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Concentrations of mercury, selenium and lead in blood samples from mothers and their newborn babies in four Greenlandic hunting districts

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Earlier investigations carried out in Greenland have shown high exposure levels of mercury and lead to be present. The levels of mercury and lead are found not to be of immediate risk to adults, but both elements are able to pass the placental barrier and thereby influence foetal development. As the foetus must be regarded as most sensitive to environmental toxicants it was found necessary to carry out a follow-up investigation in order to elucidate foetal exposure.

This investigation was started in the fall of 1981 and continued until the end of 1982. Samples of venous blood were collected from women giving birth, and the foetal exposure was evaluated on the basis of samples of cord blood. Samples were taken at the local hospitals in the four districts of Upernavik, Umanak, Scoresbysund, and Angmagssalik. In total, 98 sample pairs were collected: 14 from Upernavik, 36 from Umanak, 17 from Scoresbysund, and 31 from Angmagssalik. At the time of sampling a questionnaire was filled out with information on the age of the mother, length of pregnancy, weight of child, smoking and eating habits of the mother.

All samples were analysed for mercury and lead contents. Furthermore, the selenium concentration was analysed, as in animal experiments this trace element has been shown to alleviate toxic effects of mercury and probably of lead, too.

The high exposure level of mercury in Greenland was confirmed in this study, too. A close correlation was found between the blood of mothers and children. The children's blood contains more mercury than that of the mothers, approximately 80% more. The highest concentration seen in a newborn baby was 177 µg/l, which is close to values found to have caused mercury intoxication during the Minamata episode in Japan.

Selenium concentrations were found to be correlated between mothers and children, but in a non-linear way. The concentration level was found to exceed that of mercury on a molar basis. This might constitute a protective effect, and explain that neither in Greenland nor in other places where marine food is an important part of the total diet, has mercury intoxication been found, except in cases such as the Minamata area in Japan, where a local mercury pollution was present. Still, the high concentration in babies must give rise to concern.

No correlation was found between mercury and selenium concentrations on an individual basis, neither in mothers nor in children. This indicates that the two elements pass the placental barrier independent of each other.

As seen in other investigations, lead was also shown to pass the placental barrier, and a significant correlation was found between the blood of mothers and of children, the mean concentration being approximately the same. The mean concentration level in mothers was a little lower than should have been expected from earlier investigations. This is probably due to the fact that the blood lead level decreases during pregnancy. As shown in earlier studies from Greenland, the blood lead level was found to be on the same level as that found in European industrial areas.

The present information on heavy metal exposure in Greenlandic hunting districts should be subjected to a closer evaluation as regards the influence on the health condition in the Greenlandic population now and in the future. Such material will be highly relevant to the understanding of the significance of the global pollution by heavy metals.

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Introduction

In a population survey carried out in West Greenland in 1979 (Hansen 1981), it was shown that the mercury exposure was closely related to the amount of marine food in the diet. Furthermore, that the exposure level, especially in the hunting districts, was so high that clinical effects can be anticipated. Regarding lead, all values were found to be on the normal level, below 35 μg/100 ml, which is the upper limit for non-occupationally exposed persons within the European Economic Community. Surprisingly, in general the blood lead level found in Greenland was on a level corresponding to what was found in West European industrial cities. This is so, even though no polluting industries and only minimal car traffic are present in Greenland. These tendencies for both mercury and lead were later confirmed in an investigation carried out in 1981 in the area of Angmagssalik in East Greenland (Hansen et al., 1983b). Because of the potential risk of the actual mercury exposure and the relatively high blood lead values, and furthermore, of the fact that the foetal stage is the period most susceptible to hazardous effects of toxicants like methyl mercury and lead on which the placenta has no barrier effect (Fehr & Dennis 1975; Galster 1976; Hower et al. 1975; Cavalleri et al. 1978), it was decided to carry out a follow-up investigation on cord blood and maternal blood, in order to get further information on metal exposure and to obtain better opportunities to evaluate health risks.

Selenium was included in the study because in animal experiments it has proved to have an antagonistic effect on methyl mercury toxicity (Iwata et al. 1973; Ohi et al. 1980; Stillings et al. 1974) and probably also on the toxic effect of lead. The most important source of selenium is marine food, which is at the same time the most important source of mercury. Consequently, it seems reasonable to suppose that at the same time as toxic metals accumulate in the natural food chain they will supply detoxificating substances of which selenium is an important element.

The investigation was carried out in four hunting districts: Upernavik, Umanak, Scoresbysund, and Angmagssalik, partly because the populations in these districts represent the most heavily exposed groups and partly because these districts will provide an opportunity to evaluate geographical differences.

Population study and methods

Metal exposure was evaluated from concentrations in samples of venous blood, taken from mothers giving birth and from the cord blood of the newborn children. These groups were chosen for investigation because of the fact that lead as well as mercury are able to pass the placental barrier, and hereby possibly to affect the foetal development. Because of this, foetal life is supposed to be the period in which the risk of environmental exposure of heavy metals causing damage in a population is most pronounced.

Samples were collected at the local hospital in the four districts and were taken in Terumo Venoject test tubes with heparin as an anticoagulant. All samples were sent for analysis as quickly as possible to the Institute of Hygiene, University of Aarhus. At the same time as blood samples were taken, a questionnaire was filled in containing information on date of sampling, age of the mother, smoking habits, number of weekly meals of marine food she would normally eat, length of pregnancy and weight of the child at birth.

Sampling started in October 1981 and continued until mid-December 1982. The aim was 120 samples, but during the sampling period only 98 samples were obtained. Distribution of samples from the individual districts is seen in Table 1.

Analytical procedure

Analyses of mercury, selenium and lead were performed by atomic absorption spectrometry. For mercury and selenium determinations a mercury hydride system was used, while lead analysis was performed in a heated graphite furnace with an automatic pipetting system. The methods of mercury and lead analyses and quality control procedures are described in earlier publications (Hansen et al. 1983a and b).

For selenium determination, 0.25 ml of full blood was placed together with 1 ml of nitric acid in a teflon decomposition bomb and heated to 150°C for 1 hour to remove organic matter.

Blank determinations were below the detection limit, which is 1 ng. As a sample size of 0.25 ml is used per analysis the detection limit corresponds to a blood concentration of 4 μg/l.

Table 1. Wanted and obtained number of samples from the four sampling districts.

District	Wanted no. of samples	No. of samples obtained	Samples from both mother and child	Mother only	Child only
Upernavik	10	14	13	1	
Umanak	50	36	31	1	4
Scoresbysund	10	17	17		
Angmagssalik	50	31	28	3	
	120	98	89	5	4

The analytical error was based on in duplo determinations found to be independent of concentration level and calculated to ± 6.5 μg/l or 10% at the 65 μg/l level improving to 4.3% at the 150 μg/l level.

For further check of analytical quality analyses were carried out on standard material, animal muscles and human hair obtained from IAEA, Vienna.

	IAEA value	Own lab.
Animal muscle	0.283 mg/kg	0.287 mg/kg
Human hair	0.350 mg/kg	0.340 mg/kg

For a further check, 10 samples of human serum were re-analysed at another laboratory, which performed a routine selenium analysis, using a fluorometric technique. A satisfactory correlation was found between the findings of the two laboratories, the coefficient of correlation being + 0.9950.

Six of the samples were only analysed for mercury, because by an error these samples were sent to a different laboratory. Furthermore, a few samples were damaged or partly coagulated when received at the laboratory, for which reasons analyses could not be carried out.

Pre-analytical washing was applied to hair samples (Petering et al. 1971) to remove external contamination. The analytical procedure for hair was otherwise identical with that for blood, using approx. 0.01 gram per analysis.

Results

Based on information from the questionnaires, mean values of age of mothers, length of pregnancies, and birthweights were calculated for the individual districts and are given in Table 2. As seen from the Table there is no significant difference between the four districts.

The distribution of the material regarding smoking and eating habits of mothers is given in Table 3. These parameters do not differ in the various districts either.

Table 2. Age of mother, length of pregnancy and weight of child at birth in the four districts.

District	Age of mother Years S.D.	Range	Length of pregnancy weeks S.D.	Birth weight of child g	S.D.	Range
Upernavik	24.0 ± 3.1	20–31	37.9 ± 2.0	3419	401	2480–3900
Umanak	24.1 ± 4.5	18–34	39.7 ± 0.9	3376	508	2500–4800
Scoresbysund	26.0 ± 6.6	17–40	39.8 ± 0.6	3252	320	2750–3900
Angmagssalik	24.5 ± 7.2	16–41	39.0 ± 1.6	3162	501	2100–4400

Table 3. Distribution of samples with regard to smoking and eating habits of mothers.

