The relation between the estimated dietary intake of PCDD/Fs and levels in blood in a Flemish population (50–65 years)

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ABSTRACT

Dioxin-like activity was measured in the serum of 1425 Flemish men and women via the CALUX assay. The adults, aged between 50 and 65 years, participated in a large biomonitoring program, executed by the Flemish Center of Expertise for Environment and Health between 2002 and 2006. Within the context of this biomonitoring program also dietary intake of dioxin-like contaminants was assessed through a food frequency questionnaire.

The relation between the estimated dietary intake and the dioxin-like activity in serum was evaluated using multivariate analyses: a logistic model was performed on the total population, while a linear regression analysis was done on the subsample with quantifiable dioxin activity levels in serum. Region, gender, age, BMI, smoking status, as well as dietary habits were entered in the model, with dioxin level as an outcome estimate.

Both the logistic and linear model confirmed the contribution of dietary intake to the dioxin activity measured in serum. Also BMI and region were found to be associated with dioxin activity levels.

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1. Introduction

Flanders, the Dutch-speaking, northern half of Belgium, is one of the most densely populated regions in Europe, with a dense traffic network and industrial activities close to habitation. In order to study the influence of environmental factors on certain health outcomes, a large biomonitoring study was executed by the Flemish Center of Expertise for Environment and Health of the Flemish Community, monitoring several biomarkers of exposure and effect. All public information on the project is available online (www.milieu-en-gezondheid.be).

One of the biomarkers under study was dioxin activity in serum, measured by the chemical-activated luciferase gene expression (CALUX) assay. The CALUX bioassay uses genetically modified mammalian hepatoma cells that contain a transfected Arylhydrocar-
degradation and fat solubility, levels of dioxins in the lipid component of body tissues and fluids are a good indicator of cumulative exposure (Arft et al., 2001).

Increased levels of dioxin-like contaminants are associated with immune deficiency, dermal toxicity, reproductive effects and carcinogenicity as shown in animal and epidemiological studies on accidentally or occupationally exposed cohorts (WHO-ECEH-IPCS, 2000). Dioxin-like compounds have also endocrine disrupting properties. There is a lot of public concern on the health effects of the current environmental levels of dioxin-like compounds.

It is known that dietary intake is the most important source of human exposure: at least 90% of total exposure to dioxin-like contaminants can be attributed to dietary intake of food items of animal origin (Fries, 1995; Liem et al., 2000; Parzefall, 2002). Within the context of this biomonitoring program, a dietary intake assessment of animal fat has been evaluated, which allowed us to estimate the intake of dioxin-like contaminants through food (Bilau et al., 2008). Since the diet is known to be the most important source of dioxin-like substances in the human body and knowing that executing such a large biomonitoring program is an expensive and time-consuming task, this biomonitoring project is a unique opportunity to compare the estimated dioxin intake with measured levels of these contaminants in serum of adult men and women, in order to study the potential value of dietary assessment in predicting dioxin concentrations in the human body.

2. Materials and methods

2.1. Study population

Within the framework of the Flemish Center for Environment and Health, a biomonitoring program ran from 2002 till 2006 in eight geographical areas with different types of pollution pressure: two urban areas (city of Ghent and city of Antwerp), four areas with different types of industry (harbour, non-ferrous smelter, chemical industry, waste incinerator), a fruit growing area and a rural area. Three age groups were studied: adolescents (14–15 years), mothers and their newborn child, and adults (50–65 years). Only umbilical cord blood was analysed in the subpopulation of the mothers, and no dioxin-like activity was measured in the serum of the adolescents. Therefore, only data on the adult population will be presented.

Between September 2004 and June 2005, adults between 50 and 65 years old were sampled in municipalities, selected at random within the different study areas. The selected municipalities provided addresses of individuals who fell in the correct age range. Individuals were selected via stratified sampling in 3 age groups (50–54, 55–59 and 60–65). On the basis of a short questionnaire, it could be determined whether people fulfilled the inclusion criteria. Partners who met the inclusion criteria, could also participate in the study. People who did not meet the inclusion criteria, were randomly replaced by individuals from the same age group and the same sex.

