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Dietary cadmium intake by the Belgian adult population

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Running head: Dietary cadmium intake by the Belgian adult population

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Abstract

The aim of this study was to estimate the dietary cadmium (Cd) intake of the Belgian adult population, to compare this dietary Cd exposure to the tolerable weekly intake (TWI) recently established by the European Food Safety Authority (EFSA) and to determine the major food groups that contribute to dietary Cd exposure in Belgium. Food consumption data were derived from the 2004 Belgian food consumption survey (two 24h recalls, 3,083 participants). Cadmium concentrations in food items (n= 4,000) were gathered from the control program of the Belgian Federal Agency for the Safety of the Food Chain for the period 2006-2008. Dietary intake per individual was calculated from consumption data and median Cd concentrations. The population mean, median and 95th percentile of the dietary intake values were 0.98, 0.85 and 2.02 $\mu\text{g kg}^{-1}$ body weight per week respectively. Two percent of the Belgian adult population has a dietary Cd intake above the recent TWI of 2.5 $\mu\text{g kg}^{-1}$ body weight established by EFSA. Cereal products and potatoes contribute for more than 60% to Cd intake.

Keywords : *cadmium, dietary intake, risk assessment, cereal products.*

Introduction

Cadmium is a non essential trace element. It is mainly an environmental contaminant, which on the one hand, is naturally present in the environment and on the other hand, may originate from industrial and agricultural sources.

Food, including drinks, is the main source of Cd exposure for the non-smoking and non-occupationally exposed part of the population (WHO 1992). Fouassin and Fondu (1981) evaluated the average Cd concentration in food from the daily diet and estimated Cd dietary intake of the Belgian population at 48 μg per day. More than 2,500 food samples in big and small market were taken and analyzed by atomic absorption spectrometry or

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5 by electrothermal atomic absorption spectrometry. In 1993, Van Assche and Ciarletta
6 compared the data from Fouassin and Fondu (1981) with analysis result from 1989.
7 They observed a decline of Cd concentration in food which may presumed be due to the
8 decrease in direct atmospheric deposition of Cd onto crops and soils.
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13 Cadmium might constitute a serious health hazard for large groups of the population
14 because it can bioaccumulate (Marzec and Schlegel-Zawadzka 2004). The half-life of
15 Cd in the human body is 10 to 30 years (Nawrot et al. 2006). The most severe form of
16 foodborne chronic Cd intoxication is the Itai Itai disease (Kobayashi et al. 2009), which
17 combines bone disorders and renal effects and is characterized by extreme pain. The
18 disease was mainly diagnosed in a limited area in Japan that had been polluted.
19 Cadmium concentrations found in locally grown rice were ten times higher than in other
20 areas (Moritsugi and Kobayashi 1964 cited in EC 2007). The most critical organ, i.e. the
21 organ that exhibits the first adverse effects in long-term low-level Cd exposure, is the
22 kidney. The critical effect is renal tubular dysfunction, which is often manifested as the
23 presence of low molecular weight proteins (e.g. β -2-microglobulin) in urine
24 (FAO/WHO 2000). In the general population, i.e. at low (dietary) Cd exposure, the
25 urinary excretion of Cd reflects the amount stored in the kidney, as long as the amount
26 of absorbed Cd has not yet saturated all Cd-binding sites, and increases progressively
27 with age (Lauwerys et al. 1994). Once the binding sites become saturated (i.e. after
28 excessive exposure), further absorbed Cd is rapidly excreted in urine. When Cd-induced
29 renal tubular damage develops, a considerable increase in the urinary excretion of Cd
30 occurs because of its loss from the renal depot (Lauwerys et al. 1994). Several markers
31 of renal tubular function, such as β -2-microglobulin, are significantly and positively
32 associated with urinary Cd (Lauwerys et al. 1991).
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50 A provisional tolerable weekly intake (PTWI) for Cd of $7 \mu\text{g kg}^{-1}$ body weight was
51 established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA;
52 FAO/WHO 2004) and endorsed in 1995 by the Scientific Committee for Food of the
53 European Commission (SCF 1995). The PTWI was based on the prevalence of renal
54 tubular dysfunction, a biomarker of toxicity, and set at such a level that the Cd
55 concentration in the renal cortex would not exceed $50 \mu\text{g g}^{-1}$ after 50 years of exposure.
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The health risk related to Cd exposure has recently been re-evaluated by the Scientific Panel on Contaminants in the Food Chain (CONTAM) of the European Food Safety Authority (EFSA), which established a tolerable weekly intake (TWI) of 2.5 $\mu\text{g kg}^{-1}$ body weight (EFSA 2009). The establishment of the TWI was based on a meta-analysis to evaluate the dose-response relationship between urinary Cd and urinary β -2-microglobulin and set at a level to remain below 1 $\mu\text{g Cd g}^{-1}$ creatinine in urine in 95% of the population by age 50 (EFSA 2009).

