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Fish consumption and exposure to persistent organochlorine compounds, mercury, selenium and methylamines among Swedish fishermen

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Objectives This study assessed dietary habits and exposure to selenium, persistent organochlorine compounds, methylmercury, and methylamines among Swedish fishermen.

Methods Two hundred and fifty randomly selected subjects from a cohort of 2896 fishermen from the Swedish east coast (Baltic Sea) and 8477 fishermen from the west coast (Skagerrak and Kattegatt) were interviewed along with 250 referents. Subgroups of fishermen and referents from different coastal areas were also selected for blood and urine sampling.

Results The interview data showed that fishermen ate almost twice as much fish as the 250 referents from the general population. The blood levels of mercury were twice as high, and the plasma selenium levels were 10–15% higher in the fishermen than in the referents. There was, however, no difference between the fishermen's cohorts with respect to these variables. Fishermen from the east coast ate more fatty fish than fishermen from the west coast, and they also had higher blood levels of persistent organochlorine compounds such as polychlorinated biphenyls and polychlorinated dibenzo p-dioxins and furans (present in fatty fish species in the Baltic Sea) than both the westcoast fishermen and the referents.

Conclusions A cohort of Swedish eastcoast fishermen might be a suitable study base for epidemiologic studies on the mortality and cancer morbidity associated with dietary exposure to persistent organochlorine compounds.

Key terms fish consumption, polychlorinated biphenyls, polychlorinated dibenzo p-dioxins and furans.

Fish is an important food supplying essential trace elements and certain vitamins. The polyunsaturated n-3 fatty acids in fatty fish species are biologically important and have been associated with a decreased risk for cardiovascular diseases (1). In addition, fish contain fairly high levels of selenium (2), species of marine origin more than fresh-water fish, and they are considered an important source of selenium for the Swedish population (3). A low selenium intake, or low levels of selenium in blood, have been associated with increased risks for cancer (4) and ischemic heart disease (5, 6, 7).

However, fish can be contaminated with environmental pollutants, some of them having great toxic potential. Carcinogenic persistent organochlorine compounds such as polychlorinated biphenyls (PCB) (8), polychlorinated dibenzo-p-dioxins (PCDD), and polychlorinated dibenzofurans (PCDF) (9) are widely spread throughout the general environment. The levels of PCB in herring caught in the Baltic Sea are two to three times

higher than the corresponding levels in herring from the west coast of Sweden (10). In a recent study we found that the consumption of fatty fish from the Baltic Sea is an important source of exposure to different PCB congeners (11).

During the last decade, PCDD/PCDF have been found at surprisingly high levels in fatty fish such as herring and salmon from the Baltic Sea (12). In addition, for these substances, the levels in herring were two to three times higher in the Baltic Sea than in the Skagerrak, west of Sweden (10). We have also found a substantial impact on the blood levels of PCDD/PCDF from the consumption of fatty fish from the Baltic Sea (13).

Consumption of fish also causes exposure to methylamines. Under certain conditions dimethylamine (DMA) might form nitrosodimethylamine (NMDA), which is a potent carcinogen in a wide variety of animal species (14, 15).

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Consumption of fish is also an important source of exposure to methylmercury in humans (16, 17). Fish from some coastal areas of the Baltic Sea contain higher levels of methylmercury than fish from Kattegatt, Skagerrak, and the North Sea (18). Chromosome aberrations in humans have been reported after methylmercury exposure through fish consumption (19), but the epidemiologic data on human cancer risk from this exposure is still limited (20).

Swedish fishermen living in the southern part of the Swedish east coast had a higher consumption of fish than the average population in the same county (21). It is thus reasonable to use Swedish eastcoast fishermen as a study base for assessments of cancer incidence and mortality patterns associated with a high consumption of fatty fish from the Baltic Sea.

The objective of the present study was to assess the dietary habits and exposure to selenium, persistent organochlorine compounds, methylmercury, and methylamines among fishermen along the Swedish east and west coasts and among referents from the general population in the same regions. The cancer incidence and cause-specific mortality in Swedish east- and westcoast fishermen have been presented in a separate article (22).

