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Additives/Contaminants:	Heavy metals, Heavy metals - cadmium
Food Types:	Animal products – meat, Fruit, Potatoes, Vegetables

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## Cadmium in the food chain nearby non-ferrous metal production sites

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### Abstract

Dietary cadmium (Cd) exposure was estimated for adults living in Cd contaminated areas close to non ferrous metal plants, and compared with the dietary Cd exposure of the general Belgian adult population. To evaluate the contamination levels of locally produced food items, 35 fruit samples, 97 vegetable samples and 98 samples of potatoes and 53 samples of meat, liver and kidneys of cattle that had resided for more than 18 months in the contaminated area, were analysed for Cd. Mean Cd concentrations in fruit and vegetables were 1.1- to 9-fold higher than in samples from other regions at ambient Cd levels. Mean Cd concentrations in bovine meat, liver and kidneys were two-fold higher compared to samples from animals of other regions in Belgium. The estimated dietary intake was 31.3 and 63.3  $\mu\text{g day}^{-1}$  for average and large consumers in the contaminated area, compared to 17 and 38.3  $\mu\text{g day}^{-1}$  for the general adult population. Extensive consumption of locally produced food items in areas close to non-ferrous metal plants could result in Cd intake levels exceeding the provisional tolerable weekly intake (PTWI).

**Keywords** : *cadmium, dietary intake, risk assessment, pollution, cattle, vegetables.*

## Introduction

The level of cadmium reflects the level of industrial pollution of the local environment (Saegerman et al. 2006). During previous decades numerous non-ferrous metal production plants have been installed in industrialized countries. In Belgium, many industrial sites were created for the production and treatment of non-ferrous metals. As such, several zinc and copper smelters emerged in the Northern part of the country (Campine region). One of the adverse consequences originating from these activities is the mainly historical, local emission into air, water and soil of large amounts of contaminants such as cadmium (Cd), for which Belgium was one of the principal producers in Europe (Monography 2004). Cadmium can also occur naturally in the environment from the gradual process of erosion and abrasion of rocks and soils, and from singular events such as forest fires and volcanic eruptions. It is therefore naturally present everywhere in air, water, soils and foodstuffs (<http://www.cadmium.org/introduction.html>). In the last decades considerable attention was drawn to the toxicological effects resulting from the contamination of the local environment by heavy metals (Saegerman et al. 2006; Mench et al. 1989; Marshall and Mellinger 1980). As a consequence, progress was made in the control of emissions of these toxic elements by the industry and large efforts were (and are still) devoted for remediation actions. These remediation actions mainly concern the industrial area itself and nearby private gardens where high metal concentrations were measured. Less attention has been paid to areas a few kilometers away from the industrial sites where lower but still increased metal levels have been detected in several environmental compartments (Staessen et al. 1994; IHE 1986). These areas are typically situated within a few tens of kilometers around the industrial sites and may still form a risk for the contamination of the food chain and, as a possible consequence, for human health. Residents of six contaminated districts close to three smelters in the Campine region had higher urinary Cd excretion, a biomarker of lifetime exposure, than residents from four other districts (Staessen et al. 1994; Staessen et al. 1999). Furthermore, residence in a more contaminated district rather than a less contaminated district increased the risk of bone fractures (Staessen et al. 1999). Recently it was found that overall cancer risk was significantly associated with a doubling of 24-h cadmium excretion (Nawrot et al. 2006). In all of the ten districts, Cd in the soil was positively correlated with Cd in vegetables and in the residents' urine (Staessen et al. 1994).

The major routes of Cd transfer to humans via the food chain are illustrated in Figure 1. Soils are contaminated by Cd through wet and dry deposition of Cd emissions. The contaminated soil, in turn, can be at the origin of groundwater pollution (up to 400  $\mu\text{g l}^{-1}$  in wells located in the Campine region; IHE 1986) and of locally grown crops (fodder crops such as maize and grass as well as vegetables such as potatoes, carrots, cabbages). The fodder crops are fed to cattle, which accumulate Cd in specific organs such as kidneys and liver (López Alonso et al. 2000). At the top of the food chain, the consumer of locally produced foodstuffs will be particularly exposed mostly

1  
2 via the consumption of animal products (especially the organs) and vegetables (mostly broad-leaf  
3 and root vegetables).  
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5 The objective of this study was to estimate human Cd exposure through the food chain in  
6 some areas of Northern Belgium which are close to non-ferrous metal plants. Information was  
7 collected on Cd concentrations measured in vegetables and animal products produced in these  
8 areas and other regions in Belgium. Next, dietary Cd intake was calculated for the consumers of  
9 these locally produced food items and compared to the dietary intake of the general adult  
10 population in Belgium.  
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17 [Insert figure 1 about here]  
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## 21 **Materials and methods**