The objective of this study was to estimate the dietary Cd intake of the general adult population in Belgium, to compare this dietary Cd exposure to the new TWI established by EFSA and to determine which food groups are the major contributors to the dietary Cd exposure. Dietary Cd intake was also calculated for individuals who follow the nutritional recommendations for the consumption of vegetables or fish and compared to the TWI established by EFSA.

Materials and methods

Cadmium data

Food items were sampled in the framework of the control program of the Belgian Federal Agency for the Safety of the Food Chain (FASFC) in the period 2006-2008. The goal of this program is to control the conformity with regulations and to guarantee food safety (Maudoux et al. 2006). The samples were analyzed in different accredited laboratories and by using different analytical methods (inter alia atomic absorption spectrometry, inductively coupled plasma–mass spectrometry). The methods used are among others subject to interlaboratory trials to check the quality of the results. Only the edible portion of the samples were analyzed. The limit of detection (LOD) or quantification (LOQ) for the analyses varied with the food matrix, the analytical technique used and per laboratory. The sensitivity of an analytical method is, for cost and time reasons, often set by the laboratory to fulfill legislative requirements and not fine-tuned to optimal sensitivity. This is perfectly satisfactory for routine monitoring purposes, but does cause slight problems when results are used to calculate human exposure (EFSA 2009). The calculation of the descriptive statistics for the

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4 concentrations of Cd was performed by also taking into account the samples with results
5 below the LOD. Such samples do not necessarily indicate that Cd is not present in the
6 sample, but only that the analytical method could not detect the possible amount of Cd
7 present. These samples were assigned a value of half the limit of detection (middle
8 bound principle). In some cases, the samples were reported as a concentration value
9 below the limit of quantification (LOQ). In these cases the numeric concentration was
10 estimated as half of the limit of quantification.
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19 The results of the middle bound scenario were compared with a lower bound scenario in
20 which samples with Cd levels below the LOD or LOQ were set to zero, and an upper
21 bound (worst-case) scenario in which samples with Cd levels below the LOD or LOQ
22 were set to the LOD or LOQ respectively. According to WHO (1995), two estimates
23 using zero and LOD for all results less than LOD must be done if the proportion of
24 samples below the LOD is between 60 and 80%.
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31 *Food consumption data*

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33 A Belgian national food consumption survey was performed in 2004 by the Belgian
34 Institute for Public Health. Aims, design and methods of this survey are described
35 elsewhere (De Vriese et al. 2005). This survey describes the food consumption schema
36 of 3,083 participants over 15 years of age. Information on food intake was collected
37 using two non-consecutive 24h recalls in combination with a self-administered food
38 frequency questionnaire. The selection of interviewed people and the moment of the
39 interview were chosen in order to obtain a representative consumption profile of the
40 Belgian population spread over one year. The dietary Cd exposure of the Belgian adult
41 population (> 15 years of age) was estimated based on the mean consumption of the
42 food items over the two non-consecutive days.
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51 *Estimation of cadmium intake*

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53 Cadmium was analyzed in 55 categories (food items) of foods. Liver of horse, game and
54 bovine like kidneys of horse, game and bovine were grouped for the determination of
55 the Cd intake.
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The Cd intake was calculated by a deterministic approach multiplying for each food item the median Cd concentration by its mean consumption.