Materials and methods

Study base and dietary interviews

One hundred and fifty fishermen from the east coast and 100 from the west coast were interviewed over the telephone about their food frequencies for 27 different food items, as well as for their coffee, tobacco, and alcohol consumption. Moreover, color pictures of three different sizes of fish portions of four fish species were distributed to the interviewed subjects beforehand, together with the questionnaire. They were asked which size most resembled their usual fish portion of cod (115, 190, or 300 g), herring (135, 225, or 360 g), salmon (135, 225, or 360 g), or flatfish (280, 545, or 865 g). The average weekly consumption was then calculated from the frequencies and portion sizes indicated. One hundred and fifty east-coast and 98 westcoast referents, matched with respect to gender, age, and county of residence, were randomly selected from the population register and interviewed in the same way.

The fishermen were randomly selected from those still alive in cohorts of 8477 fishermen from the west coast of Sweden, and 2896 fishermen from the east coast of Sweden. These cohorts have been described in detail elsewhere (22). Altogether 125 new selections had, however, to be made due to dropouts, 69 subjects refused to participate, 15 subjects were too old or too sick to be able to participate, and the remaining 41 could not be inter-

viewed due to various reasons. Altogether 132 new referents had to be chosen, mainly due to the same reasons as for the fishermen.

Blood and urine sampling

Subgroups of fishermen and referents from different coastal areas were selected for blood and urine sampling (table 1 and figure 1). The subgroups from the west coast and Baltic south were selected from the aforementioned interviewed subjects. The subsamples of fishermen from the Baltic proper and the Sea of Bothnia were, due to

Table 1. Subsamples of cohorts of Swedish fishermen from different coastal areas subjected to blood sampling.

Coastal area	Fishermen			Referents		
	Number	Age (years)		Number	Age (years)	
		Mean	SD		Mean	SD
West coast ^a	29	53.2	14.4	29	52.0	14.6
East coast						
Baltic south ^a	27	59.8	15.6	29	57.3	16.4
Baltic proper ^b	28	51.2	12.2	29	48.4	9.6
Sea of Bothnia ^b	29	54.9	10.7	32	48.7	9.2

^a Randomly selected.

^b Nonrandomly selected.

Figure 1. Coastal areas in Sweden where the blood and urine samples were collected from the fishermen and referents.

practical reasons, nonrandomly selected from the cohort members according to place of residence. As referents to these nonrandomly selected fishermen, subjects were recruited from major workplaces in the areas. The referents were a mix of blue- and white-collar workers not occupationally exposed to chlorine compounds or mercury. At the time of the blood sampling, these subjects were interviewed about their dietary habits with the technique already described. The age distributions in the subgroups of fishermen were similar to that of subjects still alive in the total cohorts.

Blood was collected in metal-free evacuated tubes (Venoject®) from a cubital vein with heparin as an anti-coagulant. Whole blood was used for the mercury analysis. For the assays of lipoprotein (a), selenium, and polychlorinated organic compounds, the samples were centrifuged at 2000 *g* for 10 min, and the supernatant was drawn off for further analyses. Plasma for analyses of persistent organochlorine compounds was stored in acetone-washed glass bottles at -20°C.

Overnight urine was collected in acid-washed bottles. Aliquots of 25 ml of urine were acidified with 5 ml of 5 M acetic acid and kept at -20°C until the analysis.

Lipoprotein (a) in plasma

In samples from each subject, lipoprotein (a) was determined with the routine immunochemical method used at the Department of Clinical Chemistry, University Hospital, Lund. Levels above 300 units · l⁻¹ (discrimination level) have been shown to be associated with an increased risk for cardiovascular diseases (23).

Mercury in blood

Mercury was determined in wet-digested samples using an automated cold vapor atomic absorption technique (24). For the determination of total mercury, blood (0.5 g) was digested with concentrated nitric (0.5 ml) and perchloric (2.5 ml) acids at 65°C overnight (25). Inorganic mercury was determined after digestion with sulfuric acid (3.0 ml, 16 M) (26). All of the samples were analyzed in duplicate.

The detection limit was 0.15 pmol (30 pg) per sample. The precision for the total mercury determinations, calculated as the coefficient of variation (CV) for the duplicate analysis, was 5% below 15 (mean 9.7) nmol · l⁻¹, and 3% in the range 15–76 (mean 30) nmol · l⁻¹. For inorganic mercury, the coefficient of variation was 9% below 3 (mean 1.5) nmol · l⁻¹, and 4% in the range 3–24 (mean 5.5) nmol · l⁻¹.

