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Dietary intake of heavy metals (cadmium, lead and mercury) by the Dutch population

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Abstract

The exposure of the Dutch population to cadmium, lead and mercury via food is assessed based on concentration data from 1999-2002 and on consumption data from the third Dutch National Food Consumption Survey. To this end, the dietary intake estimation method using the MCRA (Monte Carlo Risk Analysis) programme of the Intstitute of Food Safety (RIKILT) was used in the assessment. The estimated median long-term dietary intake of cadmium by the whole population is 0.14 μg/kg body weight/day, while by 1-6 year-old children it is 0.32 μg/kg bw/day. The 97.5th percentile of the intake of the whole population is estimated at 0.32 μg/kg bw/day, which is 64 % of the tolerable daily intake (TDI). It is estimated that the TDI of 0.50 μg/kg bw/day is exceeded by 2.5 % of the 1-6 year-old children. The estimated median long-term dietary intake of lead by the whole population is 0.05 μg/kg bw/day, while by 1-6 year-old children it is 0.10 μg/kg bw/day. The estimated 95th percentiles for the intake of lead by the whole population and by 1-6 year-old children are low compared to the TDI (3.6 μg/kg bw/day). The median long-term dietary intake of mercury by the whole population and by 1-6 year-old children is estimated at 9 and 33 ng/kg bw/day, respectively. The TDI of organic mercury (0.1 μg/kg bw/day) and of inorganic mercury (2 μg/kg bw/day) are not exceeded by the 95th percentiles of the estimated long-term intake.

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Samenvatting

De blootstelling van de Nederlandse bevolking aan cadmium, lood en kwik via voeding is geschat met behulp van concentraties gemeten in 1999-2002 en met de consumptiegegevens van de derde Voedsel Consumptie Peiling. De blootstelling is berekend met het MCRA (Monte Carlo Risico Analyse) programma van het RIKILT (ontwikkeld door Biometris, Universiteit Wageningen). Omdat voor de meeste monsters de detectielimiet onbekend was, zijn de concentraties van de non-detects op nul gesteld. De berekende innames zijn daarom minimumschattingen.

De mediane lange-termijn inname van **cadmium** via de voeding van de Nederlandse bevolking wordt geschat op 0,14 µg/kg lg/dag. Voor kinderen in de leeftijd van 1 tot met 6 jaar is de geschatte inname 0,32 µg/kg lg/dag. De grootste bijdragen aan de inname van cadmium via voeding worden geleverd door tarwe, aardappels en groenten. Het 97,5^{e} percentiel van de inname van de gehele bevolking wordt geschat op 0,32 µg/kg lg/dag. Dit komt overeen met 64 % van de toelaatbare dagelijkse inname (TDI) voor de orale blootstelling aan cadmium (0,5 µg/kg lg/dag). De TDI wordt wel overschreden door ongeveer 2,5 % van Nederlandse kinderen in de leeftijd van 1 tot met 6 jaar. De consequentie hiervan is in de huidige studie niet onderzocht. De gemiddelde inname van cadmium via voeding is vergelijkbaar met de schatting van TNO voor de periode 1988-1989. Er kunnen geen conclusies getrokken worden over de tijdtrend van de cadmiuminname via voeding tussen 1988-1989 en 1999-2002 door gebrek aan metingen in koffie en rijst in de laatste periode. Het verdient aanbeveling om de cadmiumconcentraties in deze voedingsmiddelen en tevens in rund- en varkensvlees te meten. Inname van cadmium via voeding in Nederland is vergelijkbaar met de andere Europese landen.

De geschatte mediane lange-termijn inname van **lood** via voeding door de Nederlandse bevolking is 0,05 µg/kg lg/dag en door kinderen in de leeftijd van 1 tot met 6 jaar 0,10 µg/kg lg/dag. De grootste bijdrage aan de inname van lood via voeding door de Nederlandse bevolking komt van tarwe, drinkwater en groenten. De inname van lood via voeding is afgenomen in de laatste twee decennia in Nederland alsook in de andere Europese landen. De 95^{e} percentielen van de geschatte inname zijn laag ten opzichte van de TDI (3,6 µg/kg lg/dag).

De geschatte mediane lange-termijn inname van **kwik** via voeding door de gehele bevolking en door kinderen in de leeftijd van 1 tot met 6 jaar op basis van de beschikbare data is 9 ng/kg lg/dag, respectievelijk 33 ng/kg lg/dag. Omdat er geen gegevens van kwik in drank, graanproducten, groente en fruit geconsumeerd in Nederland beschikbaar zijn, is op basis van Deens onderzoek een bijdrage van 57 % van deze voedselgroepen aan de totale kwikinname geschat. Naast genoemde voedselgroepen dragen melk en sommige soorten vis (kabeljauw, tonijn en haring) bij aan de inname. Aanbevolen wordt om kwik te meten in drank, graanproducten, groente en fruit. De TDI voor orale blootstelling aan organisch kwik van 0,1 µg/kg lg/dag en voor inorganisch kwik van 2 µg/kg lg/dag worden niet overschreden door de 95^{e} percentielen van de geschatte innames.

Summary

The exposure of the Dutch population to cadmium, lead and mercury via food is assessed using concentration data from 1999-2002 and consumption data from the third Dutch National Food Consumption Survey. To this end, the dietary intake estimation method using the MCRA (Monte Carlo Risk Analysis) programme of the Institute of Food Safety (RIKILT), which was developed by Biometris, Wageningen University was applied. Because for most food samples the limit of detection (LOD) was unknown, the concentrations of non-detects were set to zero. Hence, the calculated intakes are minimum estimates.

The median long-term dietary intake of **cadmium** by the Dutch population is estimated at 0.14 µg/kg bw/day. The estimated intake by children of 1-6 years old is 0.32 µg/kg bw/day. Wheat, potato and vegetables have the highest contributions to the dietary intake of cadmium. The 97.5th percentile of the intake of the whole population is estimated at 0.32 µg/kg bw/ day, which corresponds to 64 % of the tolerable daily intake (TDI) of cadmium of 0.5 µg/kg bw/day. The TDI is exceeded by about 2.5 % of Dutch children of 1 to 6 years old. The consequence of this has not been investigated in the present study. The mean dietary intake of cadmium estimated in this study is comparable with the one estimated by TNO for the period 1988-1989. A conclusion on the time trend of the dietary intake of cadmium between 1988-1989 and 1999-2002 cannot be drawn because of the lack of measurements in coffee and rice in the last time period. Measurements of cadmium in these commodities and also in pork and beef are recommended. The dietary intake of cadmium in The Netherlands is comparable with the other European countries.

The estimated median long-term dietary intake of **lead** by the Dutch population is 0.05 µg/kg bw/day and by children of 1-6 years old is 0.10 µg/kg bw/day. Wheat, drinking water and vegetables have the highest contributions to the dietary intake. The dietary lead intake has decreased in the last two decades in The Netherlands as well as in the other European countries. The lead intakes (95th percentiles) of both the whole population and the 1-6 year-old children are low compared to the TDI (3.6 µg/kg bw/day).

The median long-term dietary intake of **mercury** by the Dutch population and by children of 1-6 years old is estimated at 9 ng/kg bw/day and 33 ng/kg bw/day respectively. Since data on mercury in beverages, cereals, fruit and vegetables consumed in The Netherlands are not available, we estimated, based on a Danish study, a contribution of these food groups to the total intake of mercury of 57 %. In addition to the food groups mentioned, milk and some sorts of fish (codfish, tuna fish and herring) have relatively high contributions to the dietary intake of mercury. It is recommended to measure mercury in beverages, cereals, fruit and vegetables to improve the dietary intake estimate. The TDI for oral exposure to organic mercury (0.1 µg/kg bw/day) and to inorganic mercury (2 µg/kg bw/day) are not exceeded by the 95th percentiles of the estimated intakes.

1. Dietary intake calculaton of cadmium, lead and mercury

1.1 Introduction

The goal of this report is first to assess the exposure of the Dutch population to cadmium, lead and mercury. These three heavy metals accumulate in humans. In case of chemicals that accumulate in the body, the accumulated amount (body burden) rather than the daily intake relates to the occurrence of adverse health effects of the chemical. The tolerable daily intakes (TDI) of these chemicals thus represent a tolerable daily intake for life-long exposure. Consequently, the chronic and not the daily dietary intakes of cadmium, lead and mercury are determined in the present investigation.
The second goal of the current study is to get insight in the probabilistic dietary intake estimation using the MCRA (Monte Carlo Risk Analysis) programme of the Institute of Food Safety (RIKILT).
The human dietary intake of contaminants is usually estimated by combining data on concentrations of contaminants in different food products and the consumption of these products. In the current study, first a short-term intake estimation has been performed by MCRA. The results of this calculation have been used to determine the contributions of the various food groups to the total intake. Next, the chronic intake distribution is calculated with the Nusser method. In the section below the MCRA-model is explained in more detail.

