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Assessment of dietary intake of polychlorinated biphenyls from a total diet study conducted in Pavia, Northern Italy

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5 **Assessment of dietary intake of polychlorinated biphenyls**
6 **from a total diet study conducted in Pavia, Northern Italy**
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Abstract

Diet is considered to be the main source of body burden of PCBs in the general population. The most cost-effective and reliable way to estimate the dietary intake is based on total diet studies. The aim of the present study was to provide a reliable estimate of recent average dietary intakes of PCBs in Northern Italy. Congener-specific analysis of PCBs were undertaken on total diet samples collected at the Pavia University cafeteria. The average daily intake for total PCBs was calculated to be 0.26 $\mu\text{g}/\text{person}/\text{day}$. The major contributor to PCB intake was accounted for by pooled samples of bread, cereals and potatoes, followed by the protein composite and fruit and vegetables. Although diverse dietary habits, and differences in sampling and analytical procedures, make comparison between different studies difficult, the daily intake of PCBs in Northern Italy can be located in the lower part of the range for values reported in the literature.

Keywords: Polychlorobiphenyls (PCBs), congeners, dietary intake, total diet study, Northern Italy

Introduction

Polychlorinated biphenyls (PCBs) comprise 209 individual chlorinated biphenyl rings, called congeners. They were typically manufactured as mixtures of up to 180 different congeners (Ishikawa et al., 2005). However, after release into the environment, the composition of commercial PCB mixtures are altered through volatilization and other kinds of partitioning, chemical or biological transformation, and preferential bioaccumulation (Bakker et al. 2003). Furthermore, 36 congeners of highest concern were identified and classified, based on potential for toxicity and frequency of occurrence in environmental samples (McFarland and Clarke 1989).

Because of their persistence, PCBs are present in all environmental media. For example, the higher chlorinated congeners, adsorb strongly to sediment and soil, where they tend to persist for long periods of time. Congeners with low chlorine content tend to be more volatile and also more soluble in water. In addition, due to their stability and lipophilicity, PCBs bioaccumulate in food chains and are stored in fatty tissues (EPA 1979, 1983, 1988, Eisenreich et al 1983, 1992, Pearson 1996).

The ability of PCBs to be degraded or transformed in the environment as well as their biological and toxic effects depend on the degree of chlorination and on the isomeric substitution pattern (Bohm et al. 1993, Hansen 1998). Human PCB exposure has been attributed to inhalation of polluted air and ingestion of contaminated food. In fact, diet has been and continues to be the major source of body burden of PCBs in the general population (Focant et al. 2002).

Because of their lipophilicity, PCBs enter the food chain and become progressively concentrated from small organisms to larger fish and mammals. Most PCBs tend to accumulate mainly in fatty tissue in fish and to a less extent in edible muscle tissue (Lazaro et al. 1999). Foods most likely to contain PCBs include chicken, turkey, beef, eggs, and dairy products.

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4 Since 1977 when manufacturing of PCBs was banned, levels in most foods
5 have declined. Nevertheless, regular surveillance programmes on PCBs in the
6 diet must be carried out to keep the situation under control. Currently, PCBs in
7 foodstuffs are routinely monitored in several countries and maximum tolerance
8 levels have been set for PCBs (total PCBs or congener-specific data) in edible
9 products (Himberg et al. 1993, Lazaro et al. 1999).

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17 Both acute and chronic health effects may be observed after exposure to PCBs.
18 Short term effects, such as throat, nose and eye irritation, may occur
19 immediately or shortly after exposure. High exposures, as well as repeated
20 (chronic) exposures can even damage the liver (ATSDR 2000). Long term
21 effects can occur at some time after exposure and can last for months or years.
22 PCBs may be teratogen in humans, and they may be passed to a child through
23 mother's milk. In addition, PCBs can affect the reproductive system of adults
24 (ATSDR 2000, Faroon et al. 2001b). High exposures can damage the nervous
25 system, causing numbness, weakness, and tingling in the arms and legs.
26 Finally, PCBs can cause a severe acne like rash (chloracne).

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36 With regard to cancer potential of PCB mixtures, there is limited (IARC 1987) or
37 inadequate (US EPA 1996) evidence of carcinogenicity in humans (Faroon et al.
38 2001a). However, animal studies provide sufficient evidence of carcinogenicity
39 (IARC, 1987, US EPA 1996). Some commercial mixtures have thus been
40 characterized as probably carcinogen to humans (IARC 1987). Of the 209
41 congeners of PCBs, a small number have been reported as having "dioxin-like"
42 toxicity. As with the dioxins, the concentrations of these congeners are assigned
43 a weighting factor based on their relative toxicities compared to the most toxic
44 dioxin congener 2,3,7,8-TCDD. The sum of the weighted concentrations forms
45 the "Toxic Equivalent Quantity" or TEQ (Safe 1990, World Health Organization
46 (WHO) 1993, van der Berg et al. 1998).

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58 During the last ten years, several studies have been carried out to evaluate
59 dietary exposure to PCBs, polychlorodibenzo-p-dioxins (PCDDs) and
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4 polychlorodibenzofurans (PCDFs) in the general population. Most available data
5 concerning daily dietary intake (PCDDs + PCDFs + PCBs), are reported in
6 terms of Toxic WHO-TEQs (Ahlborg et al. 1994). In 1998, the WHO consultation
7 recommended a Tolerable Daily Intake (TDI) for dioxins and dioxin-like PCBs of
8 1-4 pg WHO-TEQ/kg body weight (van Leeuwen and Younes 1998, 2000, WHO
9 1998). Since dioxins and PCBs have very long half-lives in the human body, the
10 Scientific Committee for Food (SCF) suggested that the tolerable intake should
11 be expressed on a weekly rather than a daily basis. In 2001, the SCF
12 established a tolerable weekly intake (TWI) of 14 pg WHO-TEQ/kg body weight.
13 TDI and TWI have been set using a precautionary approach and are
14 recommended as a tool for long term safety assessment (van Leeuwen and
15 Younes 2000).

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The most cost-effective and reliable way to estimate the dietary intake of PCBs
is based on Total Diet Studies (TDS) (Peattie et al. 1983, Pennington and
Gunderson, 1987, Pennington et al. 1996). This method has been widely used
in several European and non-European Countries. To make total diet studies
random, samples of food are usually collected in representative centers and
weighed out in the proportions in which they are consumed in the diet. This
approach is particularly important because it determines levels of the analytes
in foods as they would be consumed, so that they resemble as much as
possible the normal character of the diet. Moreover, it is suitable for estimating
the dietary intake of compounds which may be changed as a result of washing,
peeling and cooking. The average daily intake of PCBs was thus calculated
based on food consumption frequency, portion size, and PCB levels in
foodstuffs.

The aim of the present study was to provide a reliable estimate of recent
average dietary intakes of PCBs in an area of Northern Italy. For this purpose,
congener-specific analysis of PCBs were undertaken on total diet samples
collected at the Pavia University cafeteria. The results obtained were then
compared with average dietary intakes previously estimated in other areas.

Materials and methods

Food sampling

Raw, cooked, and ready-to-eat foods were collected over two consecutive weeks in July 2004, at the University cafeteria located in Pavia, Northern Italy. This big cafeteria prepares about two thousands meals a day. Some traditional breakfast foods, such as biscuits, sweets, and cereals, which were not served at the cafeteria, were purchased at three local supermarkets. All the foodstuffs (226 from the cafeteria and 22 from the supermarket) are listed in Table I.

Each sample was given a name, a number code and the list was kept on record. Collected items were immediately transferred to the laboratory where the pre-analytical treatment was performed. In the present study, the choice of the foods and their consumption values have been based on the Italian Household National Survey carried out in 1994-96 (Turrini et al. 2001). This survey is the most representative Italian food consumption study since it covered 1978 subjects randomly selected in Northern-Western Italy.

Foodstuffs representing the same food category were finally aggregated into five different food groups:

- Bread, cereals and potatoes
- Meat and meat products, fish and fish products, eggs, legumes (protein composite)
- Milk and dairy products
- Fruit and vegetables
- Beverages (soft and alcoholic drinks, including mineral water)

Standards and reagents

Sixty-one individual congeners (10 ng/μl in iso-octane) were purchased from Dr. Ehrenstorfer Laboratories (Ausburg, Germany). All solvents (hexane, diethyl ether, acetone, and *iso*-octane) were pesticide grade (Merck, Darmstadt,

Germany). Double-distilled water was produced from a Milli-Q Plus water purification system.

Sample preparation

Food samples, except for dairy products and beverages, were slightly thawed and cut into pieces. They are then pooled and homogenized with double-distilled and deionised water until completed pureed, by a STERILMIXER blender (*pbi international*). The samples were stored in polyethylene containers and frozen at -18 °C until analysis.

PCBs were analysed according to the method described and validated by Turci et al. (2002, 2004) for the determination of 60 congeners in serum, with modifications (mainly due to the different matrix).

Approximately 10 g (wet weight) of homogenate were ground with anhydrous sodium sulphate and spiked with 2,2',3,4,5,6'-hexachlorobiphenyl (#143) as the internal standard. For beverages, 20 mL of each sample were analysed. The samples were then extracted twice with a 10-mL aliquot of an *n*-hexane-diethyl ether mixture 3:1, v/v. After each addition, the samples were shaken and then sonicated for half an hour. The organic layers were combined, concentrated to a final volume of 5 mL, and cleaned by solid phase extraction (SPE) in disposable cartridges. Varian BondElut® Silica and Florisil (packing 1 g/6 mL column reservoir) SPE tubes were used (Varian Canada Inc., ON, Canada). A Silica tube was attached to the lower end of a Florisil tube using an adapter. Both the SPE Cartridges had been pre-conditioned with 10 mL of hexane. After the sample loading, PCBs were finally eluted with two 5-mL aliquots of hexane. The solvent was evaporated off under a nitrogen stream and the residue was dissolved in 100 µL of *iso*-octane before injection into the GC/MS. Test materials, fortified with target compounds, have been analyzed to demonstrate precision and accuracy of the analyses.