In an earlier study, the calculated difference between the total and inorganic mercury levels in whole blood, as determined by the methods used, showed a good correlation with the methylmercury levels determined by gas-

chromatography mass spectrometry (26). Thus what is referred to later on as methylmercury denotes the difference between total and inorganic mercury in whole blood.

Selenium in plasma

Selenium was determined fluorometrically (27). The detection limit was 0.04 µmol · l⁻¹ (3 µg · l⁻¹). All of the samples were analyzed in duplicate, and the coefficient of variation was 5%. Our average for a serum reference sample (Seronorm® trace elements, batch 112, Nycomed AS, Oslo) was 1.05 (SD 0.04) µmol · l⁻¹ (N = 18), as compared with the recommended 1.1 µmol · l⁻¹ (90 µg · l⁻¹).

Amines in urine

The dimethylamine (DMA), trimethylamine (TMA), and trimethylamine-*N*-oxide (TMAO) concentrations in urine were determined with gas-liquid chromatography (GLC) as described elsewhere (28). Creatinine in urine was determined with a modified kinetic Jaffé method (29).

Polychlorinated biphenyls, polychlorinated dibenzo p-dioxins and furans

From each of the stored glass bottles of plasma about 8 ml of plasma was drawn and pooled in new, acetone-washed Teflon® bottles in eight area pools according to table 1. These pooled samples were coded and sent for analysis to the Midwest Research Institute, Kansas City, Missouri, United States, where congener specific PCDD, PCDF and PCB were determined with high-resolution mass spectrometry (PCDD, PCDF, and coplanar PCB), and high-resolution gas chromatography with an electron capture detector (the major specific PCB isomers and total PCB). The analytical procedures were evaluated in a quality-control study organized by the World Health Organization, and the laboratory was considered qualified to analyze PCDD/PCDF and PCB (30).

Relative toxic potencies of the different PCB congeners, as compared with TCDD, expressed as toxic equivalents (TEQ), have been calculated according to the WHO interim model (31). For the different PCDD/PCDF, TCDD equivalents according to a Nordic Expert Group were used (32).

Statistical methods

The Mann-Whitney U-test was used for evaluating the group differences in blood levels of mercury and selenium and in dietary habits and alcohol and tobacco consumption. Chi-squared tests were used for investigating group differences in lipoprotein (a). Associations were

investigated by correlation coefficients (Pearson's *r*). The term "significant" refers to $P \pm 0.05$.

Results

Fish consumption

The intake of fish, expressed both as numbers of fish meals per week and as average weekly consumption of different fish species, was higher among the fishermen from the east coast than among their corresponding referents (tables 2 and 3). The eastcoast fishermen had a

higher intake of both fatty and lean fish species than the referents (table 2).

The fishermen from the west coast also had fish meals, both of fatty and lean species, more often than their referents (table 2). However, considering the fatty fish species salmon and herring, there were no differences between westcoast fishermen and the referents in the estimated average amount consumed of these species (table 3).

There were no differences in the total numbers of fish meals per week between the east- and westcoast fishermen (table 2). The two groups differed however as regards fish species consumed. The estimated average

Table 2. Food frequencies, alcohol consumption, and smoking habits of 150 fishermen from the east coast and 100 fishermen from the west coast, randomly selected from the cohorts, and 248 referents from the regional reference population, matched by age and gender.