1.2 Intake calculation method

1.2.1 Concentration and consumption data

For the intake estimation of cadmium, lead and mercury the concentration data of food products from the period 1999-2002 from the database of the Programme of Quality of Agricultural Products (KAP) of RIKILT were used. Only the monitoring data are employed, suspected samples or projects were not included.
Because for most food samples the limit of detection (LOD) was unknown, the concentrations of non-detects were set to zero. Hence, the calculated intakes in the current study are minimum estimates.
The consumption data were obtained from the Dutch National Food Consumption Survey (DNFCS). The DNFCS describes the consumption pattern of the Dutch population and includes information on the daily consumption over two consecutive days and a record of age, sex and body weight of 6250 individuals (Kistemaker et al., 1998). For the calculation of the dietary intake, the intake of primary agricultural products rather than that of individual food products on the level of the Netherlands Nutrient database (NEVO, 1996) was considered. The conversion of the NEVO food products to the primary agricultural products is made using the RIKILT CPAP conversion model (Van Dooren et al., 1995).

1.2.2 Monte Carlo Risk Analysis

The cadmium, lead and mercury dietary intake distributions for the Dutch population were calculated with a probabilistic method using the RIKILT Monte Carlo Risk Analysis programme MCRA 1.2 test version (Van der Voet et al., 2002, www2.rikilt.dlo.nl/mcra/mcra.html, March 2003). In this analysis a DNFCS-respondent is randomly selected. For this person the consumption of relevant foods is determined for one day. The consumption of a food product is multiplied with a randomly selected residue concentration in corresponding food products from the concentration data set (empirical non-parametric method). For this person the results of the multiplication are summed over all consumed food products for that day and the sum is divided by the body weight (Figure 1). The number of Monte Carlo iterations used for the calculations was 200.000. This procedure yields a short-term daily intake distribution.

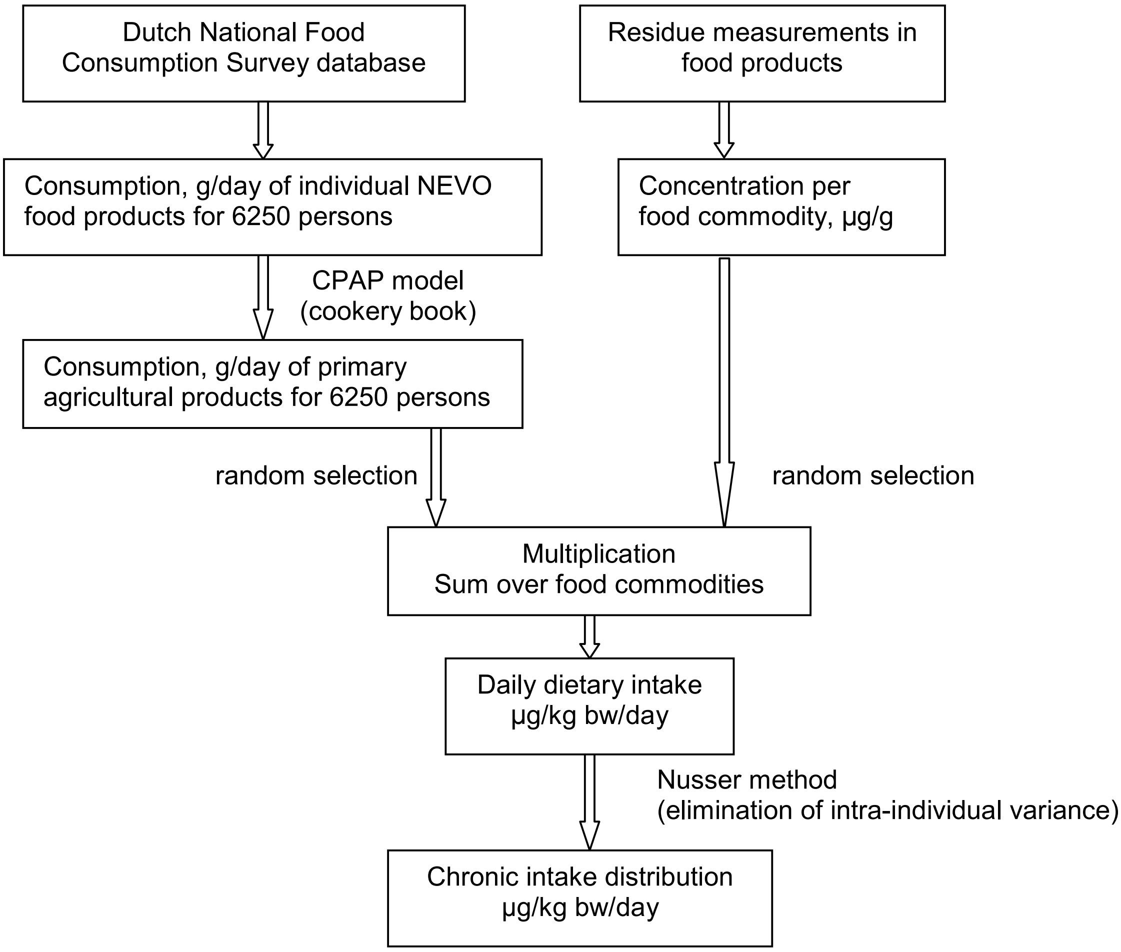

Figure 1. Flow diagram of the dietary intake distribution estimation method.

Because the daily variation of food consumption on the individual level is considerable and often higher than the long-term variation between individuals, appropriate statistical methods that eliminate the intra-individual variance component must be applied if usual intake distributions are estimated on the basis of daily measurements. In practice the tails of the short-term intake distribution are reduced, while the median value stays intact.

To estimate the long-term exposure the Nusser method (Nusser et al., 1996; Hoffman et al., 2002) is used by MCRA. The Nusser method yields the distribution percentiles of the chronic intake and the cumulative intake until the chosen age. The latter is a result of multiplication of the long-term cadmium, lead and mercury intake distribution percentiles with the number of days within the chosen period.

The cadmium, lead and mercury dietary intake distributions, the mean intakes, and the 50^{th}, 90^{th}, 95^{th}, 97.5^{th}, 99^{th}, 99.9^{th} and 99.99^{th} percentiles of intakes were calculated by MCRA.

According to Boon et al. (2001) the number of measurements per food commodity (n) required for a sensible calculation of upper-tail percentiles (p) with an empirical non-parametric method should at least equal 1/(1-p %/100). For example, at least 10 measurements are needed per food commodity to estimate 90 percentiles, 20 measurements are needed to estimate 95 percentiles, 100 measurements for 99 percentiles and 1000 for 99.9 percentiles. Every individual dataset should be carefully analysed on the number of measurements per food commodity and on the contribution of the food commodities to the total intake to determine which percentiles can be calculated. For example for a correct calculation of a 99^{th} percentile with the MCRA-method (with the empirical non-parametric method, which means that concentrations are randomly selected from the concentration database) at least 100 residue concentrations are needed per food commodity contributing significantly to the total dietary intake. It is possible to pool the data from similar food commodities in order to increase the number of residue concentrations. (Boon et al., 2001). If 100 residue concentrations per food commodity are available and the number of positive concentrations (detects) is at least 10, then both parametric (when lognormal distribution functions are assumed for residue concentration per food commodity) and non-parametric methods can be used in the MCRA. If there are less than 100 concentration data, but at least 10 positive measurements (detects), the parametric method can be used in MCRA-method.

MCRA offers the possibility to perform sensitivity analyses. This includes an analysis on the model assumptions and a bootstrap method. The latter is used to determine the uncertainty in the percentile estimates. The DNFCS dataset and concentration datasets are then resampled. It is recommended to use 500-1000 bootstrap datasets. The resulting intake distribution percentiles are determined in the form of the mean values of the corresponding percentiles from the bootstrap sets and the central 95 % confidence interval. In the present study the bootstrap method was not used.

1.3 Comparison of methods used by RIVM and RIKILT

In this section the methods used by RIVM and by RIKILT to estimate the dietary intake are compared.

To estimate the *short-term* exposure RIKILT uses the MCRA-method (developed for RIKILT by Biometris, Wageningen University) which takes into account both the distribution of consumption of food products and the distribution of residue concentrations in food products. RIVM uses the FRIDGE software which takes into account the distribution of consumption of food products and uses the mean residue concentrations per food product. It is clear that FRIDGE will give a somewhat narrower distribution than the MCRA-method.