Apparatus and analytical conditions

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4 A Supelco (Bellefonte, PA, USA) Visiprep™-DL solid phase extraction (SPE)
5 vacuum manifold was used to simultaneously process up to 24 samples. Varian
6 BondElut® Silica and Florisil (packing 1 g/6 mL column reservoir) SPE tubes
7 were used (Varian Canada Inc., ON, Canada).
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13 A Hewlett Packard (Palo Alto, CA, USA) 5890 Series II Plus GC equipped with
14 an HP 7673 auto sampler and interfaced with a mass spectrometer was used
15 for gas chromatographic separation. A 50 m × 0.2 mm × 0.5 µm, J&W 100%
16 dimethylpolysiloxane PONA capillary column (J&W Scientific Columns from
17 Agilent Technologies) was used with helium as carrier gas at a constant flow of
18 0.8 mL/min. 1 µL was injected in splitless mode with the split outlet opened after
19 0.7 min. Injector and detector temperatures were set at 270°C and 280°C,
20 respectively. The oven temperature was programmed as follows: 150°C for 1
21 min, 50°C/min to 200°C, then 5°C/min to 300°C and 8 min hold at 300°C.
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31 The mass spectrometer (HP 5972, Palo alto, CA, USA) operated in electron
32 ionisation mode (EI) at 70 eV. The MS was tuned on PFTBA by optimizing the
33 signals at m/z 209, 414, and 512. A SIM program was constructed for GC-MS
34 acquisition and quantification. Two ions (M^+ and $[M+2]^+$ ions) were monitored
35 for each level of chlorination. Retention time, masses and relative abundance of
36 the confirmation ion to the target ion were used as identification criteria.
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43 The samples were analysed for the following PCB congeners (Ballschmitter &
44 Zell numbering) #18, 21, 28, 30, 31, 37, 44, 47, 49, 52, 61, 66, 70, 74, 77, 81,
45 87, 97, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 143, 146, 149,
46 151, 153, 156, 157, 158, 167, 168, 169, 170, 171, 172, 177, 178, 180, 183, 187,
47 189, 190, 193, 194, 195, 196, 199, 201, 202, 206, 207, 208, 209.
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51 These congeners have been selected on the basis of their toxicity and their
52 frequency of occurrence in environmental and biological samples.
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57 *Dietary intake estimation*

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4 PCB intakes (ng/day) were estimated by multiplying their concentrations in any
5 one food item (ng/kg) by the amount of that food consumed, expressed as
6 grams of food/day or millilitre of beverage/day. Total intake of PCBs is then
7 obtained by summing the intakes from all food items.
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11 12 13 **Results**

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15 The GC/MS method employed for the determination of PCBs in foodstuffs
16 proved to be reliable, with a CV <20% for all the analytes. The method was also
17 shown to be accurate with a relative error <14% for both inter- and intra-day
18 experiments. Recoveries were estimated to range from 65 to 80%, depending
19 on the specific congener considered. Selectivity was assessed through analysis
20 of equipment blanks to ensure that there were no interferences.
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28 The limit of detection for each individual PCB congener in foodstuffs and in
29 beverages was calculated to be 1 ng/kg and 0.3 ng/L, respectively. In the case
30 of samples whose concentration level was below the detection limit, the value
31 was computed as zero. Due to the large number of non-detected congeners,
32 inclusion of half LOD values in the total PCB calculations would result in a high
33 degree of uncertainty (US EPA 1999).
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41 Results on the analysis of foodstuffs for individual PCB isomers are given in
42 Tables II a-c. In no sample were octa-, nona-, and deca-PCBs detected.
43 Individual congeners were added together to yield total PCB concentrations.
44 The average level of total PCBs was 4.5 ng/kg for beverages, 58 ng/kg for dairy
45 products, 154 ng/kg for fruit and vegetables, 224 ng/kg for bread, cereals, and
46 potatoes, and 540 ng/kg for the protein composite. The most abundant
47 congeners (in terms of food concentration) in the different food categories were
48 # 118 (bread, cereals, and potatoes), 101 (protein composite), 180 (dairy
49 products), 156 (fruit and vegetables), and 47 (beverages).
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58 In Tables III a-g, the estimated daily intake (EDI) of PCBs from different foods
59 (ng/day), are reported. Figure 1 illustrates the data in bar graph format, with the
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5 average daily intake expressed in ng/person/day for the 21 congeners detected
6 above the detection limit. The concentrations ranged from 2.9 to 34.7
7 ng/person/day. The predominant congener was # 101, followed by # 138 and #
8 153. The less abundant isomers were # 99 < 183 < 66.
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13 The total PCB content was obtained by summation of all the individual
14 congeners. The average daily intake for total PCBs was calculated to be 0.26
15 µg/person/day (range: 0.15 – 0.48 µg/person/day). The sum of dioxin like PCBs
16 was 39.7 ng/person/day on average (range: 38.0 – 41.5 ng/person/day). Among
17 dioxin-like PCBs, only # 118, 105, and 156 were detected above the detection
18 limit. In no samples were non-ortho coplanar PCB congeners found.
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26 Based on the results from this survey, the contribution from different classes of
27 foodstuffs to the intake of PCBs in the Italian (local) diet is illustrated in Figures
28 2 and 3. The major contribution toward PCB intake is accounted for by pooled
29 samples of bread, cereals, and potatoes (44.8%), followed by the protein
30 composite (33.4%), and fruit and vegetables (19.1%). If considering dioxin-like
31 PCBs, bread, cereals and potatoes shared 89.8% of the total intakes of these
32 congeners, followed by fruit and vegetables (9.9%).
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40 **Discussion and conclusions**

41 The primary route of human exposure to PCBs for the general population is
42 through consumption of food. The dietary intake of PCBs is estimated to
43 account for greater than 90% of human exposure to these substances (Duarte-
44 Davidson and Jones 1994, Liem et al. 2000).
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50 Levels of PCBs in foods and dietary exposures to these compounds have been
51 reported in the international literature (Mes et al. 1989, Kannan et al. 1992a,
52 1992b, 1994, Duarte-Davidson and Jones 1994, Schecter et al. 1997, Freijer et
53 al. 2001, Tsutsumi et al. 2001, Costabeber et al. 2005, Huwe and Larsen 2005).
54 Very limited information is available on dietary exposure to PCBs in Italy
55 (Fasola et al. 1998, Zuccato et al. 1999, Binelli and Provini 2003, 2004, Ghidini
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4 et al. 2005). In general, earlier studies determined levels of PCBs in retail milk
5 products, fish, and meat.
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10 Studies to investigate levels of PCBs in a broader range of foods are needed. In
11 addition, no Total Diet Studies (also known as Market Basket Surveys) were
12 conducted to assess dietary intake of PCBs of the Italian population. The
13 duplicate portion method was used by Zuccato et al. (1999) to measure the
14 daily dietary intake of PCBs for a population group living in Abruzzi, Central
15 Italy. This is the most accurate approach in estimating the actual exposure to
16 contaminants. Nevertheless, duplicate portion studies have the disadvantages
17 of only covering a short period of time and a restricted population.
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26 This paper reports the findings from a survey to determine PCBs in foods widely
27 consumed in an area of Northern Italy. This study analyzed ready-to-eat foods
28 collected at the University cafeteria located in Pavia, Northern-Western Italy.
29 The main objective of this study was not only to estimate the dietary intake of
30 PCBs for an Italian population group, but also to allow the Italian dietary
31 exposure to PCBs to be compared with similar international dietary studies.
32 Nevertheless, due to differences in sampling and analytical procedures used
33 and the range of congeners being assessed, direct comparison between
34 different diets was difficult.
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44 Moreover, PCB concentrations are sometimes expressed as sum of all PCBs
45 (Σ PCBs) or as sum of marker PCBs analyzed (e.g. Σ 7PCBs, sum of *seven*
46 *marker PCBs*). When only dioxin-like congeners are considered, PCB
47 concentrations are expressed as *TEQ*. In addition, concentrations of PCBs can
48 be expressed per wet weight (w.w.), or on a fat (lipid) weight basis. Reporting of
49 non-quantified congeners also varies between different published studies.
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56 Existing literature suggests that meat, fish, and poultry are the primary sources
57 of PCBs in the human diet with fish being the major contributing factor
58 (Schechter et al. 1997, Joint FAO/WHO 2001). In general, high levels of PCBs
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4 are found in high-fat foods, and the lowest in low-fat foods such as fruits and
5 vegetables. The congener specific PCB concentrations, expressed as ng/kg
6 w.w., in the different foodstuffs collected within our study site, are summarised
7 in Tables IIa-c.
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13 Out of 60, only 21 congeners were quantified above the detection limit using
14 HRGC interfaced with low resolution mass spectrometry. The most abundant
15 congeners (in terms of concentration) in the different food groups resulted to be
16 #118 for bread, cereals and tubers; #101 for the protein composite; #180 for
17 dairy products; #156 for fruit and vegetables, and #47 for beverages.
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24 It can be seen that less chlorinated congeners can be found in low fat food,
25 while penta-, hexa-, and hepta- chlorinated CBs are more frequently quantified
26 in high-fat foodstuffs, like meat and fish. As for total PCBs (sum 60 congeners),
27 it was noted that the highest levels were found in the protein composite,
28 followed by cereals and tubers, fruit and vegetables, dairy products, and
29 beverages. It should be highlighted that mean values have been calculated
30 excluding limits of detection for non-quantified isomers.
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38 Dioxin-like congeners were detected in pasta with seafood (#118, 105, and
39 156), pork meat (#118), vegetables (#156), and yogurt (#156). Dioxin-like and
40 EC7 (#28, 52, 101, 118, 153, 138 and 180) PCBs accounted for a mean percent
41 of total PCB concentrations in foodstuffs of 8.6%, and 57.3%, respectively.
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47 On the basis of information obtained from the Italian Household National Survey
48 (Turrini et al. 2001), concerning the average daily food consumption in Italy, and
49 using the PCB concentration measured in the individual foodstuffs (reported in
50 Tables IIa-c), the average daily intake of individual PCB congeners can be
51 estimated. The results are presented in Tables III a - g.
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57 Figure 1 shows the average concentration (ng/day) profile for all the foodstuffs
58 collected in Pavia. The major contributor is PCB #101, followed by #138, 153,
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47, 118, 180, and 52. The isomer composition of PCB in different groups of foodstuffs is shown in Figure 2. For example, it can be seen that congeners #118, 105, 99, 156, and 70 are mainly ingested through the consumption of bread, cereals, and potatoes. Intake of isomers #183, 110, 101, 47, and 31 is mainly due to the protein composite. Dietary intake through fruit and vegetables appears to be important mainly for a few lower chlorinated congeners, especially #28 and 66. Intake through beverages is negligible. Total PCB intake was then obtained by summing the intakes from all foodstuffs containing the PCB congener concerned. In the present study, the average adult daily intake (AADI) was estimated to be 0.26 $\mu\text{g}/\text{person}/\text{day}$ total PCB (range: 0.15 – 0.48 $\mu\text{g}/\text{person}/\text{day}$). Dividing by the average body weight of 65 kg, the AADI resulted to be 4.0 ng/kg body weight/day.