The inclusion criteria for participants were the following: (1) they had to live for at least 5 years in the respective area; (2) they had to be between 50 and 65 years old at the time of the study; and (3) they had to be able to complete questionnaires in Dutch. All participants signed an informed consent.

The participants provided a non-fasting blood and urine sample in which several biomarkers have been measured. They also completed an extensive questionnaire on dietary habits, residence history, education, occupation, lifestyle factors (smoking, hobbies, use of pesticides, ...) and risk perception. Body mass index (BMI) was calculated based on height and bodyweight, measured according to a standardized protocol (WHO, 1995).

In total 1582 adult men and women between 50 and 65 years old were included in the biomonitoring study. For our substudy, 157 subjects had to be excluded because no CALUX measurement has been performed. In total, 1425 subjects (48.7% males) were included in the study presented in this paper.

The biomonitoring study was approved by the Ethical Committee of the University of Antwerp.

2.2. Dietary exposure assessment

A semi-quantitative Food Frequency Questionnaire (FFQ) was used to estimate the daily intake of lipophilic contaminants (in this case PCDD/Fs) via the consumption of (animal) fat containing food items. Food groups such as meat and meat products, fish and seafood, eggs and dairy products were extensively questioned, as well as added fats (e.g. baking and frying fat). This FFQ is described in detail elsewhere (Bilau et al., 2008).

Contamination data were provided by the Belgian Federal Agency for the Safety of the Food Chain (www.lavc.be). Food items were sampled between 2003 and 2006 and PCDD/F levels were determined using the chemical-activated luciferase gene expression (CALUX) assay. The methodology used is described elsewhere (Vanderpereen et al., 2004). In order to perform the intake assessment, individual food items (1260 samples) were grouped into 21 food groups, based on fat content and fat origin. These groups were also chosen in view of the feasibility of combining consumption with contamination data. For each group, a mean PCDD/F concentration was calculated. Non-detects were assumed to be half of the limit of quantification (Bilau et al., 2008).

A simple distribution technique was used to estimate the dietary intake of PCDD/Fs, combining the observed distribution of individual food consumption data (food item level) with a point estimate for contaminant concentration (food group level) (Lambe, 2002).

2.3. Determination of PCDD/F in serum levels

Concentrations of dioxins and furans (PCDD/Fs) were determined by the CALUX in vitro bioassay in a non-fasting serum sample (5 mL). The methodology used is described in detail elsewhere (Schroijen et al., 2006; Van Wouwe et al., 2004). Summarily, since PCDD/Fs and PCBs are lipophilic, fat content of serum samples was extracted, using acetone, hexane and a celite column. After evaporation of the eluate, the amount of serum fat was gravimetrically determined. In a second step, other Arylhydrocarbon agonists were eliminated by using well specified mixtures of solvents (hexane, toluene, acetone and ethylacetate) and an acid silica column combined with an activated carbon column. In addition, PCDD/Fs were separated from PCBs: only the PCDD/F fractions were analysed in all individual samples via CALUX.

The PCDD/F concentrations were expressed per mL and per g serum fat. The CALUX analysis was performed with the pGudLuc 6.1 cell line supplied by Xenobiotic Detection Systems Inc (USA).

If dioxin concentrations were too low to be quantified, the samples were recoded to half of the limit of quantification (LOQ) in the data analysis (i.e. 0.03 pg CALUX TEQ/g serum).

This method facilitates the assessment of public health risks due to its high throughput rate and lower cost for the CALUX assay in Belgium compared to chemical analysis such as gas chromatography/mass spectrometry (GC/MS).

