Blood levels of organotin compounds and their relation to fish consumption in Finland

Panu Rantakokko⁎, Anu Turunen, Pia K. Verkasalo, Hannu Kiviranta, Satu Männistö, Terttu Vartiainen

⁎ Corresponding author. Tel.: +358 17 201 395; fax: +358 17 201 265.
E-mail address: Panu.Rantakokko@ktl.fi (P. Rantakokko).

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ABSTRACT

The objective of this study was to measure the concentrations of organotin compounds in the whole blood of Finnish male fishermen (n=133), their wives (n=94), and other family members (n=73), and to investigate their associations with background variables. The concentrations were generally low, less than the limit of quantification (LOQ) for the vast majority of compounds and samples. Of the organotin compounds (mono-, di-, and tributyltin, mono-, di-, and triphenyltin, and dioctyltin), only triphenyltin was detected in more than just a few samples (in 37 of 300 samples, LOQ=0.04 ng/ml). These were mainly the samples of fishermen (26/37) and their wives (10/37). For statistical analysis, concentrations of triphenyltin were divided into two categories, <LOQ and >LOQ. Of the different background variables, age and fish consumption contributed the most to the triphenyltin concentrations. When age and fish consumption (g/day) were divided into three categories, odds ratios comparing the highest with the lowest category were 3.88 for age (95% CI 1.36–11.09) and 3.48 for fish consumption (1.36–8.94), respectively. Compared with females, males had an odds ratio of 1.51 of having the concentration of triphenyltin >LOQ (0.72–3.14). To the best of our knowledge, this study confirmed for the first time with human samples that fish consumption can be associated with triphenyltin concentration in whole blood.

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1. Introduction

Organotin compounds (OTCs) are a large class of compounds with widely varying properties, and they have been used for many different purposes. Mono- and di-substituted compounds (e.g., monobutyltin (MBT), dibutyltin (DBT), monooctyltin (MOT), and di-octyltin (DOT)) are used extensively as heat and light stabilisers in the production of polyvinyl chloride (PVC) polymers and as catalysts in the manufacture of polyurethane and silicone elastomers. Also tri-substituted OTCs, tributyltin (TBT), and triphenyltin (TPhT) compounds have a wide range of uses mostly associated with their strong biocidal activity toward aquatic organisms, such as bacteria, fungi, algae, molluscs, and crustaceans. From the environmental point of view, most attention has been given to widespread TBT and TPhT pollution of waters, sediments, and aquatic biota resulting from their use in antifouling paints in boats and ships. TBT and TPhT are highly toxic to many aquatic species, and the most sensitive endocrine effect, imposex, occurs in some molluscs already at 1 ng/l levels of TBT (Fromme et al., 2005; Hoch, 2001).

A scientific panel of the European Food Safety Authority (EFSA) has assessed the health risks to consumers associated with exposure to OTCs in foodstuffs. Toxicologically relevant
endpoints were immunotoxicity, reproductive and developmental toxicity, neurotoxicity, genotoxicity, and carcinogenicity. However, the most critical toxicological endpoint for risk assessment was considered to be immunotoxicity. Due to immunotoxicological similarities, a group Tolerable Daily Intake (TDI) of 250 ng/kg body weight was established for the sum of TBT, DBT, TPhT, and DOT (European Food Safety Authority, 2004). Recent evidence has also shown that TBT induces differentiation of adipocytes in vitro and increases adipose mass in vivo and may thus contribute to obesity (Grun and Blumberg, 2006; Grun et al., 2006; Inadera and Shimomura, 2005). Variable amounts of OTCs have been found in many food types like beans, vegetables, fruits, eggs, milk, meat (Marcic et al., 2005; Qunfang et al., 2004), wines (Azenhava and Vasconcelos, 2002), drinking water (Sadiki and Williams, 1999), and cookies (Takahashi et al., 1999). The origin of dietary OTCs is considered to be direct or indirect (e.g. through fertilising sludge) contact between different plastics and foodstuffs. Even though these food–plastic contacts may represent a notable route of OTC dietary exposure for humans, our recent Finnish market basket study (Rantakokko et al., 2006), two Japanese studies on the dietary intake of OTCs (Toyoda et al., 2000; Tsuda et al., 1995), a French study on the levels of OTCs in seafood and their health risk implications for high-seafood consumers (Guerin et al., 2007), and a study on farm, dairy, meat, and fish products (Kannan et al., 1995) have shown that fish and fish products are generally the main source of OTCs from ordinary foods. However, detailed information on the levels of OTCs in individual seafood species from Finnish water areas is still quite limited. In a study carried out in the vicinity of twelve cities in Finland, the sum of OTCs (mostly tri-substituted) in pooled pike muscle samples was 1–33 ng cation/g fresh weight in inland fish and 8–141 ng cation/g fresh weight in coastal fish (Mannio et al., 2005). In Finnish coastal areas with a high density of shipping, OTC sums up to several hundred ng/g fresh weight in individual pike perch and burbot samples have been measured (Mannio et al., 2005; Vatanen and Niinimäki, 2005). A project aiming to study the OTC concentrations from the most commonly eaten domestic fish species from background and contaminated areas is currently underway.