The TEQ intake, calculated using factors suggested by the WHO (van der Berg et al. 1998) and using the total of the mean concentration of congeners # 118, 105, and 156 (excluding LOD values) was 9.7 pg/person/day. Average daily food intake of TEQs for an adult weighting 65 kg was estimated to be 0.15 pg WHO-TEQ/kg body weight/day. In this respect, it is noteworthy that recent reports suggested that high concentrations of the summation of mono-ortho congeners PCBs 105, 118, and 156 in adipose tissue and plasma, may be associated with the risk of breast cancer (Aronson et al. 2000, Demers et al. 2002).

The relative contribution of foodstuffs groups to the dietary intake is illustrated in Figures 3a and 3b. The three major contributors to the total PCB intake are bread, cereals, and potatoes (44.8%), the protein composite (33.4%), and fruit and vegetables (19.1%). In contrast to much of the existing literature, fish, meat and dairy products are not the prime source of dietary intake of PCBs in the area at issue. As far as dioxin-like PCBs are concerned (Figure 3b), the major contributors are cereals, which accounted for 89.8%, followed by fruit and vegetables (9.9%), and dairy products (0.3%). It must be underlined that dioxin-like congeners #118, 105, and 156 were quantified in pasta with seafood, which

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4 was included in the cereals group. In fact, the presence of these mono-ortho
5 isomers may be due to seafood.
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10 Finally, it should be noted that bread, cereals, and potatoes are not the most
11 contaminated food but they contribute significant proportions of the PCB intake
12 because they are major components of diet, at least in Northern Italy. Although
13 different dietary habits make direct comparison with results from studies in other
14 countries difficult, the daily intake of PCBs in Northern Italy is consistently lower
15 than that of other countries where comparable studies have been undertaken
16 (Table IV). However, EDIs can hardly be compared because of different dietary
17 habits in diverse countries and the studies refer to different reference years. For
18 example, in Japan (Matsumoto et al. 1987, Akutsu et al. 2005, Koizumi et al.
19 2005) and Finland (Moilanen et al. 1986) fish and seafood were the major
20 contributors to PCB intake, as found for the UK (Duarte-Davidson and Jones
21 1994, Juan et al. 2002). In Thailand (Tanabe et al. 1991), Vietnam (Kannan et
22 al. 1992a) and India (Kannan et al. 1992b) foodstuffs of agricultural origin gave
23 the highest contribution to PCB intakes. Australia (Kannan et al. 1994), Canada
24 (Mes et al. 1989, Gilman et al. 1995, Newsome et al. 1998), New Zealand
25 (Buchland et al. 1998), and the USA (Gunderson 1988) are characterized by a
26 high consumption of meat, which is the main source of PCB in diet. Dairy
27 products resulted to be the primary source of dietary intake of PCBs in
28 Germany (Brunn et al. 1989).
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45 Of course, the daily intake also varies depending on the dietary habits of each
46 individual. For example, people consuming no meat or fish products, like
47 vegetarians, nor dairy products, like vegans, would be expected to have lower
48 levels of PCB exposure through their diet. In addition, the congener profile may
49 change, being their PCB intakes dominated by the lower chlorinated congeners
50 found mainly in vegetables. Another key consideration in comparing intakes
51 based on an “amount per body weight per day” is the actual body weight used
52 in the particular study. The body weights used in the studies compared may
53 vary from a 60 kg person up to 80 kg.
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Furthermore, in most studies food samples were analysed for PCB content as purchased. It should be noted that food preparation and/or cooking method can alter PCB levels in the final food product. For example, cooking has been found to reduce PCB levels by 23-41% (Zabik et al. 1996). That is why direct comparison of the results from different surveys may be not always straightforward. The intakes estimated in this study are also below the recently established World Health Organisation tolerable daily intake (TDI) range of 1-4 pg TEQ/kg bw/day (WHO 1998).

Nevertheless, the WHO-TDI range has been created for exposure to polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and dioxin-like PCBs. The dioxin-like PCBs contribution to the total TEQ has been evaluated to represent about 50%. Our result should therefore be doubled before comparison with the recommended WHO-TDI. However, the value obtained in this study appears to be located in the lower part of the range for reported values.

In light of the above, the results from the present study can be useful as a set of reference data for exposure to PCBs of general population in a Northern-Italy area. Currently, a very few data are available for Italian population groups and moreover congener-specific data for foodstuffs are limited. Since chemical contamination of food is considered to be a major public health concern, WHO recognizes the need for all countries to undertake TDS to assure that food does not contain chemicals that would cause short- or long-term health problems. Despite declining trends are observed, there is therefore a need for monitoring PCBs (and possibly PCDDs/Fs) in foodstuffs collected in different geographical areas in Italy in an attempt to compute their typical dietary intakes.

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Table I. Detailed list of the foodstuffs collected at the university cafeteria and purchased at a supermarket, located in Pavia, Northern Italy.

Sample	N° of samples collected at the cafeteria	N° of samples purchased at the supermarket
Cereals and tubers		
Bread	10	
Pizza margherita		1
Pizza (würstel, ham, onions)	1	
Crackers, bread sticks		1
Cornflakes		1
Polenta (thick corn mush)	2	
Pasta with eggplants and peppers	1	
Pasta with tomato and ricotta cheese	2	
Pasta with tomato	9	
Pasta amatriciana	2	
Pasta with cream,peas,carrots, potatoes	1	
Pasta with zucchini, eggplants, peppers	3	
Pasta with tuna and tomato	1	
Pasta with gravy	2	
Pasta with tomato and rucola	1	
Pasta with cream and gorgonzola	1	
Pasta with seafoods	1	
Pasta with cauliflowers	1	
Risotto with spinach	2	
Risotto with pork meat	1	
Risotto with peas, carrots, and potatoes	2	
Risotto with mushrooms	1	
Risotto with peas	1	
Risotto with artichokes	1	
Fried rice balls	1	
Potato damplings with gravy	1	
Potato damplings with cream and gorgonzola	1	
Boiled potatoes	10	
Fried potatoes	9	
Meat and meat products, fish and fish products, eggs, legumes		
Beef steak	4	
Beef shank	1	
Stew (beef, peas, potatoes)	2	
Meat balls (pork, poultry, eggs)	3	
Pepper stuffed with minced meats	2	
Pork cutlet	1	

Sample	N° of samples collected at the cafeteria	N° of samples purchased at the supermarket
Pork cutlet with mushrooms	1	
Roasted turkey	6	
Grilled turkey breast	1	
Roasted chicken (wing, breast)	2	
Breaded chicken breast	2	
Breaded hamburger (pork, turkey)	1	
Hamburger (pork and turkey)	3	
Tripe	1	
Parma ham	4	
Ham steak	10	
Dried beef	4	
Speck ham	2	
Breaded cod fillets	2	
Fried cod sticks	1	
Shrimps		1
Flounder		1
Tuna fish in olive oil		1
Hard-boiled eggs	4	
Omelette with spinach and ricotta cheese	2	
Green beans	6	
Boiled peas	2	
Peas with tomato sauce	1	
Beans (French, haricot, white)		3
Green olives	1	
Milk and dairy products		
Whole milk		1
Cream		1
Cheese (fontina, smoked provola, asiago, taleggio, primo sale)	10	
Cheese (mozzarella, philadelphia, caprino)	10	
Yogurt (apricot)	1	
Yogurt (banana)	1	
Yogurt (strawberry)	1	
Yogurt (raspberry, blackcurrant, blueberry)	1	
Vegetables and fruit		
Boiled carrots	4	
Green salad	7	
Boiled cauliflowers	3	

Sample	N° of samples collected at the cafeteria	N° of samples purchased at the supermarket
Boiled beetroots	4	
Boiled fennels	5	
Boiled spinach	3	
Brussels sprouts	3	
Tomatoes salad	6	
Mixed salad	3	
Mixed big-salad (tuna fish, potatoes, peas, carrots, olives, tomatoes, green beans, corn, green salad)	2	
Mayonnaise, peas, carrots, potatoes	1	
Fruit (kiwi, peach, apple, banana)	10	
Oranges, grapefruits, mandarin oranges)		3
Nuts, peanuts		2
Dried apricots		1
Cakes and desserts		
Creamy tiramisù	1	
Chocolate pudding	1	
Crème- caramel pudding	1	
Vanilla pudding	1	
Lemon ice-cream	1	
Vanilla and chocolate ice-cream	1	
Beverages		
Bottled mineral water	1	
Bottled mineral water (sparkling)	1	
Red wine	1	
White wine	1	
Beer	1	
Cola flavored carbonated beverage	1	
Orange flavored carbonated beverage	1	
Lime flavored carbonated beverage	1	
Fats and oils		
Olive oil		1
Seed oil		1
Butter		1
Margarine		1
TOTAL	226	22

Table IIa. Concentrations (ng/kg) of trichlorobiphenyls (31, 28) and tetrachlorobiphenyls (52, 49, 47, 44, 74, 70, 66) in the foodstuffs collected from a cafeteria in Pavia (nd = not detected, below the detection limit).