### 22 *Sampling*

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28 The contaminated area is situated in the North of Belgium, around several non-ferrous metal  
29 production sites with known Cd emissions. The surface area contaminated with Cd is about 1200  
30 km<sup>2</sup> or 4% of the total Belgian surface area.  
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33 Vegetable and animal food products have been sampled in the period 2004-2005 by the  
34 Belgian Federal Agency for the Safety of the Food Chain (FASFC), both in the contaminated area  
35 and in “uncontaminated” areas of Belgium, i.e. areas at ambient environmental Cd levels. The  
36 number of samples taken by the FASFC is determined in the official control program. The  
37 methodology developed for the program is based on risk evaluation, statistical tools and current  
38 scientific knowledge (Maudoux et al. 2006). Vegetable food products included strawberries,  
39 berries, cabbages, beans, asparagus, carrots, scorzonera, celery, leek and potatoes. Field  
40 sampling of these fruits and vegetables was carried out just before harvest of the crops. Samples  
41 were taken close to the emission sources and at increasing distances (within a radius from 4 up to  
42 10 km). Animal food products (kidney, liver and meat) were sampled at random in slaughterhouses  
43 by FASFC in 2005. Tissues were sampled both from animals that had resided more than 18  
44 months in the contaminated area, and from animals that resided in areas at ambient environmental  
45 Cd levels.  
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### 54 *Analytical methods*

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59 The vegetable samples were grinded before analysis. Only edible parts of the foods were used.  
60 Potato tubers, carrots and scorzonera roots were washed thoroughly and peeled first. The method  
for the analysis of vegetable samples is derived from the EN 14084:2002 “Foodstuffs –

Determination of trace elements –Determination of lead, cadmium, zinc and iron by atomic absorption spectrometry (AAS) after microwave digestion”. The homogenized samples were microwave digested with nitric acid and hydrogen peroxide. The concentration of cadmium was quantified by mean of AAS graphite furnace. Each batch of 8 samples in duplicate additionally included two procedure blanks and at least 2 certified reference materials. In case of deviations from a set of common criteria for values obtained for the blanks and the reference materials, the analyses in that batch had to be repeated.

The limit of quantification (LOQ) for Cd was derived from inter laboratory reproducibility tests on real samples with very low concentrations of cadmium and calculated as  $LOQ = \sqrt{2.6} \cdot s_R$  where  $s_R$  represents the intra-reproducible standard deviation (VITO 2005) and equals  $0.01 \text{ mg kg}^{-1}$ . Analytical results below the LOQ were (reported  $< LOQ$ ) set equal to the  $LOQ/2$  for data analysis purposes (half weight bound principle). The analysis were carry out in the laboratory of the FASFC located in Gentbrugge.

The animal tissues were stored in a freezer until analysis. The tissues were mixed in a home mixer to homogenize the samples. Consequently the kidney cortex and medulla, which contain unequal trace element concentrations, were homogeneously mixed and the Cd concentrations were expressed on the whole organ. For each tissue, two homogenized subsamples were microwave digested with nitric acid at  $180^\circ\text{C}$ , and Cd concentrations in all samples were quantified by inductively coupled plasma-mass spectrometry (ICP-MS, VG PQ-ExCell, TJA, US). Each batch of 20 samples additionally included one procedure blank, one certified reference material (IAEA 407) and one laboratory reference material. In case of deviations from a set of common criteria for tolerable variations of blanks, and for values obtained for the reference materials, the analyses in that batch had to be repeated. The limit of quantification (LOQ) for Cd was calculated as 10 times the standard deviation of ten procedure blanks, multiplied with the dilution factor, and equals  $0.002 \text{ mg kg}^{-1}$ . Analytical results below the LOQ were set equal to the  $LOQ/2$  for data analysis purposes (half weight bound principle). All Cd concentrations are expressed on a fresh weight basis.

#### *Estimation of cadmium intake*

Average Cd intake and large Cd intake were calculated both for adults living in the contaminated area (local adult population in a contaminated area) and for adults living in areas at ambient environmental Cd levels (general adult population). Differences in Cd intake between adults from both areas are based on differences in measured Cd concentrations in locally produced food items. Differences between average and large Cd intake are based on differences in daily food consumption amounts.

Food products were classified in 13 major food groups (Table I). Vegetables were subdivided conform the definitions for the European maximum levels settings (European Commission 2001).