Globally, the levels of OTCs in human blood samples have been measured only in a few studies. The sum of butyltins in 32 whole blood samples from central Michigan was, on average, 21.3 ng/ml (MBT 8.2 ng/ml, DBT 4.9 ng/ml, and TBT 8.2 ng/ml). MBT, DBT, and TBT were detected in 53%, 81%, and 70% of the samples examined, respectively. In addition to the ingestion of contaminated foodstuffs, butyltin compounds used as stabilisers or as biocides in household articles were regarded as a source (Kannan et al., 1999). Also in the United States, the sum of butyltins in 6 whole blood samples was, on average, 88 ng/ml (MBT 27 ng/ml, DBT 40 ng/ml, and TBT 21 ng/ml). MBT, DBT, and TBT were detected in all samples. A wide variety of butyltin sources, such as those mentioned above, were proposed to explain the unexpectedly high concentrations (Whalen et al., 1999). In Germany, butyltins, octyltins, and TPhT were analysed from the serum of 8 healthy volunteers. In striking contrast to US results, the concentrations of MBT and DBT were below the limit of detection (LOD=0.02 ng/ml for all OTCs) in every sample, and TBT was only marginally above the LOD in 4 samples. All octyltins were below the LOD in every sample. The average concentration of TPhT was 0.31 ng/ml, and it was present in all samples, making TPhT the most abundant OTC in these samples (Lo et al., 2003).

The aim of this study was to measure OTC whole blood concentrations from a sample of Finnish Baltic Sea fishermen and their families, and to investigate the association with age, gender, and fish consumption. To the best of our knowledge, this is the first report where OT whole blood concentrations have been measured from a population likely to have a high OT exposure. This study is part of a larger Nutrition, Environment and Health study (the Fishermen study), which aims to evaluate the health benefits and risks of high fish consumption in a cohort of Finnish fishermen and their families (http://www.ktl.fi/portal/english/research__people__programs/environmental_health/research/chemicals/research_projects/fishermen/). During the project, whole blood/serum concentrations of many other contaminants, such as PCDD/Fs, PCBs, other groups of POPs, and methyl mercury are measured.

2. Materials and methods

2.1. Recruitment, whole blood samples, and food frequency questionnaire

The Fishermen study cohort consists of all Finnish maritime and freshwater area fishermen, their wives, and other family members. The fishermen were identified from the Professional Fishermen Register, whereas the wives and other family members (fishermen’s biological children, and biological siblings and their wives and biological children) were identified from the Population Information System of the Population Register Centre. From the original cohort, 133 fishermen, 94 fishermen’s wives, and 73 other family members living in reasonable distance from Helsinki and Turku field study locations volunteered to attend a health examination, where venous whole blood samples after 12 h of fasting were collected, and fish consumption was assessed by two independent methods. Sodium citrate was used as an anticoagulant for the whole blood samples and they were stored frozen at –80 °C until analysis. Whole blood samples were collected between August 2004 and May 2005.