To estimate the *long-term* dietary intake the RIVM uses the Statistic Exposure Model (STEM) developed at RIVM by Slob (1993). The input for STEM consists of the

individual intakes on two consecutive days based on the DNFCS data and the mean residue concentrations per food product. Analysis of the data showed that the intake is adequately described by a lognormal distribution. STEM transforms the data logarithmically, performs a regression analysis of the log-intake on age, estimates the intra-individual (day-to-day) variance from the residuals, subtracts the intra-individual variance from the total variance to obtain the inter-individual variance and returns the percentiles of the long-term (usual) intake.
At RIKILT the method of Nusser (1996) is implemented by Biometris, Wageningen University. The method of Nusser is basically the same as the method of Slob (STEM) and the results are similar. The difference is that the Nusser method allows a power transformation of the intake data, in addition to the logarithmic transformation. In contrast with the logarithmic distribution the power transformation does not require the intake data to be log-normally distributed,. In the latest version of MCRA (version 2.1), which was coming available during the reportage of the current study, the chronic intake is calculated using the mean residue concentrations instead of a probablilistic sampling method (Van der Voet et al., 2003). This means that for chronic exposure estimations the statistical methods used by RIVM and by RIKILT are comparable.

2. Cadmium

2.1 Introduction

Cadmium (Cd, atomic weight 112) is a silvery-white soft metal, one of the so-called "heavy metals". The generally bivalent cadmium compounds include soluble salts (e.g., $CdCl_2$ and $CdSO_4$) as well as virtually insoluble salts (e.g., CdS and $CdCO_3$). This widely but sparsely distributed element is found in the earth's crust at concentrations ranging from 0.1 to 1 ppm, usually in association with zinc, lead and copper ores. The general information on cadmium is from Browning (1969), Haas (1992), the ATSDR website (www.atsdr.cdc.gov, March 2003), the IPCS INCHEM website (www.inchem.org, March 2003) and the Lenntech website (www.lenntech.com/heavy-metals.htm, March 2003).
The most significant use of cadmium is in nickel/cadmium batteries. Cadmium coatings provide a good corrosion resistance, particularly in high stress environments such as marine and aerospace applications where high safety or reliability is required. Other uses of cadmium are as pigments in plastics, as plastic stabilisers, in alloys and electronic compounds. Cadmium is also present as an impurity in several products, including phosphate fertilisers, deterogents and refined petroleum products.
Cadmium derives its toxicological properties from its chemical similarity to zinc, an essential micronutrient for plants, animals and humans. Cadmium may actually displace zinc in some of its important enzymatic and organ functions interfering with these functions or preventing them from being completed. Cadmium is biopersistent and tends to bioaccumulate. Once absorbed by an organism, it remains resident for many years (half-lives for human kidney and liver have been estimated at 6-38 years and 4-19 years, respectively). Cadmium is very slowly excreted (about 0.007 % of the body burden daily).
The critical effect of long-term exposure to cadmium is renal tubular dysfunction, characterised initially by an increased excretion of low molecular weight proteins in the urine. This effect is irreversible; chronic renal failure is the final and severe endpoint. Cadmium is also able to induce bone damage. The Itay-Itay syndrome, first reported from Japan in the mid-fifties, is the best known example of this effect. Its main characteristics are osteomalaica and osteoporosis, with a tendency to fractures. Data from animal experiments indicated that chronic oral administration of Cd at low doses caused a rise of arterial blood pressure and thus may play a role in the causation of cardiovascular diseases. An overview of toxicology and background exposure to cadmium can be found in Baars et al. (2001). In view of the accumulating properties of cadmium due to its long biological half-life, the TDI for oral exposure is 0.5 μg/kg bw/day (Baars et al., 2001).
The major route of exposure to cadmium for the non-smoking general population is via the food. Agricultural soil can be contaminated from various sources as atmospheric deposition, fertiliser application, water and sewage contamination, followed by the uptake of cadmium by food and fodder crops.
Carrot, spinach, tomato, lettuce, head lettuce and celery have a high cadmium uptake from soil (Versluijs and Otte, 2001). The uptake of cadmium by potato, of which the consumption is high, is relatively low. Cereals such as wheat and rice can concentrate cadmium during the growth in the core of the kernel. Coffee and tea may contain significant cadmium levels. Seafood, such as crab, lobster, clams and oysters from

contaminated estuaries have higher cadmium levels. High levels of cadmium may also be found in certain target organs, such as the liver and kidneys of mammals.

2.2 Exposure to cadmium: literature overview

According to IPCS (1992), the average intake of an adult from air in non-contaminated areas is 0.15 µg/day, while in contaminated areas it is up to 7.5 µg/day. In (non-smoking) exposed workers, however, lung absorption following inhalation of workplace air is the major route of cadmium exposure.
Smoking 20 cigarettes daily adds 2-4 µg/day to the inhalatory intake.
Daily intake from water and food according to IPCS (1992) is 12-25 µg/day. The cadmium intake from water is low. For infants and children, cadmium intakes on a body weight basis are generally higher than that estimated for adults.
In 1993, TNO (Brussaard et al., 1993) calculated the daily dietary intake of cadmium through food and beverages in The Netherlands in a total diet study (period 1988-1989). The minimum estimate was 15.7 ± 5.3 µg/day (0.20 µg/kg bw/day) for male adults (aged 22-50), 11.6 ± 3.9 µg/day (0.18 µg/kg bw/day) for female adults (aged 22-50), 5.9 ± 2.4 µg/day and 5.5 ± 2.3 µg/day for 1-4 years old boys and girls, respectively, 8.0 ± 2.8 µg/day and 7.3 ± 2.7 µg/day day for 4-7 years old boys and girls, respectively. The contribution of product groups to cadmium dietary intake was as follows: bread 34 %, potatoes 25 %, beverages 11 %, potato products 5 %, rice and cereals 4 %. Coffee was the beverage contributing most to cadmium intake. The intake of cadmium decreased between 1976-1978 and 1988-1989.
The average cadmium intake in Germany in 1996 determined with the duplicate portion technique was 7.1 µg/day for women and 8.8 µg/day for men (Seifert et al., 1999). An average cadmium intake of adults in Germany based on market basket studies from 1988 and 1991 was found to be in the range 10-14 µg/day (Müller et al., 1998).
Järup et al. (1998) estimated the average dietary intake for the Swedish population at about 15 µg/day (0.22 µg/kg bw/day) from a number of studies.
The mean and 95th percentile (given in brackets) adult intake of cadmium in Denmark from a total diet study were 16 µg/day (24 µg/day) based on data from 1993-1997, 17 µg/day (28 µg/day) based on data from 1988-1992 and 20 µg/day (32 µg/day) based on data from 1983-1987 (Larsen et al., 2002). The dietary cadmium intakes estimated for different monitoring periods are similar, which is consistent with the largely unchanged cadmium contents in foods.
The cadmium contents of carbonated beverages, juices, beers and wines consumed in Finland was lower than 1 µg/kg and contributed only a negligible amount of cadmium to the average Finnish diet (Tahvonen, 1998).
The Council of Europe (1994) gives an overview of the levels of cadmium in European diets (Table 1).

Table 1. Levels of cadmium in European diets (Council of Europe, 1996).

Country	Mean intake µg/day	Method	Additional information
France	30	Analysis of food inventory	
West Germany	21	Total diet	
United Kingdom	12-19	Total diet	Lower and upper bound
Italy	35-64	Analysis of canteen meals	Results published in 1989
Belgium	18 45-50	Duplicate diet Total diet	Results published in 1983 Results published in 1980
Switzerland	12	Analysis of canteen meals	Results published in 1985
Netherlands	9	Duplicate diet	Median value
Denmark	20	Total diet	Data from 1983-1987

2.3 Data on cadmium residues in food products

Data on concentrations of cadmium in food products were obtained from the KAP database of RIKILT. Table 2 shows the origin of the data and the time frame of the measurements.

Table 2. The origin and the time frame of the data on cadmium residues in food products from the RIKILT KAP database.

Product category	Institution	Year
Wheat	Keuringsdienst van Waren	1999-2001
Fruit and vegetables including potatoes	Keuringsdienst van Waren	2001, 2002
Target organ and game	RVV, Keuringsdienst van Waren	2000, 2001
Fish	RVV, RIVO, Keuringsdienst van Waren	2000, 2001
Tinned fish	Keuringsdienst van Waren	2000
Milk	RVV	1999-2001

Almost 500 samples of fruit, vegetables and potatoes were analysed for cadmium residues (Van der Schee, 2003). It was found that the leafy vegetables, especially spinach, contain higher residues of cadmium. In the category fruit the raspberry has the highest residues.
The TNO total diet study 1988-1989 (Brussaard et al., 1993) reported a contribution of 11 % from beverages and 4 % from rice and cereals to the total dietary intake of cadmium. Coffee was the beverage contributing most to the cadmium intake. Unfortunately, there are neither measurements of cadmium concentrations in coffee, nor in rice in the recent years (Keuringsdienst van Waren, personal communication), thus this uncertainty in the estimated dietary intake should be kept in mind.

