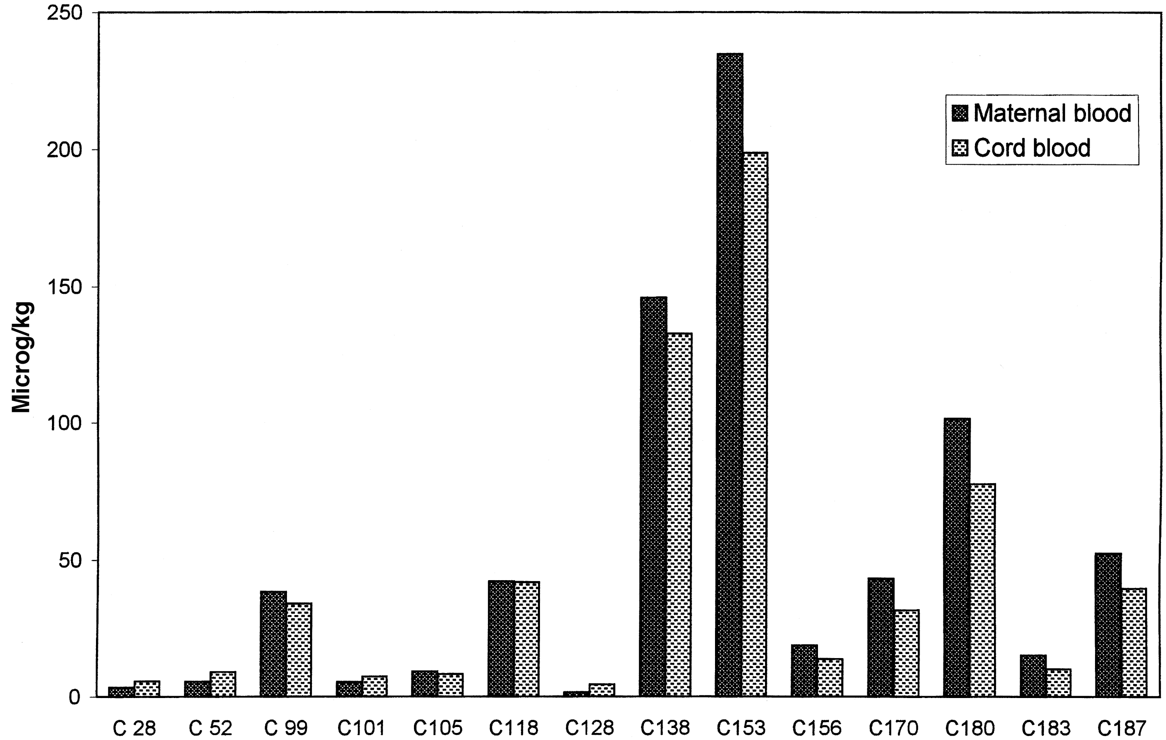

Fig. 2. Concentrations of PCB congeners in 126 sample pairs of maternal and umbilical cord plasma on a lipid basis. Greenland, 1994–1996.

was 19.1 μg/l wet wt. while in cord blood the wet wt. concentration was only 4.2 μg/l. However, when calculated on a lipid basis, concentrations were more similar although still higher in maternal blood (1978 μg/kg and 1723 μg/kg, respectively). Fig. 2 shows the PCB congener profiles for maternal and cord blood. Although maternal concentrations were higher for several congeners, the

Table 2
Whole blood or plasma concentrations (μg/l wet wt.) of metals in pregnant women and cord blood from the Disko Bay area, Greenland, 1994–1996

	Geometric mean	Arithmetic mean	S.D.	Minimum	Maximum	Mother/child correlation (R^2)
Maternal blood						
Mercury	12.8	16.8	13.6	1.9	75.6	0.71
Lead	35.7	41.5	34.5	12.1	389.3	0.10
Selenium (plasma)	63.7	65.4	15.1	32.1	134.6	0.29
Cadmium	0.9	1.4	1.2	0.02	7.0	–
Cord blood						
Mercury	25.3	35.6	32.1	2.4	181.0	0.71
Lead	29.2	32.6	18.0	9.8	143.1	0.10
Selenium (plasma)	39.7	40.5	8.4	24.7	80.3	0.29

patterns were almost identical and similar to the pattern observed in the Inuit of eastern Canada (Dewailly et al., 1994).

3.2. Metals

Metal analyses comprised mercury, lead, cadmium and selenium. Table 2 shows the statistics for these compounds in maternal and cord blood. The correlations between maternal and cord blood were not as close as for POPs and it is especially noted that mercury concentrations were considerably higher in cord blood ($P < 0.001$) while the concentrations of lead and selenium were lower ($P < 0.001$). Since the placenta acts as a partial barrier to cadmium, this compound was not measured in cord blood.

3.3. Life style, exposure and health outcome

For each contaminant (sum of PCB congeners, sum of DDE and DDT, sum of chlordanes, metals) its concentration in maternal blood was analysed in a stepwise linear regression analysis with maternal age, consumption of marine mammals (meals per month), tobacco consumption (cigarettes per day) and place of birth (Greenland or Denmark) as independent variables.