The use of the median Cd concentration in food was preferred over the use of the mean concentration because the latter is more sensitive to extreme values. The obtained results were summed up for all food items to estimate an overall exposure. The dietary Cd intake was compared to the TWI of 2.5 $\mu\text{g kg}^{-1}$ body weight set by EFSA (2009) as:

$$\% \text{ TWI} = \frac{\text{daily dietary Cd intake } (\mu\text{g day}^{-1}) \cdot 7 \text{ (day)}}{2.5 (\mu\text{g kg}^{-1} \text{body weight}) \cdot \text{body weight (kg)}} \cdot 100\% \quad (1)$$

The values of the body weight were set per individual.

The Cd intake was also determined by multiplying, for each individual, the consumption of each food (average over the two 24h recalls) by the median Cd concentration in that food item and by summing the results for all food items.

The dietary Cd intake for individuals who follow the nutritional recommendations for the consumption of vegetables or fish was similarly determined. For each individual who eats 250 g or more vegetables or 30 g or more fish per day, the consumption of a food item was multiplied with the median Cd concentration in the food items. The obtained results were then summed up for all food items to estimate an overall exposure.

Results

About 4,000 results of Cd analyses in food items were collected (Table 1). Cadmium was detected in 23% of the samples with a higher detection rate in matrices such as cereals, potatoes, root vegetables and offal. The highest concentrations were measured in offal (liver and kidney) of game and horse (Table 1). Although Cd has not been analyzed in cattle offal during the selected time period, it is known that the contamination level is quite high (Advice 01-2005; Vromman et al. 2008; Waegeneers

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4 et al. 2009). Therefore, by Royal Decree¹, bovine offal of animals over 18 months
5 slaughtered in Belgium can not be placed on the market. The Cd concentrations
6 measured by Waegeneers et al. (2009) in cattle liver and kidneys of animals of ≤ 18
7 months (median: 0.06 mg kg⁻¹ and 0.23 mg kg⁻¹, respectively; Waegeneers et al.
8 personal communication) were lower than those measured in game and horse liver and
9 kidneys. Cadmium is frequently found in cereal products. It was detected in all pasta
10 samples analyzed by FASFC (Table 1). Cadmium concentrations measured by FASFC
11 in cereals were higher than those reported by EFSA (2009). Cereals like wheat and rice
12 can concentrate cadmium during the growth in the core of the kernel (RIVM 2003).
13 Chaudri et al. (1995) analyzed 77 samples of wheat grain. On average, the concentration
14 of Cd in bran was twice that in wholemeal flour. White flour contained about 31% less
15 Cd than wholemeal flour. This corresponds to data of Cubadda et al. (2005), who found
16 that milling of durum wheat, which is used for pasta-making, reduced the Cd content
17 with 32%. Different types of flour contain different amounts of Cd. Cadmium
18 concentrations in buckwheat (0.046 mg kg⁻¹ fresh weight) were higher than in wheat
19 flour (0.025 mg kg⁻¹ fresh weight) and than in rye flour (0.017 mg kg⁻¹ fresh weight)
20 (Jorhem and Sundström 1993). This is reflected in the different types of bread, as
21 measured by Tahvonen and Kumpulainen (1994) in Finnish breads: the respective Cd
22 concentrations in rye bread, coffee bread (which is based on white wheat flour) and
23 wholewheat bread were 0.014, 0.023 and 0.030 mg Cd kg⁻¹ dry weight. The types of
24 bread that were analyzed in the current study (e.g. white, wholemeal wheat or rye
25 bread), were not specified. Biscuits, pastries and breakfast cereals were not analyzed,
26 neither was rice. The Cd concentrations in pastries and biscuits are generally slightly
27 lower than in white bread (Bordajandi et al. 2004; Karavoltos et al. 2002). Cadmium
28 concentrations in different types of rice on the Swedish market ranged from <0.001 to
29 0.088 mg kg⁻¹ fresh weight, with a mean of 0.024 mg kg⁻¹ fresh weight (Jorhem et al.
30 2008).

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34 Among vegetables, Cd was mainly found in spinach, celery, salsify and to a lesser
35 extent in potatoes, leek, parsley and carrots (Table 1). According to Versluijs and Otte
36 (2001), carrot, spinach, tomato, lettuce and celery have a high Cd uptake from soil. Van
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¹ Royal Decree of 10 August 2005 modifying Royal Decree of 9 March 1953 concerning trade of meat slaughter and regulating the expertise of animals slaughtered in the country

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der Schee (cited in RIVM 2003) analyzed 500 samples of fruits, vegetables and potatoes. He found that leafy vegetables, and more specifically spinach, contained the highest Cd concentrations. The Cd concentrations in spinach reported by EFSA (2009) are comparable to those measured by the FASFC. Cadmium concentrations in fruit, dairy products, eggs, honey and meat were low (Table 1).