District	Eating habits No. of meals of seal/week 6	3–6	3	Not stated	Smoking habits Smokers	Non-smokers	Not stated
Upernavik	5	2	7		11	3	
Umanak	5	13	17	1	29	7	
Scoresbysund	2	4	7	4	12	1	4
Angmagssalik	5	10	13	3	24	4	3
	17	29	44	8	76	15	7

Table 4. Mercury concentrations in mothers and children in the four districts.

District	Mercury μg/l Mothers N	x̄	S.D.	Range	Children N	x̄	S.D.	Range	Children/ mothers
Upernavik	14	37.8	18.5	10–77	13	65.1	28.2	15–117	1.7
Umanak	32	24.3	13.7	6–57	35	42.5	23.6	7–110	1.8
Scoresbysund	17	10.4	5.4	1–21	17	19.2	13.9	1–53	1.9
Angmagssalik	31	38.7	22.7	7–87	27	59.4	38.5	8–177	1.5

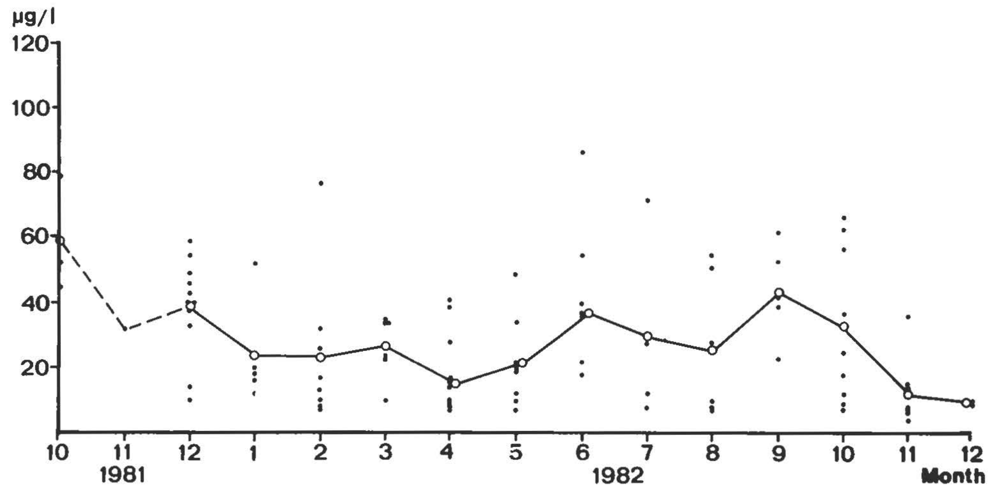

Fig. 1. Individual blood mercury concentrations in mothers according to sampling time, solid circles. Open circles, arithmetic monthly mean.

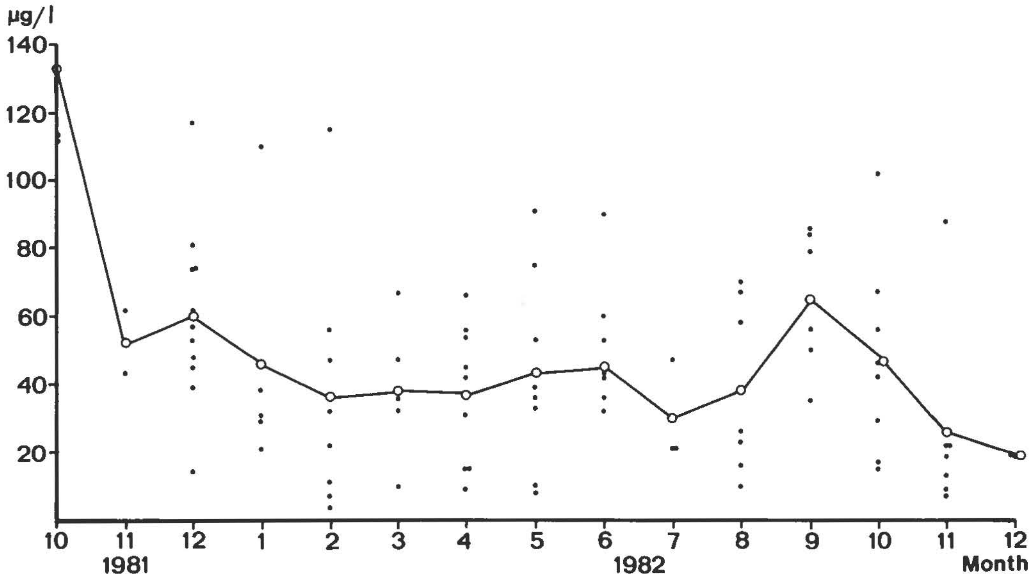

Fig. 2. Individual mercury concentrations in cord blood according to sampling time, solid circles. Open circles, arithmetic monthly mean.

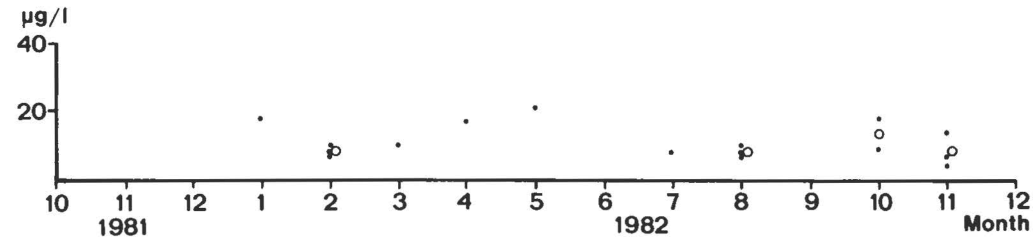

Fig. 3. Individual blood mercury concentrations in mothers from the district of Scoresbysund according to sampling time, solid circles. Open circles, arithmetic monthly mean.

Table 5. Levels of significance between differences in mean mercury concentrations in mothers and children in the four districts. d.f.: degrees of freedom.

Mothers \ Children	Upernavik	Umanak	Scoresbysund	Angmagssalik
Upernavik		t:2.6235 d.f.46 $p<0.02$	t:5.5593 d.f.28 $p<0.001$	n.s.
Umanak	t:2.4520 d.f.44 $p<0.02$		t:4.3439 d.f.47 $p<0.001$	t:2.0083 d.f.60 $p<0.05$
Scoresbysund	t:5.3570 d.f.29 $p<0.001$	t:5.0485 d.f.47 $p<0.001$		t:3.1978 d.f.42 $p<0.005$
Angmagssalik	n.s.	t:2.7551 d.f.61 $p<0.01$	t:6.6087 d.f.46 $p<0.001$	

Table 6. Concentrations of Hg, Se and Pb in mothers and children in relation to eating habits, arithmetic means and 1 S.D. indicated (numbers in brackets: number of samples).

Numbers of meals of seal per week	>6		3–6		<3	
	Mothers	Children	Mothers	Children	Mothers	Children
Hg	35.5 ± 22.9 (17)	58.6 ± 32.8 (14)	28.9 ± 18.5 (28)	46.7 ± 26.5 (29)	24.8 ± 18.1 (41)	37.6 ± 24.4 (41)
Se	258.3 ± 128.9 (16)	207.3 ± 131.4 (12)	246.2 ± 137.1 (27)	222.0 ± 134.2 (26)	210.7 ± 129.9 (40)	198.2 ± 135.9 (37)
Pb	8.1 ± 1.5 (16)	7.2 ± 2.3 (13)	9.2 ± 2.8 (23)	8.1 ± 2.3 (24)	7.8 ± 2.7 (39)	6.1 ± 2.4 (37)

Table 7. Selenium concentrations in mothers and children in the four districts.

District	Selenium µg/l								Children/ mothers
	Mothers				Children				
	N	x̄	S.D.	Range	N	x̄	S.D.	Range	
Upernavik	12*)	285.8	122.8	77–440	10*)	264.9	155.4	80–460	0.93
Umanak	32	281.1	112.5	76–540	31	238.8	132.4	38–550	0.85
Scoresbysund	17	194.6	108.1	84–820	17	170.8	101.4	36–420	0.88
Angmagssalik	27	151.0	122.2	34–468	22	129.2	100.1	28–456	0.86

*) Two extreme values omitted mother/child 1200/760 4600/2620.