Fish consumption was assessed by a validated self-administered semi-quantitative food frequency questionnaire (FFQ) designed to cover the usual diet over the preceding 12 months. The participants were asked to indicate the frequency of use of each of the following fish dishes: fish soup, frozen fish or fish sticks, salmon or rainbow trout dishes, Baltic herring dishes, whitefish, perch, vendace or pike, spiced or salted fish, tuna or other canned fish, traditional Finnish kalakukko (fish baked inside a loaf of bread), shrimp or crustacean. The nine frequency categories ranged from not at all or seldom to six or more times per day. The FFQs were checked for completeness of response by a trained study nurse. Dietary data was processed with Fineli® Finnish Food Composition Database. Frequencies were converted into amounts eaten (g/day) by multiplying the frequency with the average portion size.
In addition, our health questionnaire (HQ) had detailed questions about fish consumption. The participants were asked to indicate the frequency of use of the following fish dishes: cooked fish (e.g. in fish soup), baked fish, fried fish, smoked fish (cold or warm smoked), salted fish (e.g. raw-pickled), spiced fish (e.g. pickled herring), fish balls or fish loaf, fish sticks, traditional Finnish kalakukko, domestic canned fish, foreign canned fish, roe, and other fish dishes. The six consumption variables was 0.63.

According to our validation study, the previously described variables from the FFQ and the HQ estimate habitual fish consumption relatively well (unpublished data). For example, the Spearman correlation coefficients between fish consumption variables from the FFQ and the HQ estimate habitual fish consumption relatively well (unpublished data). For example, the Spearman correlation coefficients between fish consumption and serum concentration of fish-derived n-3 fatty acids was 0.42 for males and 0.34 for females. The respective correlation coefficient between fish consumption as meals per month and serum n-3 fatty acids was 0.37 for both sexes. The correlation coefficient between the two fish consumption variables was 0.63.

2.2. Preparation of whole blood samples for the analysis of organotin compounds

The compounds to be analysed were MBT, DBT, TBT, MPhT, DPhT, TPhT, and DOT. All weights and concentrations of OTCs are expressed as organotin cations. Individual, pure model OT-compounds were bought either from Dr Ehrenstorfer or from Acros. The purity of model compounds was checked before use. Perdeuterated analogues of MBT, DBT, TBT, MPhT, DPhT, and TPhT were used as internal standards for the respective native 1H-compounds, and these were purchased from the Swiss Federal Institute for Environmental Science and Technology where they had been synthesised (Arnold et al., 1998).

Perdeuterated DPhT was used as an internal standard for DOT. The analysis of DOT was semi-quantitative due to lack of perdeuterated analogue. Tetrabutyltin was used as the recovery standard of internal standards.

The analysis of whole blood samples (2.0 ml) was performed according to the tissue method developed by Ikonomou et al. (2002) with slight modifications. NaCl (1 g) used to aid in the extraction was added in a solid form, and the derivatisation reagent, sodium tetraethylborate, was applied as 2% solution. Three cm of basic alumina (activated at 200 °C overnight, 90 min at 300 °C, and 200 °C until use) was loaded to a Pasteur pipette, and the samples were eluted with 10 ml of 4% diet-hylether in hexane. On average, 27 actual whole blood samples were analysed in each batch.

Three-level calibration was performed by spiking 2.0 ml of whole blood with known amounts of OTCs and by treating exactly as the true samples. Whole blood used for the calibration samples was beforehand confirmed to be free of OTCs.

For MBT, DBT, and DOT, the limits of quantification (LOQ) were estimated as 8 times the standard deviation of the blank. For TBT, MPhT, DPhT, and TPhT, no blank signal was detected. For these compounds, LOQ was estimated with MassLynx software as the concentrations corresponding to 8 times the baseline noise in the channels of the monitored ions. Estimated LOQs are added to the Table 1 for each compound.

2.3. Analysis of organotin compounds by GC/MS

The GC-MS analysis was performed with HP 6890 gas chromatograph connected to Waters Autospec Ultima high resolution mass spectrometer operating in the selected ion monitoring mode. The two most intensive fragment ions of each ethylated OTC were monitored.