All the organochlorine contaminants increased significantly with maternal age ($P < 0.0001$) while the consumption of marine mammals and smoking were not significantly correlated with the organochlorines. Concentrations of mercury and selenium increased significantly with maternal age ($P = 0.013$ and $P < 0.0001$, respectively). Concentrations of mercury and cadmium increased with the consumption of marine mammals ($P = 0.005$ and $P = 0.01$, respectively), and the concentration of cadmium increased with tobacco consumption ($P < 0.0001$). Finally, the concentrations of PCB, chlordane and mercury were significantly higher among Greenlanders than among Danes.

The correlation of birth weight and gestational length with contaminants in cord blood was assessed in a general linear model with control for maternal place of birth, height, parity and smoking status, and the sex of the child. None of the contaminants or control variables showed any statistically significant association with birth weight with the exception of selenium in cord blood which was positively correlated with birth weight ($P = 0.008$). Smoking showed a statistically significant negative correlation with gestational length while none of the contaminants or the other control variables showed any statistically significant association with gestational length.

4. Discussion

The study population is representative of west Greenland with its small towns and villages, and a population with a relatively high consumption of marine mammals and fish. The participation rate among pregnant women was low (36%) but this was not due to any conscious selection of participants or to refusal by the women to be enrolled in the study. The small hospitals in Greenland are very vulnerable to shortage of staff and permanent professionals are difficult to hire. Participants were enrolled when the hospital staff had the extra time it required to administer the questionnaire and draw the blood; accordingly the participation rate was higher outside the summer period when hospital staffing is at a minimum due to vacations. An unknown bias may have been introduced by the apparent omission of babies weighing less than 2400 g.

The concentrations of PCBs and pesticides in the blood of pregnant Greenlanders are high compared with Inuit from eastern Canada and in particular compared with concentrations found at lower latitudes (AMAP, 1998). The PCB congener patterns were similar to what has previously been found in fat tissue in the eastern Canadian Arctic and Greenland (Dewailly et al., 1995). Although studies on PCBs and pesticides were conducted in Greenland in the 1970s, these are not comparable to ours due to methodological differences, so the possible existence of a time trend cannot be shown.

Mercury concentrations in this study are at the same level as earlier reported in pregnant women from west Greenland (Bjerregaard and Hansen, 1996). Lead concentrations were approximately 50% lower than in 1982 (Hansen et al., 1984), which is consistent with the reported declining trend (Hansen et al., 1990). Cadmium has not been measured in pregnant women in Greenland before but the mean concentration is at the same level as earlier reported from non-pregnant individuals (Hansen, 1981) and consistent with the concept that smoking is the main determinant of the blood cadmium concentration. Previously registered selenium levels were measured in whole blood (Hansen et al., 1984) whereas in the present study they were measured in plasma. Consequently, the concentrations are not comparable.

Maternal age was strongly correlated with the concentration of POPs and less strongly with mercury. This correlation is partly due to the increased consumption of traditional, marine Greenlandic food by age (Bjerregaard and Young, 1998) but for POPs also to bioaccumulation. Consumption of marine mammals was positively correlated with concentrations of mercury and cadmium but not with POPs. As the meat and organs of marine mammals have high concentrations of mercury and cadmium this is expected. The absence of an association between marine diet and the concentration of POPs in our statistical model may be caused by the strong collinearity of age and diet; adjusting for age in the model masks the effect of diet. Finally, smoking was as expected significantly associated with cadmium concentrations.

In Greenland, a negative association has previously been shown between blood mercury concentration and birth weight (Foldspang and Hansen, 1990) but in a reanalysis of a more complete dataset this was disproved (Bjerregaard and Hansen, 1996). Studies from the Faroe Islands have found a positive correlation between birth weight and the intake of fish and whale meat which are sources of mercury (Olsen et al., 1986; Olsen, 1993). In the present study, no association was demonstrated between POPs or metal contaminants and birth weight or gestational length.

Birth weight and gestational length, however, are rather insensitive measures of health effects. Based on experimental and epidemiological studies, a number of negative health effects are expected from prenatal exposure to contaminants in the observed concentrations: neuropsychological development disturbances, alterations in sexual and functional development, and possibly cancer (Jacobson et al., 1990; Colborn and Clement, 1992; Ahlborg et al., 1995; Jacobson and Jacobson, 1996; Grandjean et al., 1997).

The presence of high concentrations of several contaminants in pregnant women and newborn children of Greenland and other Arctic areas has by now been extensively documented. Future epidemiological studies should aim at demonstrating possible health effects of prenatal exposure in carefully conducted cohort designs. Concomitant experimental studies of the effects of natural mixes of toxic compounds on animals will also contribute to our knowledge of health effects. Finally, a continued monitoring of concentrations of contaminants in humans and in the Arctic ecosystem will show whether human exposure is stable, decreasing or even increasing. It must, however, be born in mind that the POPs that have so far been found in human tissue in the Arctic are only a fraction of what is actually there; the presence of several toxaphenes has been confirmed and it is suspected that the numerous new compounds that are developed each year have found, or will eventually find, their way to the Arctic ecosystem and to human beings in the Arctic.

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