Levels of persistent organic pollutants (POPs) in a coastal northern Norwegian population with a high fish-liver intake

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Introduction

Cod-liver and fresh cod liver-oil are rich in fat-soluble vitamins and essential fatty acids [1] and have traditionally been the most important vitamin D source for the coastal population in Northern Norway during the winter months.[2] Dietary sources of vitamin D are essential at these latitudes since the sun-induced vitamin D production ceases for a considerable part of the year.[3;4] Traditionally, human consumption of fish liver follows the seasonal harvest and came mainly from cod and saithe. The cod-liver season is connected with spawning time and lasts about three months during winter; usually from January to March/April when vitamin D in the population is low. Saithe-liver is mostly consumed from late summer until September/October. Despite the clear evidence of beneficial effects, the health benefits *vs.* health risks (mainly due to contents of POPs and mercury in marine food items) has been debated [5;6].

Un-published data from the nationwide NOrwegian Women And Cancer study (NOWAC) [7] has shown that there are still places where fish-liver and fresh fish liver oil are consumed frequently. The coastal municipality of Skjervøy, which is situated at 70^0 degrees north, was among the places that ranked highest on frequency of consumption. In this municipality, 50 % of the participants reported eating fish liver and fish-liver oil, also known by its Norwegian name, “Mølje”, 2 –3 times per month or more.

In 2003, the Norwegian Food Control Authority recommended that all women of childbearing age, pregnant women and children should avoid eating fish liver. This recommendation was based on estimated levels of dioxins and dioxin like compounds in the cod liver.[8] The decision was made to avoid exceeding the EU-recommendation for tolerable weekly intake (TWI) of 14 pg TEQ/kg bodyweight for the most vulnerable groups of the population (the unborn and newborn). There is also a fear of increased levels of all POPs due to fish liver consumption.

The aim of this study was to assess levels of POPs in human plasma in relation to fish liver consumption and other known predictors of POPs in a coastal rural northern Norwegian population with high intakes of cod liver.

Methods and materials

The participants for this present study were collected through the nutrition survey “Vitamin D security in northern Norway in relation to marine food traditions”.[3] Thirty-two volunteers, 21 men and 11 women aged 38-61 enrolled to take part in the study.

The participants answered the NOWAC study food frequency questionnaire, which was used to estimate usual daily nutrient intake.[3] This questionnaire has been described in detail elsewhere and has previously been validated.[9-11] However, the section concerning fish-liver consumption was extended from the original NOWAC questionnaire. In this new version, we discriminated between cod-liver and saithe-liver consumption and higher amounts and frequency categories were added. The blood samples collected from fasting individuals in the vitamin D study[12] were also analysed for selected POPs and assessed in a cross sectional design and constitute the material for this study. The project was approved by the Regional Committee for Research Ethics (Northern Norway region), and all subjects signed a consent form.

The samples were analysed using a semi automated solid phase extraction method described in detail elsewhere.[13] In short 2 ml of sample were spiked with C13 internal standards, extracted on a SPE column and cleaned up using one single florisil column. The compounds were determined using GC-LRMS. The lipids were determined enzymatically, using the following formula; $TL = 1.677(TC – FC) + FC + TG + PL$.

The software packages SAS version V8 and SPSS 11.0 were used for the statistical analysis. One sample was lost during clean up resulting in 31 participants remaining in the final analyses. For POPs, log transformed concentrations were used in the regression models. General linear models were used to assess predictors for levels of selected POPs in blood. Independent variables of interest for the analysis were age, gender, frequency of mølje-consumption, and body mass index (BMI). The variable for frequency of “Mølje”-consumption was merged into three categories; ‘two or three times per season’, ‘two or three times per month’, and ‘once per week or more’. Age was grouped into 3 categories; years 38-45 (n=9), 46-53 (n=11), and 54-61 (n=11).

The criteria of significance was set to p=0.05.

Results and Discussion

Nearly half of the group answered that they ate “Mølje” twice per month or more, and 17 % consumed it once per week or more during the “Mølje”-season. Slightly more than 50 % reported eating “Mølje” only two to three times per season.