	Fishermen					Referents					
	East coast (N = 150)		West coast (N = 100)		P-value ^a	East coast (N = 150)		P-value ^b	West coast (N = 98)		P-value ^b
	Mean	SD	Mean	SD		Mean	SD		Mean	SD	
Fish ^c	2.6	1.6	2.8	1.5	0.29	1.6	1.0	< 0.0001	1.5	1.1	< 0.0001
Lean fish	1.2	0.9	1.9	1.0	< 0.0001	0.8	0.6	0.0003	1.0	0.7	< 0.0001
Fatty fish	1.4	1.3	0.9	0.9	0.0002	0.8	0.8	< 0.0001	0.5	0.6	< 0.0001
Smoked fish	0.8	1.2	0.4	0.8	0.008	0.3	0.6	< 0.0001	0.2	0.6	0.04
Meat ^c	2.6	1.4	2.9	1.3	0.27	2.5	1.3	> 0.5	3.0	1.6	> 0.5
Bacon, sausages ^c	1.6	1.4	1.7	1.4	> 0.5	1.9	1.1	0.005	1.8	1.4	0.33
Fresh vegetables ^d	5.5	4.9	5.2	4.1	> 0.5	5.9	4.1	0.09	7.1	5.0	0.008
Potatoes ^c	6.4	2.2	6.2	1.6	> 0.5	5.3	1.9	0.0001	5.6	2.4	0.001
Fresh fruits ^d	6.2	5.7	7.3	5.5	0.04	6.3	4.6	0.32	7.5	5.4	> 0.5
Coffee ^e	5.6	3.7	5.4	3.6	> 0.5	4.2	2.5	0.001	4.1	2.7	0.004
Alcohol ^f	390	470	330	390	0.30	360	380	> 0.5	410	380	0.02
Smoking habits ^g	15.7	22.1	12.5	17.2	0.09	11.4	17.3	0.03	12.2	16.8	> 0.5

^a Comparison between the east- and westcoast fishermen.

^b Comparison between the fishermen and the referents.

^c Meals per week.

^d Weekly.

^e Cups per day.

^f Grams of alcohol per month.

^g Pack-years (1 pack-year = 20 cigarettes a day for one year or, eg, 10 cigarettes a day for two years)

Table 3. Estimated average consumption (grams per week) of four species of fish for 150 fishermen from the east coast, 100 fishermen from the west coast, and 248 referents, matched for age, gender and county.

	Fishermen					Referents					
	East coast (N = 150)		West coast (N = 100)		P ^a	East coast (N = 150)		P ^b	West coast (N = 98)		P ^b
	Mean	SD	Mean	SD		Mean	SD		Mean	SD	
Cod filet	161	145	270	214	< 0.0001	97	99	< 0.0001	128	138	< 0.0001
Flat fish	218	282	487	403	< 0.0001	99	148	0.0003	161	203	< 0.0001
Salmon	119	159	37	108	< 0.0001	54	90	< 0.0001	31	52	0.24
Herring	208	253	73	107	< 0.0001	103	121	0.0001	59	119	0.24

^a Comparison between the east- and westcoast fishermen.

^b Comparison between the fishermen and the referents.

weekly intake, for eastcoast fishermen, of the fatty fish species salmon and herring were about three times higher than for westcoast fishermen ($P < 0.0001$, table 3), who in turn had a higher consumption of lean fish species such as cod ($P < 0.0001$) and flat fish ($P < 0.0001$).

The referents from the east coast had, as a mean, 60% more fatty fish meals per week than the referents from the west coast ($P = 0.008$). There were, however, no differences between the reference groups as regards total number of weekly fish meals (table 2).

Among the interviewed eastcoast fishermen 28% had decreased and 15% had increased their fish consumption during the last 10–20 years, as compared with 28 and 29%, respectively, among the referents ($P = 0.05$). The corresponding proportions among the westcoast fishermen and their referents were 47 and 14%, and 22 and 26%, respectively ($P = 0.0001$).

There was no difference in the total intake of fish of fishermen who were selected randomly and nonrandomly from the east coast, subjected to blood and urine sampling. However, considering fatty fish species, those non-randomly selected had slightly more meals per week than those randomly selected (1.9 versus 1.4; $P = 0.01$).

The difference in estimated amounts of fatty fish consumed was even less impressive, 383 g a week versus 327 g a week ($P = 0.07$).

Other dietary habits and coffee, alcohol and tobacco consumption

The eastcoast fishermen consumed more potatoes and coffee than the eastern referents (table 2). The lifetime cigarette consumption was increased by about 40% among the eastcoast fishermen, as compared with their referents.

In addition, the westcoast fishermen drank more coffee and ate more potatoes than their referents. The referents, on the other hand, ate fresh vegetables more often than the fishermen, and they also drank more alcohol. The smoking habits were similar.

The eastcoast fishermen consumed less fresh fruit than the westcoast fishermen ($P = 0.04$). Otherwise there were no differences in food frequencies between the two groups of fishermen. The referents from the west coast had a higher intake of meat ($P = 0.03$) and fresh vegetables ($P = 0.04$) than the referents from the east coast (table 2).