2.4. Statistical analysis

About 23% of samples were below the LOQ for CALUX measured in serum. They were considered as half the LOQ, i.e. 0.03 pg CALUX TEQ/g serum. Since such a large part

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Median (IQR)</th>
<th>Median (IQR)</th>
<th>Median (IQR)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57.7 (54.0–60.9)</td>
<td>58.5 (54.6–61.3)</td>
<td>57.0 (53.6–60.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.4 (24.1–29.2)</td>
<td>26.9 (24.7–29.4)</td>
<td>25.7 (23.2–29.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>– BMI &gt; 25</td>
<td>30%</td>
<td>28%</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>– 25 – BMI &gt; 30</td>
<td>44%</td>
<td>51%</td>
<td>37%</td>
<td></td>
</tr>
<tr>
<td>– BMI &gt; 30</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Diet (pg CALUX TEQ/kg bw/d)</td>
<td>146 (106–199)</td>
<td>162 (120–226)</td>
<td>131 (96–179)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Estimated intake (pg CALUX TEQ/kg bw/d)</td>
<td>1.69 (1.43–2.70)</td>
<td>2.01 (1.46–2.79)</td>
<td>1.93 (1.39–2.61)</td>
<td>0.042</td>
</tr>
<tr>
<td>PCD/D/F level (pg CALUX TEQ/g serum)</td>
<td>0.12 (0.08–0.17)</td>
<td>0.12 (0.08–0.17)</td>
<td>0.12 (0.08–0.17)</td>
<td>0.592</td>
</tr>
<tr>
<td>PCD/D/F level (pg CALUX TEQ/g serum fat)</td>
<td>23.0 (12.0–32.7)</td>
<td>22.4 (11.8–32.1)</td>
<td>23.4 (12.3–33.5)</td>
<td>0.399</td>
</tr>
<tr>
<td>Smoking habits</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>– Current smokers</td>
<td>18%</td>
<td>21%</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>– Former smokers</td>
<td>37%</td>
<td>48%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>– Never smokers</td>
<td>45%</td>
<td>29%</td>
<td>61%</td>
<td></td>
</tr>
</tbody>
</table>

* IQR interquartile range.

* Differences between sexes (Mann–Whitney U test).

The selected municipalities provided addresses of individuals who fell in the correct age range. Individuals were selected via stratified sampling in 3 age groups (50–54, 55–59 and 60–65). On the basis of a short questionnaire, it could be determined whether people fulfilled the inclusion criteria. Partners who met the inclusion criteria, could also participate in the study. People who did not meet the inclusion criteria, were randomly replaced by individuals from the same age group and the same sex.

The inclusion criteria for participants were the following: (1) they had to live for at least 5 years in the respective area; (2) they had to be between 50 and 65 years old at the time of the study; and (3) they had to be able to complete questionnaires in Dutch. All participants signed an informed consent.
of the CALUX levels were below the LOQ, different analyses were performed on two
groups of the population: 1) group A, the whole study population (N=1425) and
2) group B, a subsample of the study population (N=1092) namely the subjects with
quantifiable levels of PCDD/Fs in their serum. Normality was tested for both groups
(Kolmogorov−Smirnov) and descriptive statistics were analysed for the whole
study population (median; interquartile range).

2.4.1. Univariate analysis
Non-parametric tests were used to study the relation between the estimated
dietary intake of PCDD/Fs and measured dioxin activity levels (CALUX) in serum of
participants (seeTable 2).

2.4.2. Multivariate analysis
Since PCDD/F serum levels in adult men and women are the result of a continuous
accumulation of these substances throughout the entire life, several influencing factors
have to be taken into account in a multivariate model.

In a first model, the 75th percentile (P75) of CALUX in serum was used to divide
the whole study population (N=1425) in a higher exposed group (above P75) and a
lower exposed group (below P75). A logistic regression was used to investigate the
association of sex, age, region, dietary intake, BMI and smoking status with PCDD/F serum
levels above P75 as the dependent variable, computing the odds ratios (ORs) as measures of
association. This analysis was also performed for two subgroups: in order to compare
the results of participants who have declared that their dietary habits have, versus have
not, changed in the past 5 years.