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2 These subgroups are defined as (i) vegetables, excluding leafy vegetables, fresh herbs, all fungi,  
3 stem vegetables, root vegetables and potatoes, (ii) stem vegetables and root vegetables, excluding  
4 celeriac, and (iii) leafy vegetables, fresh herbs, celeriac and all cultivated fungi. The European  
5 maximum levels of Cd for the respective categories are (i) 0.05 mg kg<sup>-1</sup>, (ii) 0.1 mg kg<sup>-1</sup>, and (iii) 0.2  
6 mg kg<sup>-1</sup>. The daily consumption of each of the major food groups and subgroups was estimated for  
7 adults between 19 and 59 years. Several food consumption models are available. A Belgian food  
8 consumption survey was carried out in 2004 (Devriese et al. 2006). The survey is based on food  
9 frequency questionnaires and two 24h dietary recall inquiries of more than 3 200 persons, and  
10 reports the median and 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 97.5<sup>th</sup> percentile consumption of major food groups. The  
11 results are not detailed enough to differentiate consumption within the food groups outlined in  
12 Table I. The UK Pesticides Safety Directory published a new chronic intake calculation model, the  
13 National Estimate of Dietary Intake (NEDI) model with mean and 97.5<sup>th</sup> percentile consumption  
14 data of different food groups and subgroups (National Estimate of Dietary Intake 2006).  
15 Consumption of fish and seafood is, however, lacking in this model. The GEMS/Food regional  
16 dietary pattern of raw and semi-processed food commodities database provides five-year average  
17 intakes for most foods and for clusters of countries (World Health Organization 2006). Although  
18 dietary consumption patterns in Belgium probably won't differ to a large extent from consumption  
19 patterns in its surrounding countries, other countries with different dietary habits are included within  
20 the same cluster, e.g. Mediterranean countries, which makes the GEMS/Food database less  
21 suitable for Cd intake calculations in Belgium. Therefore the daily consumption of the major food  
22 groups is based on the Belgian food consumption survey (Devriese et al. 2006). The NEDI  
23 consumption data (National Estimate of Dietary Intake 2006) correspond relatively well to the  
24 Belgian food consumption survey data and were used to calculate the relative intake of food from  
25 subgroups within a major food group, and these relative values were applied on the Belgian food  
26 consumption survey data. Remaining data gaps were filled in with the GEMS/Food consumption  
27 data (World Health Organization 2006). The resulting food consumption pattern is presented in  
28 Table I.  
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[Insert table I about here]

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51 Mean Cd concentrations were calculated for the major food groups or their subgroups. All  
52 measured Cd concentrations of individual food samples were averaged per (sub)group. The Cd  
53 content of food groups that had not been sampled within the framework of this study (e.g. cereals,  
54 fish, milk) were collected from literature (Beernaert et al. 1990; SCOOP 2004) or from other data  
55 gained by the FASFC (unpublished results).  
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59 Average dietary Cd intake ( $\mu\text{g day}^{-1}$ ) was calculated by multiplying the average Cd  
60 concentration in each food (sub)group ( $\mu\text{g kg}^{-1}$ ) by the average daily consumed weight of that food  
(sub)group ( $\text{kg day}^{-1}$ ). Large dietary Cd intake was calculated by using the 97.5<sup>th</sup> percentile



consumption value for each food (sub)group. In general, average Cd concentrations and the half weight bound principle (i.e. concentrations < LOQ are set equal to LOQ/2) were used in intake calculations because this methodology is recognized as giving a realistic and appropriate estimate of long-term exposure. In order to make comparisons possible, some calculations were also carried out using the median Cd concentration and the high weight bound principle (i.e. results < LOQ are considered equal to the LOQ).

The daily dietary Cd intake was compared with the provisional tolerable weekly intake (PTWI) of 7 µg/kg bw per week (World Health Organization 2001) for a 60-kg adult as

$$\% \text{ PTWI} = \frac{\text{daily dietary Cd intake } (\mu\text{g day}^{-1}) \cdot 7 (\text{day})}{7 (\mu\text{g kg}_{\text{bw}}^{-1}) \cdot 60 (\text{kg})} \cdot 100\% \quad (1)$$

Only a deterministic approach has been applied because of the absence of recent, publicly available, individual consumption data that are representative for the Belgian population. This approach gives a realistic fraction of the PTWI to which consumers of food products that are locally produced around non ferrous metal production sites, are exposed.

### *Statistical analysis*

The mean of the quantitative parameters in each group with unequal variance was compared with Welch's test (Dagnelie 1998). The limit of statistical significance of the conducted tests was defined as  $P \leq 0.05$ .

## **Results**

### *Cadmium in vegetable and animal food products*

The mean Cd concentrations analyzed in fruits, vegetables and potatoes that are sampled in the contaminated area are significantly larger (1.1- to 9-fold) than in the samples from other regions in Belgium at ambient environmental Cd concentrations (Welch'test;  $P \leq 0.001$ ) (Table II). The largest increase in Cd content is found for stem and root vegetables and for leafy vegetables. The average Cd concentration in leafy vegetables from contaminated area is above the European maximum level of 0.2 mg kg<sup>-1</sup> fresh weight. About 60% of vegetables (standard 0.2 mg kg<sup>-1</sup>) from the contaminated area were above the European maximum level. About 3% of vegetables (standard 0.2 mg kg<sup>-1</sup>) exceeded the European maximum level in other regions in Belgium. About 40% of vegetable (standard 0.1 mg kg<sup>-1</sup>) from the contaminated area exceeded the maximum level. Also 6% of the potatoes from the contaminated area were above the European maximum

