SCIENTIFIC REPORT OF EFSA

Cadmium dietary exposure in the European population[1]

European Food Safety Authority[2, 3]

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ABSTRACT

Cadmium can cause kidney failure and has been statistically associated with an increased risk of cancer. Food is the dominating source of human exposure in the non-smoking population. The Joint FAO/WHO Expert Committee on Food Additives established a provisional tolerable monthly intake of 25 µg/kg body weight, whereas the EFSA Panel on Contaminants in the Food Chain nominated a tolerable weekly intake of 2.5 µg/kg body weight to ensure sufficient protection of all consumers. To better identify major dietary sources, cadmium levels in food on the European market were reviewed and exposure estimated using detailed individual food consumption data. High levels of cadmium were found in algal formulations, cocoa-based products, crustaceans, edible offal, fungi, oilseeds, seaweeds and water molluscs. In an attempt to calculate lifetime cadmium dietary exposure, a middle bound overall weekly average was estimated at 2.04 µg/kg body weight and a potential 95th percentile at 3.66 µg/kg body weight. Individual dietary survey results varied between a weekly minimum lower bound average of 1.15 to a maximum upper bound average of 7.84 µg/kg body weight and a minimum lower bound 95th percentile of 2.01 and a maximum upper bound 95th percentile of 12.1 µg/kg body weight reflecting different dietary habits and survey methodologies. Food consumed in larger quantities had the greatest impact on dietary exposure to cadmium. This was true for the broad food categories of grains and grain products (26.9 %), vegetables and vegetable products (16.0 %) and starchy roots and tubers (13.2 %). Looking at the food categories in more detail, potatoes (13.2 %), bread and rolls (11.7%), fine bakery wares (5.1 %), chocolate products (4.3 %), leafy vegetables (3.9 %) and water molluscs (3.2 %) contributed the most to cadmium dietary exposure across age groups. The current review confirmed that children and adults at the 95th percentile exposure could exceed health-based guidance values.

KEY WORDS

Cadmium, food, dietary exposure, kidney failure, cancer

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SUMMARY

Cadmium occurs naturally in the environment in its inorganic form, and anthropogenic sources have further contributed to background levels of cadmium in soil, water and living organisms. The general population is exposed to cadmium from multiple sources, including smoking, but in the non-smoking general population food is the dominant source. Cadmium is primarily toxic to the kidney, but can also cause bone demineralisation and has been statistically associated with increased risk of cancer in the lung, endometrium, bladder, and breast.

A Provisional Tolerable Weekly Intake (PTWI) for cadmium of 7 µg/kg body weight was established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1988. In 2010, the JECFA reviewed its previous evaluation and established a provisional tolerable monthly intake (PTMI) of 25 µg/kg body weight corresponding to a weekly intake of 5.8 µg/kg body weight. In 2009 and subsequently confirmed in 2011, the Panel on Contaminants in the Food Chain issued an opinion in which they recommended that the PTWI should be reduced to a tolerable weekly intake (TWI) of 2.5 µg/kg body weight in order to ensure a high level of protection of all consumers, including exposed and vulnerable subgroups of the population.

A number of studies have investigated cadmium levels in a range of foods. In light of the recommended lowering of the health based guidance value, it was considered important to better identify major dietary sources by reviewing cadmium levels in food on the European market and estimate cadmium exposure using detailed individual data from the EFSA Comprehensive European Food Consumption Database.

In about half of the food samples available to EFSA cadmium was not detected or levels were below the limit of quantification, Individual quantified values ranged from a low of 0.001 µg/kg for drinking water to a high of 61,000 µg/kg for horse kidney. Tap water had the lowest average cadmium levels while algal supplements and seaweeds used as a vegetable had the highest average cadmium levels. Thirteen out of 144 food categories had a middle bound mean above 100 µg/kg including algal formulations, cocoa powder, bitter and bitter-sweet chocolate, crustaceans, edible offal, fish and seafood not specified beyond FoodEx Level 1, frogs' legs, cultivated fungi, wild fungi, oilseeds, seaweeds and water molluscs.

By using the more detailed and refined food consumption information now available through the EFSA Comprehensive European Food Consumption Database and weighting results from the different age groups in the survey population according to the number of years they include, average middle bound lifetime cadmium dietary exposure for the European population as a whole was estimated at 2.04 µg/kg body weight per week. It was highest in toddlers with an average of 4.85 µg/kg body weight per week and lowest in the elderly population group at 1.56 µg/kg body weight per week. Potential 95th percentile middle bound lifetime exposure, with the assumption that the same individuals retained high exposure throughout life, was estimated at 3.66 µg/kg body weight per week with a high of 8.19 µg/kg body weight per week for toddlers and a low of 2.82 µg/kg body weight per week for the elderly. Individual dietary survey results varied between a minimum lower bound mean of 1.15 and a maximum upper bound of 7.84 µg/kg body weight per week and a minimum 95th percentile lower bound of 2.01 and a maximum upper bound of 12.1 µg/kg body weight per week reflecting different dietary habits but also likely differences in survey methodologies and the countries covered for the different age classes.

Often it is not the food with the highest cadmium levels, but foods that are consumed in larger quantities that have the greatest impact on cadmium dietary exposure. This was true as the broad food categories of grains and grain products (26.9 %), vegetables and vegetable products (16.0 %) and starchy roots and tubers (13.2 %) were identified as major contributors. Looking at the food categories in more detail, potatoes (13.2 %), bread and rolls (11.7 %), fine bakery wares (5.1 %), chocolate products (4.3 %), leafy vegetables (3.9 %) and water molluscs (3.2 %) contributed the most to cadmium dietary exposure across age groups. At the finest level of detail given for the food

consumption information, wheat bread and rolls (6.4 %), boiled potatoes (5.7 %), pastries and cakes (4.0 %), potatoes without preparation specified (3.1 %), rice (3.0 %) and carrots (2.2 %) were important contributors.

Both the Chemicals Branch in the Division of Technology, Industry and Economics of the United Nations Environment Programme and the EFSA Panel on Contaminants in the Food Chain have expressed concern that the margin between the average weekly intake of cadmium from food by the general population and the health-based guidance values is small. The EFSA Panel concluded that although adverse effects are unlikely to occur in an individual with current dietary exposure, there is a need to reduce exposure to cadmium at the population level because of the limited safety margin.

The current review confirmed that children on average and adults at the 95th percentile dietary exposure could exceed health-based guidance values.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

In recent years EFSA has adopted many scientific opinions related to undesirable substances in feed and on nitrates, non-dioxin like PCBs and certain mycotoxins in food. For some of these opinions specific data collection exercises have been launched. In the frame of official control and monitoring more occurrence data is being generated. It is appropriate that this data is collected into one database, collated and analysed. Article 23 (and 33) of Regulation (EC) 178/2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety[4], entrusts the European Food Safety Authority with this task.

The integration of newly generated data into existing databases on occurrence data (e.g. dioxins and PCBs) in the field of contaminants in feed and food on a permanent basis will ensure continuity of data collection. This would enable EFSA to access accurate data when quick action is required to handle urgent requests for scientific opinions/statements e.g. in case of contamination incidents and/or requests for scientific opinions where scientific assessments are needed within a short period and separate calls for data would require too much time.

Furthermore, it is expected that the set up of these permanent data collection exercises will stimulate the generation of occurrence data in accordance with the standard sample description for feed and food and the electronic transmission of data in the appropriate reporting format[5].

The permanent data collection exercises could in principle encompass the whole field of contaminants in feed and food. However, to focus the work it is appropriate also for the competent authorities and stakeholder organisations, which have to provide the data, to identify specific topics for which a permanent occurrence data collection exercise is to be set up. Several requests for data collections were already addressed by the Commission to EFSA e.g. on heavy metals, furan, acrylamide in food, etc. In annex to this request, several topics that have not yet been the subject of a specific request are identified with an indication of priority/importance for the Commission services.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

The following tasks are related to data collection:

- publication of a report on a regular basis (every 2 years) per topic. The report should contain, besides an analysis of the received data, also recommendations for improving data collection on this topic and ensure, in co-operation with the Commission services, the appropriate follow up to these recommendations;

- provide assistance/support/information to the Commission services based on ad hoc requests related to the occurrence data present in the database. Such requests might involve negotiations of timelines should they require the use of significant resources from EFSA.

[4] OJ L 31, 1.2.2002, p. 1
[5] http://www.efsa.europa.eu/en/datexcallsfordata/datexsubmitdata.htm

ANALYSIS

1. INTRODUCTION

Cadmium occurs naturally in the environment in its inorganic form as a result of volcanic emissions and weathering of rocks. In addition, anthropogenic sources have increased the background levels of cadmium in soil, water and living organisms. Cadmium is released into the environment by wastewater and waste incineration. Contamination of agricultural soils can occur by the use of fertilisers, by air deposition and by cadmium containing sewage sludge. Increases in cadmium levels in soil result in an increase in the uptake of cadmium by plants, depending on plant species, pH and other characteristics of the soil, and thus indirectly by animals feeding on the plants. Cadmium in water can contaminate shellfish and crustaceans. Fungi that are natural accumulators of cadmium can receive high levels from soil.

The general population is exposed to cadmium from multiple sources, including smoking, with food accounting for approximately 90 % of cadmium exposure in the non-smoking general population. Less than 10 % of total exposure of the non-smoking general population occurs due to inhalation of low levels of cadmium in ambient air (Vahter *et al.*, 1991) and through drinking water (Olson *et al.,* 2002). Cadmium absorption after dietary exposure in humans is relatively low (3–5 %), but cadmium is efficiently retained in the kidney and liver, with a very long biological half-life ranging from 10 to 30 years. Cadmium is primarily toxic to the kidney, especially to the proximal tubular cells where it accumulates over time and may cause a decrease in the glomerular filtration rate, and eventually renal failure. Cadmium can also cause bone demineralisation, either through direct bone damage or indirectly as a result of renal dysfunction. The International Agency for Research on Cancer has classified cadmium as a human carcinogen (Group 1) on the basis of occupational studies (IARC, 1993). Newer data on human exposure to cadmium in the general population have been statistically associated with increased risk of cancer in the lung, endometrium, bladder, and breast.

In 1988 and subsequently in 2003, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) set and confirmed a Provisional Tolerable Weekly Intake (PTWI) of 7 µg/kg body weight (b.w.) for cadmium (FAO/WHO, 1988; 2004). In 2010, the JECFA reviewed its previous evaluation on cadmium and established a provisional tolerable monthly intake (PTMI) of 25 µg/kg b.w. which corresponds to 5.8 µg/kg b.w. as weekly intake. In 2004, the European Commission carried out an exposure assessment with the data collected in SCCOP[6] task 3.2.11 (EC, 2004). The SCOOP report served as a basis for setting and updating maximum levels for cadmium in foodstuffs. In 2009 and subsequently confirmed in 2011, the Panel on Contaminants in the Food Chain issued an opinion in which they recommended that the PTWI should be reduced to a tolerable weekly intake (TWI) of 2.5 µg/kg b.w. in order to ensure a high level of protection of consumers, including subgroups of the population such as children, vegetarians or people living in highly contaminated areas (EFSA, 2009; 2011a).

In light of the recommended lowering of the PTWI, it is important to better identify major dietary sources of cadmium exposure. The current report provides updated information on the levels of cadmium found in a range of foods on the European market and estimates exposure using detailed individual data from the EFSA Comprehensive European Food Consumption Database (hereinafter called the Comprehensive Database) covering seven age groups from infants to the very elderly.

2. MATERIALS AND METHODS

2.1. Occurrence data

The European Food Safety Authority (EFSA) has been collecting cadmium occurrence data first through a specific call issued in 2007 and later through annual data submissions as part of a

[6] The SCOOP task was carried out in the framework of scientific cooperation with Member States under Council Directive 93/5/EEC, OJ L 52, 4.3.1993, pp.18-21

Commission mandate for regular contaminant data collection activities. Cadmium occurrence data are now available from 22 Member States, 3 European Economic Area or other countries and some food business operators (Figure 1) mainly covering the years 2003 to 2011 with less than 200 results covering the period before 2003 (Figure 2). A previous subset of the data was used for the cadmium opinion published by the Panel on Contaminants in the Food Chain (EFSA, 2009).

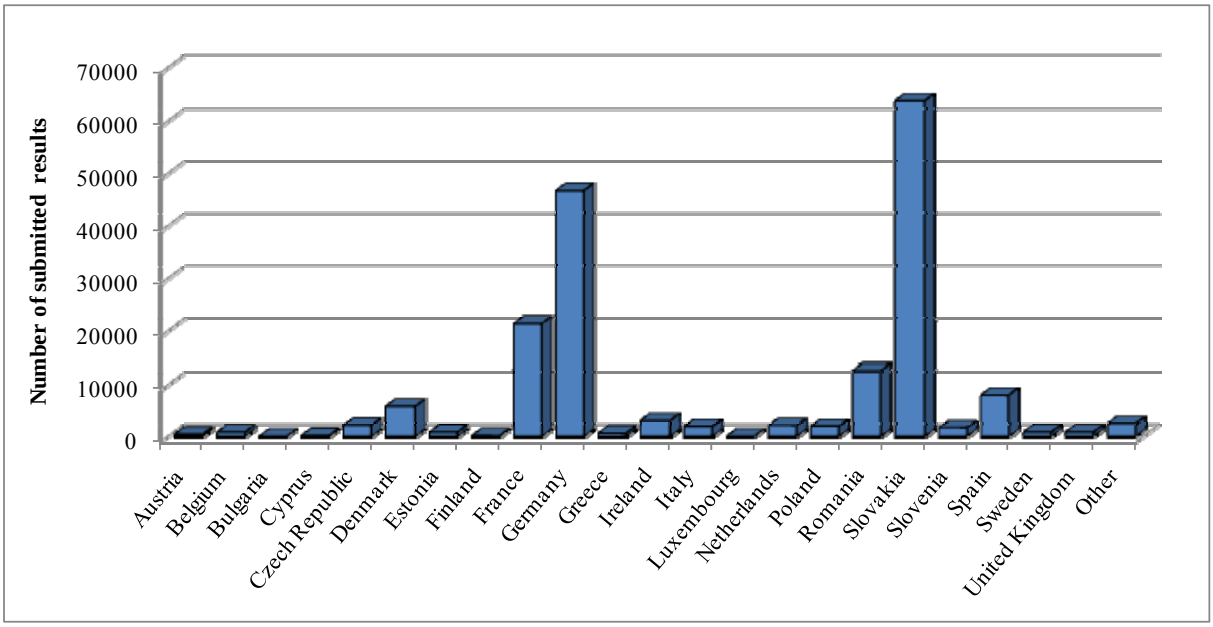

Figure 1: The number of analytical results on cadmium submitted by the respective country or other organisations.