[Insert Table 1: Overview of Cd result in food analyzed by FASFC]

Dietary Cd intake

The dietary Cd intake of the Belgian adult population, calculated by a deterministic approach as the sum of the mean consumption multiplied by the median Cd concentration for each food item, was estimated at $0.98 \mu\text{g kg}^{-1}$ body weight per week (39,3% of the TWI) (Table 2). The Cd intake was estimated at $0.77 \mu\text{g kg}^{-1}$ body weight per week (30.8% of the TWI) if the lower bound scenario (ie samples with Cd levels below LOD or LOQ set to zero) was applied and at $1.18 \mu\text{g kg}^{-1}$ body weight per week (47.2% of the TWI) if the upper bound scenario (ie samples with Cd levels below LOD or LOQ set to LOD or LOQ) was applied.

[Insert Table 2: Estimation of dietary Cd exposure by the Belgian adult population (>15 year)]

Figure I presents the distribution of the Cd intake of the Belgian adult population determined with the middle bound scenario. The mean, median and 95th percentile Cd intake were estimated at 0.98, 0.85 and $2.02 \mu\text{g kg}^{-1}$ body weight per week, respectively. Two percent of the Belgian adult population has a Cd intake above the TWI of $2.5 \mu\text{g kg}^{-1}$ body weight.

[Insert Figure I]

Additional exposure scenarios have been calculated for consumer groups who follow the nutritional recommendations for the consumption of vegetables or fish. The average

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4 vegetable intake by Belgian adults is only 138 g per day, while 350 g is recommended
5 (De Vriese et al. 2006). This amount of vegetable intake is only reached by 10% of the
6 adult population. Therefore, dietary Cd intake was determined for consumers who daily
7 consume 250 g or more of vegetables (28% of the Belgian population). Mean and 95th
8 percentile Cd intake for these consumers was estimated at 1.22 $\mu\text{g kg}^{-1}$ body weight per
9 week (48.7% of the TWI) and 2.25 $\mu\text{g kg}^{-1}$ body weight per week (90% of the TWI),
10 respectively. The Belgian Superior Health Council recommends a mean daily fish
11 consumption of 20-40 g by adults (HGR 2004), which corresponds to one to two
12 portions per week. However, the average intake by the general population is only 17.9 g
13 and three quarters of the populations does not meet the recommendations (De Vriese et
14 al. 2006). Mean and 95th percentile Cd intake for consumers who eat on average 30 g or
15 more fish per day (21% of the Belgian population), was estimated at 1.10 $\mu\text{g kg}^{-1}$ body
16 weight per week (43.8% of the TWI) and 2.21 $\mu\text{g kg}^{-1}$ body weight per week (88.3% of
17 the TWI), respectively.
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33 The deterministic estimation of dietary Cd exposure shows that cereal products have the
34 highest contribution to dietary Cd intake, followed by potatoes, pasta and vegetables
35 (Table 3). The large contribution of cereal products and potatoes results from a high
36 consumption of both food products combined with moderate Cd concentrations. Carrots
37 and spinach have the highest contribution in the vegetable category.
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45 [Insert table 3: Contribution of the food category to Cd intake of the Belgian adult
46 population]
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53 Discussion