In a second model, linear regression analysis was done on a subsample of the
population (N=1092) with quantifiable dioxin levels in order to investigate the
possibility that measured CALUX levels in serum could be predicted by dietary habits,
sex, age, region, BMI and smoking status.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman Rank Correlations (p-values) between estimated dietary intake of PCDD/Fs (pg CALUX TEQ/g serum) for different food groups and CALUX levels in serum (pg CALUX TEQ/g serum) for group B.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food Group</th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>fish and seafood</td>
<td>0.072 (0.018)</td>
<td>0.038 (0.457)</td>
<td>0.115 (0.067)</td>
</tr>
<tr>
<td>dairy products</td>
<td>0.035 (0.252)</td>
<td>−0.027 (0.600)</td>
<td>0.071 (0.065)</td>
</tr>
<tr>
<td>meat and meat products</td>
<td>0.075 (0.014)</td>
<td>−0.012 (0.814)</td>
<td>0.124 (0.001)</td>
</tr>
<tr>
<td>eggs</td>
<td>0.056 (0.062)</td>
<td>−0.039 (0.444)</td>
<td>0.072 (0.060)</td>
</tr>
<tr>
<td>added fats</td>
<td>0.000 (0.809)</td>
<td>−0.057 (0.260)</td>
<td>0.061 (0.115)</td>
</tr>
<tr>
<td>total diet</td>
<td>0.086 (0.004)</td>
<td>0.026 (0.612)</td>
<td>0.145 (0.001)</td>
</tr>
</tbody>
</table>

Data were analysed using the SPSS® software package (version 15.0). The level of
statistical significance was set at p ≤ 0.05.

3. Results

3.1. Description of the population
Main characteristics of the study population (N=1425), measured PCDD/F serum
concentrations and estimated PCDD/F intake are presented in Table 1. Regarding BMI,
511 participants (36%) have a normal weight, 626 participants (44%) are overweight
(25–BMI–30) and 287 (20%) are obese.

3.2. Univariate analysis
In group A (i.e. the whole study population) no differences were seen in CALUX
levels between men and women (Mann−Whitney U). However, CALUX levels (pg TEQ/g serum) were
significantly different between normal (BMI<25), overweight (25–BMI–30) and obese participants (BMI>30). The median CALUX levels were respectively 0.113, 0.122 and 0.122 pg CALUX TEQ/g serum. Also the estimated intake (pg TEQ/bw kg/d as well as pg TEQ/g) was different for normal, overweight and obese individuals (K−p<0.001). Their median estimated intakes were respectively 2.13, 1.96 and 1.70 pg CALUX TEQ/kg bw/d and 136, 151 and 152 pg CALUX TEQ/g serum.

To compare the estimated dietary intake of PCDD/Fs with CALUX levels in serum,
Spearman Rank Correlation was determined (r=0.086, p=0.004) in group B, the group of
participants with quantifiable levels of PCDD/Fs in their serum. Around 40% of that
group stated that their dietary habits had been changed in the last 5 years. Spearman
Rank Correlations were statistically different for people with or without changed
dietary habits (see Table 2).

3.3. Multivariate analysis
In a first stage, a logistic model was performed with CALUX levels in serum above
the P75 as a response variable and dietary intake (quartile 1, 2 and 3 vs the highest
quartile), region (average CALUX level as a reference), sex (female as a reference),
smoking status (never smoker as a reference), age (continuous variable) and BMI (continuous
variable) as predictive variables (group A, N=1425). Results for this model
are presented in Table 3.