Concentration ratios kidneys/liver/meat
The most sampled animal food products are kidney and liver because they can contain elevated cadmium concentrations. However, the most consumed animal food product is meat. Measurements of meat samples (except for horseflesh and game) are not performed in the recent years due to too low accuracy of the measurements (Keuringsdienst van Waren, personal communication). From the literature (Miranda et al., 2001; Farmer et al., 2000) the mean (weighed by the number of measurements)

ratio of cadmium residues in kidneys/liver/meat was determined to be 134/31/1 (see Appendix 1). The measurements listed in Miranda et al. (2001) are from cattle and the ratio kidney/meat ranges from 9 to 578, the ratio liver/meat ranges from 3 to 133. The measurements from Farmer et al. (2000) show that the highest metal concentrations were found in horses, then in cattle, with the lowest in sheep. These samples are from livestock around a metal production centre in eastern Kazakhstan and the ratio kidney/meat ranges from 2 to 21, the ratio liver/meat ranges from 1 to 3. Thus the low ratios kidney/liver/meat are found in polluted regions. In our dietary intake estimation we use the weighed mean cadmium concentration ratio kidneys/liver/meat = 134/31/1 to calculate concentrations in meat as shown in Table 3. This mean ratio is in good agreement with measurements performed in the Netherlands in 1987 giving the ratio of 131/26/1 (see Appendix 1).

Table 3. Sorts of meat not measured but included in the dietary intake calculation.

Sort of meat	Concentration calculated from
Beef	Kidney of manure cow
Pork	Kidney of pig
Veal	Kidney of manure calf
Lamb	Kidney of lamb
Poultry	Liver of chicken
Turkey	Liver of turkey
Roe flesh	Kidney of roe
Tame rabbit flesh	Kidney of tame rabbit
Hare	Liver of hare
Duck	Liver of duck

2.4 Dietary intake of cadmium

The short-term minimum mean dietary intake of cadmium for the Dutch population calculated with the MCRA-programme is 12 µg/day (0.18 µg/kg bw/day) for the whole population and 6 µg/day (0.38 µg/kg bw/day). In Appendix 2 an overview of the mean consumption data, the mean concentration data and the short-term cadmium intake (calculated as mean consumption times mean concentration) is presented per food commodity.

The contributions of the food groups to the total dietary intake are shown in Table 4. Wheat, potato, spinach and carrot contribute most to the total dietary intake of cadmium. When the vegetables are summed they contribute 20 % to the dietary intake of cadmium by the Dutch population (18 % for children aged 1 to 6). The categories meat, fruit and fish and shellfish have a small contribution to the total intake (Table 4).

The long-term exposure to cadmium by the Dutch population and children of 1-6 years old calculated using the method of Nusser is reported in Table 5. The median intake for the whole population is 0.14 µg/kg bw/day, which is naturally the same as the median short-term intake. The higher percentiles for the long-term intake are, logically, lower than those for the short-term intake (see Section 1.2.2). The 97.5th percentile for the whole population is 0.32 µg/kg bw/day, for children of 1-6 years it is 0.50 µg/kg bw/day. This is the highest percentile reported, since the number of residue data is too small for a reliable estimate of higher percentiles (see section 1.2.2 and Boon et al. 2001).

Table 4. Contribution of food groups to cadmium dietary intake by the Dutch population (whole population and infants 1-6 years old).

Food group	Relative contribution (%) whole population	Relative contribution (%) children 1-6 yrs
Wheat	45	48
Potato	28	27
Vegetables	20	18
Meat	4	3
Fruit	2	4
Fish and shellfish	1	< 1

Table 5. Long-term exposure of the Dutch population (whole population and children 1-6 years old) to cadmium.

Percentiles	Long-term intake, µg/kg bw/day whole population*	Long-term intake, µg/kg bw/day children 1-6 yrs*
50	0.14	0.32
90	0.24	0.43
95	0.28	0.47
97.5	0.32	0.50

*average age of DNFCS population is 36 years, average age of children is 4 years

2.5 Comparison with other studies and with TDI

The mean short-term dietary intake of cadmium by the Dutch population of 12 µg/day and by children of 1-6 years old of 6 µg/day estimated in this study, based on data from 1999-2002, is comparable with the mean (short-term) dietary intake of cadmium estimated by TNO in The Netherlands for the period 1988-1989 (Brussaard et al., 1993) of 14 µg/day and 7 µg/day, respectively. The TNO study indicated that the dietary intake of cadmium has decreased between 1976-1978 and 1988-1989. Here we cannot draw a conclusion on the decrease of the dietary intake of cadmium between 1988-1989 and 1999-2002, because of the lack of measurements in coffee in the last time period. The TNO study reported a contribution of 11 % from coffee and 4 % from rice. The mean cadmium dietary intake calculated in the current study is 14 % lower than the one from 1988-1989. This difference could be compensated by contributions from coffee and rice. The data on cadmium in wheat, which gives the largest contribution to the dietary intake, is shown in Figure 2 as a function of time. A clear trend cannot be seen from these data in the last decade.

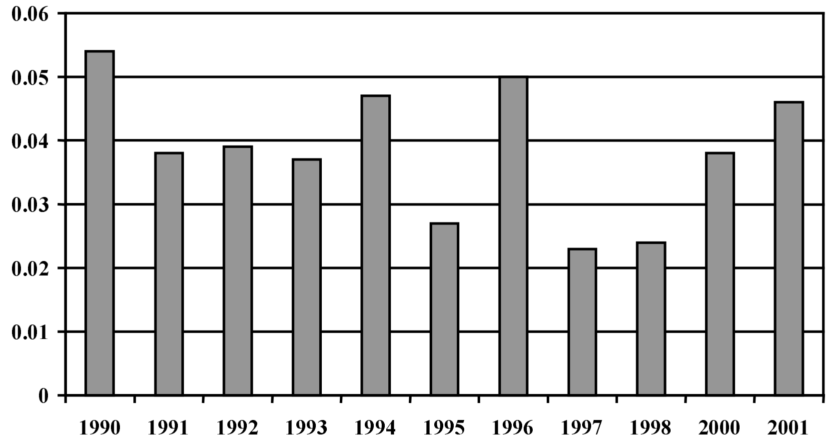

Fig. 2 Cadmium residues in wheat (mg/kg) as a function of time.

A comparison of dietary intakes of cadmium from different European studies is shown in Table 6. The dietary intake of cadmium in The Netherlands appears to be comparable with the other European countries.

Table 6. Comparison of dietary intakes of cadmium from different European studies.

Country	Mean µg/day Whole population	Mean µg/day Children 1-6 years	Method	Reference and time period
The Netherlands	12	6	Total diet	This study; 1999-2002
	14	7	Total diet	Brussaard et al., 1993; 1988-1989
Germany	8		Duplicate diet	Seifert et al., 1999; 1996
	10-14		Market basket	Műller et al., 1998; 1988-1992
		7	Duplicate diet	see Seifert et al., 1999;1989
Sweden	8.5 11		Duplicate diet women	see Järup et al., 1998 published in 1990, 1991 1994
Denmark	16		Total diet	Larsen et al., 2002;1993-1997
Finland	9		Hospital lunches	see Seifert et al., 1999;1987
Italy	32		Factory canteen meals	see Seifert et al., 1999;1992
France	30		Analysis of food inventory	Council of Europe, 1994
United Kingdom	12		Total diet	Council of Europe, 1994
Belgium	18 45		Duplicate diet Total diet	published in 1983 published in 1980 see Council of Europe, 1994
Switzerland	12		Analysis of canteen meals	published in 1985 see Council of Europe, 1994

The long-term minimum median dietary intake of cadmium by the Dutch population is 0.14 µg/kg bw/day and by children of 1-6 years old is 0.32 µg/kg bw/day. Based on these results we conclude that the TDI for oral exposure to cadmium of 0.5 µg/kg bw/day (Baars et al., 2001) is not exceeded by the whole Dutch population (97.5th percentile of the cadmium intake: 0.32 µg/kg bw/day). However, the TDI is exceeded by about 2.5 % of Dutch children of 1 to 6 years old. The consequence of this is not investigated in the present study.

2.6 Conclusions

The long-term minimum median dietary intake of cadmium by the Dutch population is 0.14 µg/kg bw/day and by children of 1-6 years old is 0.32 µg/kg bw/day. The TDI for oral exposure to cadmium of 0.5 µg/kg bw/day (Baars et al., 2001) is not exceeded by the whole Dutch population (97.5th percentile of the cadmium intake: 0.32 µg/kg bw/day). However, the TDI is exceeded by about 2.5 % of Dutch children of 1 to 6 years old.
Wheat, potato and vegetables are the food groups that contribute most to the total intake of cadmium.
The dietary intake of cadmium estimated in this study based on data from 1999-2002 is comparable with the mean dietary intake of cadmium estimated by TNO in The Netherlands for the period 1988-1989. In the current study we cannot draw a conclusion on a decrease of the cadmium dietary intake between 1988-1989 and 1999-2002, because of the lack of measurements in coffee and rice in the last time period.
It is recommended to measure cadmium concentrations in beverages (coffee), cereals (rice) and meat (beef and pork).
The cadmium dietary intake in The Netherlands is comparable with other European countries.