Lipoprotein (a) in plasma

In both groups of fishermen equal proportions of the members (27%) had plasma lipoprotein (a) levels above 300 units $\cdot$ l⁻¹. There were no statistically significant differences between the fishermen and the reference groups in numbers of subjects with lipoprotein (a) levels above this discrimination level.

Selenium

The fishermen had 10–15% higher plasma selenium levels than their referents ($P = 0.0001$ and 0.0002 , respectively; 8 fishermen and 11 referents on selenium tablets were excluded from the comparison) (figure 2). There were no differences in plasma selenium between the east- and westcoast fishermen or between the two reference groups. In a joint analysis of all fishermen and referents, plasma selenium correlated positively with the total intake of fish ($r = 0.26$; $P = 0.0001$).

Methylmercury

The blood levels of methylmercury were twice as high among the fishermen from both the east- and the westcoast as among their corresponding referents ($P = 0.0001$ and $P = 0.0001$, respectively) (figure 2). There were no significant differences in the methylmercury levels, either between east- and westcoast fishermen or between the reference groups. The methylmercury levels correlat-

Figure 2. Levels of methylmercury in blood and selenium in plasma in samples from fishermen and referents from different Swedish coastal areas (10, 25, 50, 75 and 90 percentiles indicated).

ed with the estimated total intake of fish ($r = 0.52$; $P = 0.0001$) in the joint group of fishermen and referents.

Methylamines

There were no significant differences in the urinary concentrations of DMA ($P = 0.21$), TMA ($P = 0.11$), or TMAO ($P = 0.08$) between the eastcoast fishermen and the eastcoast referents (figure 3). The fishermen from the west coast, however, had a median level of TMA that was twice as high as that of their referents ($P = 0.0001$), and also median levels of TMAO and DMA that were 40 and 20% higher, respectively, than those of the referents ($P = 0.02$ and $P = 0.01$, respectively). Furthermore, the fishermen from the west coast had almost twice the excretion of TMA in urine ($P = 0.0001$) as compared with the eastcoast fishermen (figure 3). For DMA and TMAO there were no significant differences between the two groups of fishermen ($P = 0.07$ and $P = 0.12$, respectively).

Polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins and furans

Plasma levels of PCDD/PCDF congeners with high toxicity (eg, 2,3,7,8-tetrachlorodibenzo-p-dioxin and 2,3,4,7,8-pentachlorodibenzo-furan) were two to six times higher in the three pooled plasma samples from the eastcoast fishermen than in the pooled sample from the westcoast fishermen (table 4). The levels of these congeners in the pooled sample from the westcoast fishermen were equal to the ones in the pooled sample from the westcoast referents. All three samples from the eastcoast fishermen had higher (doubled or more) PCDD/PCDF levels than the corresponding reference samples.

The eastcoast fishermen also had higher levels of non-ortho PCB (at the most two to threefold) than the westcoast fishermen (table 5). The plasma levels of the non-ortho PCB were in the same magnitude for the westcoast fishermen and the four reference groups. Furthermore, levels of other PCB were higher among the eastcoast fishermen than among those from the west coast (table 5). The sum of the PCDD/PCDF and the PCB, expressed as the TEQ, were about two times higher in the samples from the eastcoast fishermen than in that from the westcoast fishermen (table 6). The eastern fishermen had about a two times higher total TEQ than their local referents, but the total TEQ for the western fishermen was of the same magnitude as that for their local referents.

Discussion

The dietary interviews showed that fishermen from both groups had significantly higher fish consumption than

Figure 3. Urinary concentrations of dimethylamine (DMA), trimethylamine (TMA), and trimethylamine-N-oxide (TMAO) in samples from fishermen and referents from different Swedish coastal areas (10, 25, 50, 75 and 90 percentiles indicated).

their referents. This finding was reflected by the higher levels of selenium and methylmercury among the fishermen. Fishermen from the east coast had a higher intake of fatty fish than the fishermen from the west coast, who in turn had a higher intake of lean fish. This finding was in accordance with the fact that the blood levels of highly fat-soluble persistent organochlorine compounds (PCDD/PCDF and PCB) were higher in the eastcoast fishermen than in the fishermen from the west coast.