Mercury

The results of the mercury analyses appear from Table 4. The relationship between mean concentrations in mothers and children is rather constant in the four districts (1.5–1.9) in spite of the fact that the levels are different.

The mean concentration of 10.4 µg/l found in the district of Scoresbysund is significantly lower than those in the other three districts. That of the district of Umanak is lower than both Upernavik and Angmagssalik, while the two latter districts are on the same level (cf. Table 5).

Figs 1 and 2 show that there is some variation in relation to time of sampling, but a clear seasonal variation is not demonstrated. The low concentrations in Scoresbysund cannot be explained as seasonal variations as samples from this district were taken during all times of the year (cf. Fig. 3). Thus, the results point at a lower exposure level in this district compared to the others.

The relationship between mercury concentrations in the mothers and their children is illustrated in Fig. 4. The relationship is approximately linear and can be described by the equation:

$$\text{Hg Child } \mu g/l = 6.35 + 1.46 \text{ Hg Mother } \mu g/l$$

The coefficient of correlation r = +0.8639 is significantly ($p < 0.001$) different from 0. The calculation is carried out on 88 sample pairs.

Fig. 4 also shows a curve published by Fehr & Dennis (1975) calculated on Canadian data. A satisfactory agreement between the child/mother relationships is seen in the two investigations.

When the material is subgrouped in terms of eating habits, as seen in Table 6, it appears that the highest mercury concentrations in mothers as well as in children are found in the group where the mothers have indicated that they eat seal more than 6 times per week, and lowest in the group with less than three meals per week. The difference is not so clear as in the earlier investigation carried out in Angmagssalik (Hansen et al. 1983a). The difference between the extreme groups is, however, significant for the children, but not for the mothers. The overall result corresponds to that found in women in the Angmagssalik investigation (Hansen et al. 1983a).

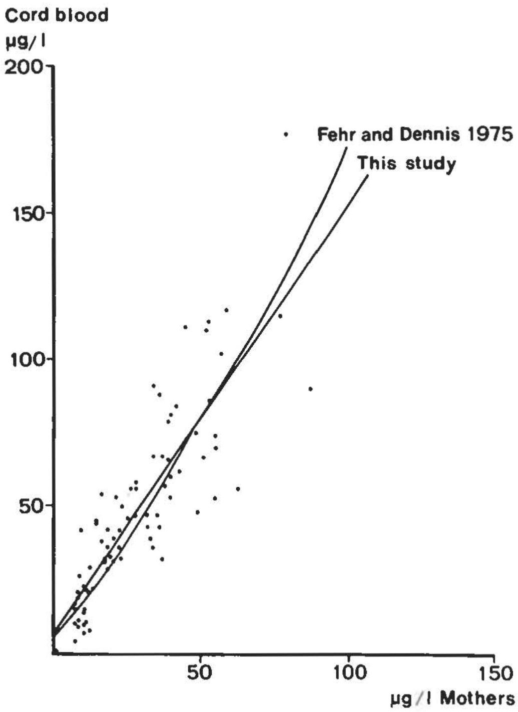

Fig. 4. Relationship between blood mercury concentrations in blood from the mothers and in cord blood.

Selenium

Table 7 shows the selenium concentration found in the four districts. It appears from the Table that the mean concentrations in the two western districts are higher than those found in the two eastern districts, while the two western and the two eastern districts are not different from each other. The difference in blood selenium concentrations between the eastern and western districts is significant for both mothers and children.

West Greenlandic mothers $\bar{x}$ = 282.4 µg/l, East Greenlandic mothers $\bar{x}$ = 167.8 µg/l t = 4.6383 d.f. 86 p <0.001.

West Greenlandic children $\bar{x}$ = 245.2 µg/l, East Greenlandic children $\bar{x}$ = 147.3 µg/l t = 3.6412 d.f. 78 p <0.001.

Selenium concentrations show a clear variation according to season in mothers as well as in children (Figs. 5 and 6), with a summer minimum and a winter maximum.

When the selenium concentrations in the blood of mothers and their babies are compared, a clear relationship is seen, and also that, in spite of the difference between eastern and western districts as to mean concentration level, the values are part of the same function

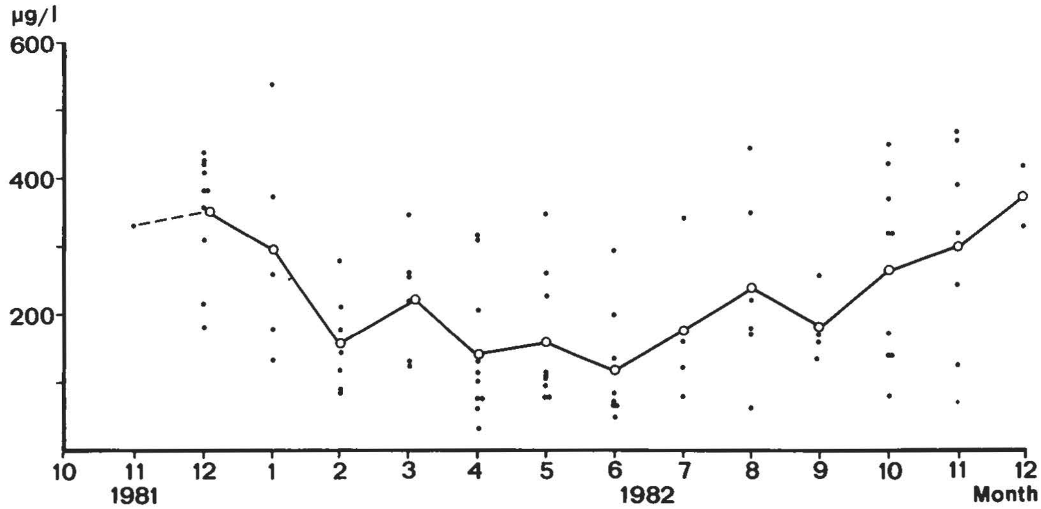

Fig. 5. Individual blood selenium concentrations in mothers according to sampling time, solid circles. Open circles, arithmetic monthly mean.

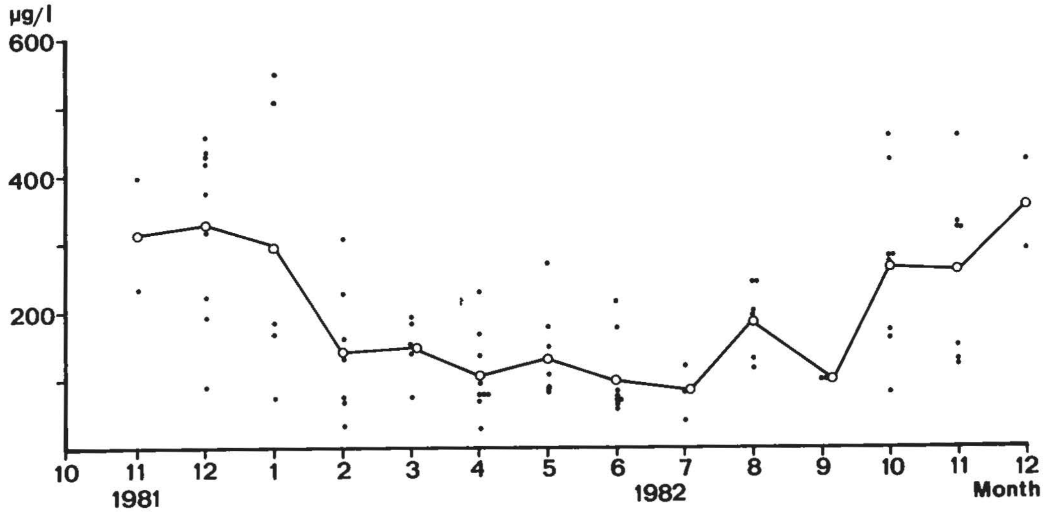

Fig. 6. Individual selenium concentrations in cord blood according to sampling time, solid circles. Open circles, arithmetic monthly mean.

as that shown in Fig. 7, where the concentrations in blood of mothers are plotted against concentrations in the blood of children. The relationship seems to be non-linear. The non-linear relationship is more clearly demonstrated in Fig. 8, where the values are grouped in intervals of 50 µg/l based upon the selenium concentrations in the blood of the mothers. It is not possible to transfer this curve to a straight line, and so the basis for carrying out a correlation analysis is not present. The curve indicates a plateau in the concentration of the children's blood corresponding to a concentration in the mothers' blood between approximately 100 and 400 µg/l, which is a concentration level found in selenium adequate areas.