3 Lead

3.1 Introduction

Lead (Pb) is a silvery-grey heavy metal with an atomic weight of 207. Lead ores are found in USA, Mexico, South America, England, Germany, Spain. The generally bivalent lead compounds include well-soluble salts (e.g., lead acetate) as well as practically insoluble ones (e.g., lead oxides). Organic lead compounds include the gasoline additives tetramethyllead and tetraethyllead. The general information on lead is from Browning (1969), Haas (1992), the ATSDR website (www.atsdr.cd.gov, March 2003), the ExtoxNet website (ace.orst.edu/info/extoxnet, March 2003) and the Lenntech website (www.lenntech.com/heavy-metals.htm, March 2003).
Human activities such as mining, manufacturing and the burning of fossil fuels are the major sources of environmental lead. Lead is among the most recycled non-ferrous metals and its secondary production has therefore grown steadily. Lead is used in production of batteries, ammunition, metal products (solder and pipes), alloys, pigments and compounds, cable sheathing, and devices to shield X-rays. Because of health concerns, lead from gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years.
Lead in the food chain comes mostly from direct deposit from the air to plants and from livestock eating soil laced with lead as they eat the plants. Although most people receive the bulk of their lead intake from food, in specific populations other sources may be more important, such as water in areas with lead piping and plumbosolvent (soft) water, air near point source emissions, soil, dust, paint flakes in old houses or contaminated land. Overall, there appears to be a declining trend for lead in food in the last two decades.
In adult humans approximately 10 % of the dietary lead is absorbed, in children and young children, however, as much as 50 % of dietary lead is absorbed. The relationship between blood lead levels and the lead concentration in exposure sources is curvilinear, i.e. at low exposure the absorption is relatively high, while at high exposure the absorption is relatively low. The half-life time for lead in the bone compartments is approximately 30 years.
An overview of toxicology and background exposure to lead can be found in Baars et al. (2001). In humans, lead can result in a wide range of effects at the subcellular level as well as effects on the overall functioning of the organism, ranging from inhibition of enzymes to the production of marked morphological changes and death. Such changes occur over a broad range of doses, the developing human generally being more sensitive than the adult.
At elevated lead blood levels the haemoglobin synthesis is decreased and anaemia has been observed. Lead has shown to be associated with impaired neurobehavioural functioning in children; decrements in intelligence quotients (IQ) are found. Deficits in cognitive functions, which are often irreversible, are found in children and adults. Sensory motor functions may be impaired and autonomous nervous system functions may be affected. Lead is known to cause proximal renal tubular damage. A decreased kidney function and a possible renal failure require chronic exposure to high lead levels. The reproductive effects of lead in the male are limited to sperm morphology and count. In the female, some adverse pregnancy outcomes have been attributed to

lead. At very high levels of lead exposure brain damage and lead poisoning (lead colic) can occur.

The TDI of lead for oral exposure is 3.6 µg/kg bw/day. At this intake level a net accumulation of lead in human organisms is considered highly unlikely (Baars et al., 2001).

Lead is contained in many foods, especially in those grown near industrial areas or busy cities or roadways. Grains, legumes, fruit, and most meat products pick up some lead. Liver and other target organs contain more lead. Drinking water may be contaminated with lead. Carrot, radish, kale, spinach, head lettuce have a high lead uptake from soil (Versluijs and Otte, 2001). The uptake of lead by potato, of which the consumption is high, is relatively low.

3.2 Exposure to lead: literature overview

In 1991 the background exposure to lead was estimated to be 1.2 µg/kg bw/day (32-34 µg/day via food and water, 2 µg/day via air for adults and 0.8 µg/day via air for children), (Vermeire et al., 1991).

The Health Council of The Netherlands estimated in 1997 the background exposure to lead resulting from the intake of food, water and air for children aged 1-4 years to be 2.0 µg/kg bw/day (including the intake of soil and dust particles). For children aged 5 years and older and adults the intake from background exposure was estimated to be 0.64 µg/kg bw/day. These estimations are based on drinking water containing 10 µg lead per liter (Gezondheidsraad, 1997).

In 1993, TNO (Brussaard et al., 1993) calculated the daily dietary intake of lead through food and beverages (minimum estimate) in a total diet study in The Netherlands (period 1988-1989). They reported an intake of 23.9 ± 24.5 µg/day (0.31 µg/kg bw/day) for male adults (aged 22-50) and of 25.0 ± 25.3 µg/day (0.38 µg/kg bw/day) for female adults (aged 22-50). The lead intake for 1-4 year-old boys and girls was 8.8 ± 10.4 µg/day and 9.6 ± 12.9 µg/day, respectively and for 4-7 year-old boys and girls 11.5 ± 8.7 µg/day and 11.7 ± 1.0 µg/day, respectively. The contribution of product groups to the intake of lead was as follows: beverages 39 %, bread 14 %, fresh fruit 13 %, pulses 5 % and potatoes 5 %. Tea and wine were the beverages contributing most to lead intake. The intake of lead declined between 1976-1978 and 1988-1989.

The daily lead intake in Germany in 1996 was studied using the duplicate portion technique (Seifert and Anke, 2000). The average lead intake was estimated to be 19 µg/day. The study of Seifert and Anke also gives an overview of duplicate diet studies on lead in different countries of the world (Table 7).

The mean and 95th percentile (given in brackets) intake of lead by adults in Denmark from a total diet study was 18 µg/day (28 µg/day) based on data from 1993-1997, 27 µg/day (46 µg/day) based on data from 1988-1992 and 42 µg/day (76 µg/day) based on data from 1983-1987 (Larsen et al., 2002). The dietary intake of lead estimated for the most recent monitoring period is markedly lower than that for the two previous monitoring periods.

The lead intake in Finland is about 12 µg/day (Tahvonen, 1998).

Table 7. Levels of lead in European diets from duplicate diet studies (from Seifert and Anke, 2000)

Country	Mean intake, µg/day	Year of study	Additional information
Austria	62/66	1981/1988	7 men/3 women, 24-h
Denmark	7.0	1988	100 men, 48-h
Germany	19	1996	31 men, 31 women, 7-d
	31.5±3.1	1990-1991	318 adults, 24-h
	21.2±9.6	1989	47 children, 24-h
	20.5	1989	49 adults, 24-h
	9.8/11.8	1989-1991	478 women/men
The Netherlands	110	1976-1978	201 volunteers, 24-h
	34	1984-1985	112 volunteers, 24-h
	31.8	1984-1986	18-year-old males
Sweden	26±7.9	1988	15 women, 24-h
	25±8	1988	7 women, 24-h

The Council of Europe (1994) gives an overview of the levels of lead in European diets (see Table 8).

Table 8. Levels of lead in European diets from Council of Europe (1994).

Country	Mean intake, µg/day	Method	Additional information
France	108 171	Duplicate diet Analysis of food inventory	Published in 1978
West Germany	58 246	Duplicate diet Total diet	Published in 1983
United Kingdom	44 20-60	Duplicate diet Total diet	Adult women Published in 1989 Whole population, lower and upper bound Published in 1989
Italy	108	Total diet	Published in 1983
Belgium	179 293	Duplicate diet Total diet	Published in 1983 Published in 1980
Switzerland	25	Analysis of canteen meals	Published in 1985
Netherlands	55	Duplicate diet	Median value
Denmark	42	Total diet	Data from 1983-1987

3.3 Data on lead residues in food products

Data on concentrations of lead in food products were obtained from the Programme of Quality of Agricultural Products (KAP) database of RIKILT. Table 2 shows the origin of the data and the time frame of the measurements.

The delivered drinking water in the majority of regions in The Netherlands has a annual mean lead concentration of at most 1 µg/l (Gezondheidsraad, 1997). The final concentration of lead at the consumers homes depends on the interaction between the pipe water and the material of the water pipe net. The Health Council of The Netherlands gives a representative value of 35 µg/l for a daily mean lead concentration in water pipes made of lead (Gezondheidsraad, 1997). In 1997 7.5 % of the Dutch households were connected to the lead drinking water pipe system

(Nationaal Kompas Volksgezondheid, 2001). In 2002 this percentage should be lower according to the Ministry of VROM (1998). In our calculations it is assumed that 5 % of the Dutch population is exposed to the high lead dose of 35 µg/l via the drinking water, the rest of the population is exposed to 0.5 µg/l lead, which is the half of the maximum annual mean concentration value in the drinking water.
Most analysed samples of animal food products are kidney and liver. However, the most consumed animal food product is meat. From the literature (Baars et al., 1990) we used the mean ratio of 20/10/1 for lead residues in kidneys/liver/meat to calculate lead residues in meat.
Almost 500 samples of fruit, vegetables and potatoes were analysed for lead residues (Van der Schee, 2003). It was found that the leafy vegetables, especially spinach, contain higher residues of lead. In the category fruit raspberry has the highest residues.
A total diet study by TNO from 1988-1989 (Brussaard et al., 1993) reported a contribution of 39 % from beverages and 5 % from pulses to the total dietary intake of lead. Tea and wine were the beverages contributing most to the lead intake. Unfortunately, there are no measurements of lead concentrations in beverages in the recent years (KvW, personal communication) and lead was not detected in pulses (Van der Schee, personal communication).