<table>
<thead>
<tr>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odds ratio (OR) and 95% confidence interval (CI) as a result of multivariate logistic regression analysis with dioxin levels (pg CALUX TEQ/g serum) above P75 as the response variable (group A; N=1425)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quartiles of dietary intake (pg PCDD/Fs TEQ/d)</th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>0.619</td>
<td>0.431−0.890</td>
<td>0.010</td>
</tr>
<tr>
<td>Q2</td>
<td>0.606</td>
<td>0.424−0.865</td>
<td>0.006</td>
</tr>
<tr>
<td>Q3</td>
<td>0.778</td>
<td>0.554−1.095</td>
<td>0.150</td>
</tr>
<tr>
<td>Q4</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Region (sex as reference) | OR | 95% CI | p-value |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Ghent</td>
<td>0.396</td>
<td>0.256−0.612</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>City of Antwerp</td>
<td>1.585</td>
<td>1.75−2.138</td>
<td>0.003</td>
</tr>
<tr>
<td>Harbour</td>
<td>0.918</td>
<td>0.654−1.289</td>
<td>0.622</td>
</tr>
<tr>
<td>Non-ferrous smelter (Olen)</td>
<td>0.961</td>
<td>0.693−1.334</td>
<td>0.844</td>
</tr>
<tr>
<td>Chemical industry (Albert Canal area)</td>
<td>0.744</td>
<td>0.523−1.059</td>
<td>0.101</td>
</tr>
<tr>
<td>Waste incinerator</td>
<td>1.352</td>
<td>0.996−1.815</td>
<td>0.053</td>
</tr>
<tr>
<td>Fruit growing area</td>
<td>1.372</td>
<td>0.985−1.912</td>
<td>0.061</td>
</tr>
<tr>
<td>Rural area</td>
<td>1.307</td>
<td>0.959−1.793</td>
<td>0.091</td>
</tr>
<tr>
<td>Sex</td>
<td>0.891</td>
<td>0.680−1.169</td>
<td>0.405</td>
</tr>
<tr>
<td>Age</td>
<td>0.960</td>
<td>0.969−1.030</td>
<td>0.999</td>
</tr>
<tr>
<td>BMI</td>
<td>1.035</td>
<td>1.004−1.066</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Smoking status | Current smoker | 0.851 | 0.594−1.221 | 0.381 |
| Former smoker | 0.868 | 0.650−1.160 | 0.339 |
| Never smoker | 1 | | |

Constant | 0.081 | 0.011 |

In group B, a subsample of the study population (N=1092) namely the subjects with
quantifiable levels of PCDD/Fs in their serum. Normality was tested for both groups
(Kolmogorov−Smirnov) and descriptive statistics were analysed for the whole
study population (median; interquartile range).

Since PCDD/F serum levels in adult men and women are the result of a continuous
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the results of participants who have declared that their dietary habits have, versus have
not, changed in the past 5 years.

In a second model, linear regression analysis was done on a subsample of the
population (N=1092) with quantifiable dioxin levels in order to investigate the
possibility that measured CALUX levels in serum could be predicted by dietary habits,
sex, age, region, BMI and smoking status.
In a second phase, linear regression was performed on the subjects with quantifiable levels of dioxin activity in their serum only (group B; N = 1052) with CALUX levels (pg TEQ/g serum) as the outcome variable. The R square of this model was 0.047. Coefficients and significance level of the introduced parameters are presented in Table 4.

4. Discussion

It is widely accepted that the diet is responsible for more than 90% of the exposure to dioxin-like contaminants in the general population (Fries 1995; Liem et al., 2000; Päpke, 1998; Parzefall 2002). Therefore, a dietary intake assessment is often performed as an exposure and risk estimate for the general population regarding this type of contaminants (Bilau et al., 2008; Bocio and Domingo, 2005; Charley and Doull, 2005; Darmerud et al., 2006; Fattore et al., 2006; Kiviranta et al., 2004; Sasamoto et al., 2006; Taïoli et al., 2005; Vrijens et al., 2002). Measurement of the concentration of dioxin-like contaminants in adipose tissue, human breast milk or serum constitutes another potential of CALUX bioassay to measure all compounds with affinity for the AhR. The reported median level of dioxin CALUX activity in serum was 23 pg CALUX TEQ/g serum lipid. In a previous Flanders Environmental and Health Study, PCDD/Fs were determined in serum fat of 200 women between 50 and 65 years using GC-HRMS (Koppen et al., 2002). The results reported were higher (48 pg TEQ/g serum fat) but a similar comparison remains difficult as the analytical methodology was different – a chemical analysis versus the CALUX test. According to Arfi et al., 2001; Hauser et al., 2005; Lee et al., 2007). Although not the primary target of the biomonitoring study, we found it of interest to study this association in our study population. The original aim of assessing the dietary exposure to dioxin-like contaminants, was to use the results of this intake estimation as an adjusting factor in the relations under study in the biomonitoring program.