Most submitted analytical results for the presence of cadmium in food originated from the Slovak Republic followed by Germany, France, Romania, Spain and Denmark.

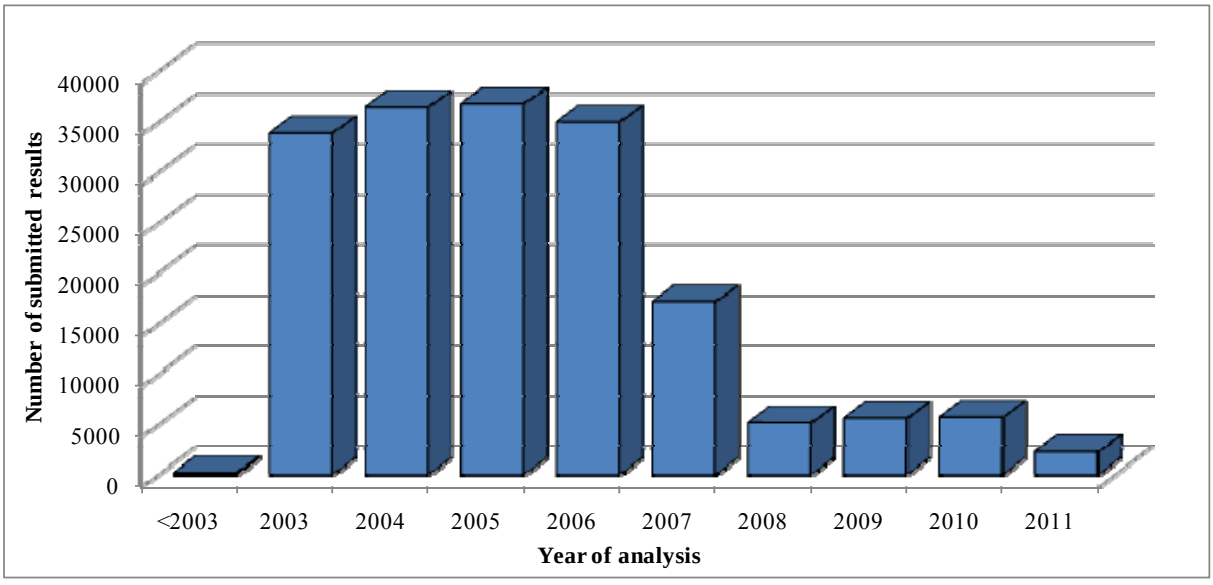

Figure 2: The number of submitted analytical results on cadmium distributed over the year of analysis.

Most results for cadmium in food were analysed in 2003 to 2007 and submitted in response to the open call for cadmium data issued in 2007.

The results were checked for accuracy. Results with a limit of detection (LOD) of more than 100 µg/kg or a limit of quantification (LOQ) of more than 200 µg/kg were excluded from the analysis. With the added data received since the initial call in 2007, the final dataset comprised 178,541 results. Foods were grouped according to the FoodEx food classification system (EFSA, 2011c). FoodEx is a food classification system developed by the DCM Unit in 2009 with the objective of simplifying the linkage between occurrence and food consumption data when assessing the exposure to hazardous substances. It contains 20 main food groups (first level), which are further divided into subgroups having 140 items at the second level, 1,261 items at the third level and reaching about 1,800 end-points (food names or generic food names) at the fourth level. The number of submitted analytical results, the left-censored proportion of the total number and the range for the left-censoring limits are shown in Table 1 for the FoodEx Level 1 food categories.

Table 1: The number of analytical results (N) on cadmium submitted for each of the FoodEx Level 1 food categories, the proportion of left-censored data (LC %) and the minimum, median and maximum left-censoring limits of detection (LOD) and quantification (LOQ) as reported in µg/kg.

FoodEx Level 1	N	N %	LC %	Reported LOD/LOQ		
				Minimum	Median	Maximum
Grains and grain-based products	17,812	10.0	21.2	0.01	5.00	200
Vegetables and vegetable products	18,665	10.5	30.8	0.01	3.00	120
Starchy roots and tubers	3,150	1.8	19.2	0.01	4.00	50.0
Legumes, nuts and oilseeds	7,264	4.1	22.1	0.01	4.00	120
Fruit and fruit products	5,524	3.1	73.5	0.01	2.00	82.5
Meat and edible offal	48,617	27.2	51.9	0.01	5.00	126
Fish and other seafood	19,538	10.9	41.2	0.01	6.00	200
Milk and dairy products	8,679	4.9	82.7	0.01	1.00	137
Eggs and egg products	1,218	0.7	80.2	0.10	1.00	50.0
Sugar and confectionary	4,933	2.8	53.7	0.10	3.20	101
Animal and vegetable fats and oils	1,986	1.1	71.0	0.01	1.00	56.2
Fruit and vegetable juices	2,567	1.4	78.2	0.10	3.00	50.0
Non-alcoholic beverages	1,511	0.8	59.8	0.01	1.00	20.0
Alcoholic beverages	4,063	2.3	84.0	0.01	1.00	40.0
Drinking water	21,514	12.0	76.9	0.01	0.20	60.0
Herbs, spices and condiments	2,520	1.4	31.0	0.08	4.00	123
Food for infants and small children	4,257	2.4	35.7	0.10	3.00	101
Products for special nutritional use	2,081	1.2	35.0	0.20	5.00	125
Composite food	1,139	0.6	51.0	0.40	2.00	120
Snacks, desserts, and other foods	1,503	0.8	43.3	0.60	1.40	130

Most of the submitted analytical results covered the meat and edible offal food category followed by the drinking water, fish and seafood, vegetables and vegetable products, and grains and grain products food categories. Close to 50 % of the overall results were left-censored. The food categories of alcoholic beverages, milk and dairy products, and eggs and egg products all had more than 80 % of left-censored data, while the least proportion of left-censored data appeared in starchy roots and tubers, grains and grain products and legumes, nuts and oilseeds.

It should be noted that many of the reported results for the meat and edible offal category have been sampled under Directive 96/23[7] and might include a high proportion of samples targeting potential problem areas and thus might not reflect an average situation.

Detailed lower, middle and upper bound mean occurrence results at Level 2 of the FoodEx system are presented in Table 2.

[7] OJ L 125, 23.05.1996, pp. 0010 - 0032

Individual quantified values ranged from a low of 0.001 µg/kg in drinking water to a high of 61,000 µg/kg in edible offal (horse kidney). The FoodEx Level 2 food category with the lowest middle bound mean was tap water while the highest middle bound mean was found for algal supplements followed by seaweeds used as a vegetable. There were 1,585 individual results with quantified cadmium levels of 1,000 µg/kg or higher belonging to 16 of the FoodEx Level 2 food categories (algal formulations, cocoa powder, chocolate products, crustaceans, edible offal, fish meat, fish offal, cultivated fungi, wild fungi, game mammals, livestock meat, oilseeds, seaweeds, spices, tea infusion and water molluscs). Thirteen of the food categories in Table 2 had a middle bound mean above 100 µg/kg including algal formulations, cocoa powder, bitter and bitter-sweet chocolate, crustaceans, edible offal, fish and seafood not specified beyond FoodEx Level 1, frogs' legs, cultivated fungi, wild fungi, oilseeds, seaweeds and water molluscs. The differences between lower and upper bound results were relatively small for most of the food categories indicating that the few high-limit left-censored results retained had little influence on overall results.

Table 2: Cadmium occurrence levels presented mainly according to FoodEx Level 2 food categories that could be matched with consumption amounts for calculating exposure. Some foods were reported only at Level 1 (in bold*) and matched at this level while some are shown here split into Level 3 (in italics**) as they deviated much from other Level 2 foods and were entered at Level 3 for calculating exposure.

		Mean µg/kg				Mean µg/kg				Mean µg/kg			
Food category	**N**	**LB**	**MB**	**UB**	**Food category**	**N**	**LB**	**MB**	**UB**	**Food category**	**N**	**LB**	**MB**	**UB**
Grains and products*	280	35.1	38.1	41.0	**Fish and seafood***	1,294	175	176	177	**Alcoholic beverages***	105	0.78	1.14	1.51
Grains for humans	9,297	32.5	33.4	34.3	Fish meat	11,106	22.6	26.0	29.5	Beer and similar	1,150	0.69	1.77	2.85
Grain milling products	3,388	23.9	24.8	25.7	Fish products	869	17.3	19.0	20.7	Wine	2,604	0.55	1.24	1.93
Bread and rolls	2,078	14.6	15.2	15.7	Fish roe	112	49.0	50.5	51.9	Fortified and liqueur wines	34	0.35	0.53	0.71
Pasta (raw)	614	21.2	21.6	22.1	Crustaceans	2,194	128	132	136	Wine-like drinks	113	0.84	1.16	1.48
Breakfast cereals	678	19.6	20.4	21.2	Water molluscs	3,866	316	317	319	Liqueur	26	5.40	6.04	6.68
Fine bakery wares	1,417	15.1	15.9	16.6	Frogs' legs	97	204	207	209	Spirits	30	1.22	1.48	1.74
Vegetables and products*	840	16.7	17.3	17.9	**Milk and dairy products***	60	4.98	6.26	7.53	Alcoholic mixed drinks	120	1.22	1.48	1.74
Root vegetables	2,091	24.4	46.3	68.3	Liquid milk	3,196	0.49	1.05	1.61	**Drinking water***	2,288	0.34	3.37	6.41
Bulb vegetables	777	12.1	12.7	13.2	*Goat milk***	55	16.3	17.2	18.1	Tap water	16,618	0.07	0.21	0.35
Fruiting vegetables	2,694	6.02	7.27	8.53	Milk based beverages	17	8.06	8.77	9.47	Bottled water	2,380	0.20	0.42	0.65
Brassica vegetables	1,952	5.39	6.43	7.47	Concentrated milk	455	4.29	7.64	11.0	Water ice	1	0.00	0.25	0.50
Leaf vegetables	3,414	35.6	36.4	37.1	Whey beverages	10	3.93	4.62	5.30	**Herbs, spices and condiments***	46	54.3	54.6	54.9
Legume vegetables	233	2.89	4.39	5.89	Cream and products	651	0.72	8.90	17.1	Herbs	554	42.4	43.9	45.4
Stem vegetables (fresh)	732	23.9	24.9	25.9	Fermented products	893	1.26	4.84	8.41	Spices	881	87.5	90.1	92.8
Chicory roots	65	25.4	25.5	25.5	Lactose	4	0.00	5.73	11.5	Herb and spice mixtures	142	54.5	61.1	67.7
Seaweeds	202	1,122	1,122	1,122	Cheese	2,872	3.24	10.8	18.3	Seasoning or extracts	183	17.9	19.7	21.5
Tea and infusions (solid)	6,044	55.1	55.3	55.5	Milk and imitates	60	8.93	11.1	13.3	Condiment	303	11.3	13.0	14.7
Cocoa powder	732	183	183	183	**Eggs and products***	25	1.68	4.37	7.06	Dressing	87	1.97	3.50	5.03
Coffee beans	4,065	11.0	12.0	13.0	Eggs, fresh	1,183	1.27	3.33	5.39	Chutney and pickles	8	10.1	10.1	10.1
Coffee imitates (solid)	210	13.0	13.3	13.6	Eggs, powder	10	0.00	10.4	20.8	Savoury sauces	64	8.14	9.32	10.5
Vegetable products	349	10.8	11.2	11.5	**Sugar and confectionary***	156	11.7	15.6	19.6	Flavourings or essences	91	12.4	16.9	21.5
Fungi, cultivated	1,926	134	135	136	Sugars	361	1.97	3.13	4.30	Baking ingredients	161	11.7	13.2	14.7
Fungi, wild, edible	791	344	344	345	Sugar substitutes	2	18.0	18.0	18.0	**Food for children***	45	14.2	14.5	14.8
Starchy roots and tubers*	-	-	-	-	Chocolate	1,286	80.1	80.9	81.8	Infant formulae powder	542	2.43	3.67	4.91
Potatoes and products	2,280	21.0	21.7	22.4	*Bitter chocolate***	30	123	123	123	Infant formulae liquid	40	3.03	3.70	4.38
Other roots and tubers	852	14.0	14.1	14.2	*Bitter-sweet chocolate***	58	135	135	135	Follow-on formula powder	512	3.56	4.19	4.82
Legumes, nuts, oilseeds*	14	27.7	30.6	33.5	*Milk chocolate***	184	18.7	19.6	20.6	Follow-on formula liquid	58	1.00	1.20	1.40
Legumes no pods	118	3.21	4.49	5.77	Confectionery (non-chocolate)	395	5.60	7.15	8.70	Cereal-based food for children	1,647	11.9	12.3	12.6
Legumes dried	2,267	19.6	20.5	21.3	Dessert sauces	14	14.8	14.9	14.9	Ready-to-eat meal for children	1,350	4.34	5.69	7.03
Tree nuts	1,368	34.2	36.2	38.1	Molasses and other syrups	178	2.64	3.28	3.91	Dairy products for children	19	4.55	6.70	8.96
Oilseeds	3,496	371	371	371	Honey	2,269	3.61	9.01	14.4	Juice and herbal tea for children	44	2.96	4.19	5.42
Fruit and fruit products*	116	7.09	7.99	8.90	**Fats and oils***	10	0.00	2.27	4.53	**Special nutritional products***	56	13.4	16.6	19.8
Citrus fruits	647	1.16	2.61	4.06	Animal fat	1,090	2.41	3.90	5.40	Food for weight reduction	27	24.6	24.9	25.3
Pome fruits	1,505	3.61	5.04	6.46	Fish oil	30	17.3	20.6	23.9	Dietary supplements	1,351	72.6	74.6	76.6
Stone fruits	470	1.06	3.53	6.01	Vegetable fat	163	5.96	6.53	7.10	*Algal formulations***	413	1,514	1,515	1,515