3.4 Dietary intake of lead

The short-term minimum mean dietary intake of lead by the whole population calculated with the MCRA-programme is 0.15 µg/kg bw/day for the whole population and 0.25 µg/kg bw/day for children aged 1-6 years. In Appendix 3 an overview of the mean consumption data, the mean concentration data and the short-term lead intake (calculated as mean consumption times mean concentration) is presented per food commodity.
A reduction of the number of households connected to the lead drinking water pipe system by 1 % will result in a decrease in mean lead dietary intake by 0.3 µg/day for the whole population and by 0.09 µg/day for children of 1-6 years old.
The contributions of food groups to the total dietary intake are shown in Table 9. Wheat, potable water, kale and spinach contribute most to the total dietary intake of lead. The categories meat, potatoes, fruit and milk have a small contribution to the total intake (Table 9).

Table 9. Contribution food groups to the dietary intake of lead by the Dutch population (whole population and children 1-6 years old).

Food group	**Relative contribution (%) whole population**	**Relative contribution (%) children 1-6 yrs**
Wheat	35	41
Potable water	28	19
Vegetables	19	20
Fish and shellfish	8	2
Meat	4	4
Potato	3	4
Fruit	2	5
Milk	1	5

The long-term exposure to lead by the whole Dutch population and by children of |1-6 years old calculated using the method of Nusser is reported in Table 10. The median intake for the whole population is 0.05 µg/kg bw/day, which is naturally the same as the median short-term intake. The higher percentiles for the long-term intake are, logically, lower than those for the short-term intake (see Section 1.2.2). The 95th percentile for the whole population is 0.11 µg/kg bw/day, for children of 1-6 years it is 0.20 µg/kg bw/day. The 95th percentile is the highest percentile reported, since the number of residue data is too small for a reliable estimate of higher percentiles (see section 1.2.2 and Boon et al. 2001).

Table 10. Long-term exposure of the Dutch population to lead (whole population and children 1-6 years old).

Percentiles	Long-term intake, µg/(kg bw day) whole population*	Long-term intake, µg/(kg bw day) children 1-6 yrs*
50	0.05	0.10
90	0.09	0.17
95	0.11	0.20

*average age of DNFCS population is 36 years, average age of children is 4 years

3.5 Comparison with other studies and with TDI

The mean dietary intake of lead by the Dutch population of 0.15 µg/kg bw/day estimated in this study is lower than the mean dietary intake of lead estimated by the Health Council of The Netherlands in 1997 of 0.64 µg/kg bw/day (Gezondheidsraad, 1997), which includes additionally about 6 % exposure from air. The estimation in the present study is made with a mean concentration of lead in drinking water of 2.2 µg/l, while the estimation of the Health Council of The Netherlands in 1997 is based on drinking water containing 10 µg lead per liter.
A reduction of the number of households connected to the lead drinking water pipe system by 1 % will result in a decrease in mean lead dietary intake by 0.3 µg/day for the whole population and by 0.09 µg/day for children of 1-6 years old.
The number of the Dutch households connected to a lead drinking water pipe system is decreasing. This decrease definitely leads to a decrease of lead dietary intake as drinking water contributes 28 % to the total intake of lead.
The concentration of lead in wheat from 1990 to 2001 is shown in Figure 3. The mean concentration of lead in the years 1995-2001 is lower than in the previous years.
A comparison of dietary intakes of lead from different European studies is shown in Table 11. The dietary intake of lead in The Netherlands is comparable with the other European countries. It is clear that the dietary lead intake is decreasing in the last two decades in The Netherlands as well as in the other European countries.

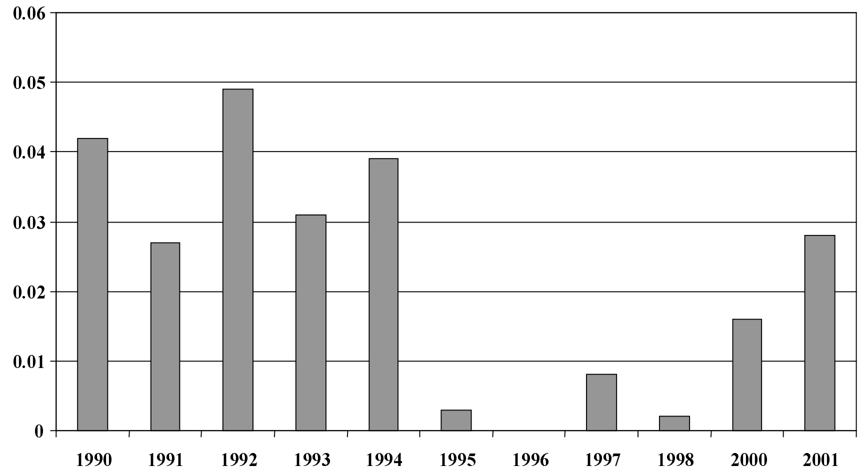

Fig. 3 Lead residues in wheat (mg/kg) as a function of time.

Table 11. Comparison of dietary intakes of lead from different European studies.

Country	**Mean (µg/day) whole population**	**Mean (µg/day) children 1-6 years**	**Method**	**Reference and time period**
The Netherlands	10	4	Total diet	This study 1999-2002
	24	10	Total diet	Brussaard et al., 1993 1988-1989
	33			Vermeire, et al., 1991
	32		Duplicate diet	1984-1986, see Seifert, 2000
	34		Duplicate diet	1984-1985, see Seifert, 2000
	110		Duplicate diet	1976-1978, see Seifert, 2000
	42	34	Food, water, air, soil, dust	Gezonheidsraad, 1997
Germany	19		Duplicate diet	1996, see Seifert, 2000
	32		Duplicate diet	1990-1991, see Seifert, 2000
		21	Duplicate diet	1989, see Seifert, 2000
	21		Duplicate diet	1989, see Seifert, 2000
	11		Duplicate diet	1989-1991, see Seifert, 2000
Austria	64		Duplicate diet	1981/1988, see Seifert, 2000
Sweden	26		Duplicate diet	1988, see Seifert, 2000
Denmark	7		Duplicate diet	1988, see Seifert, 2000
	18		Total diet	1993-1997, Larsen et al., 2002
	27		Total diet	1988-1992, Larsen et al., 2002
	42		Total diet	1983-1987, Larsen et al., 2002
Finland	12		Total diet	Tahvonen, 1998
France	108 171		Duplicate diet Analysis of food inventory	Published in 1978, see CE[1] 1994
United Kingdom	44 20		Duplicate diet Total diet	Published in 1989, see CE 1994
Italy	108		Total diet	Published in 1983, see CE 1994
Belgium	179 293		Duplicate diet Total diet	Published in 1983, see CE 1994 Published in 1980, see CE 1994
Switzerland	25		Analysis of canteen meals	Published in 1985, see CE 1994

[1]CE= Council of Europe

The long-term minimum median dietary intake of lead by the Dutch population is estimated at 0.05 µg/kg bw/day and by children of 1-6 years old 0.10 µg/kg bw/day. Based on these estimates we conclude that the TDI for oral exposure to lead of 3.6 µg/kg bw/day (Baars et al., 2001) is not exceeded by the Dutch population nor by the children of 1 to 6 years old. The 95th percentiles of the long-term minimum dietary intake of lead by the whole Dutch population is 3 % of the TDI and by children aged 1 to 6 is 6 % of the TDI.

3.6 Conclusions

The long-term minimum median dietary intake of lead by the Dutch population is estimated at 0.05 µg/kg bw/day and by children of 1-6 years old 0.10 µg/kg bw/day. The TDI for oral exposure to lead is not exceeded by the Dutch population nor by the children of 1 to 6 years old.
Wheat, drinking water and vegetables contribute most to the dietary intake of lead by the Dutch population.
A reduction of the number of households connected to the lead drinking water pipe system by 1 % will result in a decrease of 10 µg/day mean lead dietary intake for the whole population by 0.3 µg/day and of 4 µg/day mean lead dietary intake for children of 1-6 years old by 0.1 µg/day.
The dietary intake of lead has decreased in the last two decades in The Netherlands as well as in other European countries.