54 The mean dietary Cd intake of the general adult population in Belgium, estimated at
55 0.98 $\mu\text{g kg}^{-1}$ body weight per week is lower compared to earlier published mean intake
56 data in Belgium and correspond with recently estimated values in neighboring countries
57 (see below). Vromman et al. (2008) estimated the dietary Cd exposure of the Belgian
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4 adult population at $1.8 \mu\text{g kg}^{-1}$ body weight per week. This dietary exposure was based
5 on a deterministic approach. In that study, vegetables were subdivided into three groups
6 (leaf vegetables, tuber vegetables and root vegetables) according to the definition for
7 establishment of maximum limits of regulation (EC) Nr 1881/2006 (Vromman et al.
8 2008). The Cd concentration was not measured in all food groups within the framework
9 of that study, but partially collected from literature. Belgian dietary Cd intake was also
10 estimated by SCOOP in 2004 at $1.9 \mu\text{g kg}^{-1}$ body weight per week and in 1996 at 2.74
11 $\mu\text{g kg}^{-1}$ body weight per week. This latter study included a high number of food groups.
12 The mean exposure was calculated in a deterministic way by combination of the mean
13 consumption with the mean concentration in different food categories (SCOOP 1996).
14 The dietary exposure estimate in this study is close to recent estimations from most
15 other European countries (Table 4) but is 3 times larger than the dietary exposure
16 estimate in France, $0.319 \mu\text{g kg}^{-1}$ body weight per week (Leblanc et al. 2005). Cadmium
17 concentrations measured in food by Leblanc et al. (2005) were one order of magnitude
18 lower than those measured by FASFC or reported by other authors. The median dietary
19 Cd exposure calculated by EFSA (2009) for European countries, $2.3 \mu\text{g kg}^{-1}$ body
20 weight per week, was slightly lower than that reported by JECFA (2005) ($2.8\text{-}4.2 \mu\text{g kg}^{-1}$
21 body weight per week) but higher than those reported by other authors (Table 4).
22 Dietary Cd exposure assessment published by EFSA (2009) is based on the mean Cd
23 concentration for each food group (with non-detected values set at half the limit of
24 detection) and on aggregated consumption data reported in the EFSA Concise European
25 Food Consumption database. According to EFSA (2009), the differences might indicate
26 that a refined evaluation based on more disaggregated and representative samples, can
27 result into lower dietary Cd intake estimates. Further, intake values may differ from one
28 study to another according to the number and the nature of the food groups which are
29 considered, the calculation methodology and the type of food consumption survey.
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52 In the current intake calculations, Cd intake may be underestimated due to the absence
53 of some food products in the dietary exposure assessment, e.g. rice, breakfast cereals,
54 biscuits and wild mushrooms. Ingredients in mixed dishes (e.g. vegetables in soup) were
55 not taken into account either. Rice is mainly imported from outside Europe, and
56 therefore the mean Cd concentration derived by Jorhem et al. (2008), i.e. 0.024 mg kg^{-1} ,
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5 can be used to make an estimation of the contribution of rice to the total dietary Cd
6 intake. If this value is combined with the mean rice consumption of the Belgian adult
7 population, a weekly Cd intake due to the consumption of rice of $0.022 \mu\text{g kg}^{-1}$ body
8 weight can be calculated, which represents 2% of the deterministically derived intake of
9 $1.004 \mu\text{g kg}^{-1}$ body weight per week and which is less than 1% of the TWI.
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15 The robustness of the high percentiles of Cd exposure, may be questioned because these
16 percentiles are more sensitive to uncertainties linked to different sources (sampling size,
17 misreporting of consumption, variability in concentrations, analytical uncertainty, ...).
18 These percentiles are, however, important. Therefore, this methodology may be
19 valuable for mean exposure estimations, but due to the large uncertainty for estimations
20 realized for the highest percentiles, these percentiles should be considered with caution.
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29 Cereal products contribute largely to the total dietary Cd intake, both in the current
30 study (> 40%) as in other studies (RIVM 2003; FSA 2009; EFSA 2009) and former
31 Belgian estimates (SCOOP). This is mainly due to the large consumption of this food
32 group. The consumption of wholemeal cereal products is promoted as they may provide
33 protection against e.g. various cancers (Goodman et al. 1997; Chan et al. 2007; Suzuki
34 et al. 2008). The mean Cd concentration found by FASFC in bread (0.019 mg kg^{-1}) is
35 comparable to those found in white bread in other studies (range $0.015\text{-}0.023 \text{ mg kg}^{-1}$;
36 Bordajandi et al. 2004; Karavoltzos et al. 2002; Marti-Cid et al 2008; Tahvonen and
37 Kumpulainen 1994). As wholemeal flour contains about 30% more Cd than white flour
38 (Chaudri et al. 1995), consumption of wholemeal bread might increase the Cd intake up
39 to 6.6% (from 0.98 to $1.05 \mu\text{g kg}^{-1}$ body weight per week). This increase will, on the
40 other hand, be compensated to a large extent by the lower fractional absorption of Cd in
41 the gastrointestinal tract, due to the presence of phytates, nutrients and fibers in the
42 whole grain and bran fractions (Moberg et al. 1987; Berglund et al 1994; Lind et al.
43 1998; Reeves and Chaney 2002; Andersen et al. 2004). Therefore, the higher Cd content
44 does not seem to be a reason to decrease the consumption of wholemeal wheat.
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Conclusion