Food category	N	Mean µg/kg LB	MB	UB	Food category	N	Mean µg/kg LB	MB	UB	Food category	N	Mean µg/kg LB	MB	UB
Berries and small fruits	1,055	2.59	3.89	5.19	Vegetable oil	636	4.14	4.96	5.78	Food for sports people	31	44.3	48.6	52.9
Olives for oil production	5	0.00	0.50	1.00	Fats of mixed origin	2	25.0	30.0	35.0	Dietetic foods for diabetics	183	18.6	19.4	20.2
Miscellaneous fruits	528	2.92	4.19	5.46	Margarine and similar	55	1.82	4.57	7.33	Food for medical management	20	22.5	23.0	23.4
Dried fruits	403	2.25	4.71	7.18	**Fruit and vegetable juices***	118	2.49	2.94	3.39	**Composite food***	80	4.32	11.7	19.0
Jam and spreads	192	2.87	5.86	8.85	Fruit juice	1,944	2.16	3.51	4.85	Cereal-based dishes	66	11.3	13.9	16.6
Other fruit products	602	3.17	4.46	5.74	Concentrated fruit juice	9	0.44	1.04	1.64	Rice-based meals	21	57.1	58.7	60.4
Meat and edible offal*	908	8.30	11.3	15.5	Fruit nectar	169	0.48	2.13	3.79	Potato based dishes	2	11.0	11.0	11.0
Livestock meat	15,462	7.60	11.3	15.0	Mixed fruit juice	62	1.31	3.15	4.98	Beans-based meals	16	1.44	14.1	26.7
*Horse meat***	1,402	359	362	366	Powdered fruit juice	25	2.24	2.54	2.84	Meat-based meals	502	5.59	7.11	8.63
Poultry	4,821	3.21	7.99	12.8	Vegetable juice	218	8.90	9.61	10.3	Fish and seafood meals	113	23.7	24.5	25.3
Game mammals	2,479	3.04	4.37	5.69	Mixed vegetable juice	8	4.75	7.88	11.0	Vegetable-based meals	7	0.67	12.9	25.2
Game birds	680	1.78	4.70	7.63	Mixed fruit/vegetable juice	14	3.59	5.49	7.38	Egg-based meal	8,281	1.27	3.33	5.39
Mixed meat	184	1.23	2.74	4.25	**Non-alcoholic beverages***	44	44.1	44.5	44.9	Mushroom-based meals	791	344	344	345
Edible offal	18,296	315	317	319	Soft drinks	972	0.98	1.53	2.07	Ready to eat soups	223	8.20	10.2	12.1
Preserved meat	416	2.61	7.37	12.1	Tea (Infusion)	1,511	0.92	0.92	0.93	Prepared salads	109	13.9	23.2	32.5
Sausages	2,663	6.19	15.9	25.6	Coffee (Beverage)	813	0.61	0.66	0.72	**Snacks, desserts, other foods***	1	0.00	10.0	20.0
Meat specialities	88	2.64	4.68	6.72	Coffee imitates beverage	35	0.72	0.74	0.75	Snack food	587	26.8	27.0	27.2
Pâtés and terrines	310	4.86	11.3	17.7	Cocoa beverage	2,196	2.75	2.75	2.85	Ices and desserts	659	3.62	4.11	4.59
Meat imitates	311	22.2	22.9	23.6						Other non classifiable foods	256	19.0	28.0	37.0

* Food classified only at the FoodEx Level 1
** Food classified at the FoodEx Level 3

2.2. Consumption data

During 2010, the EFSA Comprehensive European Food Consumption Database (Comprehensive Database) was built from existing national information on food consumption at a detailed level. Competent organisations in the European Union Member States provided EFSA with data from the most recent national dietary survey in their country at the level of consumption by the individual consumer. Survey results for children were mainly obtained through the EFSA Article 36 project "Individual food consumption data and exposure assessment studies for children" through the EXPOCHI consortium (EFSA, 2011b). Results from a total of 32 different dietary surveys carried out in 22 different Member States covering more than 67,000 individuals are included in the Comprehensive Database version 1 as published (EFSA, 2011b).

Although the food consumption data in the Comprehensive Database are the most complete and detailed currently available in the EU, it should be pointed out that different methodologies were used between surveys to collect the data and thus direct country-to-country comparisons can be misleading. Only surveys covering more than one day and thus appropriate for calculating chronic exposure were selected as described in Table 3.

Table 3: Surveys included from the Comprehensive Database version1 for calculating exposure.

ISO	Country	Survey	N	Method	Days	Age	Year
BE1	Belgium	Regional Flanders	661	Dietary record	3	2-6	2003
BE	Belgium	Diet National 2004	3245	24-h dietary recall	2	15-105	2004
BG	Bulgaria	NUTRICHILD	1723	24-h dietary recall	2	0.1-5	2007
CY	Cyprus	Childhealth	303	Dietary record	3	11-18	2003
CZ	Czech Republic	SISP04	1751	24-h dietary recall	2	4-64	2004
DE1	Germany	DONALD 2006	303	Dietary record	3	1-10	2006
DE2	Germany	DONALD 2007	311	Dietary record	3	1-10	2007
DE3	Germany	DONALD 2008	307	Dietary record	3	1-10	2008
DE	Germany	National Nutrition Survey II	13926	24-h dietary recall	2	14-80	2006
DK	Denmark	Danish Dietary Survey	4118	Food record	7	4-75	2001
ES1	Spain	enKid	382	24-h dietary recall	2	1-14	2000
ES2	Spain	NUT INK05	760	24-h dietary recall	2	4-18	2005
ES3	Spain	AESAN	418	24-h dietary recall	2	18-60	2009
ES	Spain	AESAN FIAB	1068	Dietary record	3	17-60	2001
FI1	Finland	DIPP	1448	Dietary record	3	1-6	2005
FI2	Finland	STRIP	250	Dietary record	4	7-8	2000
FI	Finland	FINDIET 2007	2038	48-h dietary recall	2	25-74	2007
FR	France	INCA2	4079	Dietary record	7	3-79	2006
GB	United Kingdom	NDNS	1724	Dietary record	7	19-64	2001
GR	Greece	Regional Crete	874	Dietary record	3	4-6	2005
HU	Hungary	National Representative Survey	1360	Dietary record	3	18-96	2003
IE	Ireland	NSIFCS	958	Dietary record	7	18-64	1998
IT	Italy	INRAN SCAI 2005/06	3323	Dietary record	3	0.1-98	2006
LV	Latvia	EFSA TEST	2070	24-h dietary recall	2	7-66	2008
NE1	The Netherlands	VCP kids	1279	Dietary record	3	2-6	2006
NE	The Netherlands	DNFCS 2003	750	24-h dietary recall	2	19-30	2003
SE1	Sweden	NFA	2495	24-h dietary recall	4	3-18	2003
SE	Sweden	Riksmaten 1997/98	1210	Dietary record	7	18-74	1997

Individuals were categorised into seven age groups covering infants (<1 year), toddlers (1 - <3 years), other children (3 - <10 years), adolescents (10 - <18 years), adults (18 - <65 years), elderly (65 - <75 years) and the very elderly (≥75 years) (EFSA, 2011b).

2.3. Exposure assessment

Cadmium results at different levels of aggregation were inspected for homogeneity. Dietary exposure was calculated using overall European lower, middle and upper bound mean occurrence of cadmium mainly at Level 2 of the FoodEx food categories as presented in Table 2. They were matched with survey specific reported food consumption and body weight at individual level. Exceptions were horse meat, goat milk, chocolate and algal formulations matched at Level 3 since they had much higher cadmium levels than the rest of the foods in the respective Level 2 food category. Some cadmium occurrence results or food consumption amounts were reported only at Level 1 and were matched at this level.

It is important to point out that the different food consumption surveys varied in the methodology used and their coverage of age groups. As indicated above only surveys with more than one survey day were used for calculating average consumption over the number of survey days to estimate chronic exposure. The 95th percentile exposure estimates were only calculated for surveys that included 60 or more subjects.

Lower bound exposure was used to establish a relative ranking for the contributions of the different food groups to negate the influence of left-censored data and left-censoring limits as much as possible. When splitting FoodEx Level 2 food groups for calculating the relative contributions of food groups at FoodEx Level 3 only differences in amounts consumed of the respective food were considered since the relative homogeneity of cadmium levels at Level 3 had already been established. Exceptions were the food groups already listed above that deviated in cadmium concentrations at Level 3 from the rest of the respective foods at the aggregated Level 2.

3. RESULTS

3.1. Exposure assessment by country, survey and age group

European mean and 95th percentile lower, middle and upper bound dietary exposure were assessed. The detailed results of the exposure calculations are presented in Tables 4-10 for the respective survey and age group. Each table provides an indication of the range of results for the surveys included with the minimum, median and maximum of mean and 95th percentile exposure across dietary surveys.

3.1.1. Infants

There were two surveys available reporting food consumption information for infants, one of which included very few survey participants (Table 4). Therefore, the middle bound mean variation in cadmium exposure of between 2.61 and 2.74 µg/kg b.w. per week should be taken only as a rough indication for European infants.

Table 4: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in infants in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BG	NUTRICHILD	860	1.97	2.74	3.51	4.98	6.59	8.43
IT	INRAN_SCAI_2005_06	16	1.86	2.61	3.35			
Minimum			**1.86**	**2.61**	**3.35**			
Median								
Maximum			**1.97**	**2.74**	**3.51**			

3.1.2. Toddlers

There were nine surveys available reporting food consumption information for toddlers covering an overall 1,597 survey participants (Table 5). The middle bound mean cadmium exposure varied between 3.84 and 6.77 µg/kg b.w. per week and the middle bound 95th percentile exposure ranged from 5.32 to 10.1 µg/kg b.w. per week.

Table 5: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in toddlers in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BE1	Regional Flanders	36	5.70	6.77	7.84			
BG	NUTRICHILD	428	3.90	5.00	6.10	6.71	8.01	9.61
DE1	DONALD 2006	92	2.97	3.92	4.87	4.67	5.80	6.92
DE2	DONALD 2007	85	2.99	3.91	4.83	4.57	5.89	7.08
DE3	DONALD 2008	84	2.85	3.84	4.83	4.37	5.32	6.74
ES1	enKid	17	5.04	5.95	6.86			
FI1	DIPP	497	4.18	5.08	5.98	8.26	10.1	12.1
IT	INRAN SCAI 2005/06	36	3.94	4.80	5.65			
NE1	VCP kids	322	3.48	4.79	6.10	5.51	7.11	9.12
Minimum			**2.85**	**3.84**	**4.83**	**4.37**	**5.32**	**6.74**
Median			**3.90**	**4.80**	**5.98**	**5.09**	**6.50**	**8.10**
Maximum			**5.70**	**6.77**	**7.84**	**8.26**	**10.1**	**12.1**

3.1.3. Other children

There were seventeen surveys available reporting food consumption information for other children covering an overall 8,468 survey participants (Table 6). The middle bound mean cadmium exposure varied between 3.13 and 5.03 µg/kg b.w. per week and the middle bound 95th percentile exposure ranged from 4.58 to 10.2 µg/kg b.w. per week.

Table 6: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in other children in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BE1	Regional Flanders	625	4.18	5.03	5.87	7.00	8.21	9.42
BG	NUTRICHILD	433	3.74	4.63	5.51	6.06	7.32	8.55
CZ	SISP04	389	3.26	3.83	4.39	6.11	7.01	7.78
DE1	DONALD 2006	211	2.59	3.18	3.77	3.95	4.70	5.43
DE2	DONALD 2007	226	2.66	3.24	3.83	4.09	4.75	5.41
DE3	DONALD 2008	223	2.63	3.21	3.79	3.93	4.58	5.29
DK	Danish Dietary Survey	490	2.86	3.47	4.08	4.45	5.25	6.00
ES1	enKid	156	3.52	4.16	4.79	6.36	7.42	8.85
ES2	NUT INK05	399	3.38	4.03	4.67	5.87	6.64	7.41
FI12	DIPP	933	3.20	4.02	4.84	5.25	6.21	7.30
FI	STRIP	250	2.89	3.48	4.07	4.45	5.36	5.93
FR	INCA2	482	3.32	3.92	4.52	5.49	6.31	7.04
GR	Regional Crete	839	3.58	4.38	5.19	6.88	7.92	8.88
IT	INRAN SCAI 2005/06	193	4.19	4.77	5.34	9.43	10.2	11.4
LV	EFSA TEST	189	2.60	3.13	3.65	5.24	6.11	7.24
NE1	VCP kids	957	2.98	3.99	5.00	4.70	5.89	7.26
SE1	NFA	1,473	2.96	3.62	4.28	4.98	5.88	6.85
Minimum			**2.59**	**3.13**	**3.65**	**3.93**	**4.58**	**5.29**
Median			**3.20**	**3.92**	**4.52**	**5.25**	**6.21**	**7.26**
Maximum			**4.19**	**5.03**	**5.87**	**9.43**	**10.2**	**11.4**

3.1.4. Adolescents

There were twelve surveys available reporting food consumption information for adolescents covering an overall 6,329 survey participants (Table 7). The middle bound mean cadmium exposure varied between 1.51 and 3.16 µg/kg b.w. per week and the middle bound 95th percentile exposure ranged from 2.65 to 6.97 µg/kg b.w. per week.

Table 7: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in adolescents in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BE	Diet National 2004	584	1.74	2.03	2.31	3.27	3.71	4.16
CY	Childhealth	303	1.70	1.97	2.24	3.70	4.03	4.37
CZ	SISP04	298	2.17	2.58	2.98	4.13	4.61	5.30
DE	National Nutrition Survey II	1,011	1.23	1.51	1.80	2.19	2.65	3.10
DK	Danish Dietary Survey	479	1.72	2.07	2.42	2.85	3.41	3.92
ES	AESAN FIAB	86	1.99	2.30	2.61	3.87	4.30	4.66
ES1	enKid	209	2.33	2.69	3.05	4.93	5.31	5.78
ES2	NUT INK05	651	2.30	2.66	3.02	4.55	5.01	5.42
FR	INCA2	973	1.89	2.18	2.48	3.49	4.01	4.50
IT	INRAN SCAI 2005/06	247	2.82	3.16	3.50	6.55	6.97	7.35
LV	EFSA TEST	470	1.97	2.36	2.75	3.81	4.48	5.10
SE1	NFA	1,018	1.94	2.33	2.73	3.23	3.79	4.41
Minimum			**1.23**	**1.51**	**1.80**	**2.19**	**2.65**	**3.10**
Median			**1.95**	**2.32**	**2.67**	**3.76**	**4.16**	**4.58**
Maximum			**2.82**	**3.16**	**3.50**	**6.55**	**6.97**	**7.35**

3.1.5. Adults

There were fifteen surveys available reporting food consumption for adults covering an overall 30,788 survey participants (Table 8). The middle bound mean cadmium exposure varied between 1.50 and 2.23 µg/kg b.w. per week and the middle bound 95th percentile exposure ranged from 2.47 to 4.81 µg/kg b.w. per week.