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2 level. About 3% of the vegetables (standard  $0.2 \text{ mg kg}^{-1}$ ) exceeded the European maximum level  
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4 in other regions in Belgium. Potatoes and vegetables (standard  $0.1 \text{ mg kg}^{-1}$ ) from other regions in  
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6 Belgium were below the European maximum level.  
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10 The mean Cd concentrations analyzed in meat, liver and kidney that are sampled in the  
11 contaminated area are significantly larger (twofold) than in the samples from other regions in  
12 Belgium at ambient environmental Cd concentrations (Welch'test;  $P \leq 0.001$ ). The average Cd  
13 concentration in kidneys of bovine animals, both from contaminated and uncontaminated areas,  
14 exceeds the European maximum level of  $1.0 \text{ mg kg}^{-1}$  fresh weight (Table II). About 75% of the  
15 kidneys from the contaminated area were above the maximum level and were not suitable to enter  
16 the food chain. Also 50% of the kidneys from other regions in Belgium surpassed the limit value.  
17 The average Cd concentration in livers from the contaminated area is close to the European  
18 maximum level of  $0.5 \text{ mg kg}^{-1}$  fresh weight, 25% of the samples were above the limit value. Six  
19 percent of livers from other regions in Belgium were above the European maximum level.  
20 Cadmium concentrations were, however, far below the European maximum level of  $0.05 \text{ mg kg}^{-1}$   
21 fresh weight in all meat samples from Belgian cattle.  
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31 [Insert table II about here]  
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#### 34 *Dietary Cd intake*

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38 Dietary Cd intake was calculated for adult populations (19-59 years; assumed mean weight 60 kg)  
39 living in the Cd contaminated area or living somewhere else in Belgium, i.e. at ambient  
40 environmental Cd levels. It was assumed that the vegetables, potatoes and small fruit (berries)  
41 consumed by adults living in the contaminated area, were locally produced. As a large number of  
42 cattle farms are established in the contaminated area, it was also assumed that the consumed  
43 cattle meat and offal was locally produced. In general, this meat is nationally distributed, but  
44 farmers might have slaughtered some of their cattle for private consumption (e.g. Saegerman et al.  
45 2002). At average food consumption levels (Table I), adults living in the Cd contaminated area  
46 have an estimated daily Cd intake of  $31 \mu\text{g day}^{-1}$  (Table III), which is almost double the estimated  
47 intake of the general adult population ( $17 \mu\text{g day}^{-1}$ ; Table IV). Potatoes consumption is responsible  
48 for 46% of the daily Cd intake in the contaminated area and accounts for 24% of the PTWI (Table  
49 III). The Cd content of potatoes is lower at ambient environmental Cd levels, as a result of which  
50 they only contribute for 10% of the PTWI in those areas (Table IV). Other major contributors to the  
51 average daily Cd intake are vegetables and cereals. Despite the large Cd concentrations found in  
52 cattle offal, their contribution to the daily Cd intake is negligible (Table III & IV). The percentage of  
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2 the PTWI due to cattle offal consumption is less than 0.1%, regardless the environmental Cd  
3 levels.  
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5 The influence of the variability in food consumption on Cd intake is taken into account by  
6 calculating the daily Cd intake based on a 97.5<sup>th</sup> percentile consumption pattern (Table I). With a  
7 daily Cd intake of 38.3  $\mu\text{g day}^{-1}$ , the general adult population in Belgium reaches 63.8% of the  
8 PTWI (Table IV). Adults consuming locally produced food items in the Cd contaminated area would  
9 have an estimated daily Cd intake of 63.3  $\mu\text{g day}^{-1}$  (Table III). This is more than the provisional  
10 tolerable intake level for a 60-kg person, for 105.5% of the PTWI is reached at this exposure  
11 scenario. Potatoes and cereals remain the most important sources of Cd intake, together they  
12 account for 32% of the PTWI in the general population and 55% of the PTWI for the local  
13 population in the contaminated area.  
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24 [Insert table IV about here]  
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## 30 Discussion