The laboratory reagent blank samples were treated and analysed with the same method as the actual samples, one blank for each series of samples. The blank result was subtracted from the sample measurements. All glassware in contact with the samples was washed and soaked in 1 M HNO₃ overnight before use.

To our knowledge, no certified reference material exists for OTCs in whole blood. For this reason, an in-house made spiked (5.0 ng/ml) whole blood sample was analysed as a quality control sample in each series of samples. In the course of measurements, deviations from the supposed spiked concentrations were observed for MBT, MPhT, and DPhT. For MBT, the reason for the deviation is not clear, but decreased concentration of DPhT and increased concentration of MPhT is most likely due to dephenylation of DPhT to MPhT in the spiking solution (Van et al., 2005). Actual spiked levels were estimated afterwards using fresh solutions of MBT, MPhT, and DPhT, and those values are displayed in Table 1. Certified mussel tissue CRM 477 was analysed in most series of samples to have an external quality control material. It has certified concentrations for MBT, DBT, and TBT, and indicative concentrations for MPhT, DPhT, and TPhT, respectively (Pellegrino et al., 2000).

### Table 1 – Limits of quantification (LOQs) and quality control data

<table>
<thead>
<tr>
<th>Parameter/compound</th>
<th>MBT</th>
<th>DBT</th>
<th>TBT</th>
<th>MPhT</th>
<th>DPhT</th>
<th>TPhT</th>
<th>DOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOQ (ng/ml)</td>
<td>0.20</td>
<td>0.18</td>
<td>0.32</td>
<td>0.35</td>
<td>0.03</td>
<td>0.04</td>
<td>0.72</td>
</tr>
<tr>
<td>Control blood sample, spiked (ng/ml)</td>
<td>*7.3</td>
<td>5.0</td>
<td>5.0</td>
<td>*8.2</td>
<td>*1.7</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Control blood, recovery ± rsd (%) (n=11)</td>
<td>91±13</td>
<td>106±13</td>
<td>107±12</td>
<td>107±12</td>
<td>103±9</td>
<td>102±10</td>
<td>113±32</td>
</tr>
<tr>
<td>CRM 477 certified/indicative values ± 95% CI (ng/g)</td>
<td>1496±281</td>
<td>1550±118</td>
<td>2199±195</td>
<td>890±462</td>
<td>138±69</td>
<td>1592±413</td>
<td></td>
</tr>
<tr>
<td>CRM 477, recovery ± rsd (%) (n=8)</td>
<td>98±8</td>
<td>96±6</td>
<td>90±7</td>
<td>135±15</td>
<td>101±25</td>
<td>95±3</td>
<td></td>
</tr>
</tbody>
</table>

* The reason for the inaccurate level of MBT in the spiked control whole blood sample is unclear. In the spiking solution, DPhT had dephenylated to MPhT, and for this reason, the concentrations of MPhT and DPhT in the control whole blood sample were not 5.0 ng/ml. The actual spiked levels were estimated afterwards using fresh solutions of MBT, MPhT, and DPhT.

b No certified/indicative values are given for DOT in CRM477.
The results of the quality control samples are presented in Table 1. For the most part, results are in reasonable good agreement with spiked/certified/indicative concentrations. Large RSD (32%) in the analysis of DOT from control whole blood samples is due to semi-quantitative nature of its analysis. In the analysis of DPhT from CRM 477, a relatively large RSD (25%) is mainly due to two extreme values. However, those values were still within the 95% CI of the indicative concentrations.

To confirm the identity of the OTC-peak, peak retention times had to match within ±3 s of those of the calibration samples. The area ratio of primary and secondary ions in the MS-chromatograms had to be within 20% of the theoretical value.

2.5. Statistical analysis

Statistical analyses were performed by SPSS version 15.0 software. Logistic regression analysis was used to study the relationship between age, gender, fish consumption, and OTC concentrations.