Table 8: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in adults in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BE	Diet National 2004	1,304	1.60	1.88	2.16	3.00	3.38	3.78
CZ	SISP04	1,666	1.31	1.61	1.90	2.45	2.90	3.36
DE	National Nutrition Survey II	10,419	1.21	1.50	1.79	2.20	2.61	3.03
DK	Danish Dietary Survey	2,822	1.30	1.57	1.84	2.11	2.47	2.86
ES3	AESAN	410	1.74	2.02	2.30	4.02	4.40	4.77
ES	AESAN FIAB	981	1.94	2.23	2.53	4.11	4.45	4.78
FI	FINDIET 2007	1,575	1.22	1.52	1.81	2.24	2.62	3.04
FR	INCA2	2,276	1.54	1.79	2.05	2.79	3.13	3.46
GB	NDNS	1,724	1.38	1.66	1.95	2.32	2.68	3.07
HU	National Representative Survey	1,074	1.62	1.89	2.16	3.44	3.74	4.08
IE	NSIFCS	958	1.63	1.97	2.31	2.74	3.20	3.75
IT	INRAN SCAI 2005 06	2,313	1.94	2.20	2.45	4.48	4.81	5.08
LV	EFSA TEST	1,306	1.41	1.72	2.02	2.82	3.33	3.83
NE	DNFCS 2003	750	1.37	1.68	1.99	2.33	2.77	3.22
SE	Riksmaten 1997/98	1,210	1.44	1.77	2.09	2.40	2.85	3.34
Minimum			**1.21**	**1.50**	**1.79**	**2.11**	**2.47**	**2.86**
Median			**1.44**	**1.77**	**2.05**	**2.74**	**3.13**	**3.46**
Maximum			**1.94**	**2.23**	**2.53**	**4.48**	**4.81**	**5.08**

3.1.6. Elderly

There were seven surveys available reporting food consumption for the elderly covering an overall 4,056 survey participants (Table 9). The middle bound mean cadmium exposure varied between 1.40 and 2.01 µg/kg b.w. per week and the middle bound 95th percentile exposure ranged from 2.42 to 4.42 µg/kg b.w. per week.

Table 9: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in elderly in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BE	Diet National 2004	518	1.46	1.73	1.99	2.94	3.23	3.47
DE	National Nutrition Survey II	2,006	1.17	1.44	1.71	2.06	2.42	2.80
DK	Danish Dietary Survey	309	1.31	1.58	1.85	2.10	2.48	2.90
FI	FINDIET 2007	463	1.15	1.40	1.64	2.11	2.56	3.01
FR	INCA2	264	1.63	1.89	2.14	2.94	3.23	3.59
HU	National Representative Survey	206	1.38	1.62	1.85	2.68	2.89	3.15
IT	INRAN SCAI 2005/06	290	1.78	2.01	2.25	4.22	4.42	4.66
Minimum			**1.15**	**1.40**	**1.64**	**2.06**	**2.42**	**2.80**
Median			**1.38**	**1.62**	**1.85**	**2.68**	**2.89**	**3.15**
Maximum			**1.78**	**2.01**	**2.25**	**4.22**	**4.42**	**4.66**

3.1.7. Very elderly

There were six surveys available reporting food consumption for the very elderly covering an overall 1,614 survey participants (Table 10). The middle bound mean cadmium exposure varied between 1.43 and 1.83 µg/kg b.w. per week and the middle bound 95th percentile ranged from 2.44 to 3.61 µg/kg b.w. per week.

Table 10: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) cadmium exposure in the very elderly in µg/kg b.w. per week.

Country	Survey	N	Mean			P95		
			LB	MB	UB	LB	MB	UB
BE	Diet National 2004	712	1.44	1.69	1.94	2.63	2.96	3.30
DE	National Nutrition Survey II	490	1.16	1.43	1.69	2.01	2.44	2.80
DK	Danish Dietary Survey	20	1.33	1.60	1.87			
FR	INCA2	84	1.54	1.79	2.03	2.54	2.87	3.20
HU	National Representative Survey	80	1.43	1.66	1.89	2.53	2.80	3.04
IT	INRAN SCAI 2005/06	228	1.59	1.83	2.06	3.33	3.61	3.87
Minimum			**1.16**	**1.43**	**1.69**	**2.01**	**2.44**	**2.80**
Median			**1.43**	**1.67**	**1.92**	**2.54**	**2.87**	**3.20**
Maximum			**1.59**	**1.83**	**2.06**	**3.33**	**3.61**	**3.87**

When setting health based guidance values consideration must be given to dietary exposure reflecting consumption patterns in all European Union countries across all age groups. In summary, cadmium dietary exposure varied between a lower bound minimum of 1.15 to an upper bound maximum of 7.84 µg/kg b.w. per week for mean survey results and a lower bound minimum of 2.01 and an upper bound maximum of 12.1 µg/kg b.w per week for 95th percentile survey results.

3.2. Overall European population dietary exposure estimate

As a second step the results from the calculation of dietary cadmium exposure from the individual surveys were summarised by merging the respective survey results per age group as shown in Table 11. By weighting results from the different age groups in the survey population according to the

number of years included out of an average life span of 77 years[8], average middle bound (lower bound and upper bound range in brackets) cadmium dietary exposure can roughly be estimated at about 2.04 (1.68-2.39) µg/kg b.w. per week over a lifetime. Average estimates for the different age classes ranged from a low of 1.56 (1.30-1.82) µg/kg b.w. per week for the elderly to a high of 4.85 (3.80-5.90) µg/kg b.w. per week for toddlers. Although speculative and potentially unrealistic, 95th percentile lifetime exposure was nevertheless calculated as an indication only with the assumption that the same individuals retained high exposure through life. Using this assumption 95th percentile middle bound lifetime exposure (lower bound and upper bound range in brackets) was estimated at 3.66 (3.17-4.18) µg/kg b.w. per week. Estimates for the 95th percentile across the different age classes ranged from 2.82 (2.47-3.18) µg/kg b.w. per week for the elderly to 8.19 (6.76-9.84) µg/kg b.w. per week for toddlers.

Table 11: Lower (LB), middle (MB) and upper (UB) bound mean and 95th percentile (P95) dietary cadmium exposure in µg/kg b.w. per week for each age groups and as a mean and 95th percentile average lifetime exposure calculated by weighting the contribution of each age group according to the number of years covered (different range of countries covered in the respective age group).

Age group	N	Mean			P95		
		LB	MB	UB	LB	MB	UB
Infants	876	1.97	2.74	3.50	4.97	6.56	8.42
Toddlers	1,597	3.80	4.85	5.90	6.76	8.19	9.84
Other children	8,468	3.23	3.96	4.69	5.55	6.58	7.66
Adolescents	6,329	1.87	2.20	2.54	3.66	4.17	4.70
Adults	30,788	1.41	1.70	1.98	2.72	3.09	3.50
Elderly	4,056	1.30	1.56	1.82	2.47	2.82	3.18
Very elderly	1,614	1.38	1.63	1.89	2.56	2.87	3.21
Adjusted average[8]		**1.68**	**2.04**	**2.39**	**3.17**	**3.66**	**4.18**

3.3. Contribution of broad food categories to dietary exposure

The contribution of each of the FoodEx Level 1 food categories to overall cadmium exposure was calculated for each age class and the European population as shown in Figure 3. The highest contributors as averaged across all age groups for the lower bound results (less influenced by left-censored data and limits) were grains and grain products at 26.9 % followed by vegetables and vegetable products at 16.0 %, starchy roots and tubers at 13.2 %, meat and edible offal at 7.7 % and fish and seafood at 7.5 %.

[8] The age groups represent 1 year for infants (1.3%), 2 years for toddlers (2.6%), 7 years for other children (9.1%), 8 years for adolescents (10.4%), 47 years for adults (61.0%), 10 years for the elderly (13.0%) and 2 years for the very elderly (2.6%).

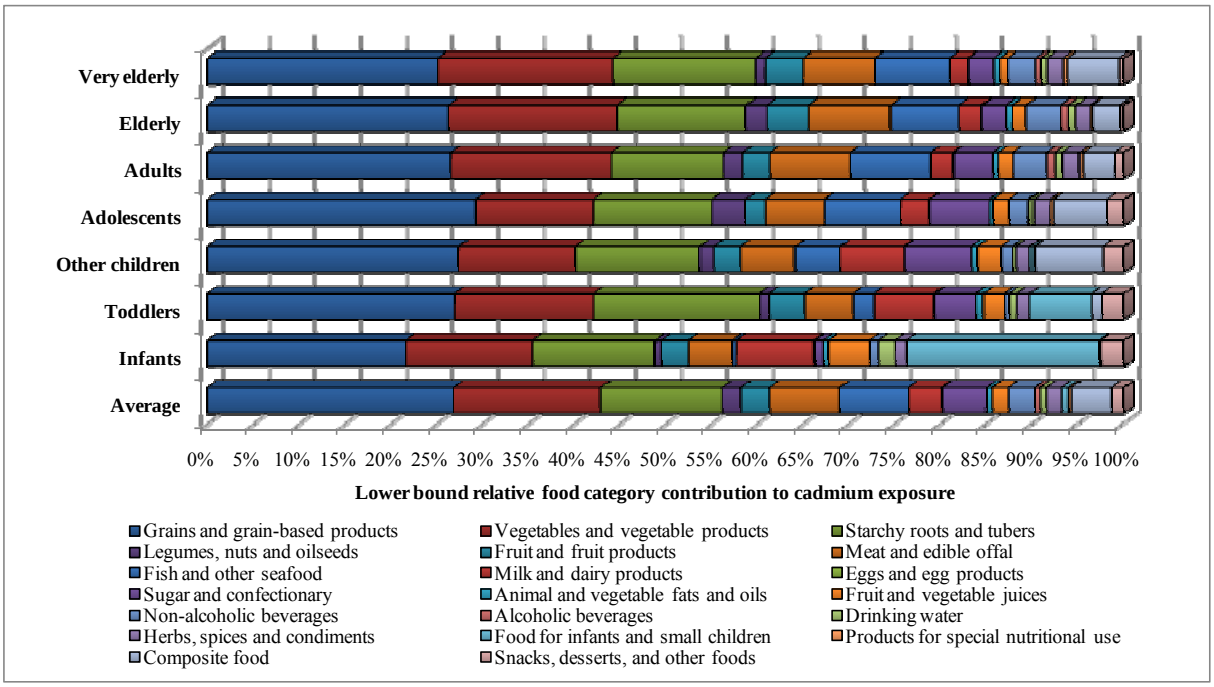

Figure 3: Contributions of twenty broad food categories to overall lower bound mean cadmium exposure per age group and as an average in the total population[9].

The different age groups were further split into results for each separate survey (infants not shown) to explore differences in eating patterns across Europe. Minimum and maximum contributions of the twenty broad food categories to overall lower bound mean cadmium exposure across the surveys included for each age group are shown in Table 12.

Table 12: Minimum and maximum relative contributions in percent of twenty broad food categories to overall lower bound mean cadmium exposure across the surveys included for each age group.

Food categories	Toddlers		Other children		Adolescents		Adults		Elderly		Very elderly	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Grains and grain-based products	15.7	34.5	19.2	35.1	21.0	35.5	17.1	33.0	20.9	29.0	21.3	30.5
Vegetables and vegetable products	9.02	20.5	3.70	21.4	3.45	19.9	4.66	25.9	16.1	28.4	14.5	27.4
Starchy roots and tubers	6.49	26.0	6.54	20.7	6.07	19.7	5.54	30.5	6.60	22.5	7.46	26.3
Legumes, nuts and oilseeds	0.16	3.53	0.23	8.86	0.44	14.8	0.64	5.17	0.44	4.29	0.59	2.32
Fruit and fruit products	2.41	6.74	1.82	5.04	1.54	3.57	1.49	3.94	3.06	5.48	3.07	5.86
Meat and edible offal	2.36	10.9	2.72	9.95	3.86	10.0	5.51	24.5	7.26	19.2	5.58	14.2
Fish and other seafood	1.08	15.9	1.31	22.8	0.85	28.3	1.20	31.2	0.80	19.6	0.80	13.0
Milk and dairy products	3.95	11.3	1.43	11.8	1.38	7.38	1.25	4.37	1.46	4.45	1.69	4.08
Eggs and egg products	0.00	0.22	0.00	0.20	0.00	0.19	0.05	0.20	0.07	0.20	0.07	0.19
Sugar and confectionary	0.83	15.7	2.20	17.7	2.22	11.9	1.02	7.86	0.57	4.13	0.53	3.73
Animal and vegetable fats and oils	0.15	1.00	0.16	2.36	0.16	0.91	0.23	1.94	0.46	1.80	0.52	1.01
Fruit and vegetable juices	1.00	4.63	0.78	4.37	0.70	5.85	0.33	3.61	0.29	2.44	0.17	2.21
Non-alcoholic beverages	0.00	1.24	0.16	4.02	0.45	4.50	0.42	6.79	0.58	5.27	0.66	5.30
Alcoholic beverages	0.00	0.01	0.00	0.04	0.00	0.43	0.26	2.04	0.25	1.51	0.19	1.61
Drinking water	0.24	1.91	0.00	1.08	0.00	1.31	0.10	1.43	0.16	1.15	0.11	1.03
Herbs, spices and condiments	0.47	6.44	0.05	3.02	0.09	3.04	0.73	2.93	0.57	2.22	0.67	3.14
Food for infants and small children	1.12	15.6	0.09	1.11	0.00	0.04	0.00	0.02	0.00	0.00	0.01	0.01
Products for special nutritional use	0.00	0.28	0.01	0.63	0.01	3.13	0.05	1.64	0.04	1.08	0.04	1.21
Composite food	0.00	6.78	0.03	28.5	0.05	18.9	0.05	22.2	0.04	7.48	0.03	8.96
Snacks, desserts, and other foods	0.00	5.18	0.67	4.43	0.68	2.91	0.21	2.85	0.15	0.58	0.17	0.65

[9] The availability of food consumption data for different age classes across countries may influence the overall result.