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32 The dietary Cd intake of the general adult population in Belgium, estimated at 17  $\mu\text{g day}^{-1}$ , is  
33 comparable to earlier published mean intake data of 23.1  $\mu\text{g day}^{-1}$  (range 13.4-41.8  $\mu\text{g day}^{-1}$ ; Van  
34 Cauwenbergh et al. 2000) and 18  $\mu\text{g day}^{-1}$  (range 2.1-88.1  $\mu\text{g day}^{-1}$ ; Buchet et al. 1983). Although  
35 these Cd intake values are based on duplicate meals, they confirm that the Cd intake for the  
36 general adult population in this study is a realistic estimate. The dietary exposure estimate is also  
37 close to recent estimates from the United Kingdom: 14  $\mu\text{g day}^{-1}$  (Ysart et al. 2000); Denmark: 16  
38  $\mu\text{g day}^{-1}$  (Larsen et al. 2002); Tarragona, Spain: 14.3  $\mu\text{g day}^{-1}$  (Bocio et al. 2005); Catalonia, Spain:  
39 12.03-15.73  $\mu\text{g day}^{-1}$  for females- males (Llobet et al. 2003), but 6-fold larger than the most recent  
40 dietary exposure estimate in France: 2.7  $\mu\text{g d}^{-1}$  (Leblanc et al. 2005).  
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48 Potatoes, cereals and vegetables are the main sources of Cd for the Belgian adult population  
49 together they provide 71% of the daily Cd intake. The large consumption amount of these food  
50 groups and the larger Cd content of potatoes and vegetables in the contaminated area results in a  
51 large average daily Cd intake in the contaminated area, corresponding to 44% of the PTWI.  
52 Although the mean Cd concentration in potatoes and vegetables produced in the contaminated  
53 area was below the European maximum levels, several samples exceeded this value. The high Cd  
54 concentrations in cattle offal are relatively unimportant in terms of Cd intake due to its low  
55 consumption, even in the large consumption scenario. However, the consumption data are based  
56 on the general population. Assuming that offal is eaten as a replacement of meat, i.e. 143 g meat  
57 is replaced by an equal amount of liver or kidney, it can be calculated that the large figures for  
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2 cattle liver and kidney consumption presented in Table I correspond to two portions of cattle liver  
3 per year and one portion of cattle kidneys every two years. These figures might be realistic for  
4 average Belgian adults between 19 and 59 years. It is, however, not unlikely that some people,  
5 and especially cattle farmers, consume more regularly livers or kidneys. In case cattle liver,  
6 originating from the contaminated area, is eaten at a ration of once per month, this would increase  
7 the average weekly intake of Cd with 14.9  $\mu\text{g}$ , or 3.5% of the PTWI. One portion of cattle kidneys  
8 per month would increase the average weekly Cd intake with 95.5  $\mu\text{g}$  or 22.7% of the PTWI. Thus,  
9 the high Cd concentrations in cattle offal are not that unimportant. Actions have been taken by the  
10 federal government, which involve a ban on bringing kidneys of bovine animals that resided at  
11 least 18 months in the contaminated area, into the food chain for human consumption, and a ban  
12 on the export of such animals. Furthermore, offal that is suspected to contain contaminants in such  
13 amounts that there might be a risk for the consumer's health can be confiscated.  
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21 For the local adult population in a contaminated area as well for the general adult population,  
22 the intake is twofold larger for large consumption scenario compared to average consumption  
23 scenario. Hence, the large consumption scenario in the contaminated area reveals that more than  
24 100% of the PTWI of Cd would be consumed. It might be argued that not all food groups would be  
25 consumed at such large amounts at the same time. However, a Cd intake of 38.3  $\mu\text{g day}^{-1}$  for the  
26 general population falls within the range of daily Cd intakes measured in the duplicate meal study  
27 of Van Cauwenbergh et al. (2000). The Cd intake estimation in the contaminated area assumes  
28 that 100% of several food groups are produced in the area, which is an extreme but not unreal  
29 assumption.  
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36 Less than 50% of results were below the LOQ. According to WHO (1995), if the proportion of  
37 results  $< \text{LOD}$  is  $\leq 60\%$ ,  $\text{LOD}/2$  should be used for all results less than LOD. The LOD is  
38 meaningless in the case of determination by ICP-MS. Hence, for the intake calculations, results  
39  $< \text{LOQ}$  were set equal to  $\text{LOQ}/2$  (i.e. half weight bound principle). If we use the high weight bound  
40 principle (i.e. results  $< \text{LOQ}$  are considered equal to the LOQ), the percentage of the PTWI reached  
41 is slightly higher (+ 4%). Moreover mean Cd concentration was used for the intake calculations.  
42 The percentage of PTWI reached when the mean Cd concentration is replaced by the median  
43 concentration in intake calculation is slightly lower (- 7%). In this case, the PTWI is 98.1% instead  
44 of 105.5% for a large intake scenario in the contaminated area. When both the median and high  
45 weight bound principles are applied together, the PTWI reaches 101.1 % for a large intake  
46 scenario in the contaminated area. Intake estimations could be improved by applying a  
47 probabilistic approach taking into account individual variations in food consumption and/or by using  
48 a more extensive database for Cd concentrations in food items.  
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## Conclusion

A deterministic approach to determine Cd intake of an adult population living in a Cd contaminated area nearby to non-ferrous metal plants, reveals that such population might consume almost twice as much Cd as the general adult population in Belgium (large consumption scenario assuming that the local population will consume exclusively foodstuffs produced in the contaminated area). Cadmium intake by adults consuming large amounts of food even surpasses the PTWI. Average Cd concentrations in fruit, vegetables, potatoes, meat and offal are found to be larger in the contaminated area than in other regions of Belgium. It is recommended to improve Cd intake estimation by applying a probabilistic approach which takes into account (i) the distribution of individual consumption data of the sub-population living in the contaminated areas around non ferrous metal plants and of the general Belgian population, and (ii) geographic distribution of Cd concentrations in an extended array of food items. Such data are, however, not available at the moment.