From Table 7 it is furthermore seen that the children's blood in all districts contains less selenium than that of the mothers (85–91%).

The most important source of selenium is supposed to be marine food, and differences in selenium concentrations in relation to eating habits should be anticipated as shown in the Angmagssalik investigation. However, it

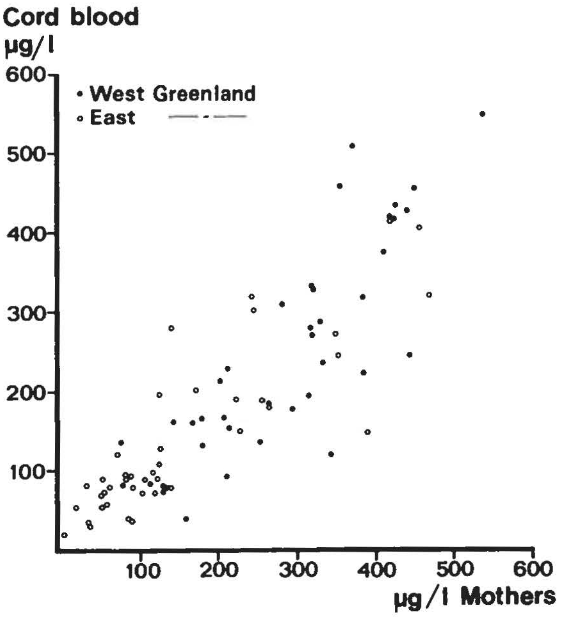

Fig. 7. Relationship between blood selenium concentrations in mothers and in cord blood.

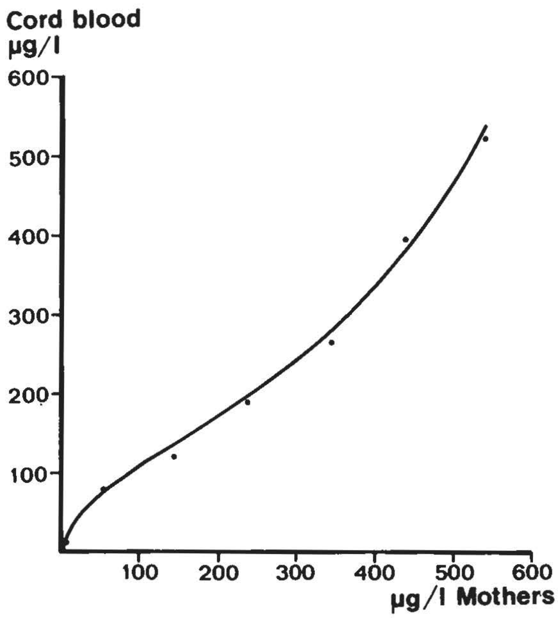

Fig. 8. Relationship between blood selenium concentrations in mothers and in cord blood. Grouped data in intervals of 50 µg/l according to concentrations in mothers' blood.

appears from Table 6 that there are only minor differences, which are neither significant in mothers nor in children. The overall blood selenium level found in this investigation is in satisfactory agreement with levels found earlier in the Angmagssalik investigation, where the samples were taken in May 1981 (Hansen et al. 1984).

The relationship between mercury and selenium

Because of the antagonistic effect of selenium on the toxicity of mercury, and because the two elements are supplied by the same source, i.e. marine food, it is important to investigate the relationship between the two elements. Through a calculation carried out on results from each district separately, it is seen (Table 8) that the two elements are positively correlated in both mothers and children in the West Greenland district, but not in the eastern districts. This is in agreement with the earlier Angmagssalik investigation, which also failed to demonstrate any relationship on an individual basis.

When the actual concentrations are transformed to molar concentrations as seen in Table 9, it appears that in all districts selenium is found in greater amounts than mercury. The selenium/mercury ratio varies considerably as seen from the table, being in all four districts approximately twice as high in the mothers as in the children. Furthermore, it is seen that this ratio is lowest in the district of Angmagssalik. A ratio of approximately 10 in mothers corresponds, however, closely to what was found earlier in the same district in women with corresponding selenium and mercury concentrations (Hansen et al. 1984). The difference in the selenium/mercury ratio between the districts shows that the two elements are taken up independently of each other, and the difference between mothers and children shows that the placental barrier can be passed independently by both.

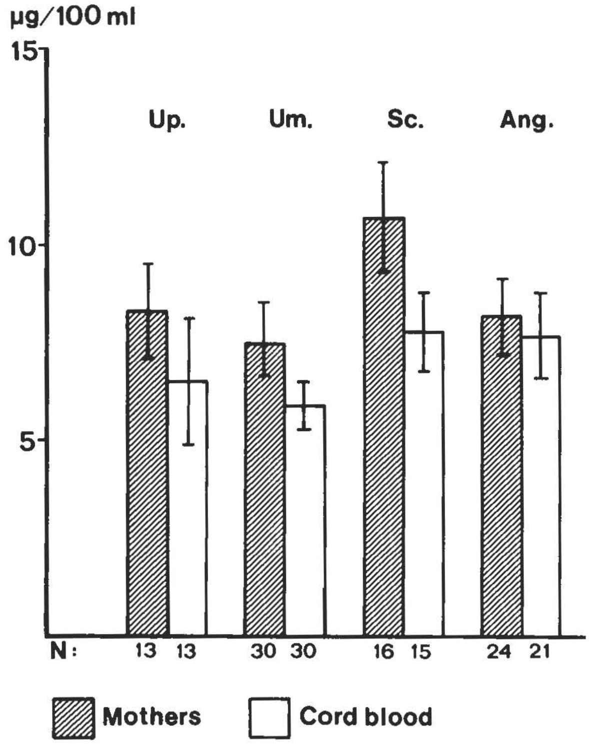

Fig. 9. Blood lead concentrations in mothers and in cord blood from the four districts. Mean and 95% confidence interval indicated.

Table 8. Relationships between mercury and selenium concentrations in mothers and children in the four districts.

District	Mothers: No. of pairs	Mothers: r	Mothers: t	Mothers: Level of significance P	Children: No. of pairs	Children: r	Children: t	Children: Level of significance P
Upernavik	12	+0.9143	7.1371	0.001	10	+0.7049	2.8109	0.025
Umanak	32	+0.5743	3.8422	0.001	31	+0.5495	3.5422	0.005
Scoresbysund	17	+0.3461	1.4288	N.S.	17	+0.4225	1.8054	N.S.
Angmagssalik	27	+0.0411	0.2064	N.S.	22	+0.0139	0.0632	N.S.

Table 9. Relationships between molar concentrations of selenium and mercury in blood from mothers and children.

District	Hg Mothers µ mol	Se Mothers µ mol	Se/Hg	Hg Children µ mol	Se Children µ mol	Se/Hg
Upernavik	0.189	3.811	20.2	0.326	3.532	10.8
Umanak	0.122	3.748	30.7	0.213	3.184	14.9
Scoresbysund	0.052	2.595	49.9	0.096	2.277	23.7
Angmagssalik	0.194	2.013	10.4	0.297	1.723	5.8

Table 10. Lead concentrations in mothers and children in the four districts.

District	Mothers N	Mothers x̄	Mothers S.D.	Mothers Range	Children N	Children x̄	Children S.D	Children Range	Children/ mothers
Upernavik	13	8.3	2.1	4.3–13.0	13	6.5	2.9	2.0–11.0	0.76
Umanak	30	7.5	2.8	2.5–15.4	30	6.0	2.0	2.2–11.0	0.80
Scoresbysund	16	10.7	2.2	6.1–15.0	15	7.8	2.1	3.5–11.2	0.73
Angmagssalik	24	8.2	2.2	4.8–13.3	21	7.7	2.6	3.3–12.9	0.94

Lead

In Table 10, the lead concentrations found are demonstrated. No great differences between the four districts were found, and it is furthermore seen from the Table that the children had lead concentrations just a little lower than those of the mothers, varying from 73 to 94%.