Some particular differences were noted in relation to toddlers as shown in Figure 4. In Belgium and the Netherlands, the sugar and confectionary category constituted 13 % and 16 %, respectively, while it did not exceed 4 % in the other surveys. In the three German surveys and in Finland, food for infants and small children contributed between 12 % and 16 %, while it was only between 1 % and 6 % in the other surveys.

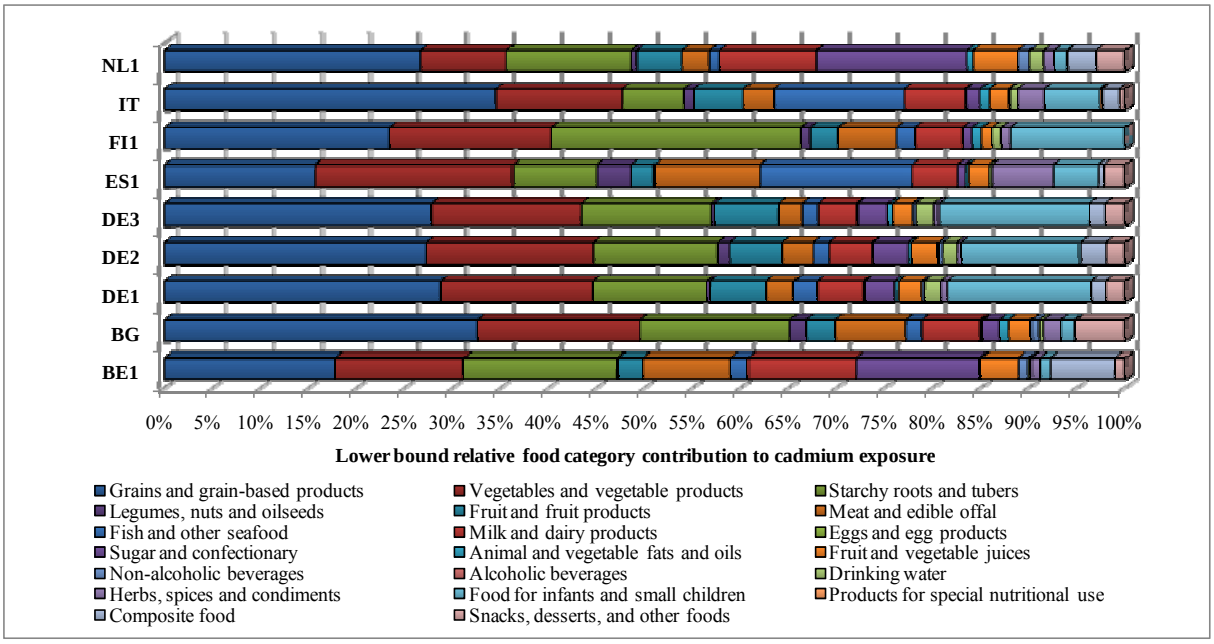

Figure 4: Contributions of twenty broad food categories to overall lower bound mean cadmium exposure in toddlers shown separately for each of the nine individual surveys.

Dietary exposure patterns differ also among the surveys covering "other children" as illustrated in Figure 5. In Italy (23 %) but also in Spain (12-13 %) and France (9 %) the contribution of fish and seafood, and specifically water molluscs, to exposure was particularly high. Grain and grain products contributed most to exposure in a Finnish survey (35 %) and was more than 20 % in all except the Greek survey. Potato consumption was especially high in a Finnish survey (21 %), in Latvia (18 %) and in Sweden (17 %). High composite food consumption was recorded in Greece (28 %), while sugar and confectionary consumption remained high in the Netherlands (18 %).

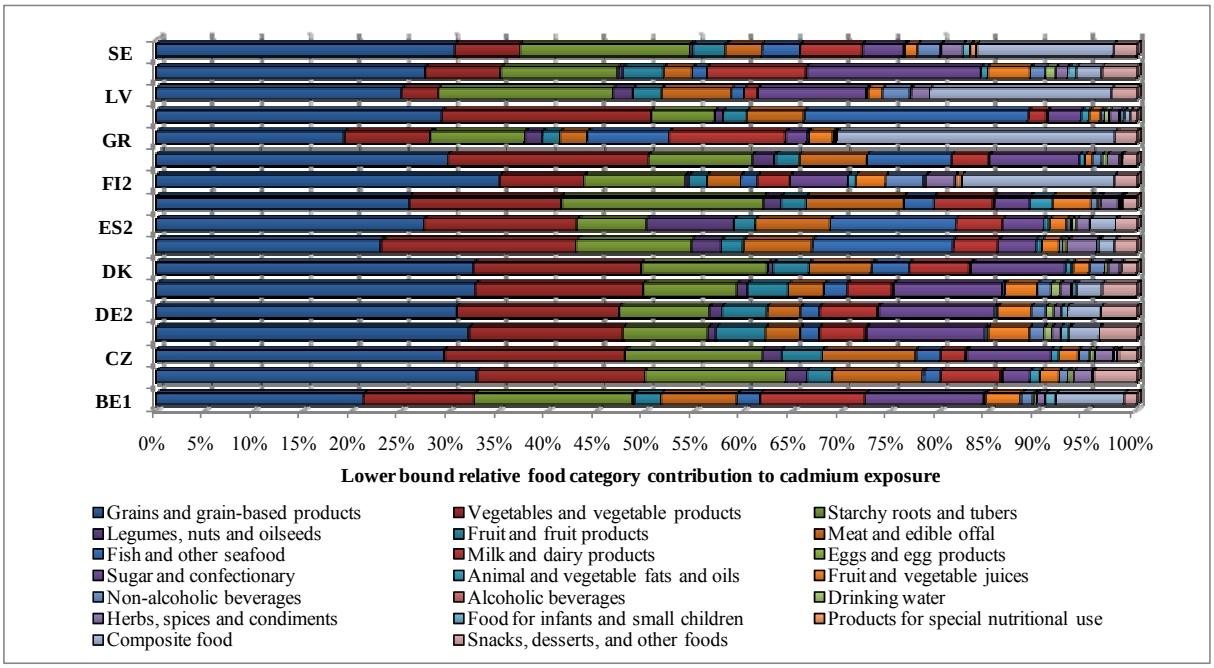

Figure 5: Contribution of twenty broad food categories to overall lower bound mean cadmium exposure in other children shown separately for each of the seventeen individual surveys.

Fish and other seafood (28 %), grains and grain products (25 %) and vegetables and vegetable products (20 %) contributed most to exposure in Italian adolescents with a similar situation in Spain and Cyprus (Figure 6). In Swedish (20 %), Latvian (19 %), Danish (16 %) and Czech (16 %) adolescents, potato consumption contributed significantly to exposure as did legumes, nuts and pulses in a Spanish survey (15 %).

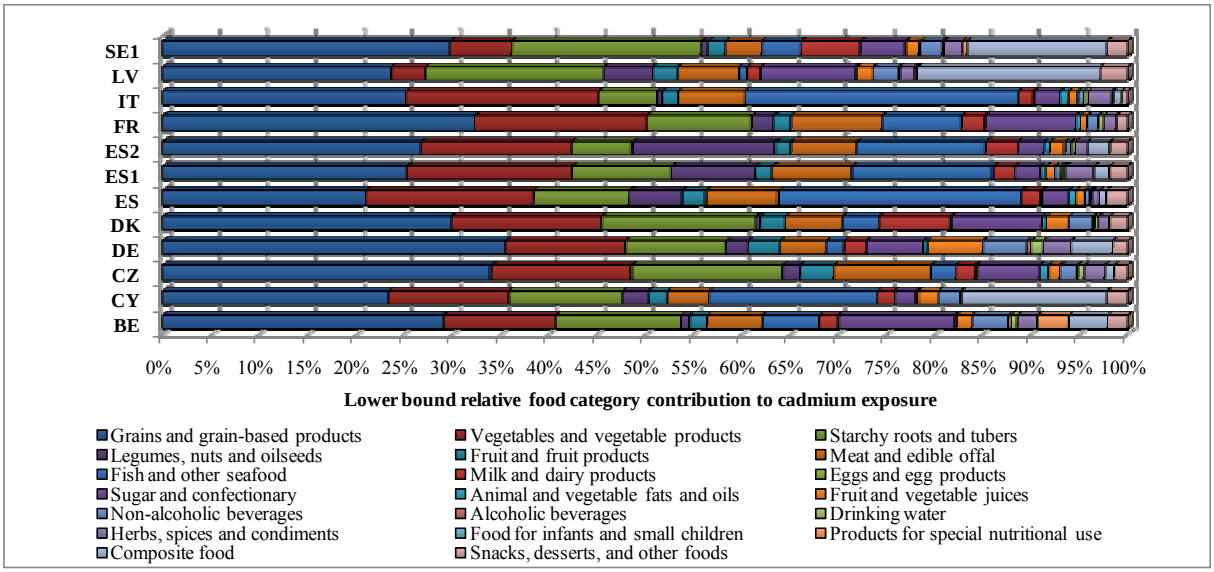

Figure 6: Contribution of twenty broad food categories to overall lower bound mean cadmium exposure in adolescents shown separately for each of the twelve individual surveys.

Potato consumption contributed close to a third of exposure in Irish adults (30 %) and remained fairly high in many surveys except in Italy, Spain and France (Figure 7). Meat and edible offal contributed to 25 % of exposure in Hungarian adults and 15 % in Czech adults, while fish and other seafood peaked in Spanish (31 %) and Italian (23 %) adults. The contribution of composite foods to exposure was high

in Latvia (22 %) and Sweden (20 %), to a large extent due to consumption amounts reported at this level rather than split into individual ingredient level as requested when collecting the data for the Comprehensive Database.

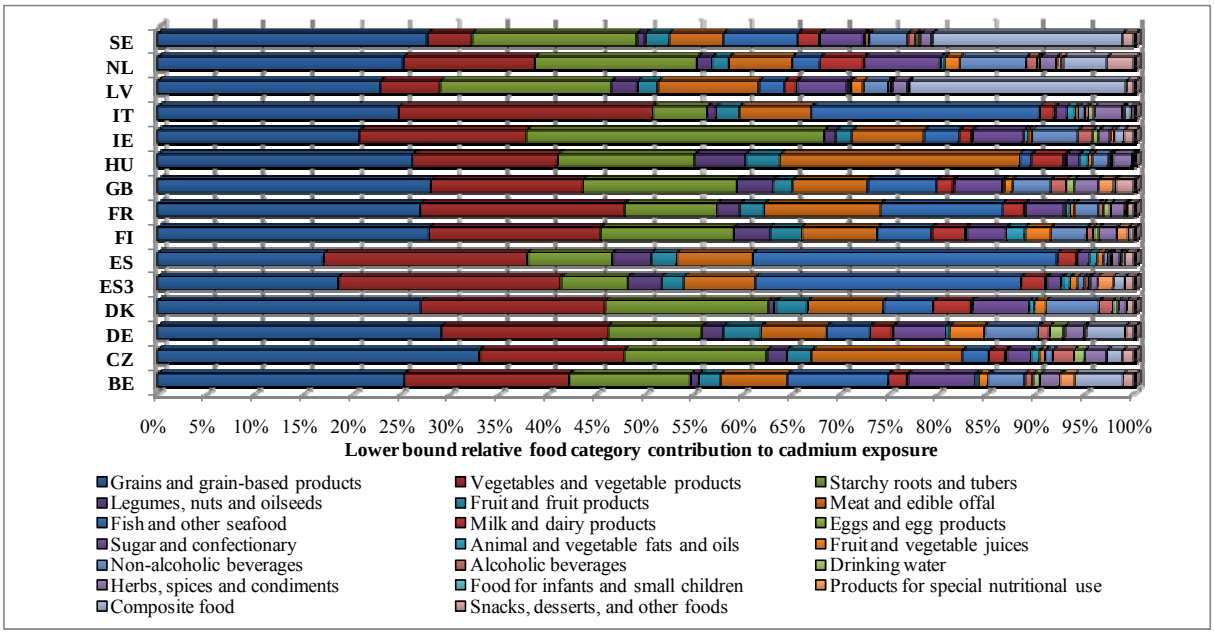

Figure 7: Contribution of twenty broad food categories to overall lower bound mean cadmium exposure in adults shown separately for each of the fifteen individual surveys.

Cadmium exposure in the elderly exhibited the same pattern as for the other age groups with grains and grain products, vegetable and vegetable products, and starchy roots and tubers contributing together between 55 % and 63 % in all surveys (Figure 8). Again the contribution to exposure from consumption of fish and other seafood was high in Italy (20 %) and from meat and edible offal in Hungary (19 %).

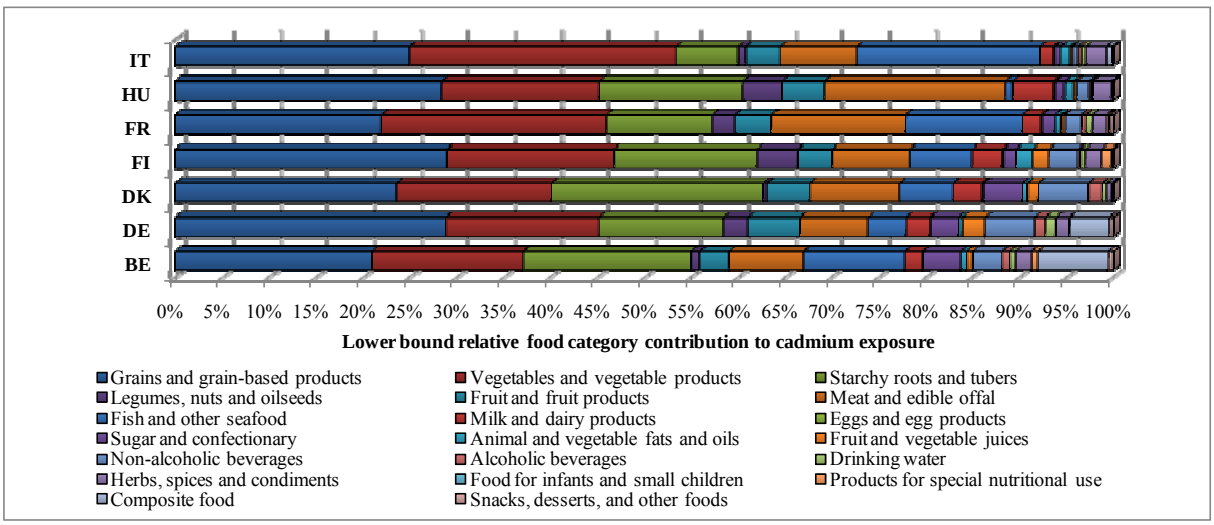

Figure 8: Contribution of twenty broad food categories to overall lower bound mean cadmium exposure in the elderly shown separately for each of the seven individual surveys.