4.1. PCDD/F levels measured in serum

The reported median level of dioxin CALUX activity in serum was 23 pg CALUX TEQ/g serum lipid. In a previous Flanders Environmental and Health Study, PCDD/Fs were determined in serum fat of 200 women between 50 and 65 years using GC-HRMS (Koppen et al., 2002). The results reported were higher (48 pg TEQ/g serum fat) but a direct comparison remains difficult as the analytical methodology was different – a chemical analysis versus the CALUX test. According to Arfi et al., 2001; Hauser et al., 2005; Lee et al., 2007). Although not the primary target of the biomonitoring study, we found it of interest to study this association in our study population. The original aim of assessing the dietary exposure to dioxin-like contaminants, was to use the results of this intake estimation as an adjusting factor in the relations under study in the biomonitoring program.

4.3. Methodological considerations

4.3.1. Calux measurement in serum

Although measuring PCDD/F levels in adipose tissue is known to be the best parameter for body burden, it was impossible to use this invasive measurement in a large biomonitoring study (Allam and Lucena, 2001). Analysing dioxin levels in serum by measuring CALUX activity is a reasonable proxy for estimating the PCDD/F body burden, certainly if no other media (such as adipose tissue) are present (Whitcomb et al., 2005).

The CALUX bioassay measures an activity level rather than an exact concentration of congeners, although with the clean-up procedure used in this study, a strong correlation between CALUX and gas chromatography-high resolution mass spectrometry (GC-HRMS) results was observed (Van Wouwe et al., 2004). Moreover, there might be some influence of short term dietary intake, since participants did not have to be fasting at the moment the blood sample was taken. Consequently it was possible that the levels in serum were not always in equilibrium with the levels in adipose tissue at the moment of sampling.

4.3.2. Dietary intake assessment

On the other hand, the intake assessment is also prone to measurement error. It is, above all, an almost impossible task, to assess the life-long dietary habits of individuals at an age of 50 to
65 years old. As a proxy for life-long dietary intake, participants were asked to report dietary habits of the year before the study. Although one year is only a relatively short period when compared to the age reached at the moment of blood sampling, this is a long period when one considers the fact that the FFQ depends completely on the memory of participants.

Also, certain changes in dietary habits could have occurred throughout their life, resulting in incorrect estimation of life-long dietary intake. This was confirmed: almost 30% of the study population stated that their dietary habits have changed within the last 5 years. Of those 395 participants, 60% stated that their consumption of fish and seafood has increased over the last 5 years, while 81% stated that their consumption of meat and meat products has decreased over the last 5 years. The majority of the participants with changed dietary habits (54%) stated that their egg consumption decreased as well. However, in order to study this in detail, more information would be needed. Therefore, statistical analyses were done on the group who stated not to have changed their diet: the associations found were stronger, despite the smaller population under study. This uncertainty on dietary exposure may, in part, explain the relatively low R² values in the regression models.

4.3.3. Contaminant data

Also the contaminant levels in food items were affected by uncertainties, due to the sampling strategy, the methodology used and the evolution in time. For all participants the same contaminant levels were used, although it was possible that some participants consumed on average food items with higher contaminant levels than did others (e.g. participants consuming more or more often locally grown eggs).

5. Conclusion

Total dietary exposure (predominantly found via meat, meat products, fish and seafood) to PCDD/Fs was associated with concentrations of PCDD/Fs, measured by CALUX in non-fasting serum samples of Flemish adults between 50 and 65 years old. However, estimated food intake in a general population with a rather homogenous dietary pattern seemed a less important factor in explaining the variation in dioxin activity in serum by CALUX compared to BMI and region, although the diet is the main contributor of PCDD/F exposure.

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References

Arisawa K, Ozakai M, Yutaka T, Varaien T, Market basket study on dietary intake of PCDD/Fs, PCBs, and PBBs in Finland. Environ Int 2004;30:923–32.