Fig. 9 shows as earlier proved to be true in West Greenland (Hansen 1981), that there is a tendency to higher values in the northern districts than in the southern ones. The differences are, however, only significant in mothers in the two eastern districts ($p < 0.001$). Mean values in mothers in Scoresbysund are also significantly higher than in Umanak ($p < 0.001$) and in Upernavik ($p < 0.005$). In the children the differences are less pronounced, but the mean value from Umanak is significantly lower than those from Angmagssalik ($p < 0.005$) and Scoresbysund ($p < 0.01$).

The observed lead concentrations are lower than those found in men from the West Greenlandic investigation (Hansen 1981) and in the Angmagssalik investigation (Hansen et al. 1983b) where it was found that the lead concentrations in women in relation to age could be described by the equation:

$$\log \text{Blood-Pb} (\mu g/100\ ml) = 0.9088 + (0.0067 \times \text{age (years)})$$

In an age group like that of the present investigation with a mean age of 24.6 years, a mean value of 11.8 μg/100 ml should be anticipated. The difference between the anticipated and actually found value cannot be explained through seasonal variations, because, as shown in Figs 10 and 11, such a thing does not exist. The difference may be due to the fact that blood lead levels decrease during pregnancy. Fig. 11 shows that in children a weak tendency to an increasing blood lead level was found during the period of investigation. The reason for this cannot be explained by the present data. The blood lead level in Greenland shown here corresponds to the

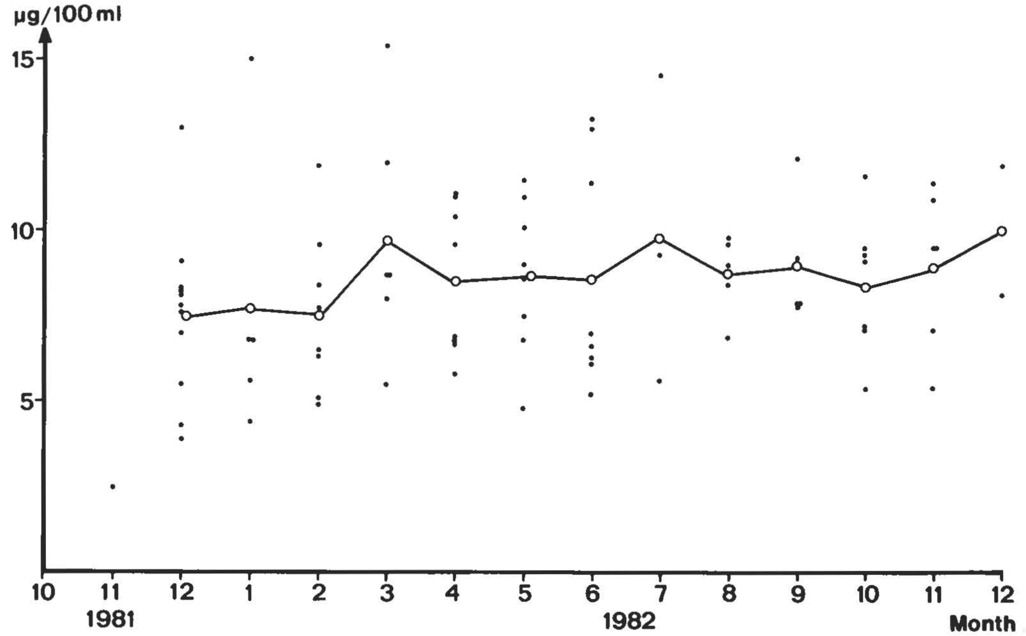

Fig. 10. Individual blood lead concentrations in mothers according to sampling time, solid circles. Open circles, arithmetic monthly mean.

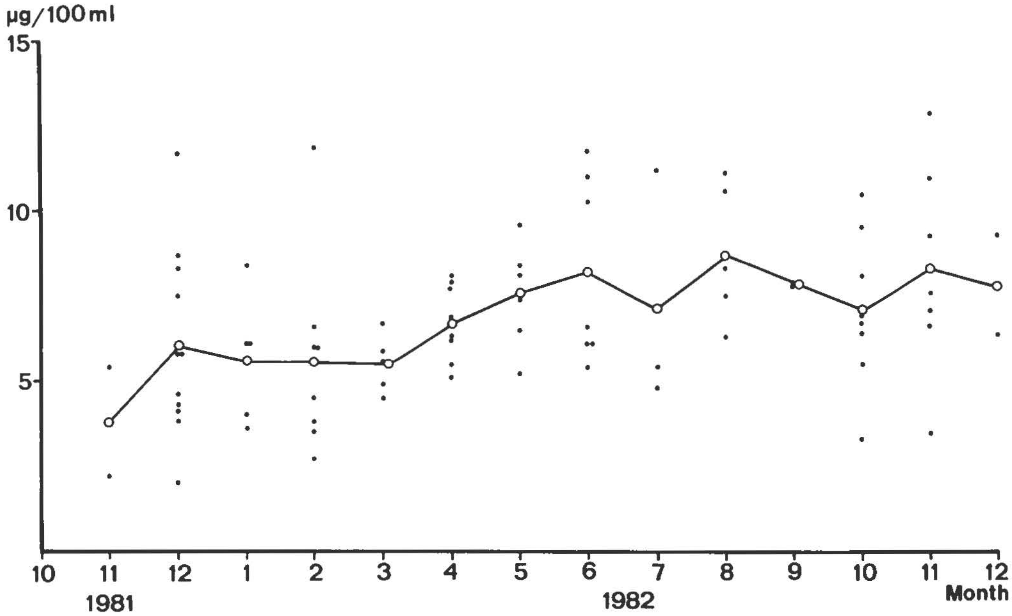

Fig. 11. Individual lead concentrations in cord blood according to sampling time, solid circles. Open circles, arithmetic monthly mean.

concentration in Danish non-pregnant women (Bach 1979).

The blood lead concentrations are found not to vary according to eating habits (Table 6). A significant correlation was found between lead concentrations in the blood of mothers and their children (Fig. 12). The correlation coefficient is + 0.5734, which is significant on the 0.5% level.

Blood lead levels in relation to smoking habits

A relationship between blood lead concentrations and smoking has been reported (Hasselblad & Nelson 1975;

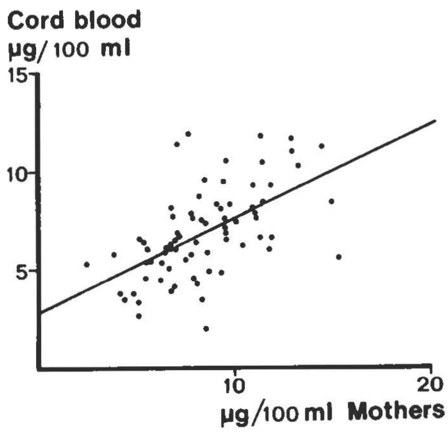

Fig. 12. Relationships between blood lead concentrations in mothers and in cord blood.

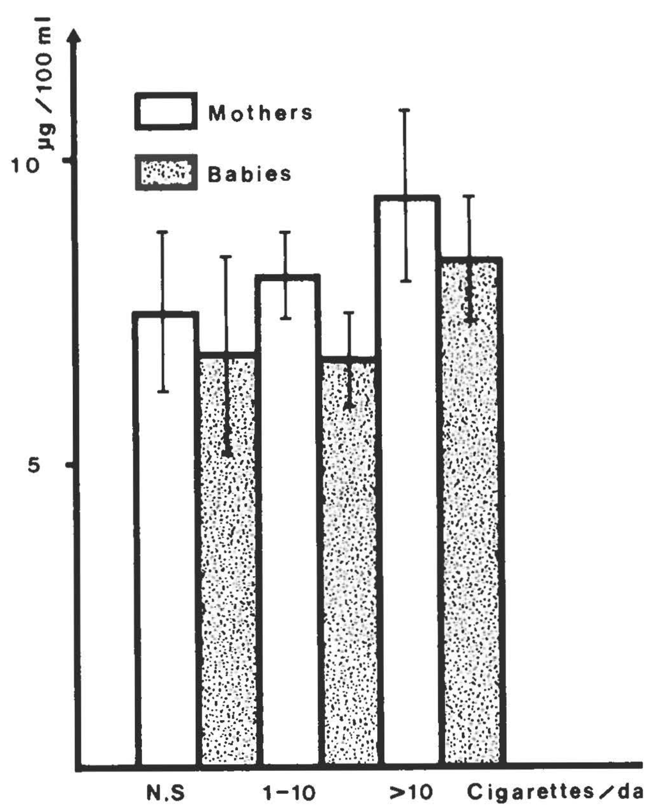

Fig. 13. Blood lead concentrations in mothers and babies according to smoking habits.