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #								
	31	28	52	49	47	44	74	70	66
Bread	nd	1.5	nd	nd	nd	nd	nd	nd	nd
Pizza margherita	nd	nd	nd	nd	4.8	nd	nd	nd	nd
Pizza (würstel, ham, onions)	2.1	nd	nd	nd	6.3	nd	1.8	nd	nd
Crackers, bread sticks	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cornflakes	5.3	12.4	28.8	7.4	13.8	13.9	6.3	22.5	11.8
Polenta (thick corn mush)	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with eggplant and peppers	3.6	2.0	1.8	nd	4.2	nd	nd	nd	nd
Pasta with tomato and ricotta cheese	nd	nd	nd	nd	1.6	nd	nd	nd	nd
Pasta with tomato	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta amatriciana	nd	nd	nd	nd	1.2	nd	nd	nd	nd
Pasta with cream, peas, carrots, potatoes	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with zucchini, eggplants, peppers	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with tuna and tomatoes	6.6	nd	11.6	7.7	13.7	4.9	nd	nd	nd
Pasta with gravy	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with tomatoes and rucola	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with cream and gorgonzola	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with seafood	21.0	15.3	12.3	13.2	16.8	nd	22.5	12.3	nd
Pasta with cauliflowers	nd	nd	9.6	nd	12.1	nd	7.1	nd	nd
Potato damplings with gravy	nd	nd	nd	nd	nd	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #								
	31	28	52	49	47	44	74	70	66
Potato dampings with cream and gorgonzola	nd	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with spinach	nd	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with pork meat	27.0	nd	13.0	19.0	61.0	nd	nd	nd	nd
Risotto with peas, carrots and potatoes	11.3	nd	4.7	4.7	1.8	2.1	4.7	nd	nd
Risotto with mushrooms	nd	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with peas	nd	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with artichokes	nd	nd	3.4	2.9	3.1	nd	nd	nd	nd
Fried rice balls	nd	nd	5.9	nd	6.7	nd	nd	nd	nd
Boiled potatoes	nd	8.0	nd	nd	1.6	nd	nd	nd	nd
Fried potatoes	nd	8.4	nd	nd	2.1	nd	nd	nd	nd
Potato puree	nd	nd	nd	nd	nd	nd	nd	nd	nd
Beef steak	nd	5.1	nd	nd	3.2	nd	nd	nd	nd
Pepper stuffed with minced meats	nd	nd	nd	nd	nd	nd	nd	nd	nd
Meat balls (pork, poultry, eggs)	nd	1.2	nd	nd	5.1	nd	nd	nd	nd
Stew (beef, peas, potatoes)	nd	8.2	11.3	nd	11.7	6.5	6.7	nd	nd
Beef shank	nd	3.0	61.5	nd	nd	nd	nd	nd	nd
Pork cutlet	nd	21	nd	nd	nd	nd	nd	nd	nd
Pork cutlet with mushrooms	nd	20	nd	nd	nd	nd	nd	nd	nd
Hamburger (pork and turkey)	nd	12.1	32.1	nd	nd	nd	nd	nd	nd
Roasted turkey	nd	nd	nd	nd	nd	nd	nd	nd	nd
Breaded chicken breast	nd	nd	nd	nd	nd	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #								
	31	28	52	49	47	44	74	70	66
Roasted chicken (wing, breast)	nd	1.8	nd	nd	nd	nd	nd	nd	nd
Breaded hamburger (pork, turkey)	58	nd	nd	nd	86	nd	nd	nd	nd
Grilled turkey breast	nd	nd	nd	nd	21.3	nd	nd	nd	nd
Parma ham	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ham steak	nd	nd	6.3	nd	12	nd	nd	nd	nd
Dried beef	2.1	nd	nd	nd	14.7	nd	nd	nd	nd
Speck ham	nd	1.3	nd	nd	21	nd	nd	nd	nd
Breaded cod fillets	nd	nd	67	nd	94	nd	nd	nd	nd
Fried cod sticks	221	nd	141	nd	131	nd	nd	nd	nd
Shrimps	39	nd	20	19	78	nd	nd	nd	nd
Flounder	nd	nd	131	nd	47	97	nd	nd	nd
Tuna fish in olive oil	nd	nd	445	nd	1151	nd	nd	nd	nd
Hard boiled eggs	73	nd	24	32	83	nd	29	nd	nd
Omelette with spinach and ricotta cheese	85	nd	38	36	98	nd	40	nd	nd
Boiled carrots	nd	nd	nd	nd	nd	nd	nd	nd	nd
Green salad	nd	nd	nd	nd	nd	nd	nd	nd	nd
Boiled cauliflowers	11	25	10	nd	nd	nd	nd	nd	nd
Boiled beetroots	7.1	46.4	17.3	nd	nd	nd	nd	nd	nd
Boiled fennels	19.9	24.8	19.8	7.6	8.6	12.6	9.1	20.2	19.2
Boiled spinach	2.1	12.9	14.6	nd	14.8	28.3	12.5	nd	nd
Brussels sprouts	nd	nd	nd	nd	nd	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #								
	31	28	52	49	47	44	74	70	66
Mixed salad	nd	nd	nd	1.3	1.4	4.0	nd	nd	nd
Tomatoes salad	nd	nd	nd	nd	nd	nd	nd	nd	nd
Green beans	nd	nd	nd	nd	nd	nd	nd	nd	nd
Peas with tomato sauce	nd	nd	nd	nd	nd	nd	nd	nd	nd
Boiled peas	nd	nd	nd	nd	nd	nd	nd	nd	nd
Beans (French, haricot, white)	nd	nd	nd	nd	nd	nd	nd	nd	nd
Whole milk	nd	nd	nd	nd	2.93	nd	nd	nd	nd
Yogurt (apricot)	nd	8.5	nd	nd	9.9	nd	nd	nd	nd
Yogurt (banana)	nd	nd	nd	nd	nd	nd	nd	nd	nd
Yogurt (strawberry)	7.3	10.1	10.4	nd	9.4	nd	nd	nd	nd
Yogurt (raspberry, blueberry, etc.)	nd	10.4	12.0	nd	9.9	nd	nd	nd	nd
Cheese	4.8	nd	nd	nd	18	nd	nd	nd	nd
Chocolate pudding	nd	nd	0.8	nd	1.1	nd	nd	nd	nd
Crème caramel pudding	nd	nd	1.4	nd	3.8	nd	1.0	1.4	1.1
Creamy tiramisu	nd	nd	nd	nd	nd	nd	nd	nd	nd
Vanilla pudding	nd	nd	1.3	nd	0.8	nd	nd	nd	nd
Lemon ice-cream	nd	nd	1.2	nd	0.91	nd	nd	nd	nd
Vanilla and chocolate ice-cream	nd	nd	1.4	nd	nd	nd	nd	nd	nd
Oranges, grapefruits, mandarin oranges	1.7	nd	nd	nd	2.2	nd	nd	nd	nd
Fruit (kiwi, peach, apple, banana)	4.7	7.7	3.1	nd	4.0	nd	2.6	nd	nd
Nuts, peanuts	nd	nd	nd	nd	nd	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #								
	31	28	52	49	47	44	74	70	66
Dried apricots	nd	nd	nd	nd	4.2	nd	7.6	nd	nd
Cola flavored bev.	0.71	nd	0.33	0.61	3.3	nd	1.3	nd	nd
Orange flavored bev.	0.55	nd	0.93	nd	4.7	nd	1.9	nd	nd
Lime flavored bev.	nd	nd	0.50	nd	3.2	nd	1.0	nd	nd
Beer	nd	nd	0.35	0.68	2.9	1.1	nd	nd	nd
Red wine	nd	nd	0.63	nd	3.7	nd	1.5	nd	nd
White wine	nd	nd	0.50	nd	0.33	nd	nd	nd	nd
Bottled mineral water	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table IIb. Concentrations (ng/kg) of pentachlorobiphenyls (101, 99, 110, 118, 105) and hexachlorobiphenyls (153, 138, 156) in the foodstuffs collected from a cafeteria in Pavia (nd = not detected, below the detection limit).