The food consumption pattern for the very elderly did not differ much from the elderly age group in the six surveys (Figure 9). Potatoes contributed most to exposure in Denmark (26 %) and least in Italy

(7 %). On the contrary, fish and other seafood contributed most to exposure in Italy (13 %) and least in Hungary (1 %).

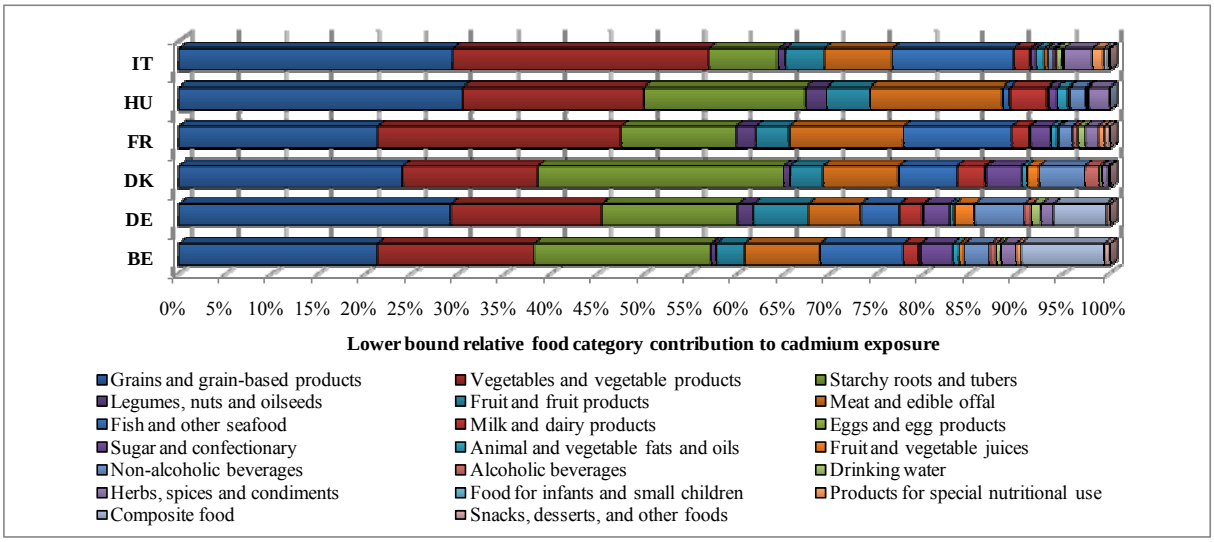

Figure 9: Contribution of twenty broad food categories to overall lower bound mean cadmium exposure in the very elderly shown separately for each of the six individual surveys.

In conclusion, based on lower bound estimates cadmium dietary exposure patterns varied considerably across the different surveys even at the broad food category level. Consistently, grains and grain products, vegetables and vegetable products, and starchy roots and tubers contributed about 50 % or more to exposure in all surveys, while fish and other seafood, meat and edible offal or sugar and confectionary contributed significantly to exposure in some individual surveys.

3.4. The detailed influence of food groups to cadmium exposure

To explore the impact of different food groupings to exposure in more detail the relative contributions of the different food groups at FoodEx Level 1, and for each Level 1 group further split into the relative contribution of the Level 2 groups, are illustrated for lower bound mean exposure in Table 13 for the respective age group.

Table 13: Relative contribution (%) over the different age groups at FoodEx Level 1 and within each Level 1 category the relative contribution of the Level 2 food categories, calculated for lower bound mean exposure.

Food category in FoodEx	Relative contribution (%) to dietary exposure						
	Infants	Toddlers	Other children	Adolescents	Adults	Elderly	Very elderly
Grains and grain-based products	21.7	27.1	27.5	29.2	26.6	26.3	25.1
Unspecified	-	0.2	0.2	-	0.1	0	-
Grains for human consumption	16.5	10.3	12	14.5	11.5	8.3	7.6
Grain milling products	17.2	27.9	11.7	6.3	10.6	12.9	3.9
Bread and rolls	40.8	34.5	36.1	40.1	46.1	49.5	53.4
Pasta (raw)	4.8	7.2	9.8	11.9	9.1	7.6	10.2
Breakfast cereals	0.1	3.8	8.2	6.4	4.8	3.4	4.3
Fine bakery wares	20.6	16.2	22	20.8	17.8	18.3	20.5
Vegetables and vegetable products	13.8	15.1	12.7	12.9	17.4	18.3	19.1
Unspecified	-	0.4	0.8	0.9	0.4	0.2	0.2

Food category in FoodEx	Relative contribution (%) to dietary exposure						
	Infants	Toddlers	Other children	Adolescents	Adults	Elderly	Very elderly
Root vegetables	34.4	37.8	21.1	13.5	15.2	16.7	12.6
Bulb vegetables	11.1	7.0	3.9	3.8	4.3	3.5	2.9
Fruiting vegetables	19.5	18.9	16.0	13.7	14.4	13.0	10.4
Brassica vegetables	1.4	4	2.4	1.6	2.6	3.4	2.9
Leaf vegetables	11.4	9.3	14.6	21.2	27.8	30.3	30.7
Legume vegetables	0.2	0.4	0.4	0.3	0.3	0.4	0.4
Stem vegetables (fresh)	9.1	5.1	3.7	3.6	4.6	7.7	8.4
Sugar plants	-	0.3	0.2	0.3	0.4	2.3	6.3
Sea weeds	-	-	0	0.3	1.1	0.1	4.8
Tea and herbs for infusions (solid)	-	-	1.1	0.3	0.3	-	-
Cocoa beans and cocoa products	0.5	3.7	23.7	25.5	3.6	1.6	1.9
Coffee beans and coffee products (solid)	-	-	0	0.1	0.3	0	0.1
Coffee imitates (solid)	-	0	0	0	0	0.1	0.4
Vegetable products	0.5	3.2	2	2.2	3.3	3.1	2
Fungi, cultivated	12.0	9.4	7.7	10.9	16.6	11.9	13.3
Fungi, wild, edible	-	0.4	2.5	1.7	4.7	5.7	2.9
Starchy roots and tubers	13.3	18.0	13.6	12.8	12.3	14.1	15.6
Potatoes and potato products	100	100	100	99.9	99.9	99.8	99.7
Other starchy roots and tubers	-	0	0	0.1	0.1	0.2	0.3
Legumes, nuts and oilseeds	0.7	1.1	1.5	3.8	2.1	2.3	1.1
Unspecified	-	-	0.1	0.1	0.1	0.1	0.1
Legumes, beans, dried	66.4	65.7	46	32.9	38.9	33.9	38.5
Legumes, beans, green, without pods	29.0	9.6	5.3	2.9	5.8	5.8	15.2
Tree nuts	4.6	8.3	9.9	9.2	19.8	15.1	20.3
Oilseeds	-	16.4	38.7	55	35.4	45.2	26
Fruit and fruit products	3.0	3.8	3.0	2.1	2.9	4.5	4.1
Unspecified	-	0.1	0.7	0.4	0.2	0.4	-
Citrus fruits	0.5	2.4	5.4	6.3	6.4	4.9	6.4
Pome fruits	36.5	35.5	49.5	51.2	53.4	56.7	54.8
Stone fruits	6.4	4.2	1.9	2.7	3.0	2.8	3.4
Berries and small fruits	2.3	12.0	7.6	7.0	6.8	8.5	6.1
Miscellaneous fruits	37.3	37.3	24.7	18.7	17.9	11.8	12.1
Dried fruits	0	0.9	0.5	0.3	0.5	0.5	0.4
Jam, marmalade and other fruit spreads	0.1	1.2	3.3	4.7	5.1	6.5	7.0
Other fruit products	16.8	6.4	6.3	8.7	6.6	7.9	9.8
Meat and edible offal	4.8	5.3	5.9	6.5	8.7	9.0	7.9
Unspecified	-	0.8	0.8	1.6	2.0	2.3	2.3
Livestock meat	18.0	43.6	35	47.2	33.9	32.3	44.5
Poultry	22.2	13.1	8.3	8.1	6.1	4.4	5.3
Game mammals	-	0.3	0.3	0.1	0.2	0.3	0.2
Game birds	-	0	0	0	0	0	0
Mixed meat	1.0	1.4	0.7	0.4	0.2	0.3	0.4
Edible offal, farmed animals	55.3	23.4	31.0	20.2	40.7	45.3	33.7
Preserved meat	0.1	1.5	2.7	3.6	3.0	2.8	3.6
Sausages	3.3	14.6	19.4	17.2	12.7	11.3	8.7
Meat specialities	-	0.1	0.2	0.2	0.3	0.4	0.2
Pastes, pâtés and terrines	0.1	0.7	1.1	1	0.6	0.6	0.9
Meat imitates	-	0.4	0.5	0.5	0.4	0.1	0.1
Fish and other seafood	0.4	2.4	5.0	8.2	8.9	7.5	8.1
Unspecified	-	-	2.9	3.2	2.5	2.6	2.7

Food category in FoodEx	Relative contribution (%) to dietary exposure						
	Infants	Toddlers	Other children	Adolescents	Adults	Elderly	Very elderly
Fish meat	100	77.5	40.9	27.4	33.3	48.9	39.4
Fish products	-	8	9.2	5.4	2.2	2.1	1.8
Fish offal	-	-	1.8	0.7	0.6	0.4	0.2
Crustaceans	-	3.6	8.7	11.1	16.8	11.4	15.1
Water molluscs	-	10.9	35.5	52.0	44.1	33.9	40.0
Amphibians, reptiles, snails, insects	-	-	0.9	0.4	0.6	0.7	0.8
Milk and dairy products	8.4	6.5	6.9	3.2	2.3	2.4	2.0
Unspecified	-	0.3	0.1	0.1	-	-	-
Liquid milk	19.0	27.4	24.8	24.7	21.1	16.9	16.2
Milk based beverages	3.7	19.6	33.1	38.0	15.4	10.9	10.3
Concentrated milk	-	0.3	8.5	0.3	2.9	5.1	3.9
Whey and whey products	-	1.4	0.9	0	0.7	0.7	0.2
Cream and cream products	0	0.3	0.4	0.7	1.4	1.5	1.0
Fermented milk products	66.7	30.2	16.6	15.4	19.1	20.6	16.6
Milk derivatives	-	0	0	0	0	0	0
Cheese	10.6	11.1	9.6	18.6	34.4	36.5	47.9
Milk and milk product imitates	-	9.4	6.0	2.1	5.0	7.8	3.9
Eggs and egg products	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Unspecified	-	-	-	-	0.3	-	-
Eggs, fresh	100	100	100	100	99.7	100	100
Eggs, powder	0	0	0	0	0	0	-
Sugar and confectionary	0.9	4.5	7.3	6.4	4.3	2.6	2.7
Unspecified	-	-	-	-	0	-	-
Sugars	83.5	4.7	1.3	1.1	3.1	4.6	4.4
Sugar substitutes	-	0	0	0	0.5	1.4	1.6
Chocolate (cocoa) products	15.3	81.3	87.2	92.2	90.8	86.0	88.7
Confectionery (non-chocolate)	0.4	3.6	5.3	4.7	3.4	1.9	1.3
Dessert sauces	-	9.5	5.3	0.8	0.7	2.5	1.4
Molasses and other syrups	-	0.5	0.6	0.9	0.5	0.5	0.3
Honey	0.8	0.3	0.3	0.3	0.9	3.1	2.3
Animal and vegetable fats and oils	0.6	0.8	0.7	0.4	0.6	0.7	0.7
Unspecified	-	0	0	0	0	0	0
Animal fat	51.1	14.0	12.2	24.7	25.8	27.9	31.6
Fish oil	-	-	-	0	0.1	0	-
Vegetable fat	-	8.0	5.6	1.6	1.1	0.5	0.2
Vegetable oil	48.5	46.3	29.8	55.5	43.7	29.8	35.9
Fats of mixed origin	-	21.1	35.0	0.2	10.5	18.2	2.7
Margarine and similar products	0.4	10.6	17.5	17.9	18.8	23.6	29.7
Fruit and vegetable juices	4.5	2.3	2.5	1.8	1.6	1.5	0.9
Unspecified	-	-	3.5	3.6	1.9	-	-
Fruit juice	46.6	79.1	84.7	84.6	83.5	84.5	83.7
Concentrated fruit juice	-	2.4	2.1	2.2	1.0	0.6	0.3
Fruit nectar	2.7	3.4	0.8	0.2	1.1	0.2	0.1
Dehydrated/powdered fruit juice	-	-	0	-	-	0	-
Mixed fruit juice	4.8	8.8	7.4	5.8	6.9	4.8	5.9
Vegetable juice	45.9	5.0	1.0	2.6	5.2	9.4	8.1
Mixed vegetable juice	-	-	0	0.2	0.1	-	-
Mixed fruit and vegetable juice	-	1.3	0.5	0.8	0.2	0.4	1.8
Non-alcoholic beverages	1.0	0.5	1.3	2.1	3.6	3.7	2.9
Unspecified	-	1.7	6.2	0.5	0.4	0.3	0.2