Tepper & Levin 1975). Alcohol consumption, which often parallels smoking may, however, be a confounding factor (Olsen et al. 1981).

There is an increase of blood lead in relation to the smoking habits of the mothers, the difference is, however, not significant (Fig. 13). As regards babies only the blood of those whose mothers smoked more than 10 cigarettes per day exhibit a higher (though not significantly) mean value (Fig. 13).

When the age dependency of blood lead concentrations was examined in the three smoking groups a significant relationship was found in the group of non-smokers ($r = + 0.6119$, $p < 0.05$) and in the group smoking 1–10 cigarettes per day ($r = 0.3264$, $p < 0.05$), whereas in the group smoking more than 10 cigarettes per day the correlation disappears ($r = + 0.0060$).

Birth weight

A low birth weight of babies whose mothers are heavy smokers has often been reported. In Greenland it has been found that babies born in East Greenland have a lower average birth weight than babies born in West Greenland (Jørgensen et al. 1982). This is partly supported in this study. As seen in Fig. 14, there is a lower mean birth weight of babies born by smoking East Greenlandic mothers than of babies born by West Greenlandic mothers who smoked. In non-smokers the reverse situation is found. None of the differences are, however, significant. The Figure also shows a relationship between birth weight of the babies and smoking habits of the mothers, but significance is attained only between babies of non-smoking and heavy smoking mothers in East Greenland ($p < 0.05$).

Discussion and toxicological evaluation

Because of the fact that most samples were partly haemolyzed at the time they were received at the laboratory, it has not been possible to separate the blood and carry out mercury determinations separately on plasma and cells. This could have provided some information on the nature of mercury exposure, as methyl mercury exposure gives a high cell-to-plasma ratio (approximately 10), while exposure to inorganic mercury compounds leads to a low ratio (approximately 1). Investigations from West Greenland showed clearly that the mercury exposure in Greenlanders is due to methyl mercury, which is in accordance with the fact that this form of mercury is mainly found in fish and marine mammals (Johansen 1982). For this reason it is supposed that in humans of the present study mercury is in the methylated form, too.

Placentally transferred methyl mercury is reported by several authors (Tejning 1968; Suzuki et al. 1971; Fehr & Dennis 1975; Amin-Zaki et al. 1976 and Galster 1976). All reports state that the blood concentrations in

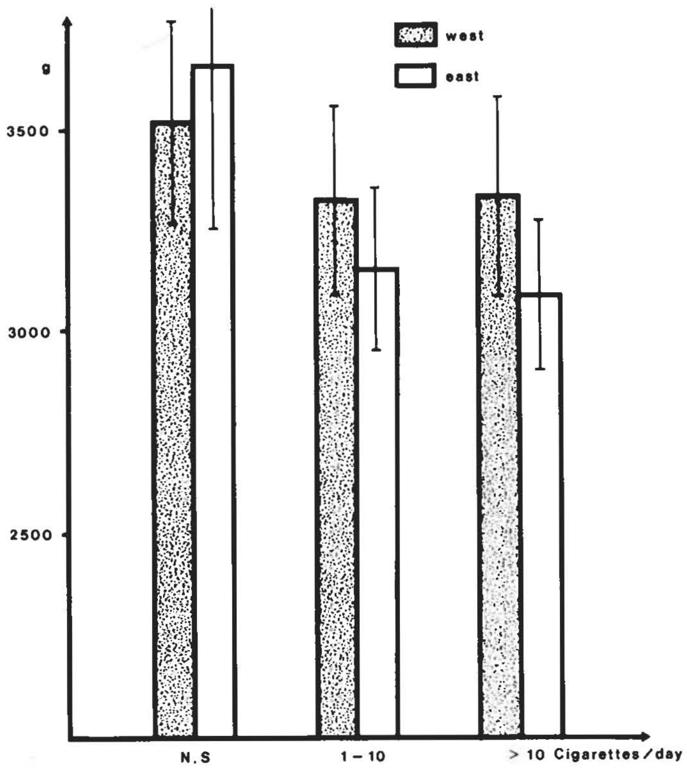

Fig. 14. Mean birth weight in West and East Greenland in relation to smoking habits. Mean and 95% confidence interval indicated.

newborn babies are higher than those of their mothers, even after correction for differences in haematocrit values. Fehr & Dennis (1975) indicated the relationship between mother and child by the equation:

Hg child = $0.0038x^2 + 1.3151x + 5.0670$
x = Hg mother

As seen in Fig. 4, the relationship found by Fehr and Dennis (1975) corresponds well with the results in the present study, i.e. that the relationship between mothers and children is the same as in the Canadian study. The concentration level in the Canadian study was, however, lower than that found in the present study, with mean values of 15.0 and 26.7 for Canadian mothers and children, respectively.

Clarkson et al. (1975) indicate, that the first signs of methyl mercury intoxication occur at blood concentrations between 200 and 600 µg/l in adults. As the foetus must be considered more sensitive to toxic effects than adults (Khera 1973), a blood concentration as high as 177 µg/l in a newborn child, as found in this study must give rise to concern regarding the present exposure level. Two clinical studies of population groups with a high mercury exposure through the diet resulting in high mercury blood concentrations had been negative in spite of the fact than in one study carried out in North Quebec, values as high as 306 µg/l (Bernstein 1974) were found. In another study carried out in Peru, the highest value was 275 µg/l (Turner et al. 1980). These studies were, however, carried out on adult populations. Information on the blood concentration level on which damage to the foetal tissues can occur is still lacking.

As a hypothesis it is presumed that mercury taken up by humans from the marine food chain is less dangerous than the equivalent amount of mercury taken up after direct pollution of foods. This hypothesis is supported by animal experiments which have shown that meat from marine mammals protects partly against toxic effects of methyl mercury (Ohi et al. 1980), and furthermore by the negative clinical findings in the above mentioned epidemiological investigations. An important factor in this difference in toxicity could be selenium. The antagonistic effect of selenium on the toxicity of methyl mercury is well documented in animal experiments (Iwata et al. 1973; Potter & Matrone 1974; Stilling et al. 1974), while information on interaction in humans is still lacking. Such data may, however, be available in the near future.

At present, the mechanism of interaction between the essential trace element selenium and the toxic methyl mercury is not known in details, but the selenium effect is not caused by an increased mercury excretion (Kristensen & Hansen 1980). In experimental animals, concomitant exposure to selenium and methyl mercury results in a change in the distribution of mercury compared to animals receiving only mercury. Alexander & Norseth (1979) and Mengel & Karlog (1980) have shown that selenium exposure increases brain concentrations of methyl mercury in rats.

Alexander & Norseth (1979) found a maximum brain retention when mercury and selenium were given in equimolar concentration or selenium in excess in relation to mercury. As in the Greenlandic blood samples selenium is found in excess of mercury, and assuming that the same reaction pattern is found in humans as in experimental animals, an increased retention of mercury induced by selenium in brains may be possible.

Animal experiments have shown, however, that an alleviation of toxic methyl mercury effects is obtained at a lower supply of selenium than in equimolar concentrations compared to mercury (Potter & Matrone 1974). Based on in-vitro experiments on rabbit blood Naganuma & Imura (1980) have shown the formation of bis-methyl-mercuric-selenide as the reaction product. Whether it is in this form methyl mercury is retained in organs, especially in the brain, is not known. Furthermore, very little is known of the toxicological effects of this mercury compound.

The selenium concentrations demonstrated in this study are high even on an international scale. They are especially much higher than those found in Scandinavia, which is a low selenium area (cf. Fig. 15). The Greenlandic blood selenium values are on the same level as, or even higher than those found in Americans, who are regarded to reflect adequate supplies. In this way the Greenlandic diet seems to supply optimum amounts of the essential micro-element selenium.

The amount of dietary selenium is not only important for the evaluation of the exposure to mercury, but also in the discussion of polyunsaturated fatty acids in connection with the characteristic disease pattern found in Greenland, as selenium, as part of the enzyme glutathione peroxidase, plays an important role in the metabolism of polyunsaturated fatty acids (Flohé et al. 1976).