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #							
	101	99	110	118	105	153	138	156
Bread	nd	nd	nd	nd	nd	nd	nd	nd
Pizza margherita	nd	nd	nd	nd	nd	2.7	nd	nd
Pizza (würstel, ham, onions)	nd	nd	nd	nd	nd	6.7	nd	nd
Crackers, bread sticks	28	nd	nd	nd	nd	7.5	nd	nd
Cornflakes	nd	nd	nd	nd	nd	12.5	12.1	nd
Polenta (thick corn mush)	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with eggplants and peppers	nd	nd	nd	nd	nd	nd	4.3	nd
Pasta with tomato and ricotta cheese	nd	nd	nd	nd	nd	1.3	nd	nd
Pasta with tomato	nd	nd	nd	nd	nd	1.6	nd	nd
Pasta amatriciana	nd	nd	nd	nd	nd	4.6	1.2	nd
Pasta with cream, peas, carrots, potatoes	nd	nd	nd	nd	nd	42.5	57.5	nd
Pasta with zucchini, eggplants, peppers	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with tuna and tomato	19.1	nd	nd	nd	nd	167	168	nd
Pasta with gravy	nd	nd	nd	nd	nd	nd	11.5	nd
Pasta with tomato and rucola	nd	nd	nd	nd	nd	nd	nd	nd
Pasta with cream and gorgonzola	nd	nd	nd	nd	nd	0.17	nd	nd
Pasta with seafood	19.3	nd	nd	96.5	58.3	159	164	75.6
Pasta with cauliflowers	7.4	nd	nd	nd	nd	18	22	nd
Potato damplings with gravy	nd	nd	nd	nd	nd	2.2	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #							
	101	99	110	118	105	153	138	156
Potato damplings with cream and gorgonzola	nd	nd	nd	nd	nd	0.12	nd	nd
Risotto with spinach	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with pork meat	63	nd	nd	nd	nd	36	44	nd
Risotto with peas, carrots and potatoes	9.3	nd	nd	nd	nd	6.8	7.0	nd
Risotto with mushrooms	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with peas	nd	nd	nd	nd	nd	nd	nd	nd
Risotto with artichokes	6.9	nd	nd	nd	nd	3.7	2.1	nd
Fried rice balls	23	3.8	12	nd	nd	15	19	nd
Boiled potatoes	nd	nd	nd	nd	nd	nd	nd	nd
Fried potatoes	nd	nd	nd	nd	nd	nd	nd	nd
Potato puree	nd	nd	nd	nd	nd	nd	nd	nd
Beef steak	5.2	nd	nd	nd	nd	2.9	3.6	nd
Pepper stuffed with minced meats	nd	nd	nd	nd	nd	50	72	nd
Meat balls (pork, poultry, eggs)	nd	nd	nd	nd	nd	21	19	nd
Stew (beef, peas, potatoes)	11	nd	nd	nd	nd	15	15	nd
Beef shank	9.7	nd	nd	nd	nd	31	51	nd
Pork cutlet	6.3	nd	nd	3.1	nd	6.1	13	nd
Pork cutlet with mushrooms	5.4	nd	nd	2.5	nd	10	10	nd
Hamburger (pork and turkey)	131	nd	nd	nd	nd	211	204	nd
Roasted turkey	nd	nd	nd	nd	nd	47	31	nd
Breaded chicken breast	nd	nd	nd	nd	nd	59	20	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #							
	101	99	110	118	105	153	138	156
Roasted chicken (wing, breast)	nd	nd	nd	nd	nd	31	10	nd
Breaded hamburger (pork, turkey)	48	nd	nd	nd	nd	54	nd	nd
Grilled turkey breast	nd	nd	nd	nd	nd	21	26	nd
Parma ham	nd	nd	nd	nd	nd	26	33	nd
Ham steak	14	nd	nd	nd	nd	16	11	nd
Dried beef	1.5	nd	nd	nd	nd	36	46	nd
Speck ham	16	nd	nd	nd	nd	9.2	12.3	nd
Breaded cod fillets	156	nd	184	nd	nd	77	66	nd
Fried cod sticks	1256	nd	350	nd	nd	260	140	nd
Shrimps	nd	nd	nd	nd	nd	57	93	nd
Flounder	nd	nd	nd	nd	nd	620	410	nd
Tuna fish in olive oil	nd	nd	nd	nd	nd	89	nd	nd
Hard boiled eggs	87	nd	nd	nd	nd	140	131	nd
Omelette with spinach and ricotta cheese	125	nd	nd	nd	nd	179	148	nd
Boiled carrots	nd	nd	nd	nd	nd	nd	nd	nd
Green salad	nd	nd	nd	nd	nd	nd	nd	nd
Boiled cauliflowers	nd	nd	nd	nd	nd	3.4	3.2	nd
Boiled beetroots	59.7	nd	nd	nd	nd	87	81	70.2
Boiled fennels	50.0	nd	46.3	nd	nd	117	99	30.1
Boiled spinach	10.9	nd	nd	nd	nd	14.7	13.9	nd
Brussels sprouts	nd	nd	nd	nd	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #							
	101	99	110	118	105	153	138	156
Mixed salad	5.8	nd	nd	nd	nd	2.7	3.9	nd
Tomatoes salad	nd	nd	nd	nd	nd	nd	nd	nd
Green beans	nd	nd	nd	nd	nd	nd	nd	nd
Peas with tomato sauce	nd	nd	nd	nd	nd	nd	nd	nd
Boiled peas	nd	nd	nd	nd	nd	nd	nd	nd
Beans (French, haricot, white)	nd	nd	nd	nd	nd	nd	nd	nd
Whole milk	0.60	nd	nd	nd	nd	1.5	1.6	nd
Yogurt (apricot)	28.9	nd	nd	nd	nd	22.9	26.2	nd
Yogurt (banana)	22.6	nd	nd	nd	nd	nd	nd	nd
Yogurt (strawberry)	55.5	nd	nd	nd	nd	15.8	14.4	nd
Yogurt (raspberry, blackcurrant, blueberry)	63.4	nd	nd	nd	nd	25.5	22.6	4.3
Cheese	11.5	nd	nd	nd	nd	18.5	25	nd
Chocolate pudding	nd	nd	nd	nd	nd	1.6	1.8	nd
Crème caramel pudding	nd	nd	nd	nd	nd	1.2	1.3	nd
Creamy tiramisu	nd	nd	nd	nd	nd	nd	nd	nd
Vanilla pudding	nd	nd	nd	nd	nd	3.9	2.9	nd
Lemon ice-cream	3.6	nd	nd	nd	nd	1.2	1.4	nd
Vanilla and chocolate ice-cream	nd	nd	nd	nd	nd	1.03	1.2	nd
Oranges, grapefruits, mandarin oranges	nd	nd	nd	nd	nd	3.4	3.9	nd
Fruit (kiwi, peach, apple, banana)	nd	nd	nd	nd	nd	1.2	1.8	nd
Nuts, peanuts	nd	nd	nd	nd	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #							
	101	99	110	118	105	153	138	156
Dried apricots	nd	nd	nd	nd	nd	4.0	5.0	nd
Cola flavored bev.	nd	nd	nd	nd	nd	1.2	0.42	nd
Orange flavored bev.	nd	nd	nd	nd	nd	nd	nd	nd
Lime flavored bev.	nd	nd	nd	nd	nd	nd	nd	nd
Beer	nd	nd	nd	nd	nd	nd	nd	nd
Red wine	nd	nd	nd	nd	nd	nd	nd	nd
White wine	nd	nd	nd	nd	nd	nd	nd	nd
Bottled mineral water	nd	nd	nd	nd	nd	nd	nd	nd

Table IIc. Concentrations (ng/kg) of heptachlorobiphenyls (187, 183, 180, 170) in the foodstuffs collected from a cafeteria in Pavia (nd = not detected, below the detection limit).

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #			
	187	183	180	170
Bread	nd	nd	nd	nd
Pizza margherita	nd	nd	nd	nd
Pizza (würstel, ham, onions)	nd	nd	5.3	nd
Crackers, bread sticks	nd	nd	1.5	nd
Cornflakes	nd	nd	1.0	nd
Polenta (thick corn mush)	nd	nd	nd	nd
Pasta with eggplants and peppers	nd	nd	4.5	nd
Pasta with tomato and ricotta cheese	nd	nd	1.3	nd
Pasta with tomato	nd	nd	1.2	nd
Pasta amatriciana	nd	nd	3.7	nd
Pasta with cream, peas, carrots, potatoes	nd	nd	33	nd
Pasta with zucchini, eggplants, peppers	nd	nd	1.1	nd
Pasta with tuna and tomato	nd	nd	127	30
Pasta with gravy	nd	nd	5.9	nd
Pasta with tomato and	nd	nd	1.3	nd
Pasta with cream and gorgonzola	nd	nd	0.80	nd
Pasta with seafood	32	nd	152	46
Pasta with cauliflowers	nd	nd	18.1	nd
Potato damplings with gravy	nd	nd	1.6	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #			
	187	183	180	170
Potato damplings with cream and gorgonzola	nd	nd	1.4	nd
Risotto with spinach	nd	nd	nd	nd
Risotto with pork meat	nd	nd	14	nd
Risotto with peas, carrots and potatoes	nd	nd	1.2	nd
Risotto with mushrooms	nd	nd	nd	nd
Risotto with peas	nd	nd	nd	nd
Risotto with artichokes	nd	nd	1.4	nd
Fried rice balls	nd	nd	7.1	6.2
Boiled potatoes	nd	nd	nd	nd
Fried potatoes	nd	nd	nd	nd
Potato puree	nd	nd	nd	nd
Beef steak	nd	nd	6.7	nd
Pepper stuffed with minced meats	nd	nd	14	nd
Meat balls (pork, poultry, eggs)	nd	nd	13	nd
Stew (beef, peas, potatoes)	nd	nd	12	nd
Beef shank	nd	nd	24	nd
Pork cutlet	nd	nd	11	nd
Pork cutlet with mushrooms	nd	nd	9.8	nd
Hamburger (pork and turkey)	nd	nd	220	nd
Roasted turkey	nd	nd	nd	nd
Breaded chicken breast	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #			
	187	183	180	170
Roasted chicken (wing, breast)	nd	nd	nd	nd
Breaded hamburger (pork, turkey)	nd	nd	14	nd
Grilled turkey breast	nd	nd	nd	nd
Parma ham	nd	nd	nd	nd
Ham steak	nd	nd	6.7	nd
Dried beef	nd	nd	nd	nd
Speck ham	nd	nd	8.3	13
Breaded cod fillets	nd	nd	nd	nd
Fried cod sticks	nd	nd	nd	nd
Shrimps	109	nd	29	nd
Flounder	86	28	71	nd
Tuna fish in olive oil	nd	nd	nd	nd
Hard boiled eggs	nd	nd	46	nd
Omelette with spinach and ricotta cheese	60	94	104	nd
Boiled carrots	nd	nd	nd	nd
Green salad	nd	nd	nd	nd
Boiled cauliflowers	nd	nd	1.9	nd
Boiled beetroots	nd	nd	94	18
Boiled fennels	9.0	9.3	100	44
Boiled spinach	nd	nd	4.3	nd
Brussels sprouts	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #			
	187	183	180	170
Mixed salad	nd	nd	2.3	nd
Tomatoes salad	nd	nd	nd	nd
Green beans	nd	nd	nd	nd
Peas with tomato sauce	nd	nd	nd	nd
Boiled peas	nd	nd	nd	nd
Beans (French, haricot, white)	nd	nd	nd	nd
Whole milk	nd	nd	nd	nd
Yogurt (apricot)	nd	nd	14	nd
Yogurt (banana)	nd	nd	nd	nd
Yogurt (strawberry)	nd	nd	15	nd
Yogurt (raspberry, blackcurrant, blueberry)	nd	nd	29	nd
Cheese	nd	nd	41	nd
Chocolate pudding	nd	nd	2.1	nd
Crème caramel pudding	nd	nd	nd	nd
Creamy tiramisu	nd	nd	nd	nd
Vanilla pudding	nd	nd	nd	nd
Lemon ice-cream	nd	nd	nd	nd
Vanilla and chocolate ice-cream	nd	nd	nd	nd
Oranges, grapefruits, mandarin oranges	2.1	2.1	3.8	nd
Fruit (kiwi, peach, apple, banana)	nd	nd	nd	nd
Nuts, peanuts	nd	nd	nd	nd