3. Results

Table 2 summarises the whole blood concentrations of OTCs of the whole study population. TPhT concentration was >LOQ in 37 of the 300 samples (12%), but all the other OTCs were below the LOQ in virtually all samples. In samples with TPhT > LOQ, the average concentration was 0.09 ng/ml (2.3 LOQ) and the median concentration was 0.06 ng/ml (1.5 LOQ), respectively. The mean was skewed by the maximum value of 0.56 ng/ml which was more than 3 times higher than the second highest value (0.18 ng/ml). Due to very low levels, meaningful statistical analysis on the associations between OT-concentrations and background variables could only be performed for TPhT. Even in the case of TPhT, the number of samples > LOQ was so low that it was necessary to divide the data of TPhT in just two categories (≤ LOQ and > LOQ) for binary logistic regression.

Table 3 shows the odds ratios (ORs) and 95% confidence intervals (CI) of the dichotomised TPhT concentrations by different background variables from logistic regression analysis.

The notations "n=xx/yy" in the parenthesis refer to the number of subjects with TPhT concentration > LOQ divided with the total number of subjects in each category of the study population. The sum of xcs over different categories is always 37 (number of TPhT > LOQ) and the sum of yys is always 300 (size of the study population).

### Table 2 – Summary of the OTC concentrations (ng/ml) in whole blood samples (n=300)

<table>
<thead>
<tr>
<th>OTC</th>
<th>MBT</th>
<th>DBT</th>
<th>TBT</th>
<th>MPhT</th>
<th>DPhT</th>
<th>TPhT</th>
<th>DOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOQ (ng/ml)</td>
<td>0.20</td>
<td>0.18</td>
<td>0.32</td>
<td>0.35</td>
<td>0.03</td>
<td>0.04</td>
<td>0.72</td>
</tr>
<tr>
<td>Number of samples &gt; LOQ</td>
<td>22</td>
<td>14</td>
<td>12</td>
<td>16</td>
<td>10</td>
<td>7</td>
<td>37</td>
</tr>
<tr>
<td>Percent of samples &gt; LOQ (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum concentration (ng/ml)</td>
<td>0.38</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Average of samples &gt; LOQ (ng/ml)</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>Average of samples &gt; LOQ/LOQ</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
</tr>
<tr>
<td>Median of samples &gt; LOQ (ng/ml)</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>Median of samples &gt; LOQ/LOQ</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
<td>1.80</td>
</tr>
</tbody>
</table>

a The average or median concentrations of samples > LOQ divided with the LOQ, i.e. for TPhT, 0.09/0.04 = 2.3.

### Table 3 – Odds ratios and 95% confidence intervals (CI) of the dichotomised TPhT concentrations (< LOQ, > LOQ) against different background variables from logistic regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Women (n=15/162, reference category)</td>
<td>1</td>
</tr>
<tr>
<td>Men (n=22/138)</td>
<td>1.51 (0.72–3.14)</td>
</tr>
<tr>
<td>Age (years)&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>&lt;45 years (n=5/80, reference category)</td>
<td>1</td>
</tr>
<tr>
<td>45–60 years (n=13/137)</td>
<td>1.40 (0.47–4.12)</td>
</tr>
<tr>
<td>&gt;60 years (n=15/83)</td>
<td>3.88 (1.36–11.09)</td>
</tr>
<tr>
<td>Fish consumption (g/day)&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>≤50 g/day (n=9/132, reference category)</td>
<td>1</td>
</tr>
<tr>
<td>50–100 g/day (n=15/115)</td>
<td>1.83 (0.76–4.41)</td>
</tr>
<tr>
<td>&gt;100 g/day (n=13/53)</td>
<td>3.48 (1.36–8.94)</td>
</tr>
<tr>
<td>Fish consumption (meals/month)&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>&lt;10 meals/month (n=9/141, reference category)</td>
<td>1</td>
</tr>
<tr>
<td>≥10 meals/month (n=17/111)</td>
<td>2.26 (0.95–5.36)</td>
</tr>
<tr>
<td>≥20 meals/month (n=11/48)</td>
<td>3.50 (1.32–9.29)</td>
</tr>
</tbody>
</table>

The notations "n=xx/yy" in the parenthesis refer to the number of subjects with TPhT concentration > LOQ divided with the total number of subjects in each category of the study population. The sum of xcs over different categories is always 37 (number of TPhT > LOQ) and the sum of yys is always 300 (size of the study population).