4 Mercury

4.1 Introduction

Mercury (Hg) is a silvery heavy metallic liquid with an atomic weight of 201. Mercury occurs chiefly as cinnabar (HgS), also as free metal in minute droplets in rock layers, chiefly in Spain, Italy and parts of America. Mercury combines with other elements, such as chlorine, sulphur, or oxygen, to form inorganic mercury compounds. Mercury also combines with carbon to make organic mercury compounds, e.g. methylmercury, which is very poisonous. The general information on mercury is from Browning (1969), Haas (1992), the ATSDR website (www.atsdr.cdc.gov, March 2003) and the Lenntech website (www.lenntech.com/ heavy metals.htm, March 2003).
Users of mercury are the electrical, chloroalkali and cosmetics industry, but it is also used in paints, pesticides, medicines (i.e. dental amalgams), chemicals and reagents, and instrumentation like switches and thermometers. Coal burning releases mercury into the atmosphere. Disposal of industrial and household waste will be the major source of soil contamination. It can spread by volatilisation but also within short distances in water-soluble forms. Inorganic mercury can change into organic methyl mercury that accumulates in the food chain.
The absorption of inorganic mercury salts in the gastro-intestinal tract ranges from 2 to 38 %. Organic mercury is nearly completely absorbed. Mercury accumulates in the kidneys and it can also be found in the brain. Mercury is eliminated via urine and faeces. The half-life is 60 days for the whole body and the kidneys.
An overview of toxicology and background exposure to mercury can be found in Baars et al. (2001). Death of humans was reported following inhalation of metallic mercury vapours after heating. Oral intake of inorganic mercury by humans leads to gastrointestinal lesions, cardiovascular collapse, and serious renal effects. According to ATSDR (1999) the latter can lead to death.
The chronic inhalation of metallic mercury vapours increases the frequency of mild tremors and affect cognitive skills. Chronic oral exposure to inorganic mercury leads to renal and endocrine effects in experimental animals. For organic mercury the information from studies with experimental animals indicate neurotoxicity and teratogenicity. In children exposure to high doses of organic mercury that may be passed from the mother to the fetus can lead to developmental effects.
The tolerable daily intake (TDI) of organic mercury for oral exposure is 0.1 μg/kg bw/day (Baars et al., 2001). The TDI of inorganic mercury for oral exposure is 2 μg/kg bw/day.
Fish may contain varying amounts of mercury. Mercury concentrations usually increase with the size of the fish. Carrot and spinach have a high mercury uptake from soil (Versluijs and Otte, 2001). The uptake of mercury by potato, of which the consumption is high, is relatively low.

4.2 Exposure to mercury: literature overview

According to Vermeire et al. (1991) the total daily intake of mercury in The Netherlands amounts to 5 up to 10 µg /day. According to IPCS (1991) and ATSDR (1999) the major contributors to mercury exposure of the population are foods and dental amalgams. The exposure to elemental mercury vapours from dental amalgams is in the range of 1 to 5 µg/day. The contribution from air and water is negligible. Data reported since 1991 indicate a mean weekly intake of 14 µg of total mercury from a series of duplicate diets in The Netherlands (Council of Europe, 1994). Thus the intake of total mercury from food is 2 µg/day or 0.04 µg/kg bw/day. According to IPCS (1991) the oral intake of organic-mercury from food is about half of the total intake of mercury and about equal to the oral intake of inorganic mercury from food.
The mean and 95th percentile (given in brackets) adult intake of mercury in Denmark from a total diet study was 3.5 µg/day (5.8 µg/day) based on data from 1993-1997, 5.0 µg/day (9.0 µg/day) based on data from 1988-1992 and 7.0 µg/day (15 µg/day) based on data from 1983-1987 (Larsen et al., 2002). The estimated overall mercury intake for 1993-1997 is lower than those estimated for the two previous monitoring periods.
An assessment of U.S. general population to methylmercury exposure through the consumption of fish is performed by EPA (1997). The average exposure to methylmercury among males and females fish consumers of reproductive age is found to be 0.1 µg/kg bw/day.
The Council of Europe (1994) gives an overview of the levels of mercury in European diets (see Table 12).

Table 12. Levels of mercury in European diets from Council of Europe (1994).

Country	Mean intake, µg/day	Method	Additional information
France	10	Analysis of food inventory	
West Germany	31	Total diet	
United Kingdom	2-3	Total diet	Published in 1987
Italy	8		Sea food consumers Published in 1982
Belgium	14	Duplicate diet	Published in 1983
Switzerland	<5	Analysis of canteen meals	Published in 1985
Netherlands	2	Duplicate diet	Median value
Denmark	7	Total diet	Data from 1983-1987

4.3 Data on mercury residues in food products

Data on concentrations of mercury in food products are from the Programme of Quality of Agricultural Products (KAP) database of RIKILT. Table 13 shows the origin of the data and the time frame of the measurements. The measurements are available for fish, including tinned fish, milk and target organs. Data on mercury concentrations in fruit and vegetables, cereals and beverages were not available.
Most analysed samples of animal food products are kidney and liver. However, the most consumed animal food product is meat. Measurements of mercury in kidneys, liver and meat of cattle, sheep and pigs were carried out in The Netherlands in 1978-1986 (Veterinaire hoofdinspectie van de Volksgezondheid, 1997). The mean mercury concentration found in cattle was 0.001 mg/kg in meat, 0.003 mg/kg in liver and 0.008 mg/kg in kidneys. The mean mercury concentration found in pigs was

0.001 mg/kg in meat, 0.001 mg/kg in liver and 0.003 mg/kg in kidneys. We used the mean ratio for cattle and pigs (the most consumed meat is beef and pork) of 6/2/1 for mercury residues in kidneys/liver/meat to calculate mercury residues in meat.

Table 13. The origin and the time frame of the data on mercury residues in food products from the RIKILT KAP database.

Product category	Institution	Year
Target organs	RVV, Keuringsdienst van Waren	2000, 2001
Fish	RVV, RIVO, Keuringsdienst van Waren	2000, 2001
Tinned fish	Keuringsdienst van Waren	2000
Milk	RVV	1999-2001

4.4 Dietary intake of mercury

The short-term minimum mean dietary intake of mercury calculated with the MCRA-programme, is 0.6 µg/day (9 ng/kg bw/day) for the whole population and 0.3 µg/day (17 ng/kg bw/day) for children aged 1-6 years. In Appendix 4 an overview of the mean consumption data, the mean concentration data and the short-term mercury intake (calculated as mean consumption times mean concentration) is presented per food commodity.
The contributions of the food groups to the total dietary intake is shown in Table 14. Milk and some sorts of fish (codfish, tuna fish, herring, salmon), beef and pork contribute most to the total dietary intake of mercury.

Table 14. Contribution of food groups to the dietary intake of mercury by the Dutch population (whole population and children 1-6 years old).

Food group	Relative contribution (%) whole population	Relative contribution (%) children 1-6 yrs
Fish and shellfish	59	15
Milk	30	75
Meat	11	10

Version 1.2 of MCRA calculates the long-term intake by multiplying the consumption of a randomly selected DNFCS respondent with randomly selected concentrations of the consumed products. Since there was a large number of non-detects for mercury in the analysed food groups (milk, meat and fish) for a large part (~50%) of the DNFCS respondents the calculated long-term intake of mercury is zero. As the Nusser method can only be used if the percentage of positive intakes is high (> ~98 %), the long-term intake could not been calculated with this version of MCRA. In the latest version of MCRA (version 2.1, 2003) the long-term intake is calculated using mean concentration data instead of randomly selected concentration data. Therefore, with the new version of the programme, the long-term exposure to mercury could be calculated. The results of the calculation of the long-term intake with version 3.0 of MCRA is reported in Table 15. The 95th percentile for the whole population is 9.0 ng/kg bw/day, for children of 1-6 years it is 23.9 µg/kg bw/day. This is the highest percentile reported, since the number of residue data is too small for a reliable estimate of higher percentiles (see section 1.2.2 and Boon et al. 2001).

Table 15. Results of probabilistic assessment of the long-term mercury dietary intake by the Dutch population (whole population and children 1-6 years old): mean, 90 and 95 percentiles.

	Intake, ng/(kg bw day) whole population*	**Intake, ng/(kg bw day) children 1-6 yrs***
	Mercury	
50 percentile	3.7	14.1
90 percentile	6.8	22.2
95 percentile	9.0	23.9

*average age of DNFCS population is 36 years, average age of children is 4 years

4.5 Comparison with other studies on mercury and with TDI

The short-term mean adult dietary intake of mercury found in Denmark is 3.5 µg/day (total diet study based on data from 1993-1997, Larsen et al. 2002). The contributions to the mercury intake from cereals and beverages are based on (unpublished) data from the mid-1980s (Larsen et al., 2002). The comparison of the mercury intakes in The Netherlands and in Denmark is shown in Table 16. Data on mercury in beverages, cereals, fruit and vegetables consumed in The Netherlands are not available. The short-term intake of mercury by the consumption of fish, milk an meat is 0.6 µg/day in The Netherlands (Table 16). Assuming that the contribution of fish, milk and meat to the total intake is 43 % as in Denmark (Table 16), the “corrected” short-term mean intake of the Dutch population is 1.4 µg/day. The corrected long-term mercury intakes are presented in Table 17. Note that it is not clear if this correction factor is applicable either to children or to the higher percentiles, so these figures should be taken with care.
It is reccommended to measure mercury in beverages, cereals, fruit and vegetables to improve the dietary intake estimate.