The mean, median and 95th percentile dietary exposure to Cd of the Belgian adult population were estimated at 0.98, 0.85 and 2.02 $\mu\text{g kg}^{-1}$ body weight per week. Cadmium intake was estimated to be lower than the TWI of 2.5 $\mu\text{g kg}^{-1}$ body weight for 98% of the Belgian adult population. Dietary exposure to Cd for specific consumer groups such as consumers who follow the nutritional recommendations for the consumption of vegetables and fish, is higher than for the general adult population.

Dietary Cd exposure of the Belgian adult population was comparable to that in several other European countries. Cereal products and potatoes are the main food groups that contribute to Cd exposure in Belgium.

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Table 1: Overview of various food items in which Cd was measured by FASFC in 2006, 2007 and 2008 (Number of samples analyzed, number of samples < quantification limit (LOQ), percent of samples < LOQ, minimum, maximum, mean and median (P50) Cd concentration. The concentrations are expressed on a fresh weight basis.

Food	Number sample	Nb <LOQ	Percent of sample <LOQ	Min (mg kg ⁻¹)	Max (mg kg ⁻¹)	Mean (mg kg ⁻¹)	P50 (mg kg ⁻¹)
Bread	40	1	3	0.005	0.051	0.019	0.019
Pasta, noodle	38	0	0	0.011	0.130	0.060	0.054
Cereals (wheat)	10	0	0	0.025	0.099	0.051	0.052
Potatoes	88	21	24	0.005	0.140	0.023	0.021
Garlic	7	3	43	0.005	0.048	0.014	0.011
Courgette	7	5	71	0.005	0.047	0.012	0.005
Tomato	10	7	70	0.005	0.021	0.008	0.005
Pea	15	15	100	0.050	0.050	0.050	0.050
Onion	33	18	55	0.005	0.059	0.014	0.005
Carrot	96	13	14	0.005	0.084	0.025	0.021
Radish	5	4	80	0.005	0.014	0.007	0.005
Salsify	34	0	0	0.014	0.081	0.045	0.042
Leek	30	10	33	0.005	0.15	0.030	0.0185
Celery	29	3	10	0.005	0.240	0.044	0.027
Celeriac	18	3	17	0.005	0.180	0.068	0.059
Lettuce (lettuce, lamb's lettuce rocket,...)	59	24	41	0.005	0.087	0.022	0.011
Spinach	50	0	0	0.017	0.290	0.079	0.066
Fennel	10	8	80	0.005	0.026	0.008	0.005
Parsley	16	3	19	0.005	0.110	0.032	0.024
Endive	6	4	67	0.005	0.023	0.009	0.005
Cabbage (white cabbage, cauliflower,...)	56	52	93	0.002	0.005	0.005	0.005
Cultivated mushroom	55	39	71	0.005	3.000	0.098	0.005
Gooseberry	9	9	100	0.005	0.005	0.005	0.005
Strawberry	11	11	100	0.005	0.005	0.005	0.005
Grape	6	6	100	0.005	0.005	0.005	0.005
Dried fruit – pine nuts	5	0	0	0.106	0.153	0.128	0.124
Melon	9	8	89	0.005	0.012	0.006	0.005
Honey	141	130	92	0.001	0.079	0.004	0.0025
Milk	179	171	96	0.00025	0.007	0.001	0.0005
Cheese	25	21	84	0.0005	0.009	0.002	0.001
Yoghurt	20	19	95	0	0.003	0.001	0.001
Eggs	137	135	99	0.00005	0.0131	0.001	0.0005
Fish	952	895	94	0.001	1.5	0.031	0.025
Molluscs	46	4	9	0.005	0.88	0.212	0.18
Crustaceans	157	113	72	0.005	0.37	0.039	0.025
Duck meat	18	18	100	0.005	0.005	0.005	0.005
Rabbit meat	35	34	97	0.001	0.029	0.005	0.005
Chicken meat	121	120	99	0.005	0.2	0.007	0.005
Turkey meat	30	30	100	0.005	0.005	0.005	0.005
Snail	8	8	0	0.031	0.3	0.129	0.094
Sheep & lamb meat	41	41	100	0.001	0.005	0.005	0.005
Pork meat	225	225	100	0.001	0.01	0.005	0.005
Bovine meat	268	267	99.6	0.005	0.043	0.005	0.005
Veal meat	34	34	100	0.005	0.005	0.005	0.005
Bovine liver*	11	0	0	0.04	0.143	0.072	0.059
Bovine kidney*	11	0	0	0.093	0.635	0.257	0.23
Horse meat	70	8	11	0.005	0.36	0.042	0.031
Horse liver	20	0	0	0.028	72.6	5.315	1.64
Horse kidney	15	0	0	4.430	71.7	19.463	14.7