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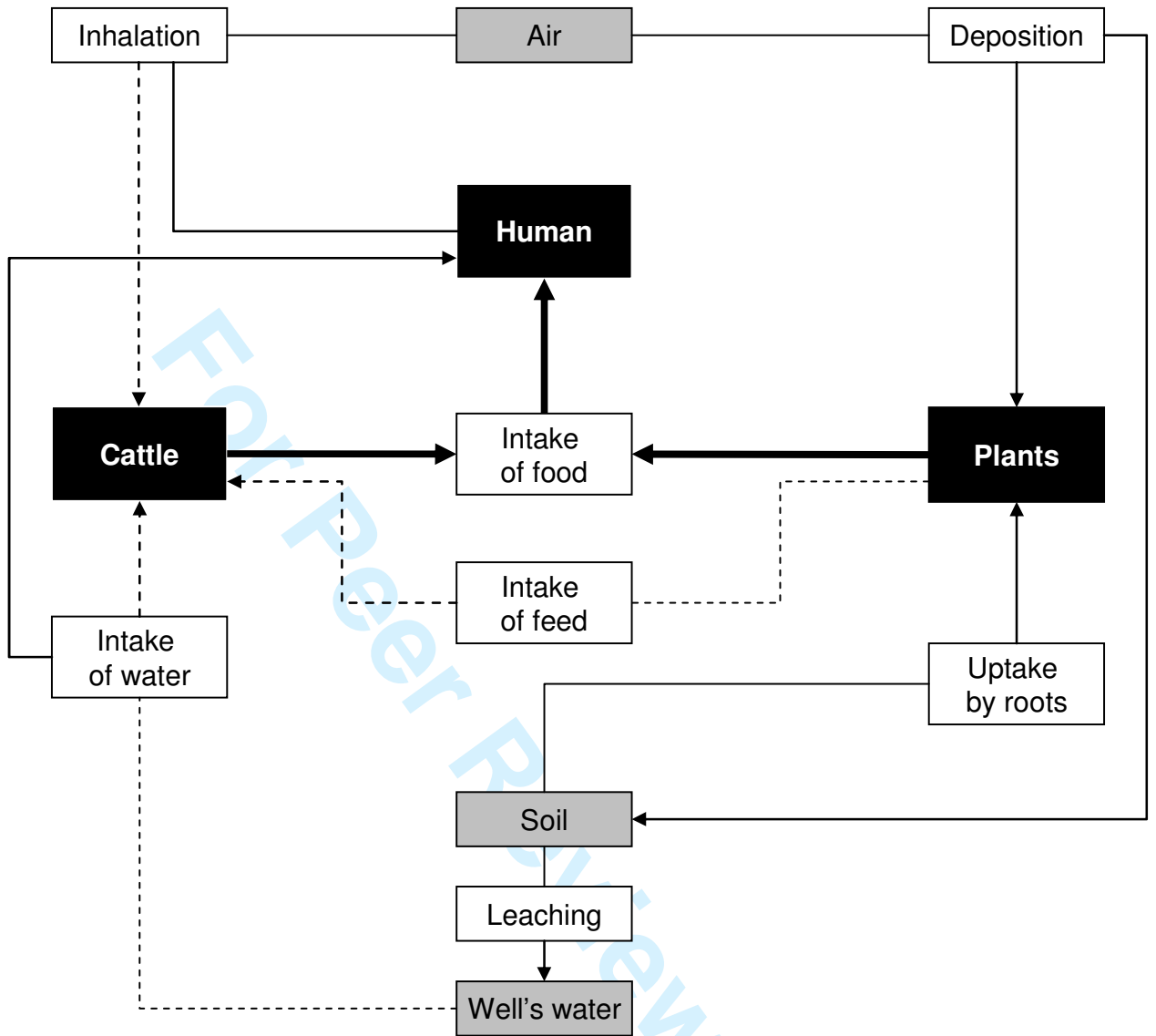
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13 **Figure 1.** Main routes considered in this study for the entry of cadmium in the food  
14 chain and for the uptake by humans (----: contamination of cattle from the environment;  
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16 —: contamination of humans through food consumption).  
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**Figure 1:** Main routes considered in this study for the entry of cadmium in the food chain and for the uptake by humans (----: contamination of cattle from the environment; —: contamination of humans through food consumption).

## Tables

**Table I.** Average and 97.5<sup>th</sup> percentile consumption ( $\text{kg day}^{-1}$ ) of different food groups by Belgian adults between 19 and 59 years.

**Table II.** Average cadmium concentration ( $\text{mg kg}^{-1}$  fresh weight) in fruits, vegetables bovine muscle, liver and kidney sampled in the polluted area versus other regions in Belgium at ambient environmental Cd levels. The number of samples from which the mean is calculated, is indicated between brackets.

**Table III.** *Local adult population in a polluted area* - mean Cd concentration ( $\text{mg kg}^{-1}$  fresh weight) of food groups, daily Cd intake ( $\mu\text{g day}^{-1}$ ) by a 60-kg adult living in a Cd polluted area, with an average consumption pattern or with a 97.5<sup>th</sup> percentile consumption pattern, and percentage of the PTWI attained for each consumption pattern and food group.

**Table IV.** *General adult population* - mean Cd concentration ( $\text{mg kg}^{-1}$  fresh weight) of food groups, daily Cd intake ( $\mu\text{g day}^{-1}$ ) by a 60-kg adult living in a region at ambient Cd

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4 levels, with an average consumption pattern or with a 97.5<sup>th</sup> percentile consumption  
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Table I. Average and 97.5<sup>th</sup> percentile consumption (kg day<sup>-1</sup>) of different food groups by Belgian adults between 19 and 59 years.