Only few studies have been carried out to show the influence of selenium on placental transport of mercury. Parizek et al. (1969 and 1971) showed that selenium lowered the transport of inorganic mercury. Yokihiro et al. (1977) found that in rats selenium exposure decreased a foetal blood concentration of methyl mercury, while Satoh & Suzuki (1979) found that methyl mercury concentrations in the brains of mouse foetuses increased when selenium was co-administered. An investigation of mercury and selenium contents in umbilical cords from children born in the Minamata area during the intoxication period, showed that both elements appeared, but were individually uncorrelated (Nishigaki & Harada 1975). This observation is in accordance with the lack of correlation on an individual basis in the Angmagssalik (Hansen et al. 1983b) as well in the present study.

Plantin & Meurling (1980) in the blood of newborn Swedish children and their mothers have found 38 µg/l selenium in the former and 26 µg/l in the latter. This gives a child/mother ratio of 1.5, which is higher than

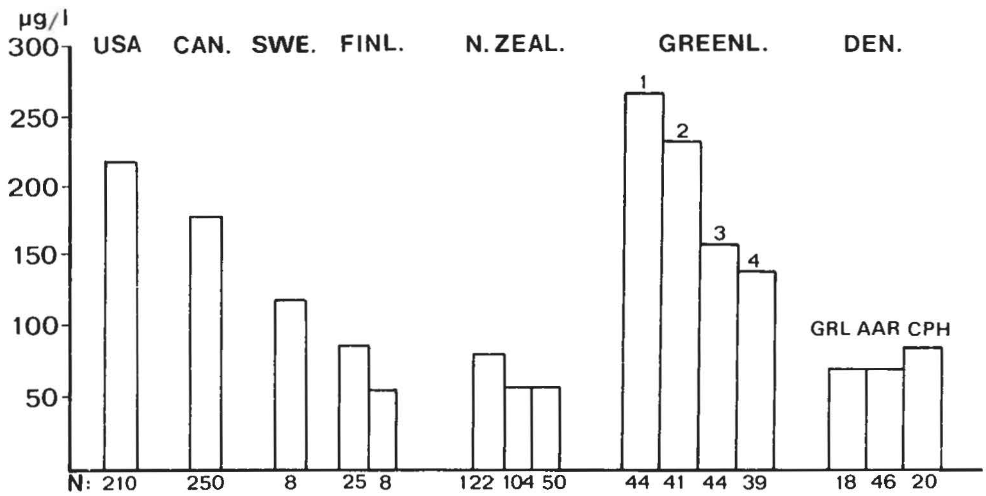

Fig. 15. Blood selenium concentrations in various areas. U.S.A. (Allaway et al. 1968), Canada (Dickson & Tomlinson 1967), Sweden (Brune et al. 1966), Finland (Westermarck et al. 1977), New Zealand (Robinson et al. 1978; McKenzie et al. 1978; Kay & Knight 1979), Denmark (Hansen, unpubl. data; Jensen et al. 1980). Values from Greenland: 1: mothers, western districts; 2: children, western districts; 3: mothers, eastern districts; 4: children, eastern districts.

the mean ratio found in this study, but is in accordance with the relationship shown in Fig. 8, i.e. that in the low concentration area the child/mother ratio is higher than 1.

In earlier Greenlandic investigations it has been shown that the blood lead level was surprisingly high and comparable to what was found in West European industrial cities. Placental transfer of lead is described by many authors (Gershanik et al. 1974; Hower et al. 1975; Kuhnert et al. 1977; Cavalleri 1978; Singh et al. 1978; Lauwerys et al. 1978; Rabinowitz & Needleman 1982).

As to the level demonstrated in women giving birth it is lower than blood lead levels in Greenland in general (cf. Hansen 1981; Hansen et al. 1983b). Whether this difference is caused by the fact that blood lead concentrations are declining during pregnancy or it is an expression of a generally decreasing tendency cannot be stated.

Corresponding investigations carried out in U.S.A. have shown an average blood concentration in newborn babies (approx. 12.000) of 6.56 µg/100 ml (Rabinowitz & Needleman 1982). In Belgium an average of 10.2 µg/100 ml was found in 503 women giving birth and of 8.4 µg/100 ml in the newborn babies (Lauwerys et al. 1978). So, there seems to be agreement between the Greenlandic values and values found in industrial areas. This corresponds with the earlier reports on lead exposure in Greenland.

The relatively high blood lead levels in Greenland have still not been explained, but could possibly be a result of long distance transport of airborne lead particles. Contrary to all expectations the atmosphere of arctic Alaska contains an abundance of pollution-derived aerosol, particularly during the winter term, which is in great contrast to the Antarctic (Murozumi et al. 1969). Studies in Barrow, Alaska by Rahn & McCaffrey (1980) have shown that its aerosol changes drastically from summer to winter, winter aerosol being at least an order of magnitude more concentrated than the summer aerosol. The seasonal variation is also known to happen in Spitsbergen, Bear Island, and Greenland, which indicates that the phenomenon is Arctic-wide and that transport from mid-latitudes to the Arctic is more effective in winter than in summer (Rahn & McCaffrey 1980).

According to Rahn & McCaffrey (1980) there are four main sources of atmospheric pollution in the Arctic, i.e. the Far East industrial areas (Japan, China, Korea), Central Sibiria, the north-eastern United States and Europe (Fig. 16). Rahn & McCaffrey (1980) regard Europe as the main source followed by the United States, while the Asian sources are regarded as being without significance to arctic pollution.

The European airstream moves to the north-east and into European Russia, from where it turns northward to the Arctic, splitting into two branches, one that flows southward along the east coast of Greenland and another that flows westward along northern Greenland and the Canadian arctic islands. The pathway from the north-eastern United States basically follows the jet stream through the Icelandic low, east of Greenland, with a branch around the western side of Greenland during periods when the Baffin Island low is strong. This model will also explain the pattern of higher blood lead concentrations found in East Greenland than in West Greenland and higher concentrations in the north than in the south of Greenland, as the northern areas are influenced by the strong European sources as well as by the American, while the southern parts of the coun-

Fig. 16. Transport of aerosols from industrialized areas to the Arctic (after Rahn & McCaffrey 1980).

try are only influenced by the American source. The studies of Murozomi et al. (1969) and Rahn & McCaffrey (1980) both indicate that a combination of midlatitude pollution and meteorological conditions can be responsible for the actual lead exposure level in Greenland.

This investigation confirms that the level of blood lead exposure in Greenland is the same as it is in the industrialized countries. Because of the potentially adverse health effects of environmental lead pollution, especially to children, efforts have been made in various countries to reduce the exposure of the general population to lead, in the first place by lowering the lead levels of petrol. In their study of 12000 samples of cord blood carried out in the period from April 1979 to April 1981 Rabinowitz & Needleman (1982) showed that in U.S.A. there is a decreasing tendency with a reduction of approximately 11% per year.

Prenatal lead poisoning has been observed by Singh et al. (1978) in a single case with biochemically demonstrated lead intoxication in a liveborn child. At birth, the blood concentration in the child was 50 μg/100 ml. So it is still far from this level down to the level shown to exist in Greenland today with a mean value of 12.9 μg/l Consequently there is hardly any risk in Greenland, but the exposure level must be evaluated on the same line as the lead exposure problems in the industrialized part of the world.

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Heavy metals Greenland 1981/82

Code to the table:

Column no.