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Game meat	268	245	91	0.005	0.029	0.006	0.005
Game liver	46	0	0	0.015	52.27	2.341	0.17
Game kidney	37	0	0	0.2	14.47	2.768	1.63
Fruit juice	56	54	96	0.005	0.016	0.005	0.005
Mineral water (FAL^{**}, 2000-2003)	14	0	0	0.00005	0.0003	0.0002	0.0002
Chocolate	10	5	50	0.010	0.090	0.034	0.025

*Waegeneers et al. personal communication; **Institute of Plant Nutrition and Soil Science, Federal Agricultural Research Center (FAL) Braunschweig (2000-2003)

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Table 2: Estimation of Cd dietary exposure by the Belgian adult population (>15 year)

Food	Mean consumption (kg kg ⁻¹ body weight per day)	Exposure* (µg kg ⁻¹ body weight per week)	%TWI (= 2,5 µg kg ⁻¹ body weight per week)
Bread	1.75E-03	0.233	9.31
Pasta, noodle	4.66E-04	0.176	7.05
Cereals (wheat)	3.70E-06	0.001	0.05
Potatoes	1.57E-03	0.226	9.03
Garlic	2.58E-06	0.0002	0.01
Courgette	2.52E-05	0.001	0.04
Tomato	4.55E-04	0.016	0.64
Pea	3.37E-05	0.012	0.47
Onion	9.24E-05	0.003	0.13
Carrot	1.66E-04	0.024	0.97
Radish	2.46E-06	0.0001	0.00
Salsify	5.95E-06	0.002	0.07
Leek	5.28E-05	0.007	0.27
Celery	1.33E-05	0.003	0.10
Celeriac	1.08E-05	0.004	0,18
Lettuce (lettuce, lamb's lettuce, rocket,...)	9.76E-05	0.008	0.30
Spinach	4.89E-05	0.022	0.90
Fennel	3.96E-06	0,0001	0.01
Parsley	6.81E-07	0.0001	0,00
Endive	1.48E-05	0.001	0.02
Cabbage (white cabbage, cauliflower,...)	2.07E-04	0.007	0.29
Cultivated mushroom	4.23E-05	0.001	0.06
Gooseberry	3.89E-06	0.0001	0.01
Strawberry	7.64E-05	0.003	0.11
Grape	8.05E-05	0.003	0.11
Dried fruit – pine nuts	3.33E-07	0.0003	0.01
Melon	6.11E-05	0.002	0.09
Honey	1.61E-05	0.0003	0.01
Milk	1.40E-03	0.005	0.20
Cheese	1.48E-04	0.001	0.04
Yoghurt	5.15E-04	0.004	0.14
Eggs	1.44E-04	0.001	0.02
Fish	2.51E-04	0.044	1.76
Molluscs	2.56E-05	0.032	1.29
Crustaceans	4.05E-05	0.007	0.28
Duck meat	4.89E-06	0.0002	0.01
Rabbit meat	1.85E-05	0.001	0.03
Chicken meat	2.48E-04	0.009	0.35
Turkey meat	5.48E-05	0.002	0.08
Snail	9.18E-07	0.001	0.02
Sheep & lamb meat	3.35E-04	0,012	0.47
Pork meat	1.99E-04	0.007	0.28
Bovine meat	2.54E-04	0.009	0.36