FOOD HOMOGENIZED FOR ANALYSIS	CONGENER #			
	187	183	180	170
Dried apricots	nd	nd	nd	nd
Cola flavored bev.	nd	nd	nd	nd
Orange flavored bev.	nd	nd	nd	nd
Lime flavored bev.	nd	nd	nd	nd
Beer	nd	nd	nd	nd
Red wine	nd	nd	nd	nd
White wine	nd	nd	nd	nd
Bottled mineral water	nd	nd	nd	nd

Table III (a-g). Estimated daily Intake of PCBs from different foods (ng/day).

IIIa

FOODS	SAMPLE SIZE (g)	31			28			52		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread / pizza	138.6	0.51	0.29	0.73	0.96	0.21	1.72	3.99	3.99	3.99
Pasta	131.9	1.37	0.47	2.77	1.14	0.26	2.02	1.16	0.24	1.62
Rice	25.3	0.48	0.37	0.68	-	-	-	0.17	0.09	0.33
Potatoes	37.5	-	-	-	0.31	0.30	0.32	-	-	-
Beaf	46.7	-	-	-	0.20	0.06	0.38	1.70	0.06	2.87
Pork	5.0	-	-	-	0.10	0.10	0.10	-	-	-
Poultry	36.8	2.13	2.13	2.13	0.26	0.07	0.45	1.18	1.18	1.18
Ham	27.6	0.06	0.06	0.06	0.04	0.04	0.04	0.17	0.17	0.17
Fish	34.2	4.45	1.33	7.56	-	-	-	5.50	0.68	15.22
Eggs	12.5	0.99	0.91	1.06	-	-	-	0.39	0.3	0.48
Milk	0.1214	-	-	-	-	-	-	-	-	-
Yogurt	22.0	0.16	0.16	0.16	0.21	0.19	0.23	0.25	0.23	0.26
Cheese	45.9	0.22	0.20	0.24	-	-	-	-	-	-
Puddings	43.0	-	-	-	-	-	-	0.05	0.03	0.06
Ice cream	14.7	-	-	-	-	-	-	0.02	0.02	0.02
Vegetables	85.2	0.85	0.18	1.70	2.32	1.10	3.95	1.31	0.85	1.69
Legumes	16.2	-	-	-	-	-	-	-	-	-
Citrus fruit	69.1	0.12	0.12	0.12	-	-	-	-	-	-
Fresh fruit	174.9	0.82	0.82	0.82	1.35	1.35	1.35	0.55	0.55	0.55
Bottled mineral water	0.659	-	-	-	-	-	-	-	-	-
Soft drinks	0.035	0.02	0.02	0.02	-	-	-	0.02	0.01	0.03
Beer	0.027	-	-	-	-	-	-	0.01	0.01	0.01
Wine	0.084	-	-	-	-	-	-	0.05	0.04	0.05

IIIb

FOODS	SAMPLE SIZE (g)	49			47			44		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread / pizza	138.6	1.03	1.03	1.03	1.15	0.66	1.91	1.93	1.93	1.93
Pasta	131.9	1.38	1.02	1.74	1.09	0.16	2.22	0.65	0.65	0.65
Rice	25.3	0.22	0.07	0.48	0.46	0.04	1.54	0.05	0.05	0.05
Potatoes	37.5	-	-	-	0.07	0.06	0.08	-	-	-
Beaf	46.7	-	-	-	0.31	0.15	0.55	0.30	0.30	0.30
Pork	5.0	-	-	-	0.06	0.06	0.06	-	-	-
Poultry	36.8	-	-	-	1.65	0.78	3.16	-	-	-
Ham	27.6	-	-	-	0.44	0.33	0.58	-	-	-
Fish	34.2	0.65	0.65	0.65	10.27	1.61	39.36	3.32	3.32	3.32
Eggs	12.5	0.43	0.40	0.45	1.13	1.04	1.23	-	-	-
Milk	0.1214	-	-	-	0.04	0.04	0.04	-	-	-
Yogurt	22.0	-	-	-	0.21	0.21	0.22	-	-	-
Cheese	45.9	-	-	-	0.83	0.69	0.96	-	-	-
Dessert	43.0	-	-	-	0.08	0.03	0.16	-	-	-
Ice cream	14.7	-	-	-	0.01	0.01	0.01	-	-	-
Vegetables	85.2	0.38	0.11	0.65	0.75	0.12	1.26	1.28	0.34	2.41
Legumes	16.2	-	-	-	-	-	-	-	-	-
Citrus fruit	69.1	-	-	-	0.15	0.15	0.15	-	-	-
Fresh fruit	174.9	-	-	-	0.71	0.71	0.71	-	-	-
Bottled mineral water	0.659	-	-	-	-	-	-	-	-	-
Soft drinks	0.035	0.02	0.02	0.02	0.13	0.11	0.16	-	-	-
Beer	0.027	0.02	0.02	0.02	0.08	0.08	0.08	0.03	0.03	0.03
Wine	0.084	-	-	-	0.17	0.03	0.31	-	-	-

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FOODS	SAMPLE SIZE (g)	74			70			66		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread / pizza	138.6	0.56	0.25	0.87	3.12	3.12	3.12	1.64	1.64	1.64
Pasta	131.9	1.95	0.94	2.97	1.62	1.62	1.62	-	-	-
Rice	25.3	0.12	0.12	0.12	-	-	-	-	-	-
Potatoes	37.5	-	-	-	-	-	-	-	-	-
Beaf	46.7	0.31	0.31	0.31	-	-	-	-	-	-
Pork	5.0	-	-	-	-	-	-	-	-	-
Poultry	36.8	-	-	-	-	-	-	-	-	-
Ham	27.6	-	-	-	-	-	-	-	-	-
Fish	34.2	-	-	-	-	-	-	-	-	-
Eggs	12.5	0.43	0.36	0.50	-	-	-	-	-	-
Milk	0.1214	-	-	-	-	-	-	-	-	-
Yogurt	22.0	-	-	-	-	-	-	-	-	-
Cheese	45.9	-	-	-	-	-	-	-	-	-
Dessert	43.0	0.04	0.04	0.04	0.06	0.06	0.06	0.05	0.05	0.05
Ice cream	14.7	-	-	-	-	-	-	-	-	-
Vegetables	85.2	0.92	0.78	1.07	1.72	1.72	1.72	1.64	1.64	1.64
Legumes	16.2	-	-	-	-	-	-	-	-	-
Citrus fruit	69.1	-	-	-	-	-	-	-	-	-
Fresh fruit	174.9	0.46	0.46	0.46	-	-	-	-	-	-
Bottled mineral water	0.659	-	-	-	-	-	-	-	-	-
Soft drinks	0.035	0.05	0.04	0.07	-	-	-	-	-	-
Beer	0.027	-	-	-	-	-	-	-	-	-
Wine	0.084	0.13	0.13	0.13	-	-	-	-	-	-

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FOODS	SAMPLE SIZE (g)	101			99			110		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread / pizza	138.6	4.32	3.85	4.80	2.29	2.29	2.29	-	-	-
Pasta	131.9	2.64	0.98	4.52	-	-	-	-	-	-
Rice	25.3	0.65	0.17	1.59	0.10	0.10	0.10	0.30	0.30	0.30
Potatoes	37.5	-	-	-	-	-	-	-	-	-
Beaf	46.7	0.40	0.24	0.50	-	-	-	-	-	-
Pork	5.0	0.03	0.03	0.03	-	-	-	-	-	-
Poultry	36.8	3.29	1.77	4.82	-	-	-	-	-	-
Ham	27.6	0.29	0.04	0.44	-	-	-	-	-	-
Fish	34.2	17.49	4.17	42.96	-	-	-	7.46	4.10	11.97
Eggs	12.5	1.33	1.09	1.56	0.53	0.53	0.53	0.45	0.45	0.45
Milk	0.1214	0.01	0.01	0.01	-	-	-	-	-	-
Yogurt	22.0	0.94	0.50	1.39	-	-	-	-	-	-
Cheese	45.9	0.53	0.46	0.60	-	-	-	-	-	-
Dessert	43.0	-	-	-	-	-	-	-	-	-
Ice cream	14.7	0.05	0.05	0.05	-	-	-	-	-	-
Vegetables	85.2	2.69	0.49	5.09	-	-	-	2.43	0.91	3.94
Legumes	16.2	-	-	-	-	-	-	-	-	-
Citrus fruit	69.1	-	-	-	-	-	-	-	-	-
Fresh fruit	174.9	-	-	-	-	-	-	-	-	-
Bottled mineral water	0.659	-	-	-	-	-	-	-	-	-
Soft drinks	0.035	-	-	-	-	-	-	-	-	-
Beer	0.027	-	-	-	-	-	-	-	-	-
Wine	0.084	-	-	-	-	-	-	-	-	-