<sup>a</sup> Adjusted for age (years) and fish consumption (g/day).
<sup>b</sup> Adjusted for age (years).
<sup>c</sup> Adjusted for fish consumption (g/day).
<sup>d</sup> FFQ-based fish consumption.
<sup>e</sup> HQ-based fish consumption.
concentration only one other family member (biological children) had TPhT, other family members) and TPhT concentration, because only one other family member (biological children) had TPhT concentration >LOQ.

4. Discussion

OTC concentrations in whole blood were generally quite low among the Finnish fishermen, their wives, and other family members. Concentrations were less than the LOQ (0.03–0.72 ng/ml, depending on the compound) for most of the samples. Only TPhT was detected in more than just a few samples (37/300). One aim of this study was to perform an epidemiological investigation of the possible human health effects of OTCs. However, it is for statistical reasons difficult to try to find associations between TPhT concentrations and possible health outcomes, because the median TPhT concentration of these 37 samples >LOQ was only 1.5 ng/ml. For this reason, this study concentrated on the factors that contributed to the measured OTC concentrations.

Despite the small number of samples where the concentration of TPhT was >LOQ, age and fish consumption had statistically significant association with the TPhT concentration in whole blood. The odds were very similar for categorised fish consumption (about 3.5) whether using FFQ- or HQ-based consumption variable. The average fish consumption in Finland is 40 g/day. If that had been set as the limit between the lowest and the middle category of the FFQ-based fish consumption, the odds of having TPhT >LOQ would have increased to 5.0 in the highest category compared to the lowest category. However, to have round figures as category limits and to keep the number of cases TPhT >LOQ relatively similar in each category, the division presented in Table 3 was adopted. The role of fish consumption as the other significant contributor to the TPhT concentrations was in agreement with our results (Lo et al., 2006). Together, these studies give strong support to the hypothesis that fish is the main dietary source of TPhT for humans in Finland.

If limits of quantification are taken into account, concentrations of butyltins in serum of 8 healthy donors from Germany were in agreement with our results (<LOQ), whereas in Germany TPhT was detected in every sample (average 0.31 ng/ml, range 0.18–0.67 ng/ml) (Lo et al., 2003). However, the methodological differences make the direct comparison of these results difficult: serum was used in the German study, whereas whole blood was used in our study. Also the number of randomly selected subjects in the German study was very small, whereas we used much larger pre-selected cohort. As for the possible dietary sources of TPhT in Germany, agricultural products may have contributed to intake in addition to fish when the study of Lo et al. was performed. In Finland, TPhT was used for the treatment of potato crops, sugar beets, and hops under the trade name Brestan (Hoch, 2001). In France, phenyltin contamination of rivers in 2001 was attributed to TPhT used in corn culture (Bancon-Montigny et al., 2004). This widespread use might partly explain the relatively uniform occurrence of TPhT in German serum samples that were collected before TPhT was withdrawn from agricultural pesticide use in Europe in 2002 (European Union, 2002a; European Union, 2002b). It is noteworthy that after the ban in 2004, TPhT was not detected in any of the whole blood samples collected from 91 volunteers in the Netherlands. However, as a methodological limitation, it has to be taken into consideration that the method detection limit in the Dutch study was much higher, 0.4 ng/ml (Peters, 2004).

Possible health effects of these generally very low levels of TPhT found in this study are unknown. For this reason we performed risk assessment for high fish consumers indirectly. Average fish consumption in the highest category of use was about 150 g/day estimated with the FFQ. The sum of OTCs in pooled fish samples in the vicinity of large coastal cities in Finland seldom exceed 150 ng/g fresh weight in any fish species (Mannio et al., 2005; Vatanen and Niinimäki, 2005). Using the average weight of Finnish adult population (77 kg), an estimate of daily intake would be 290 ng/kg body weight for the high consumers using contaminated fish. This exceeds slightly the TDI (250 ng/kg bw) set by EFSA for the sum of four OTCs (European Food Safety Authority, 2004). However, 150 ng/g fw for the sum of OTCs represent contaminated species from contaminated areas, and can mainly be seen as a theoretical maximum. Very little data on dietary fish is currently available from important fishing areas of Finland.

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