Commodity	Consumption		Data source
	Average	P97.5	
Fruit (all)	0.111	0.288	Devriese et al. 2006
berries	0.006	0.015	NEDI 2006
other fruit	0.106	0.273	calculated from Devriese et al. 2006 and NEDI 2006
Vegetables (all)	0.141	0.257	Devriese et al. 2006
vegetables (standard* 0.05 mg kg <sup>-1</sup> )	0.102	0.186	Calculated from Devriese et al. 2006 and NEDI 2006
vegetables (standard 0.1 mg kg <sup>-1</sup> )	0.023	0.042	Calculated from Devriese et al. 2006 and NEDI 2006
vegetables (standard 0.2 mg kg <sup>-1</sup> )	0.016	0.030	Calculated from Devriese et al. 2006 and NEDI 2006
Potatoes	0.281	0.466	Devriese et al. 2006
Meat (all)	0.143	0.285	Devriese et al. 2006
poultry meat	0.019	0.053	Devriese et al. 2006
cattle meat	0.068	0.128	Calculated from WHO 2006 and Devriese et al. 2006
pig meat	0.056	0.104	Calculated from WHO 2006 and Devriese et al. 2006
Offal (all)	3.0 10 <sup>-4</sup>	0.003	Devriese et al. 2006 and NEDI 2006
cattle offal	1.2 10 <sup>-4</sup>	0.001	Calculated from WHO 2006 and NEDI 2006
kidney	2.0 10 <sup>-5</sup>	1.7 10 <sup>-4</sup>	NEDI 2006
liver	9.7 10 <sup>-5</sup>	8.4 10 <sup>-4</sup>	NEDI 2006
other offal	1.8 10 <sup>-4</sup>	0.002	Calculated from WHO 2006 and NEDI 2006
Cereals	0.194	0.402	Devriese et al. 2006
Eggs	0.010	0.028	Devriese et al. 2006
Milk & milk products (excluding cheese)	0.164	0.483	Devriese et al. 2006
Cheese	0.032	0.075	Devriese et al. 2006
Fish	0.017	0.050	Devriese et al. 2006
Seafood	0.006	0.025	Devriese et al. 2006
Oils and fats	0.021	0.073	Devriese et al. 2006
Other (e.g. sweets, sugar)	0.295	0.987	Devriese et al. 2006
Total	1.417	3.421	

\*Standard refers to food or food group according to the European maximum limit.

Table II. Average cadmium concentration ( $\text{mg kg}^{-1}$  fresh weight) in fruits, vegetables, bovine muscle, liver and kidney sampled in the polluted area versus other regions in Belgium at ambient environmental Cd levels. The number of samples from which the mean is calculated, is indicated between brackets.

Commodity	Polluted area			Regions at ambient Cd levels		
	Mean (Number)	S.D.	Range	Mean (Number)	S.D.	Range
Berries (standard* 0.05 mg kg <sup>-1</sup> )	0.012 (n=35)	0.0106	0.005-0.043	0.0061 (n=35)	0.0026	0.005-0.014
Strawberries	0.012 (n=28)	0.011	0.005-0.043	0.006 (n=28)	0.0026	0.005-0.014
Other berries	0.011 (n=7)	0.01	0.005-0.03	0.006 (n=7)	0.0027	0.005-0.011
Vegetables (standard 0.05 mg kg <sup>-1</sup> )	0.008 (n=25)	0.0054	0.005-0.026	0.0072 (n=90)	0.0047	0.005-0.025
Cabbage	0.009 (n=21)	0.006	0.005-0.026	0.006 (n=30)	0.0026	0.005-0.018
Others (onion, bean, tomato...)	0.007 (n=4)	0.004	0.005-0.013	0.0079 (n=60)	0.0053	0.005-0.025
Vegetables (standard 0.1 mg kg <sup>-1</sup> )	0.085 (n=41)	0.0767	0.005-0.320	0.0207 (n=69)	0.018	0.005-0.088
Asparagus	0.009 (n=11)	0.004	0.005-0.015	0.011 (n=10)	0.009	0.005-0.032
Leek	0.065 (n=5)	0.043	0.011-0.13	0.0143 (n=10)	0.008	0.005-0.025
Carrot	0.124 (n=15)	0.073	0.043-0.32	0.03 (n=29)	0.02	0.005-0.088
Others (celery, fennel, scorzonera...)	0.12 (n=10)	0.073	0.029-0.28	0.015 (n=20)	0.016	0.005-0.065
Vegetables (standard 0.2 mg kg <sup>-1</sup> )	0.277 (n=31)	N.A.\$	0.07-1.20	0.0304 (n=68)	0.054	0.005-0.36
Lettuce	N.A.	N.A.	N.A.	0.015 (n=27)	0.017	0.005-0.065
Others (spinach, parsley, mushroom...)	N.A.	N.A.	N.A.	0.04 (n=41)	0.067	0.005-0.36
Potatoes (standard 0.1 mg kg <sup>-1</sup> )	0.051 (n=98)	0.0297	0.011-0.15	0.0209 (n=26)	0.014	0.005-0.067
Meat (standard 0.05 mg kg <sup>-1</sup> )	0.004 (n=53)	0.004	0.001-0.019	0.002 (n=99)	0.003	0.001-0.021
Liver (standard 0.5 mg kg <sup>-1</sup> )	0.446 (n=53)	0.473	0.055-2.66	0.203 (n=99)	0.159	0.029-0.854
Kidney (standard 1.0 mg kg <sup>-1</sup> )	2.862 (n=53)	2.655	0.193-15.3	1.250 (n=99)	1.187	0.093-6.96

\*Standard refers to food or food group according to the European maximum limit.