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FOODS	SAMPLE SIZE (g)	118			105			153		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread pizza	138.6	4.984	4.984	4.984	0	0	0	1.019	0.374	1.732
Pasta	131.9	12.728	12.728	12.728	7.690	7.690	7.690	5.230	0.016	22.027
Rice	25.3	0	0	0	0	0	0	0.391	0.093	0.910
Potatoes	37.5	0	0	0	0	0	0	0	0	0
Beaf	46.7	0	0	0	0	0	0	1.126	0.135	2.360
Pork	5.0	0.014	0.012	0.015	0	0	0	0.040	0.030	0.050
Poultry	36.8	0	0	0	0	0	0	2.594	0.776	7.765
Ham	27.6	0	0	0	0	0	0	0.602	0.254	0.994
Fish	34.2	0	0	0	0	0	0	7.544	1.949	21.204
Eggs	12.5	0	0	0	0	0	0	1.994	1.750	2.237
Milk	0.1214	0	0	0	0	0	0	0.185	0.185	0.185
Yogurt	22.0	0	0	0	0	0	0	0.471	0.347	0.561
Cheese	45.9	0	0	0	0	0	0	0.849	0.734	0.964
Dessert	43.0	0	0	0	0	0	0	0.096	0.052	0.168
Ice cream	14.7	0	0	0	0	0	0	0.016	0.015	0.018
Vegetables	85.2	0	0	0	0	0	0	3.831	0.230	9.968
Legumes	16.2	0	0	0	0	0	0	0	0	0
Citrus fruit	69.1	0	0	0	0	0	0	0.235	0.235	0.235
Fresh fruit	174.9	0	0	0	0	0	0	0.210	0.210	0.210
Bottled mineral water	0.659	0	0	0	0	0	0	0	0	0
Soft drinks	0.035	0	0	0	0	0	0	0.043	0.043	0.043
Beer	0.027	0	0	0	0	0	0	0	0	0
Wine	0.084	0	0	0	0	0	0	0	0	0

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FOODS	SAMPLE SIZE (g)	138			156			170		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread pizza	138.6	1.677	1.677	1.677	0	0	0	0	0	0
Pasta	131.9	8.074	0.158	22.159	9.972	9.972	9.972	4.986	3.957	6.014
Rice	25.3	0.458	0.053	1.113	0	0	0	0.157	0.157	0.157
Potatoes	37.5	0	0	0	0	0	0	0	0	0
Beaf	46.7	1.500	0.168	3.339	0	0	0	0	0	0
Pork	5.0	0.057	0.050	0.064	0	0	0	0	0	0
Poultry	36.8	2.146	0.376	7.507	0	0	0	0	0	0
Ham	27.6	0.706	0.304	1.270	0	0	0	0.359	0.359	0.359
Fish	34.2	6.062	2.257	14.022	0	0	0	0	0	0
Eggs	12.5	1.744	1.637	1.850	0	0	0	0	0	0
Milk	0.1214	0.196	0.196	0.196	0	0	0	0	0	0
Yogurt	22.0	0.463	0.317	0.576	0.095	0.095	0.095	0	0	0
Cheese	45.9	1.147	0.918	1.377	0	0	0	0	0	0
Dessert	43.0	0.086	0.056	0.125	0	0	0	0	0	0
Ice cream	14.7	0.019	0.018	0.020	0	0	0	0	0	0
Vegetables	85.2	3.425	0.273	8.435	4.273	2.564	5.981	2.633	1.542	3.723
Legumes	16.2	0	0	0	0	0	0	0	0	0
Citrus fruit	69.1	0.269	0.269	0.269	0	0	0	0	0	0
Fresh fruit	174.9	0.315	0.315	0.315	0	0	0	0	0	0
Bottled mineral water	0.659	0	0	0	0	0	0	0	0	0
Soft drinks	0.035	0.015	0.015	0.015	0	0	0	0	0	0
Beer	0.027	0	0	0	0	0	0	0	0	0
Wine	0.084	0	0	0	0	0	0	0	0	0

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FOODS	SAMPLE SIZE (g)	187			183			180		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Bread pizza	138.6	0	0	0	0	0	0	0.360	0.138	0.735
Pasta	131.9	4.234	4.234	4.234	0	0	0	3.321	0.105	20.048
Rice	25.3	0	0	0	0	0	0	0.150	0.030	0.354
Potatoes	37.5	0	0	0	0	0	0	0	0	0
Beaf	46.7	0	0	0	0	0	0	0.661	0.313	1.135
Pork	5.0	0	0	0	0	0	0	0.052	0.049	0.054
Poultry	36.8	0	0	0	0	0	0	4.311	0.526	8.096
Ham	27.6	0	0	0	0	0	0	0.207	0.185	0.229
Fish	34.2	3.334	2.941	3.728	0.958	0.958	0.958	1.710	0.992	2.428
Eggs	12.5	0.750	0.750	0.750	1.175	1.175	1.175	0.937	0.575	1.300
Milk	0.1214	0	0	0	0	0	0	0	0	0
Yogurt	22.0	0	0	0	0	0	0	0.425	0.306	0.642
Cheese	45.9	0	0	0	0	0	0	1.859	1.652	2.065
Dessert	43.0	0	0	0	0	0	0	0.090	0.090	0.090
Ice cream	14.7	0	0	0	0	0	0	0	0	0
Vegetables	85.2	0.767	0.767	0.767	0.792	0.792	0.792	3.443	0.162	8.520
Legumes	16.2	0	0	0	0	0	0	0	0	0
Citrus fruit	69.1	0.145	0.145	0.145	0.145	0.145	0.145	0.263	0.263	0.263
Fresh fruit	174.9	0	0	0	0	0	0	0	0	0
Bottled mineral water	0.659	0	0	0	0	0	0	0	0	0
Soft drinks	0.035	0	0	0	0	0	0	0	0	0
Beer	0.027	0	0	0	0	0	0	0	0	0
Wine	0.084	0	0	0	0	0	0	0	0	0

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Table IV – Estimated PCBs dietary intake in different countries ($\mu\text{g}/\text{person}/\text{day}$).

Country	Total daily intake ($\mu\text{g}/\text{person}/\text{day}$)	Reference
Italy (Northern Italy)	0.26	This study
Japan	0.166 – 0.523	Koizumi et al., 2005
Japan	0.7 - 4.4	Akutsu et al., 2005
UK	0.22 – 0.46	Juan et al., 2002
Italy (Central Italy)	3.72	Zuccato et al., 1999
Australia	6.9	Kannan et al., 1994
UK	0.53	Duarte et al., 1994
India	0.86	Kannan et al., 1992a
Vietnam	3.7	Kannan et al., 1992b
Thailand	1.5	Tanabe et al., 1991
West Germany	4.1	Brunn et al., 1989
Japan	4.3	Matsumoto et al., 1987
USA	1.6	Gunderson et al., 1988
Finland	14.4	Moilanen et al., 1986

Figure 1. Average daily intake (ng/person/day) of 21 PCB congeners from total diet samples collected in Pavia, Northern Italy.

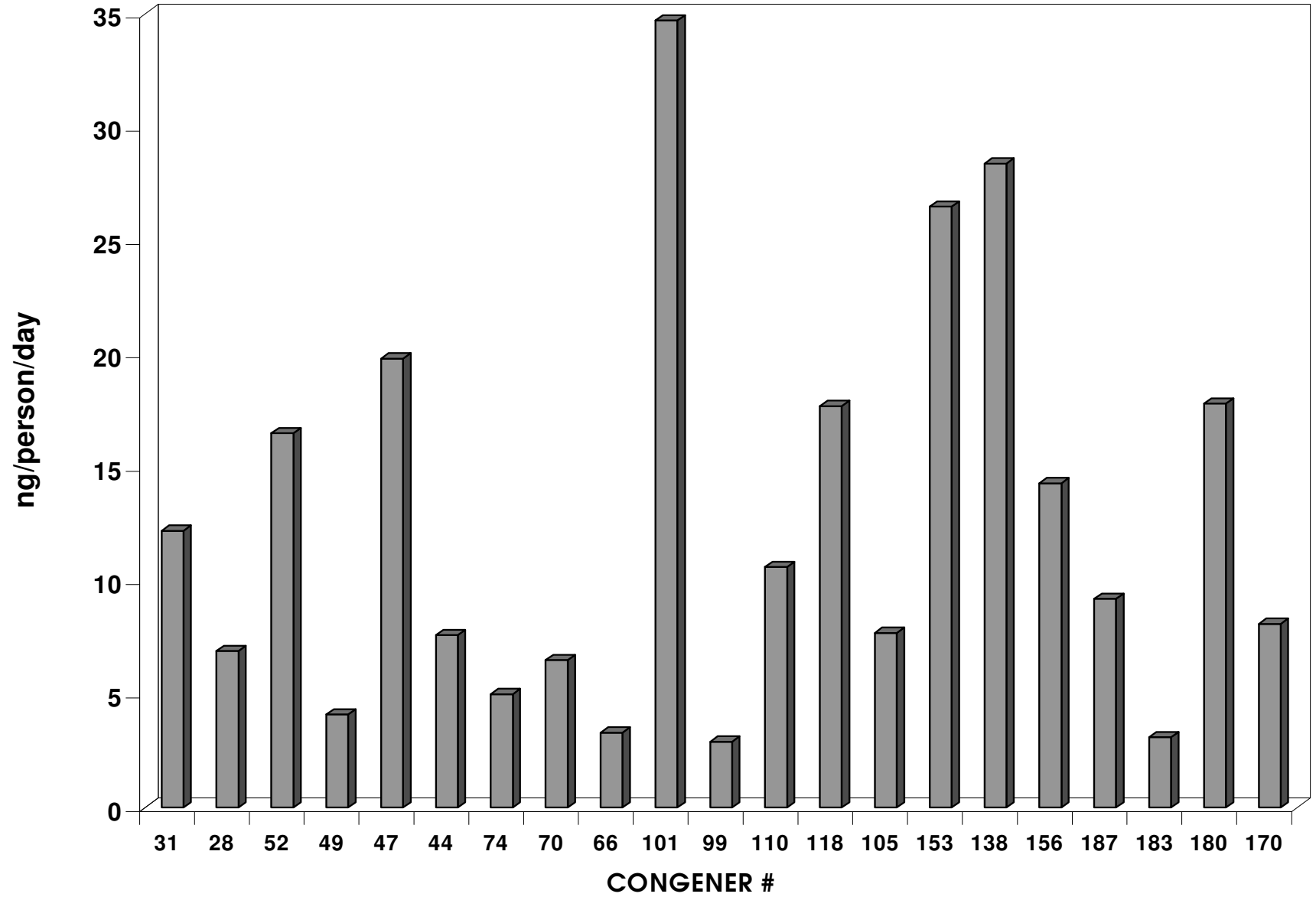


Figure 2. Contribution from the different groups of foodstuffs to the dietary intake of 21 PCB congeners.