Food category in FoodEx	Relative contribution (%) to dietary exposure						
	Infants	Toddlers	Other children	Adolescents	Adults	Elderly	Very elderly
Soft drinks	3.8	49.4	75.6	62.9	21.7	5	7.9
Tea (infusion)	96.2	47.7	13.2	21.6	37.7	43.7	39.6
Coffee (beverage)	-	0.4	0.7	3.7	37.2	48.6	48.9
Coffee imitates beverage	-	-	0	0	0.2	1.0	2.0
Cocoa beverage	-	0.7	4.3	11.3	2.7	1.3	1.5
Alcoholic beverages	0	0	0	0.1	0.9	0.9	0.6
Unspecified	-	-	-	0.9	0.2	0.4	0.2
Beer and beer-like beverage	-	48.1	54.8	70.2	70.1	63.7	54.8
Wine	98.6	37.8	5.2	5.3	20	28.6	36.9
Fortified and liqueur wines	1.4	2.8	0.1	0.2	0.2	0.3	1.0
Wine-like drinks (e.g. Cider, Perry)	-	-	38.0	5.8	2.5	1.6	1.3
Liqueur	-	9.5	0	8.4	2.7	2.5	2.3
Spirits	-	1.7	0.4	3.2	2.3	2.3	2.0
Alcoholic mixed drinks	-	-	1.5	5.9	1.9	0.7	1.5
Drinking water	1.7	0.8	0.4	0.5	0.8	0.8	0.7
Unspecified	-	44.5	28.2	1.0	8.6	1.5	1.5
Tap water	61.5	40.1	35.6	34.4	21.4	19.9	12.7
Bottled water	38.5	15.4	36.2	64.7	70	78.6	85.8
Water ice (for consumption)	-	0	0	0	0	0	-
Herbs, spices and condiments	1.3	1.4	1.5	1.8	1.8	1.5	1.8
Unspecified	-	-	0.6	1.2	-	-	-
Herbs	45.8	27.7	8	5.1	7.2	8.7	7.9
Spices	41.5	19.9	5.2	9.2	18.8	14.7	25.3
Herb and spice mixtures	-	2.8	2.2	0.7	0.8	0.7	0.4
Seasoning or extracts	10.6	27	22.2	15.9	14.7	22.3	25.0
Condiment	1.8	6.9	25.6	18.0	14.5	8.5	5.2
Dressing	0.1	0.6	2.0	3.4	4.5	5.2	3.7
Chutney and pickles	-	-	1.0	3.0	1.3	0.7	0.5
Savoury sauces	-	13.2	30.9	42.5	36.3	36.4	31.7
Flavourings or essences	0.1	0	0	0	0	0	0
Baking ingredients	0.1	1.9	2.3	0.9	1.8	2.7	0.3
Food for infants and small children	21.0	6.7	0.4	0	0	0	0
Unspecified	-	-	1.6	-	-	-	-
Infant formulae, powder	20.0	1.4	0.1	-	-	-	-
Infant formulae, liquid	5.9	47.6	1.8	21.2	-	-	-
Follow-on formulae, powder	1.6	1.6	0.4	-	-	-	-
Follow-on formulae, liquid	1.4	0.8	2.8	0.8	1.7	-	13.3
Yoghurt, cheese and milk-based dessert	0.4	0.5	1.5	-	3.6	-	-
Cereal-based food	9.2	22.6	76.8	53.9	76.9	100	55.7
Fruit juice and herbal tea	0.1	1.8	0.3	6.2	4.3	-	1.9
Ready-to-eat meal	61.5	23.7	14.7	18.0	13.4	-	29.1
Products for special nutritional use	0	0	0.1	0.4	0.4	0.3	0.5
Unspecified	-	-	-	-	0.2	0.3	1
Food for weight reduction	-	-	-	0.1	12.7	18.3	8.6
Dietary supplements	100	68.3	61.8	6.1	21.1	40.0	9.0
Food for sports people	-	-	12.9	92.8	60.5	26.5	38.1
Dietetic food for diabetics	-	23.1	0.6	0.9	2.7	14.0	31.1
Medical food for medical supervision	-	8.6	24.6	-	2.7	0.9	12.3
Composite food	0.2	1.1	7.5	5.9	3.5	3.1	5.6
Unspecified	-	0.8	0.7	0.9	0.4	0	0

Food category in FoodEx	Relative contribution (%) to dietary exposure						
	Infants	Toddlers	Other children	Adolescents	Adults	Elderly	Very elderly
Cereal-based dishes	-	19.8	20.7	24.5	14.9	4.4	2.6
Rice-based meals	-	2.1	31.1	19.7	7.4	0.2	-
Potato based dishes	-	0.3	3.2	1.9	2.1	0.2	-
Beans-based meals	-	0.3	0.7	0.1	0	0	-
Meat-based meals	17.2	18.9	9.1	8.0	5.7	2.3	1.3
Fish and seafood based meals	-	4.0	2.4	1.5	1.5	0.6	0.2
Vegetable-based meals	5	1.2	0.3	0.4	0.6	0.9	0.4
Egg-based meal (e.g., omelette)	-	0.6	0.6	0.9	0.6	0.6	0.2
Mushroom-based meals	-	-	2.0	2.6	7.3	-	-
Ready to eat soups	77.8	47.0	22.9	29.8	47.0	90.0	93.7
Prepared salads	-	5.1	6.4	9.7	12.4	0.8	1.6
Snacks, desserts and other foods	2.5	2.4	2.3	1.8	0.9	0.4	0.5
Unspecified	-	-	-	-	0	-	-
Snack food	26.0	40.3	50.8	70.0	62.9	20.0	13.3
Ices and desserts	0.6	24.7	41.7	29.7	35.6	77.3	86.0
Other non classifiable foods	73.4	35.0	7.5	0.3	1.5	2.7	0.7

In many of the Level 1 FoodEx food categories there were clearly dominating contributions from specific Level 2 categories that were driving exposure, in most cases due to high consumption. In the grains and grain product category, bread and rolls dominated in most age groups with more than half of the contribution for this category in the very elderly. The most prominent food was wheat bread and rolls. In the vegetables and vegetable products category, root vegetables were important for the younger children, while cocoa beans and cocoa products peaked in older children and adolescents and leafy vegetables in adults and older people. Carrot was the most common root vegetable covering 80 % of exposure from this food category while unspecified leaf vegetables and lettuce excluding iceberg lettuce were the two most important foods in the leaf vegetable category covering 34 % and 28 % of exposure, respectively.

There is little consumption of other than potatoes and potato products in the starchy roots and tubers category. Potatoes are most commonly consumed as boiled according to the Comprehensive Database and thus boiled potatoes were estimated to contribute to 43 % of exposure for the starchy roots and tubers category. Although the legume category contributed little to exposure, the two dominant sources were dried beans for young children in particular and oilseeds for adolescents. Peas were the dominating legumes while sunflower seeds contributed to 51 % of oilseed exposure.

The clearly dominating foods contributing the most to exposure from fruits and fruit products were apples in the pome fruit category followed by bananas in the miscellaneous fruit category. However, the overall contribution of fruit and fruit products to exposure was small. Important contributors to meat and edible offal exposure were livestock meat, with equal high share between beef and pork, and edible offal, with equal share between unspecified offal and pork liver. The latter two are examples where a high cadmium content drives the exposure rather than a high consumption. This is also the case for water molluscs in the fish and seafood category, and for squid and mussels in particular.

There is a relative high contribution of milk and dairy products to cadmium exposure in young children mainly driven by high consumption of fermented milk products and liquid milk and not by high cadmium content. Eggs as well as fats and oils contribute little to cadmium exposure while chocolate products, especially dark chocolate, are the main drivers to exposure from sugar and confectionary. Fruit juice is relatively important as a source of cadmium exposure for infants while

soft drinks dominate the non-alcoholic beverages categories for older children, and coffee and tea for adults. Of course, infant formula contributes significantly to young children exposure together with cereal foods for infants and young children.

Among herbs, spices and condiments, there is a rather uniform contribution to cadmium exposure with savoury sauces on the high side. The products for special nutritional use do not contribute much to exposure even if one of the foods with the highest mean cadmium levels, algal formulations, belongs to this category. Composite foods on the other hand, with a large range of ready-to-eat products, are a more important contributor with ready-to-eat soups, rice-based dishes in toddlers and cereal-based dishes in adolescents and adults adding the most to cadmium exposure. Potato crisps provide more than half of the snack food category's contribution to cadmium exposure.

3.5. Ranking of food group contributions to cadmium exposure

The 20 highest contributors for each age group at FoodEx Level 2 are shown in Tables 14 to 20 with their relative contributions to overall exposure. Potatoes and potato products contributed most to cadmium dietary exposure followed by bread and rolls in all age groups except infants where ready-to-eat meals were the second highest contributor just before bread and rolls. The 20 food groups in Table 14 contributed in total to about 85 % of infant exposure.

Table 14: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in infants.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	13.3%
2	Food for infants and small children	Ready-to-eat meal	12.9%
3	Grains and grain-based products	Bread and rolls	8.86%
4	Milk and dairy products	Fermented milk products	5.60%
5	Vegetables and vegetable products	Root vegetables	4.74%
6	Grains and grain-based products	Fine bakery wares	4.47%
7	Non-alcoholic beverages	Tea (infusion)	4.29%
8	Food for infants and small children	Infant formulae, powder	4.21%
9	Grains and grain-based products	Grain milling products	3.73%
10	Grains and grain-based products	Grains for human consumption	3.58%
11	Vegetables and vegetable products	Fruiting vegetables	2.69%
12	Meat and edible offal	Edible offal, farmed animals	2.64%
13	Fruit and vegetable juices	Fruit juice	2.08%
14	Fruit and vegetable juices	Vegetable juice	2.05%
15	Food for infants and small children	Cereal-based food	1.93%
16	Snacks, desserts, and other foods	Other food non classifiable	1.85%
17	Vegetables and vegetable products	Fungi, cultivated	1.65%
18	Milk and dairy products	Liquid milk	1.59%
19	Vegetables and vegetable products	Leaf vegetables	1.57%
20	Vegetables and vegetable products	Bulb vegetables	1.53%

In toddlers, grain-milling products, root vegetables, fine bakery wares, chocolate products and infant formula all contributed more than 3 % to overall exposure. The 20 food groups in Table 15 contributed in total to about 77 % of exposure in toddlers.

Table 15: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in toddlers.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	18.0%
2	Grains and grain-based products	Bread and rolls	9.33%
3	Grains and grain-based products	Grain milling products	7.54%
4	Vegetables and vegetable products	Root vegetables	5.73%
5	Grains and grain-based products	Fine bakery wares	4.38%
6	Sugar and confectionary	Chocolate (cocoa) products	3.68%
7	Food for infants and small children	Infant formulae, liquid	3.20%
8	Vegetables and vegetable products	Fruiting vegetables	2.87%
9	Grains and grain-based products	Grains for human consumption	2.78%
10	Meat and edible offal	Livestock meat	2.31%
11	Milk and dairy products	Fermented milk products	1.96%
12	Grains and grain-based products	Pasta (raw)	1.94%
13	Fruit and vegetable juices	Fruit juice	1.83%
14	Fish and other seafood	Fish meat	1.82%
15	Milk and dairy products	Liquid milk	1.78%
16	Food for infants and small children	Ready-to-eat meal	1.59%
17	Food for infants and small children	Cereal-based food	1.52%
18	Fruit and fruit products	Miscellaneous fruits	1.43%
19	Vegetables and vegetable products	Fungi, cultivated	1.42%
20	Vegetables and vegetable products	Leaf vegetables	1.41%

The importance of chocolate to overall exposure increased in the "other children" group. Adding chocolate products and cocoa beans together, the group contributed close to 10 % to exposure. The 20 food groups in Table 16 contributed in total to about 73 % of exposure in other children.

Table 16: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in other children.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	13.6%
2	Grains and grain-based products	Bread and rolls	9.90%
3	Sugar and confectionary	Chocolate (cocoa) products	6.39%
4	Grains and grain-based products	Fine bakery wares	6.04%
5	Grains and grain-based products	Grains for human consumption	3.30%
6	Grains and grain-based products	Grain milling products	3.22%
7	Vegetables and vegetable products	Cocoa beans and cocoa products	3.00%
8	Grains and grain-based products	Pasta (raw)	2.69%
9	Vegetables and vegetable products	Root vegetables	2.67%
10	Composite food	Rice-based meals	2.33%
11	Milk and dairy products	Milk based beverages	2.28%
12	Grains and grain-based products	Breakfast cereals	2.26%
13	Fruit and vegetable juices	Fruit juice	2.14%
14	Meat and edible offal	Livestock meat	2.05%
15	Fish and other seafood	Fish meat	2.04%
16	Vegetables and vegetable products	Fruiting vegetables	2.03%
17	Non-alcoholic beverages	Soft drinks	1.91%
18	Vegetables and vegetable products	Leaf vegetables	1.86%
19	Meat and edible offal	Edible offal, farmed animals	1.82%
20	Fish and other seafood	Water molluscs	1.76%

The eating pattern is much the same for adolescents compared to other children except a higher consumption of water molluscs that is now ranked as the fifth highest contributor to cadmium exposure. The 20 food groups in Table 17 contributed in total to about 75 % of exposure in adolescents.

Table 17: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in adolescents.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	12.8%
2	Grains and grain-based products	Bread and rolls	11.7%
3	Grains and grain-based products	Fine bakery wares	6.09%
4	Sugar and confectionary	Chocolate (cocoa) products	5.88%
5	Fish and other seafood	Water molluscs	4.27%
6	Grains and grain-based products	Grains for human consumption	4.23%
7	Grains and grain-based products	Pasta (raw)	3.47%
8	Vegetables and vegetable products	Cocoa beans and cocoa products	3.30%
9	Meat and edible offal	Livestock meat	3.06%
10	Vegetables and vegetable products	Leaf vegetables	2.74%
11	Fish and other seafood	Fish meat	2.25%
12	Legumes, nuts and oilseeds	Oilseeds	2.06%
13	Grains and grain-based products	Breakfast cereals	1.88%
14	Grains and grain-based products	Grain milling products	1.84%
15	Vegetables and vegetable products	Fruiting vegetables	1.77%
16	Composite food	Ready-to-eat soups	1.74%
17	Vegetables and vegetable products	Root vegetables	1.74%
18	Fruit and vegetable juices	Fruit juice	1.53%
19	Composite food	Cereal-based dishes	1.43%
20	Vegetables and vegetable products	Fungi, cultivated	1.40%

Adults seem to be eating more leafy vegetables than the previous age groups since they increased in ranking. Also edible offal played a more prominent role. The 20 food groups in Table 18 contributed in total to about 75 % of total exposure in adults.