1	District 1: Upernavik, 2: Umanak, 3: Scoresbysund, 4: Angmagssalik.
2 3	Sample no.
4 5	Year of sampling
6 7	Month of sampling
8 9	Date of sampling
10 11	Age of mother
12 13	Length of pregnancy/week
14 15	Birth weight of child, g × 100
16 17	No. of cigarettes smoked per day
18	Eating habits 1: more than 6 meals/week, 2: 3–6/week, 3: less than 3/week
19 20 21	Mercury in mothers blood µg/l
22 23 24	Mercury in cord blood µg/l
25 26 27 28	Selenium in mothers blood µg/l
29 30 31 32	Selenium in cord blood µg/l
33 34	Lead in mothers blood µg%
35 36	Lead in cord blood µg%

101811	204204	034063	040053	042604	360804
102811	210253	828103	014045	0184	0404
103811	210214	035053	055074	120007	600802
104811	210244	035103	040081	035804	600908
105811	218224	037201	046074	042404	180808
106811	217254	038002	059117	044004	300806
107811	218234	032063	038057	038402	241312
108820	219223	636101	077115	460026	200605
109820	222313	633003	026056	021402	280812
110820	301293	637041	035047	022201	540905
111820	311253	638001	034067	025601	380906
112820	407203	634 3	010015	007700	810706
113820	401253	639 2	014045	013200	801108
114820	427243	625101	041	0312	
201811	12320	31073	032043	033202	360305
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203811	203213	833002	033039	031401	940605
204811	205244	039003	043062	038403	200406
205811	12320	29103	062	03	98 02
206820	114254	041203	016038	037405	100606
207811	230274	035053	010014	021800	920704
208820	111204	034103	052110	054005	500706
209820	205194	036053	013022	018001	330504
210820	128274	033101	020031	013600	760704
211820	128224	030103	012021	018001	670404
212820	209224	035083	017032	028003	100706
213820	220334	048053	032047	014501	620503
214820	311334	030183	034036	026401	841506
215820	409264	033153	016054	020801	680708
216820	321214	034101	024	0350	06
217820	407294	040003	009042	007601	381006
218820	325214	03810	023032	013400	760805
219820	426244	034002	028056	032002	32
220820	514214	037003	010010	011600	84 05
221820	622204	135102	022042	029401	760605
222820	627283	827052	018036	020202	141310
223820	702284	037082	028047	034401	200605
224820	705203	830053	012021	016200	380905
225820	814184	030052	028058	044602	440706
226820	904294	028051	042084	0256	09
227821	015204	028072	012029	017201	600506
228821	014203	827002	025046	032002	720707
229821	023194	030101	037067	032002	800908
230821	031294	044202	057102	045004	561010
231821	119184	038062	006007	032003	281008
232821	203264	039051	009019	042004	200806
233821	201294	035052	010019	032802	881209
234820	922264	038072	035		
235820	824344	034003	016		
236820	914244	028032	056		
301820	10935		018029	026001	861508
302820	214		010007	008800	361007
303820	220		007004	012000	690704
304820	216		008011	009200	760811
305820	324404	036063	010010	012501	951207
306820	422283	931053	017031	011600	961108
307820	50921	34122	021053	022801	501208
308820	620324	039133	001001	008400	8406
309820	710254	028072	008021	012400	841511
310820	822244	031103	010023	017202	001011
311820	815184	037061	007010	035202	4409
312820	814173	832131	008026	022401	881008
313821	005224	031012	018042	042004	20 06
314821	117254	033082	014022	024403	201107
315821	124214	030203	004009	012801	281007
316821	023324	034002	009015	014002	801211
317821	125244	029103	007013	039201	481110
401811	0		053113		
402811	0		079177		
403811	0		045111		
404820	416184	033053	007015	006200	770705
405820	422274	029033	039066	010400	701007
406820	430184	023103	008009	003400	280606
407820	514193	732053	007	0079	09
408820	514 3	932043	049075	026401	801007
409820	524233	731003	012008	0096	05
410820	523224	029042	034091	010800	880910
411820	523293	8 103	022036	008000	9211
412820	522264	144003	019033	035002	740807
413820	523203	836042	020039	012401	080708
414820	601264	133202	040060	013600	761310
415820	611162	308031	055053	006800	690706
416820	617243	631201	087090	007200	721112
417820	626214	031103	036043	006800	580607
418820	630183	640022	037032	005100	660706
419820	721243	625042	072	0080	
420820	804223	934133	051067	018001	160808
421820	816413	621022	055070	006401	28 11
422820	905194	036102	023050	014001	0008
423820	903224	031102	062	021201	2012
424820	908244	029101	039079	0172	0808
425820	912244	030182	053086	016001	000808
426821	004174	033051	007017	008000	720707
427821	005224	040003	067	0140	09
428821	010224	030053	063056	036801	72 03
429821	106164	034003	008019	007201	200504
430821	111273	927131	036088	046803	200711
431821	129243	929072	015022	045602	56 13

1981

3. Jens C. Hansen:
"A survey of human exposure to mercury, cadmium and lead in Greenland". 36 pp.

Analyses of lead, mercury and cadmium in tissues from seal and fish have shown high concentrations of mercury and cadmium. A toxicological evaluation of the actual concentrations has revealed that in some districts of Greenland, the population may exceed the provisionally tolerable weekly intake (WHO, 1977) of cadmium with from 2 to 20 times and of mercury with from 2 to 40 times. Lead intake was below the provisionally tolerable weekly intake. As these high dietary intakes might have adverse health effects in the consumers, an investigation was undertaken in order to evaluate the human exposure as reflected in blood and hair concentrations. Five districts in Greenland and a control group of Greenlanders living in Denmark have been examined.

A total of 144 persons (including the control group) have participated.

Samples were taken in September and October 1979.

Mercury. Strong evidence was found for a connection between mercury exposure and seal-eating. The mercury levels found indicate that the exposure calculated from food analyses is overestimated, but still the most highly exposed groups are on an exposure level where subclinical effects may be anticipated.

Cadmium. In general the blood cadmium concentrations are higher in Greenland than in Denmark, but the groups in Greenland were found to be very similar. In hair concentrations no differences between the groups were observed. Separation of data on blood cadmium between smokers and non-smokers showed the differences between the mean values to be highly significant. In spite of the presumably higher dietary intake, no influence on blood concentrations could be observed. Contrary to blood, hair reflected dietary intake but not smoking. The results indicate that neither blood nor hair as only parameter reflects total cadmium exposure.

A positively significant correlation was demonstrated between lead and cadmium concentrations in hair, but not in blood.

Lead. Blood concentrations were found to be at the same level as found in Western European countries, but all to be below the limit of 35 μg/100 ml which is the upper individual limit in the EEC-countries.

The highest blood-values were found in the two northern districts, where the level is significantly higher than the level in the two southern districts. The difference was found to be related to varying eating habits, also smoking habits were found to be reflected in blood and hair. Blood was found to be a better index medium than hair for evaluating lead exposure.

Selenium. A potentially toxicity-modifying micronutrient selenium was determined in a limited number of hairsamples. No evidence of a high selenium intake could be provided.

Further research is needed especially concerning mercury exposure. Concerning lead and cadmium, the levels found are well below what is regarded a critical level. As, however, the concentrations are on the same level as those found in industrialized countries, follow-up studies seem to be needed in order to observe trends of exposure.

Instructions to authors

Manuscripts will be forwarded to referees for evaluation. Authors will be notified as quickly as possible about acceptance, rejection, or desired alterations. The final decision rests with the editor. Authors receive two page proofs. Prompt return to the editor is requested.

Alterations against the ms. will be charged to the author(s). Twenty five offprints are supplied free. Order form, quoting price, for additional copies accompanies 2nd proof. Manuscripts (including illustrations) are not returned to the author(s) after printing unless especially requested.

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All Greenland place names in text and illustrations must be those authorized. Therefore sketch-maps with all the required names should be forwarded to the Secretary for checking before the ms. is submitted.

Language. – Manuscripts should be in English (preferred language), French, or German. When appropriate, the language of the ms. must be revised before submission.

Title. – Titles should be kept as short as possible and with emphasis on words useful for indexing and information retrieval.

Abstract. – An English abstract should accompany the ms. It should be short, outline main features, and stress novel information and conclusions.

Typescript. – Page 1 should contain: (1) title, (2) name(s) of author(s), (3) abstract, and (4) author's full postal address(es). Large mss. should be accompanied by a Table of Contents, typed on separate sheet(s). The text should start on p. 2. Consult a recent issue of the series for general lay-out.

Double space throughout and leave a 4 cm left margin. Footnotes should be avoided. Desired position of illustrations and tables should be indicated with pencil in left margin.

Underlining should only be used in generic and species names. The use of italics in other connections is indicated by wavy line in pencil under appropriate words. The editor undertakes all other type selection.

Use three or fewer grades of headings, but do not underline. Avoid long headings.

References. – Reference to figures and tables in the text should have this form: Fig. 1; Figs 2–4, Table 3. Bibliographic references in the text are given as: Shergold (1975: 16) and (Jago & Daily 1974b).

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Journal: Macpherson, A. H. 1965. The origin of diversity in mammals of the Canadian arctic tundra. – System. Zool. 14: 153–173.

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Chapter (part): Wolfe, J. A. & Hopkins, D. M. 1967. Climatic changes recorded by Tertiary landfloras in northwestern North America. – In: Hatai, K. (ed.), Tertiary correlations and climatic changes in the Pacific. – 11th Pacific Sci. Congr. Tokyo 1966, Symp.: 67–76.

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