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5	Veal meat	5.22E-05	0.002	0.07
6	Horse meat	1.31E-05	0.003	0.11
7	Game meat	1.73E-05	0.001	0.02
8	Liver (horse, game, bovine)	1.75E-06	0.003	0.11
9	Kidneys (horse, game, bovine)	2.43E-07	0.003	0.12
10	Fruit juice	9.96E-04	0.035	1.39
11	Mineral water (FAL 2000-2003)	8.80E-03	0.012	0.49
12	Chocolate	2.01E-04	0.035	1.41
13	Sum		0.98	39.3
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Table 3 : Contribution of food categories to the dietary exposure of the Belgian adult population

Categories of food	Contribution to exposure (%)
Cereals (wheat), bread	23.83
Potatoes	22.99
Pasta, noodle	17.94
Vegetables	11.34
Beverages (water, juice)	4.80
Meat (poultry, bovine, pork, horse, game)	4.57
Fish	4.47
Crustaceans, bivalves	4.01
Chocolate	3.58
Dairy products	0.97
Fruit	0.82
Offal (horse, game, bovine)	0.57
Eggs	0.05
Honey	0.03

Table 4. Comparison of dietary Cd intake in different European countries.

Country	Cd intake ($\mu\text{g kg}^{-1}$ body weight per week)	Reference
Belgium	0.98	This study
The Netherlands	1.26 (short-term intake) 0.98 (long-term intake)	RIVM 2003
United Kingdom	0.98-1.19	FSA 2009
Germany	1.45	BfR 2009
Denmark	1.87	Larsen et al. 2002
Sweden	1.75	Åkesson et al. 2008
Spain (Tarragona)	1.67	Bocio et al. 2005
Spain (Catalonia)	1.4/1.83 (females/males)	Llobet et al. 2003
Spain (Huelva)	0.77	Bordajandi et al. 2004
Spain (Canary Islands)	1.1	Rubio et al. 2006
France	0.319	Leblanc et al. 2005
Europe	1.9-3.0	EFSA 2009
Belgium	2.33	

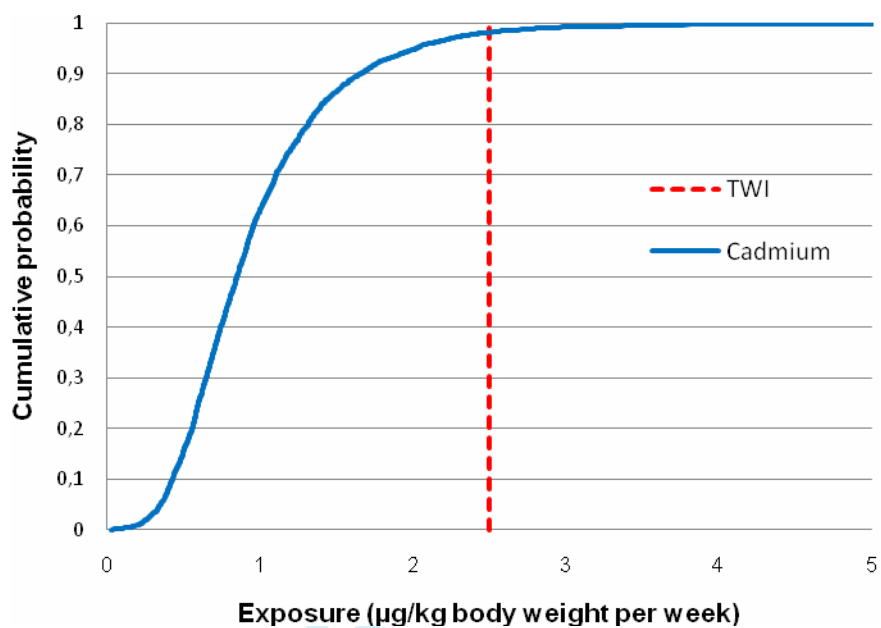


Figure 1: Distribution of dietary Cd Intake for the Belgian adult population. The TWI value established by EFSA is shown as the vertical line.