Table 18: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in adults.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	12.3%
2	Grains and grain-based products	Bread and rolls	12.3%
3	Vegetables and vegetable products	Leaf vegetables	4.84%
4	Grains and grain-based products	Fine bakery wares	4.74%
5	Fish and other seafood	Water molluscs	3.91%
6	Sugar and confectionary	Chocolate (cocoa) products	3.88%
7	Meat and edible offal	Edible offal, farmed animals	3.55%
8	Grains and grain-based products	Grains for human consumption	3.06%
9	Meat and edible offal	Livestock meat	2.96%
10	Fish and other seafood	Fish meat	2.95%
11	Vegetables and vegetable products	Fungi, cultivated	2.89%
12	Grains and grain-based products	Grain milling products	2.82%
13	Vegetables and vegetable products	Root vegetables	2.65%
14	Vegetables and vegetable products	Fruiting vegetables	2.51%
15	Grains and grain-based products	Pasta (raw)	2.43%
16	Composite food	Ready-to-eat soups	1.66%
17	Fruit and fruit products	Pome fruits	1.57%
18	Fish and other seafood	Crustaceans	1.48%
19	Fruit and vegetable juices	Fruit juice	1.38%
20	Grains and grain-based products	Breakfast cereals	1.28%

Chocolate products decreased considerably in the elderly while there was a slight increase in the contribution from ready-to-eat soup. The 20 food groups in Table 19 contributed in total to about 77 % of total exposure in the elderly.

Table 19: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in the elderly.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	14.1%
2	Grains and grain-based products	Bread and rolls	13.0%
3	Vegetables and vegetable products	Leaf vegetables	5.55%
4	Grains and grain-based products	Fine bakery wares	4.83%
5	Meat and edible offal	Edible offal, farmed animals	4.05%
6	Fish and other seafood	Fish meat	3.66%
7	Grains and grain-based products	Grain milling products	3.39%
8	Vegetables and vegetable products	Root vegetables	3.06%
9	Meat and edible offal	Livestock meat	2.89%
10	Composite food	Ready-to-eat soups	2.76%
11	Fruit and fruit products	Pome fruits	2.56%
12	Fish and other seafood	Water molluscs	2.53%
13	Vegetables and vegetable products	Fruiting vegetables	2.38%
14	Sugar and confectionary	Chocolate (cocoa) products	2.25%
15	Grains and grain-based products	Grains for human consumption	2.19%
16	Vegetables and vegetable products	Fungi, cultivated	2.18%
17	Grains and grain-based products	Pasta (raw)	2.00%
18	Vegetables and vegetable products	Stem vegetables (fresh)	1.41%
19	Fruit and vegetable juices	Fruit juice	1.29%
20	Vegetables and vegetable products	Fungi, wild, edible	1.04%

The contribution of ready-to-eat soup to cadmium exposure increased even further in the very elderly. The contribution from potatoes and potato products was the second highest after toddlers. The 20 food groups in Table 20 contributed in total to about 79 % of total exposure in the very elderly.

Table 20: Relative contributions of food groups at FoodEx Level 2 to dietary cadmium exposure in very elderly.

Rank	Level 1	Level 2	Proportion
1	Starchy roots and tubers	Potatoes and potato products	15.52%
2	Grains and grain-based products	Bread and rolls	13.41%
3	Vegetables and vegetable products	Leaf vegetables	5.86%
4	Composite food	Ready-to-eat soups	5.29%
5	Grains and grain-based products	Fine bakery wares	5.15%
6	Meat and edible offal	Livestock meat	3.52%
7	Fish and other seafood	Water molluscs	3.25%
8	Fish and other seafood	Fish meat	3.19%
9	Meat and edible offal	Edible offal, farmed animals	2.66%
10	Grains and grain-based products	Pasta (raw)	2.57%
11	Vegetables and vegetable products	Fungi, cultivated	2.53%
12	Vegetables and vegetable products	Root vegetables	2.40%
13	Sugar and confectionary	Chocolate (cocoa) products	2.36%
14	Fruit and fruit products	Pome fruits	2.24%
15	Vegetables and vegetable products	Fruiting vegetables	1.99%
16	Grains and grain-based products	Grains for human consumption	1.92%
17	Vegetables and vegetable products	Stem vegetables (fresh)	1.61%
18	Fish and other seafood	Crustaceans	1.23%
19	Vegetables and vegetable products	Sugar plants	1.20%
20	Grains and grain-based products	Breakfast cereals	1.09%

4. DISCUSSION

A number of studies have reviewed the cadmium content in a range of different foods. In a collaborative effort under the SCOOP framework involving 13 EU Member States, cadmium concentrations in the foods tested ranged from not detected in many foods to a high mean of 1,200 µg/kg for cephalopods (EC, 2004). Equally, in the current study about half of the foods tested had levels of cadmium at less than detection or quantification limits. The highest mean at FoodEx Level 2 of 1,500 µg/kg was recorded for algal formulations followed by 1,100 µg/kg for seaweeds as a vegetable, 400 µg/kg for oilseeds as well as horsemeat and 300 µg/kg for wild mushrooms and mushroom-based meals, edible offal and water molluscs. The mean cadmium level in 13 out of the 144 specific FoodEx Level 2 food categories with consumption information exceeded 100 µg/kg, as did 89 specific foods out of about 1,900 at FoodEx Level 4. Looking at specific foods at FoodEx Level 4, revealed that edible offal had a mean of 1,600 µg/kg driven mainly by high levels of cadmium in horse offal, and scallops had a mean of 1,400 µg/kg as the highest food in the water mollusc food category followed by whelk at 900 µg/kg.

Often it is not the food with the highest cadmium levels, but foods that are consumed in larger quantities that have the greatest impact on cadmium dietary exposure as indicated in a United Kingdom national dietary study identifying potatoes (24 %), miscellaneous cereals (21 %) and bread (19 %) as the highest contributors (FSA, 2009). Equally, the JECFA identified seven commodity groups that contributed significantly to total exposure to cadmium, including rice, wheat, root vegetables, tuber vegetables, leafy vegetables, and other vegetables all consumed in larger quantities, but also molluscs due to their higher cadmium levels (FAO/WHO, 2000). These commodities accounted for 40 - 85 % of the total intake of cadmium in five regions covered by the World Health Organisation Global Environment Monitoring System – Food Contamination Monitoring and Assessment Programme (GEMS/Food). The current study highlighted at the broad FoodEx Level 1

grains and grain products (26.9 %), vegetables and vegetable products (16.0 %) and starchy roots and tubers (13.2 %) as the major contributors to cadmium dietary exposure. Looking at the food categories in more detail, potatoes (13.2 %), bread and rolls (11.7 %), fine bakery wares (5.1 %), chocolate products (4.3 %), leafy vegetables (3.9 %) and water molluscs (3.2 %) contributed the most to cadmium dietary exposure across age groups. At the finest detail, wheat bread and rolls (6.4 %), boiled potatoes (5.7 %), pastries and cakes (4.0 %), potatoes unspecified (3.1 %), rice (3.0 %) and carrots (2.2 %) were important contributors.

Using the more detailed and refined information now available through the Comprehensive Database, a more precise cadmium dietary exposure, including children exposure, could be estimated compared to the calculations published in the previous EFSA opinion (EFSA, 2009). In the previous opinion, the middle bound mean dietary exposure in the adult population in Europe was calculated to be 2.27 (range 1.89-2.96) µg/kg b.w. per week and the high exposure 3.02 (range 2.54-3.91) µg/kg b.w. per week both as medians for the countries that provided consumption information. The current exposure calculations indicate a middle bound mean of 1.77 (range 1.50-2.23) µg/kg b.w. per week as median estimate for the surveys covering the adult age group, which is 22 % lower than the previous estimate for the same age group. However, the 95th percentile exposure of 3.13 (range 2.47-4.81) µg/kg b.w. per week was slightly higher than the previous estimate of high exposure possibly due to the latter having been obtained with a less precise methodology as prescribed in the EFSA guidance document when using a limited number of broad food categories with the only aim to indicate high exposure (EFSA, 2009).

Children exposure was given as an indication only at a mean of 2.97 µg/kg b.w. per week and a high of 5.49 µg/kg b.w. per week in the previous opinion due to the limited coverage of one country only. In the current report, children were divided into three age groups. Middle bound mean exposure was estimated to be 2.68 µg/kg b.w. per week for infants as an average of the two surveys. With a broader range of survey results available, middle bound mean exposure was estimated to be 4.80 (range 3.84-6.77) µg/kg b.w. per week for toddlers, and 3.92 (range 3.13-5.03) µg/kg b.w. per week for other children as survey median estimates. The corresponding middle bound 95th percentile exposure values were 6.59 µg/kg b.w. per week for infants, 6.50 (range 5.32-10.1) µg/kg b.w. per week for toddlers and 6.21 (range 4.58-10.2) µg/kg b.w. per week for other children.

In summary, lifetime cadmium dietary exposure for the European population as a whole can be roughly estimated at about 2.04 µg/kg b.w. per week as an overall middle bound average for all age groups, which is within the TWI of 2.5 µg/kg b.w. recommended by EFSA. It was highest in toddlers with an overall average of 4.85 µg/kg b.w. per week (close to the survey median in the preceding paragraph) and lowest in the elderly population group at 1.56 µg/kg b.w. per week. A limited segment of the population, apart from children, will clearly exceed the recommended health-based guidance value as indicated by an overall estimated lifetime exposure of 3.66 µg/kg b.w. per week at the middle bound 95th percentile or up to 8.19 µg/kg b.w. per week during the toddler age period.

The United Nations Environment Programme – Division of Technology, Industry and Economics, Chemicals Branch has indicated that the margin between the health-based guidance value reconfirmed by JECFA in 2003, valid at the time, and an average weekly intake of cadmium from food by the general population in most countries of 0.7-2.8 µg/kg b.w. is small, and that this margin may be even smaller in smokers or non-existent in some populations at high risk (UNEP, 2006, 2008).

The EFSA Panel on Contaminants in the Food Chain stated in a requested re-assessment of its previous opinion that their current recommended TWI of 2.5 µg/kg b.w. for cadmium established in 2009 should be maintained in order to ensure a high level of protection of all consumers, including exposed and vulnerable subgroups of the population. Considering non-dietary exposure, the Panel anticipated that the total exposure of some subgroups of the population could exceed both their TWI as well as the JECFA PTMI (EFSA, 2011a). They concluded that although adverse effects are unlikely to occur in an individual with current dietary exposure, there is a need to reduce exposure to cadmium at the population level because of the limited safety margin.

The current review confirmed that children and adults at the 95th percentile exposure could exceed the health-based guidance values.

5. UNCERTAINTIES

In Table 21, a summary of the uncertainty evaluation is presented, highlighting the main sources of uncertainty and indicating an estimate of whether the respective source of uncertainty might have led to an over- or underestimation of the exposure or the calculated dietary exposure.

Table 21: Summary of qualitative evaluation of the impact of uncertainties on the dietary exposure to cadmium.

Sources of uncertainty	Direction [(a)]
Uncertainty of the analytical measurements	+/-
Sampling strategy: random/targeted	+
Occurrence data on food available from a limited number of countries	+/-
Use of UB occurrence data in the exposure estimations	+
Use of MB occurrence data in the exposure estimations	+/-
Use of LB occurrence data in the exposure estimations	-
Limited food consumption data on infants	+/-

(a): + = uncertainty with potential to cause over-estimation of exposure; - = uncertainty with potential to cause under-estimation of exposure

The vast majority of occurrence data were from a limited number of countries thus the occurrence data may not be fully representative for Europe. Data obtained on targeted samples collected in cadmium contaminated areas may lead to an overestimation of the exposure estimates. The use of the UB approach for high percentage of occurrence data < LODs/LOQs is conservative, i.e. it represents a clear overestimation of exposure. MB may over- or under-estimate the exposure. There was a lack of dietary surveys reporting consumption data for children younger than 1 year, which led to an uncertainty in this area.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- Using detailed individual food consumption data, middle bound average and 95th percentile lifetime cadmium dietary exposure for the European population was estimated at 2.04 and 3.66 µg/kg b.w. per week, respectively. It was highest in toddlers and lowest in the elderly population group. Individual dietary survey results varied between a weekly minimum lower bound average of 1.15 to a maximum upper bound average of 7.84 µg/kg b.w. and a minimum lower bound 95th percentile of 2.01 and a maximum upper bound 95th percentile of 12.1 µg/kg b.w. reflecting different dietary habits and survey methodologies.

- The mean cadmium level in 13 out of 144 specific food categories with consumption information exceeded 100 µg/kg including algal formulations, cocoa powder and other cocoa-based products, crustaceans, edible offal, unspecified fish and seafood, frog's legs, cultivated fungi, wild fungi, oilseeds, seaweeds and water molluscs.

- About half of the foods tested had levels of cadmium at less than detection or quantification limits, while individual quantified values ranged from a low of 0.001 µg/kg for drinking water to a high of 61,000 µg/kg for edible offal (horse kidney).

- Food consumed in larger quantities had the greatest impact on cadmium dietary exposure and this was true for the broad food categories of grains and grain products (26.9 %), vegetables and vegetable products (16.0 %) and starchy roots and tubers (13.2 %). At a more detailed level potatoes (13.2 %), bread and rolls (11.7 %), fine bakery wares (5.1 %), chocolate confectionary products (4.3 %), leafy vegetables (3.9 %) and water molluscs (3.2 %) contributed the most across age groups. At the finest detail wheat bread and rolls (6.4 %), boiled potatoes (5.7 %), pastries and cakes (4.0 %), potatoes unspecified (3.1 %), rice (3.0 %) and carrots (2.2 %) were important contributors.

- Health-based guidance values have been established by JECFA at 25 µg/kg b.w. as a provisional tolerable monthly intake (PTMI) corresponding to a weekly intake of 5.8 µg/kg b.w. and by the EFSA Panel on Contaminants in the Food Chain at 2.5 µg/kg b.w. as a tolerable weekly intake (TWI). The current review confirmed that children and consumers at the 95th percentile exposure can exceed the health-based guidance values.

RECOMMENDATIONS

- It would be valuable to have a better coverage of the European food market since sample results submitted to EFSA come from a limited number of countries. These might not be fully representative of the European situation.

- For a few food categories rather high limits of detection and quantification were reported. To increase precision and accuracy in calculating exposure, it would be important to lower such limits as much as possible.

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GLOSSARY AND ABBREVIATIONS

b.w.	Body weight
Comprehensive Database	EFSA Comprehensive European Food Consumption Database
EFSA	European Food Safety Authority
EXPOCHI	Individual food consumption data and exposure assessment studies for children
FoodEx	Food classification system developed by EFSA for undertaking exposure assessments
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LB	Lower bound - left-censored result entered as zero
LC	Left-censored result – results below the respective analytical limit
MB	Middle bound - left-censored result entered at half of the respective analytical limit
UB	Upper bound – left-censored result entered at the respective analytical limit
PTMI	Provisional Tolerable Monthly Intake
PTWI	Provisional Tolerable Weekly Intake