The lipid weight levels of the measured PCBs and pesticides are shown in Table 1.

Table 1. Lipid weight levels (μg/kg lipids) of PCBs and pesticides in human plasma samples from inhabitants of Skjervøy (n= 31).

	GM	AM	SD	MIN	MAX
PCB 28	<LOD				
PCB 52	<LOD				
PCB 99	13.7	15.3	7.75	4.38	37.1
PCB 101	<LOD				
PCB 105	9.51	10.9	6.50	4.21	31.0
PCB 118	37.5	45.2	30.8	12.8	133
PCB 128	<LOD				
PCB 138	99.6	112	56.3	37.6	254
PCB 153	168	188	96.6	59.8	499
PCB 156	17.1	19.1	9.52	6.41	51.1
PCB 170	43.4	47.5	21.2	18.7	113
PCB 180	106	117	57.3	42.3	309
PCB 183	10.7	12.1	6.15	3.67	28.2
PCB 187	39.1	43.9	21.9	13.9	116
SUM PCB	558	621	301	217	1510
***p,p'*-DDE**	179	225	161	46.1	666
***p,p'*-DDT**	<LOD				
HCB	33.4	36.3	15.2	16.2	72.5
β-HCH	<LOD				
***oxy*-CD**	13.5	15.2	7.92	6.06	36.9
***t*-CD**	<LOD				
***c*-CD**	<LOD				
***t*-NC**	20.3	24.8	15.7	6.78	59.7
***c*-NC**	5.31	5.99	3.05	2.06	12.9

GM-Geometric mean, AM-Arithmetic mean, SD-Standard deviation, MIN-Minimum value, MAX-Maximum value, HCB - hexachlorobenzene, β-HCH - β–hexachlorocyclohexane, *oxy*-CD – *oxy*-chlordane, *t*-CD – *trans*-chlordane, *c*-CD – *cis*-chlordane, *t*-NC – *trans*-nonachlor, *c*-NC – *cis*-nonachlor, LOD – limit of detection

The levels of POPs increased with increased frequency of “mølje-consumption”; however, age and/or gender explained this difference between the intake groups (Table 2). *p,p'*-DDE was not explained by any of these variables. Age was the most significant predictor, being significant for all the other compounds. For oxy-chlordane, *trans*-Nonachlor and *cis*-Nonachlor, both age and gender were significant. Besides that gender was only significant for PCB 180.

Table 2. Predictors for selected POPs in human plasma identified by a general linear model (levels considered were lipid normalised and log transformed)

Predictor variables	Frequency of mølje-consumption	Gender	Age
POPs	*p-values*	*p-values*	*p-values*
PCB 138	0.28	0.18	0.05
PCB 153	0.37	0.08	**0.04**
PCB 180	0.64	**0.02**	**0.03**
SUM PCB	0.35	0.08	**0.03**
***p,p'*-DDE**	0.44	0.92	0.60
HCB	0.21	0.31	**<0.01**
***oxy*-CD**	0.14	**0.03**	**<0.01**
***t*-NC**	0.11	**<0.01**	**<0.01**
***c*-NC**	0.20	**0.01**	**0.02**

Numbers in bold indicate significant p values ($p<0.05$).