The plasma selenium levels were in accordance with those previously reported from Sweden (33, 34, 35, and

Table 4. Lipid-related plasma levels (pg · g lipid⁻¹) of PCDD/F, with chlorine in the 2,3,7,8 positions, in eight pooled blood samples from fishermen and referents living in different coastal areas in Sweden. (TCDD = tetrachlorodibenzo-p-dioxin, PeCDD = pentachlorodibenzodioxin, HxCDD = hexachlorodibenzodioxin, HpCdd = heptachlorodibenzodioxin, OCDD = octachlorodibenzodioxin, TcCDF = tetrachlorodibenzofuran, PeCDF = pentachlorodibenzofuran, HxCDF = hexachlorodibenzofuran, HpCDF = heptachlorodibenzofuran, OCDF = octachlorodibenzofuran, ND = below the detection limit)

Compound	Sea of Bothnia		Baltic Proper		Baltic South		West coast	
	Fisher-men	Referents	Fisher-men	Referents	Fisher-men	Referents	Fisher-men	Referents
2,3,7,8TCDD	27	6.1	6.9	4.0	17	6.4	5.7	4.0
1,2,3,7,8PeCDD	35	12	20	10	33	14	11	13
1,2,3,4,7,8HxCDD	6.2	4.2	4.6	3.4	8.8	5.8	4.9	ND
1,2,3,6,7,8HxCDD	66	38	44	32	75	53	36	34
1,2,3,7,8,9HxCDD	12	6.6	ND	5.7	ND	8.5	6.0	ND
1,2,3,4,6,7,8HpCDD	84	67	58	58	110	100	54	85
OCDD	551	574	351	364	585	605	367	553
2,3,7,8TCDF	4.8	ND	ND	ND	4.8	2.6	ND	ND
1,2,3,7,8PeCDF	ND	ND	ND	ND	ND	ND	ND	ND
2,3,4,7,8PeCDF	198	40	110	41	163	59	47	42
1,2,3,4,7,8HxCDF	ND	5.9	9.7	7.0	19	10	8.0	8.9
1,2,3,6,7,8HxCDF	ND	6.8	12	7.0	23	10	8.0	9.6
2,3,4,6,7,8HxCDF	5.0	ND	4.0	2.6	7.3	ND	3.0	4.8
1,2,3,7,8,9HxCDF	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,4,6,7,8HpCDF	16	19	16	15	31	20	14	18
1,2,3,4,7,8,9HpCDF	ND	ND	ND	0.8	ND	ND	ND	ND
OCDF	ND	ND	ND	3.2	ND	6.8	2.9	3.2

Table 5. Lipid-related plasma levels of different PCB (polychlorinated biphenyl) congeners in eight pooled blood samples from fishermen and referents living in different coastal areas in Sweden. (ND = below detection limit)

PCB ^{a, b}	Sea of Bothnia		Baltic Proper		Baltic South		West coast	
	Fisher-men	Referents	Fisher-men	Referents	Fisher-men	Referents	Fisher-men	Referents
Non-ortho PCB (pg · g ⁻¹)								
77	216	236	165	111	206	79	153	151
126	612	256	560	329	1050	437	368	282
169	555	183	608	216	907	308	292	180
Mono-ortho PCB (ng · g ⁻¹)								
105	32	10	22	14	40	18	16	10
118	120	36	82	52	167	77	65	61
156	76	37	68	39	108	59	59	41
Di-ortho PCB (ng · g ⁻¹)								
128	60	16	36	17	76	29	27	17
138	307	114	216	117	442	88	186	123
153	541	216	415	226	836	345	336	234
170	246	126	209	125	306	172	165	127
180	476	200	396	220	661	347	290	212
Other PCB (ng · g ⁻¹)								
74	34	13	29	30	52	38	25	21
99	60	18	41	28	71	33	31	21
101	60	52	35	31	23	21	25	18
183	57	21	40	22	82	34	30	22
187	129	50	107	55	202	76	80	50
Total (ng · g ⁻¹)	2200	908	1696	976	3067	1337	1336	956

^a The non-, mono- and di-ortho congeners indicated are also chlorinated in both *para* and at least two *meta* positions.

^b By IUPAC number (IUPAC = International Union of Pure and Applied Chemistry).