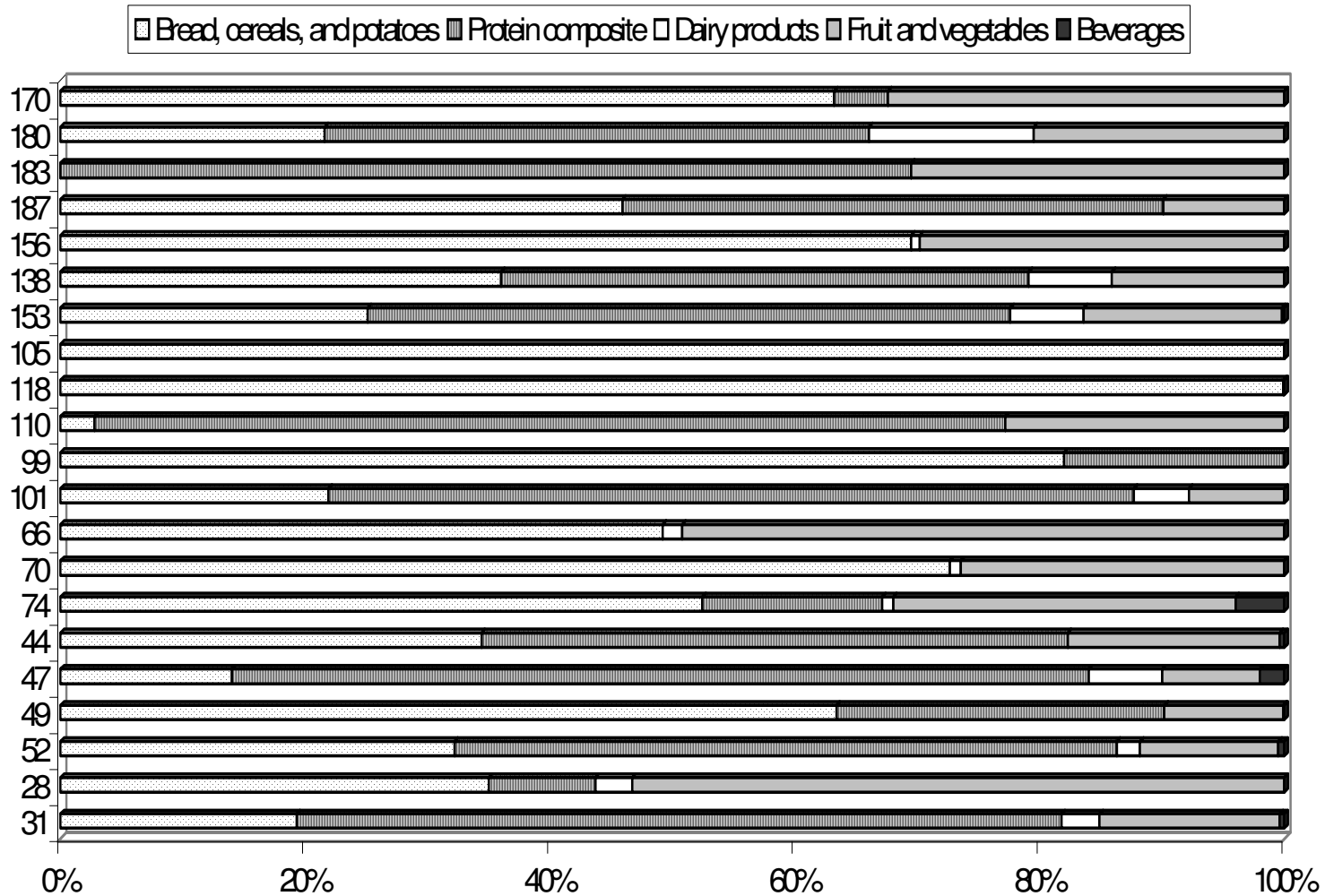
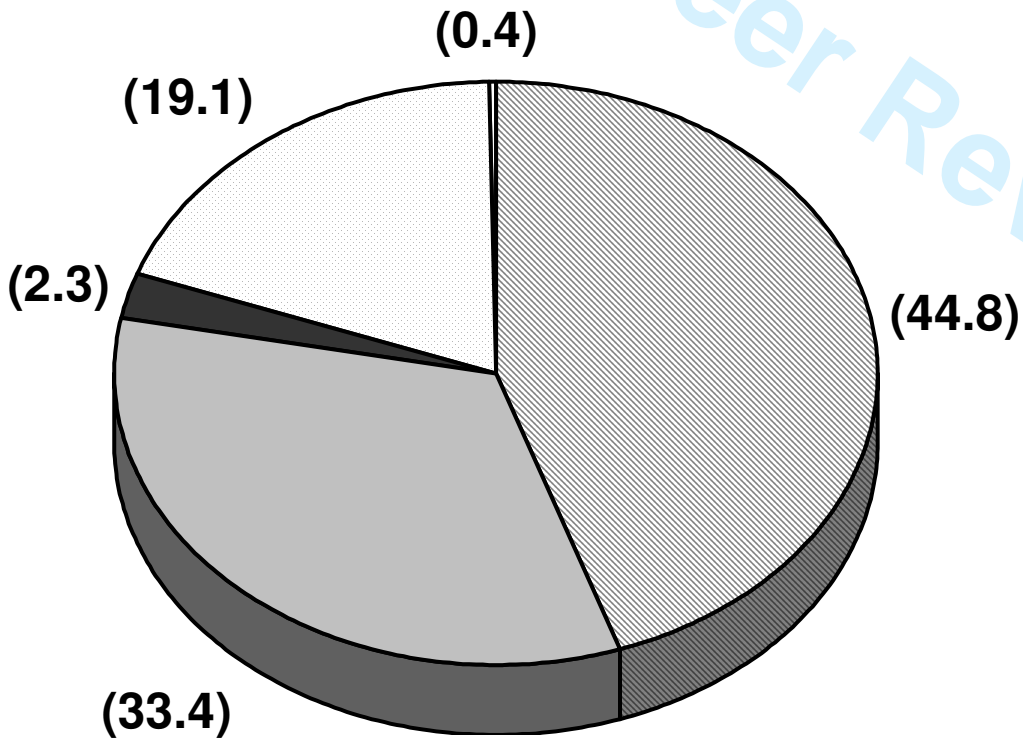
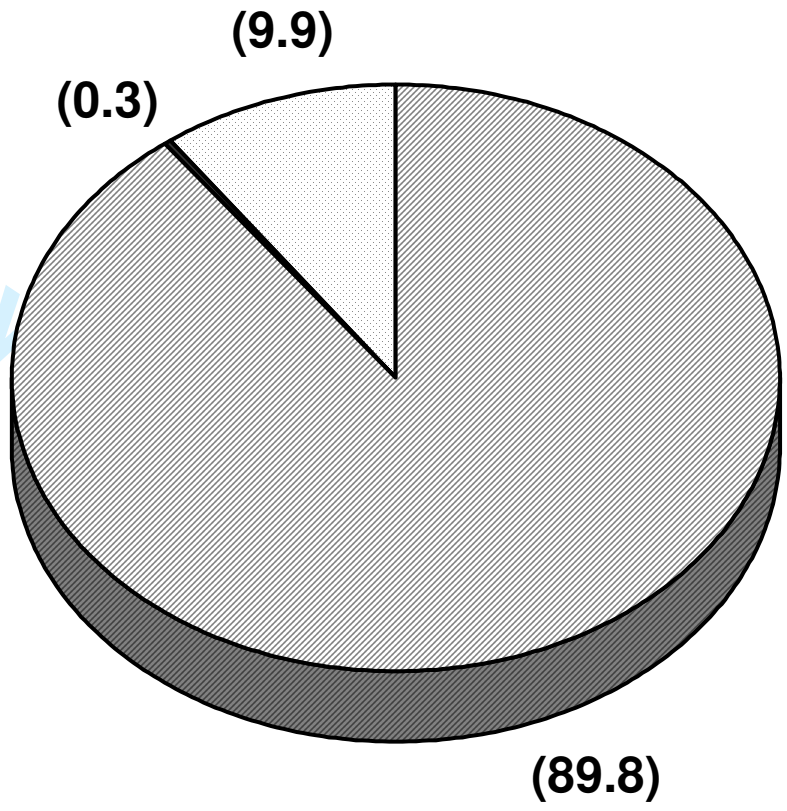


Figure 3. Contribution from different groups of foodstuffs to the dietary intake of TOTAL PCBs (3a) and DIOXIN-LIKE PCBs (3b). Figures in parentheses indicate the percentage contribution.



3a



3b