Age was the most important predictor, being significant for all compounds except *p,p'*-DDE. This age factor is reported in several other studies.[14;15] It has also been reported that in communities where people consume large quantities of fish, consumption of more fish earlier in life might strengthen the age factor.[15] Despite, the relatively narrow age span of the participants (38 – 61 years), the age factor is the most significant predictor of POP levels (Table 3), supporting the observation by Grimvall et al.[15] The reason for this enhanced age difference is that people ate more fish historically and the levels of most POPs peaked in fish in the early 1980's.
There was also a significant gender difference in levels for several of the compounds, but gender proved to be much less important than age. The lower levels in women has previously been reported, and is believed to be a result of previous lactation.[16;17] There was no significant gender or age difference in the levels of *p,p'*-DDE and the reason for this is not known.[16;18]
The frequency of "Mølje" consumption had no significant effect on the levels of either PCBs or *p,p'*-DDE. The reported intake of this traditional dish had little effect on their contaminant levels in blood, indicating the importance of other potential sources of POPs. The reported consumption of "Mølje" and BMI were not significantly associated with the levels of any of the analysed compounds.
Dioxins and dioxin like compounds were not quantified in this study due to the cost of analyses. There are, however, several studies that clearly show that PCBs and dioxin-like compounds are highly correlated.[19;20] Thus, the lack of difference in levels between the different intake groups observed for the non planar PCBs would likely be absent for the dioxins and dioxin-like compounds.
The "Mølje" consumption reported by the participants from Skjervøy matches the data obtained through the NOWAC study, clearly supporting the expected high intake in this group.
The women from Skjervøy had a geometric mean level of sum PCB of 2.85 μg/L, which is comparable to women from Vestvågøy (2.38 μg/L).[17] The GM level of *p,p'*-DDE (1.2 μg/L) in the participants from from Skjervøy (no gender difference) was also similar to the women from Vestvågøy (1.2 μg/L).[17]
The sum PCB levels seemed lower in the women from Skjervøy (GM; 460 μg/kg lipids) than what was found in 50 Swedish women (GM; 620 μg/kg lipids)[15] who were or had been married to fishermen. The geometric mean sum PCB levels in the men from Skjervøy (620 μg/kg lipids) seemed to be lower than the reference group of men (1180 μg/kg lipids) in a Norwegian study looking at the effects of crab consumption on the levels of PCBs, PCDDs and PCDFs.[21]
On the basis of these comparisons, it is clear that the levels of POPs in the study participants with a high intake of fish liver are not elevated as compared to other studies. Thus, fish liver consumption does not seem to be a significant predictor of levels of POPs in a community with high intake of fish liver.

There remain an interesting issue for discussion; whether these levels of POPs that were not found to be elevated can justify the public recommendation not to consume fish liver.
Health effects have been studied in several studies looking at potential effects of POP exposure. Lately, some studies have indicated that POP exposure might be associated with a greater susceptibility to infectious diseases and in particular middle ear infections among children.[22-24] One study on auditory P300 effects, it was concluded that exposure through breast-feeding was not associated with the same adverse effects as through prenatal exposure.[25] Female fertility has also been investigated in relation to fatty fish contaminated by POPs and no evidence of reduced fertility was found.[26] In that study, it was concluded that a possible explanation for this could be that the positive effects of some of the constituents in fatty fish could be strong enough to disguise the potential for adverse effects from exposure to POPs.
Fish consumption, especially consumption of fatty fish, has been found to be protective against coronary vascular disease (CVD) mortality.[27-29] In the Nurses' Health Study, a strong inverse relationship was observed between fish consumption and CVH deaths, with more than 60% reduction for the highest fish intake group and approximately 30% reduction for women eating one to three fish meals per month.[30] Further, there are indications that fatty fish consumption decreases the risk of developing endometrial cancer.[31] The human nervous system contains a high amount of the n-3 fatty acid docosahexaenoic (DHA), which is essential for children. It is believed to be crucial for optimal brain development and function.[32] Breast milk from vegan women contains relatively low levels of DHA,[33] whereas the content in breast milk from mothers who regularly eat fish is higher.[34] DHA has been suggested to affect children's cognitive development. Helland et al.[35] found that after cod-liver oil supplementation during pregnancy, intake of DHA during pregnancy was the only variable of significance for the children's mental processing at 4 years. Similar results have been found regarding fish consumption during pregnancy and children's cognitive development.[36] The fact that the positive effects of fish liver consumption can outweigh the negative effects from POPs is important to consider when the consequence of potential increased exposure is evaluated. This implies that it is not only the magnitude of exposure to the POPs, but rather the sum of both positive and negative aspects with fish consumption in the population that should govern risk evaluations and recommendations.
There is no reason to believe that the moderate levels of PCBs and pesticides found in the inhabitants of Skjervøy could cause adverse health effects that would outweigh the positive effects from fish or fish liver

consumption. Further, it should be noted that the levels of PCBs and several of the persistent pesticides are declining in the environment.

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