Schütz et al, unpublished report). An association between plasma selenium and fish intake has also been found in other studies (17, 35, 36, and Schütz et al, unpublished report). The impact on plasma selenium levels from fish consumption is, however, limited, with a 10–15% difference between fishermen and referents. A

similar effect was seen in a “fish-feeding” study (37), where intake of 150–200 g of fish per day for 11 weeks resulted in a 13% rise in plasma selenium.

The chemical form of selenium in fish is virtually unknown (2). Furthermore, information on the absorption of selenium from fish and its bioavailability is either

Table 6. Total plasma levels of polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/PCDF) and polychlorinated biphenyls (PCB), expressed as the Nordic toxic equivalents (TEQ) for PCDD/PCDF and as WHO interim TEQ for PCBs (pg · g lipid⁻¹) in eight pooled blood samples from fishermen and referents living in different coastal areas in Sweden. (WHO = World Health Organization)

TEQ	Sea of Bothnia		Baltic Proper		Baltic South		West coast	
	Fisher-men	Referents	Fisher-men	Referents	Fisher-men	Referents	Fisher-men	Referents
PCDD/PCDF	154	40	80	37	131	54	42	39
Non- <i>ortho</i> PCB	67	28	62	35	114	47	40	30
Mono- and di- <i>ortho</i> -PCB	83	38	69	41	112	60	57	42
Total	304	106	211	113	357	161	139	111

lacking or inconclusive (38). However, no previous data indicate that the fat content of the fish is of any importance for the dietary load of selenium. Consequently no difference in plasma selenium levels was seen between east- and westcoast fishermen, in spite of the discrepancy in fish species consumed.

The fishermen, with a consumption of fish twice as high as the local referents, had methylmercury levels in blood that were twice as high as those of the referents. Out of the total mercury in blood, only a minor fraction was inorganic (10 and 14% in fishermen and referents, respectively), and thus the main part was probably methylmercury. The present data support the earlier findings indicating that methylmercury intake through fish is a major source of mercury exposure in the Swedish population. The mercury concentrations were in accordance with those found in other studies of Swedes, by use of the same (or similar) analytical technique (33, 35, 36, 39, and Schütz et al, unpublished report).

The mercury levels determined in our study were, however, far lower than recorded for Swedish "fish-eaters" during the 1960s and 1970s (19, 40). This is probably a result of dietary recommendations and decreasing methylmercury levels in fish, as a result of reductions in mercury pollution.

The measured urinary levels of methylamines agreed with the limited information on the concentrations of these amines in humans (28, 41, 42). The higher levels of amines in the marine fish from the west coast, as compared with those of the brackish-water fish from the Baltic Sea (43), are the most probable explanation for the observed difference in amine excretion between the east- and westcoast fishermen.

The eastcoast fishermen had higher blood levels of PCDD/PCDF and PCB, expressed as the TEQ, than the westcoast fishermen, who in turn had blood levels of these substances of the same magnitude as the referents from both the east and west coast. The levels of the organochlorine compounds were thus related to the estimated exposure to these compounds from fatty fish consumption.

The levels of PCDD/PCDF in the pooled plasma samples from the eastcoast fishermen were systematically higher than those previously found among high consumers of fish from the Baltic Sea (13). However, the analyses have been performed at different laboratories. The laboratory used in the previous study (13) re-analyzed the pooled plasma samples from the Sea of Bothnia and the west coast in the present study. The level of PCDD/PCDF found, expressed as the TEQ, was very similar to that previously measured for high consumers of fatty fish from the Baltic Sea, and this level was about four times higher than that found in our westcoast sample.

For the non-*ortho* PCB, the levels were in reasonable accordance with those found in another study on high consumers of fish from the Baltic Sea (11). Overall agreement was also found between the levels of the mono-*ortho* and other PCB in our pooled plasma samples and those previously reported (11), with the exception of the PCB congener IUPAC 153, which was lower than before.

The most essential findings in our study were that the dietary intake of fatty fish from the Baltic Sea was substantially higher among the eastcoast fishermen than among both the westcoast fishermen and referents from the general population and that this difference was reflected in corresponding differences in plasma levels of persistent organochlorine compounds.

It is thus justified to use the eastcoast fishermen as a study base for assessing cancer incidence and cause-specific mortality in association with a high dietary intake of persistent organochlorine compounds (22).

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