\$N.A.: Not available. The Cd content of this food group has not been determined in the framework of this study but is derived from unpublished data owned by the Federal Agency for the Safety of the Food Chain.

Table III. *Local adult population in a polluted area* - mean Cd concentration ( $\text{mg kg}^{-1}$  fresh weight) of food groups, daily Cd intake ( $\mu\text{g day}^{-1}$ ) by a 60-kg adult living in a Cd polluted area, with an average consumption pattern or with a 97.5<sup>th</sup> percentile consumption pattern, and percentage of the PTWI attained for each consumption pattern and food group.

Commodity	Mean Cd concentration $\text{mg kg}^{-1}$	Average consumption		97.5 <sup>th</sup> percentile consumption	
		Daily Cd intake $\mu\text{g day}^{-1}$	%PTWI	Daily Cd intake $\mu\text{g day}^{-1}$	%PTWI
Fruit (all)					
berries	0.012	0.07	0.11	0.18	0.29
other fruit	0.004	0.42	0.70	1.09	1.82
Vegetables (all)					
vegetables (standard* $0.05 \text{ mg kg}^{-1}$ )	0.008	0.82	1.36	1.48	2.47
vegetables (standard $0.1 \text{ mg kg}^{-1}$ )	0.085	1.95	3.24	3.54	5.90
vegetables (standard $0.2 \text{ mg kg}^{-1}$ )	0.277	4.55	7.57	8.27	13.8
Potatoes	0.051	14.3	23.9	23.8	39.6
Meat (all)					
poultry meat	0.005	0.09	0.16	0.26	0.44
cattle meat	0.004	0.27	0.45	0.51	0.85
pig meat	0.007	0.39	0.65	0.73	1.22
Offal (all)					
cattle offal					
kidney	2.862	0.06	0.09	0.49	0.82
liver	0.446	0.04	0.07	0.37	0.63
other offal	0.063	0.01	0.02	0.10	0.17
Cereals	0.023	4.47	7.45	9.25	15.4
Eggs	0.003	0.03	0.05	0.08	0.14
Milk & milk products (excluding cheese)	$0.4 \times 10^{-3}$	0.07	0.11	0.19	0.32
Cheese	$0.9 \times 10^{-3}$	0.03	0.05	0.07	0.11
Fish	0.007	0.12	0.20	0.35	0.58
Seafood	0.136	0.86	1.43	3.41	5.69
Oils and fats	0.004	0.07	0.12	0.26	0.44
Other (e.g. sweets, sugar)	0.009	2.66	4.43	8.88	14.81
Total		31.3	52.2	63.3	105.5

\*Standard refers to food or food group according to the European maximum limit.

Table IV. *General adult population* - mean Cd concentration ( $\text{mg kg}^{-1}$  fresh weight) of food groups, daily Cd intake ( $\mu\text{g day}^{-1}$ ) by a 60-kg adult living in a region at ambient Cd levels, with an average consumption pattern or with a 97.5<sup>th</sup> percentile consumption pattern, and percentage of the PTWI attained for each consumption pattern and food group.

Commodity	Mean Cd concentration $\text{mg kg}^{-1}$	Average consumption		97.5 <sup>th</sup> percentile consumption	
		Daily Cd intake $\mu\text{g day}^{-1}$	%PTWI	Daily Cd intake $\mu\text{g day}^{-1}$	%PTWI
Fruit (all)					
berries	0.006	0.04	0.06	0.09	0.15
other fruit	0.004	0.42	0.70	1.09	1.82
Vegetables (all)					
vegetables (standard* $0.05 \text{ mg kg}^{-1}$ )	0.007	0.73	1.22	1.34	2.23
vegetables (standard $0.1 \text{ mg kg}^{-1}$ )	0.021	0.47	0.79	0.86	1.44
vegetables (standard $0.2 \text{ mg kg}^{-1}$ )	0.031	0.50	0.83	0.91	1.51
Potatoes	0.021	5.88	9.80	9.74	16.2
Meat (all)					
poultry meat	0.005	0.09	0.16	0.26	0.44
cattle meat	0.002	0.14	0.23	0.26	0.43
pig meat	0.007	0.39	0.65	0.73	1.22
Offal (all)					
cattle offal					
kidney	1.250	0.03	0.04	0.22	0.36
liver	0.203	0.02	0.03	0.17	0.28
other offal	0.063	0.01	0.02	0.10	0.17
Cereals	0.023	4.47	7.45	9.25	15.4
Eggs	0.003	0.03	0.05	0.08	0.14
Milk & milk products (excluding cheese)	$0.4 \times 10^{-3}$	0.07	0.11	0.19	0.32
Cheese	$0.9 \times 10^{-3}$	0.03	0.05	0.07	0.11
Fish	0.007	0.12	0.20	0.35	0.58
Seafood	0.136	0.86	1.43	3.41	5.69
Oils and fats	0.004	0.07	0.12	0.26	0.44
Other (e.g. sweets, sugar)	0.009	2.66	4.43	8.88	14.81
Total		17.0	28.4	38.3	63.8

\*Standard refers to food or food group according to the European maximum limit.