Table 16. Comparison of dietary intakes of mercury in The Netherlands (current study) and Denmark (Larsen et al., 2002) per food group.

Food goup	**Mean intake (µg/day) Denmark**	**contribution (%)**	**Mean intake, (µg/day) The Netherlands**
Fish	0.95	27	0.35
Beverages	0.7	20	-
Cereals	0.6	17	-
Milk	0.35	10	0.18
Fruit	0.3	9	-
Vegetables	0.3	9	-
Meat	0.2	6	0.06
Cheese, eggs, fats	<0.5	< 2	-

Table 17. Corrected long-term mercury dietary intake by the Dutch population (whole population and children 1-6 years old): mean, 90 and 95 percentiles, assuming that only 43 % of the mercury intake comes from the intake of milk, fish and meat.

	Intake, ng/(kg bw day) whole population	**Intake, ng/(kg bw day) children 1-6 yrs**
Mercury		
50 percentile	9	33
90 percentile	16	52
95 percentile	21	55

A comparison of mean dietary intakes of mercury from different studies is shown in Table 18. The mercury dietary intake in The Netherlands is comparable with the other European countries.
The mean short-term dietary intake of mercury by the Dutch population of 1.4 µg/day estimated in this study is in good agreement with the mean dietary intake of mercury from a series of duplicate diets in The Netherlands of 2 µg/day (Council of Europe, 1994).

Table 18. Comparison of dietary intakes of mercury from different studies.

Country	**Mean dietary intake of mercury, µg/day whole population**	**Method**	**Reference and time period**
The Netherlands	1.4* (0.6)#	Total diet	This study, 1999-2001
	2	Duplicate diet	Council of Europe, 1994
Denmark	3.5	Total diet	1993-1997 Larsen et al., 2002
	5.0	Total diet	1988-1992 Larsen et al., 2002
	7.0	Total diet	1983-1987 Larsen et al., 2002
USA	7	Fish consumers, fish only	EPA, 1997
France	10	Analysis of food inventory	Council of Europe, 1994
Germany	31	Total diet	Council of Europe, 1994
United Kingdom	2-3	Total diet	Published in 1987, see Council of Europe, 1994
Italy	8	Sea food consumers	Published in 1982, see Council of Europe, 1994
Belgium	14	Duplicate diet	Published in 1983, see Council of Europe, 1994
Switzerland	<5	Analysis of canteen meals	Published in 1985, see Council of Europe, 1994

* based on comparison with Danish data, # based only on measurements from 1999-2001

The data on mercury in codfish and herring are shown in Figures 4 and 5, respectively, as a function of time. A clear trend cannot be seen in these data in the last two decades. The measurements of mercury in beverages, cereals, fruit and vegetables are missing, thus conclusions could not be drawn on a trend in the dietary intake of mercury.

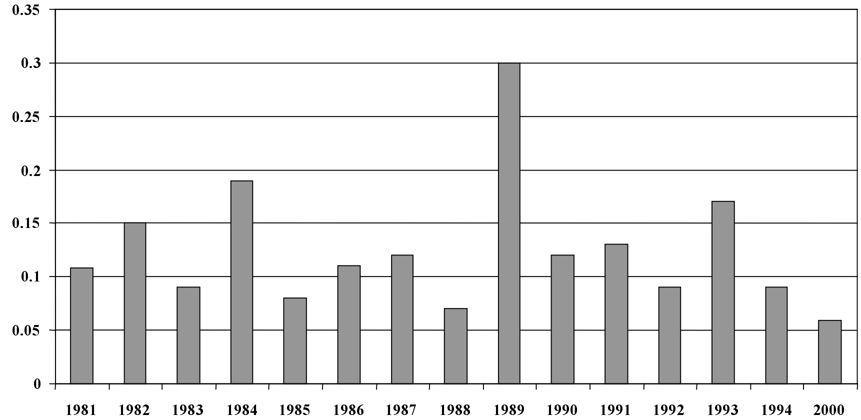

Fig. 4 Mercury residues in codfish (mg/kg) as a function of time.

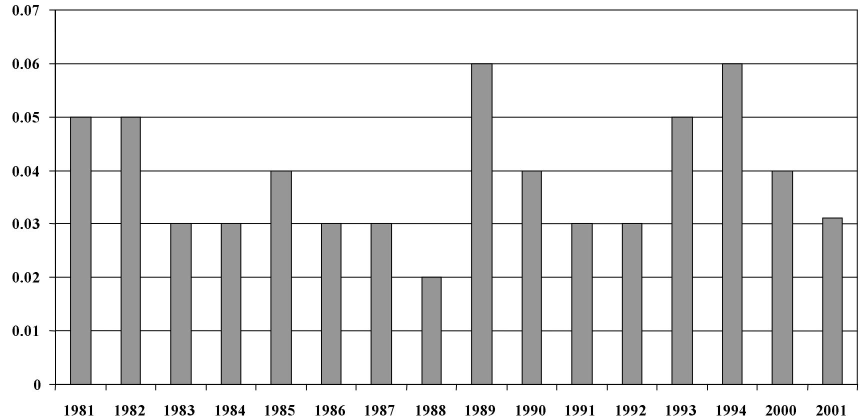

Fig. 5. Mercury residues in herring (mg/kg) as a function of time.

Comparison with TDI

Methyl mercury (organic mercury) is found in fish. Assuming that all mercury in fish is present as methyl mercury (Larsen et al., 2002; EPA, 1997), the conclusion can be drawn that 59 % of the dietary intake of mercury by the Dutch population and 15 % of the dietary intake of mercury by children aged 1 to 6 is organic mercury.

The "corrected" 95th percentiles of the long-term intake of organic mercury of the whole population and 1-6 year-old children (59 % of 21 ng/kg/day and 15 % of 55 ng/kg bw/day, respectively) are lower than the TDI for organic mercury (100 ng/kg bw/day Baars et al., 2001). In addition, the "corrected" 95th percentiles of the long-term-intake of inorganic mercury for the whole population and 1-6 year-old children (41 % of 21 ng/kg bw/day and 85 % of 55 ng/kg bw/day, respectively) are low compared to the TDI for inorganic mercury (2 µg/kg bw/day, Baars et al., 2001). Therefore we conclude that the TDI for oral exposure to mercury is not exceeded by the Dutch population nor by children of 1 to 6 years old.

4.6 Conclusions

Based on data in fish, milk and meat, the calculated minimum median long-term dietary intake of mercury by the whole Dutch population is 3.7 ng/kg bw/day and by children of 1-6 years old 14.1 ng/kg bw/day. Data on mercury in beverages, cereals, fruit and vegetables consumed in The Netherlands are not available. Assuming that the contribution of fish, milk and meat to the total intake is 43 %, the mercury intake by the Dutch population will be 21 ng/kg bw/day and 39 ng/kg bw/day for children of 1-6 years old.
The tolerable daily intake for the oral exposure to organic mercury of 0.1 µg/kg bw/day and for oral exposure to inorganic mercury of 2 µg/kg bw/day are not exceeded by the 95th percentiles of the long-term intake of the Dutch population nor by that of children of 1 to 6 years old. It is recommended to measure mercury in beverages, cereals, fruit and vegetables to improve the dietary intake estimate.
The mean dietary intake of mercury by the Dutch population of 1.4 µg/day estimated in this study is in good agreement with the mean dietary intake of mercury from a series of duplicate diets in The Netherlands of 2 µg/day.

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Voet, H. van der; Boer, W.J. de; Boon, P.E.; Donkersgoed, G. van; Klaveren, J.D. van 2003) MCRA a Genstat program for Monte Carlo Risk Assessment, Release 2, Reference Guide, Biometris/RIKILT, Wageningen

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Appendix 1 Ratios of cadmium residues in meat, liver and kidneys

Table 1.1 Ratios of cadmium residues in meat, liver and kidneys. No. – number of measured samples.

Ratio kidney/meat	No.	Ratio liver/meat	No.	Country and reference
81	312	16	312	Spain, Miranda et al. (2001)
370	174	60	179	Australia, Miranda et al. (2001)
22	1227	6	1100	Australia, Miranda et al. (2001)
578	262	133	262	Australia, Miranda et al. (2001)
131	210	26	146	The Netherlands, Miranda et al. (2001)
9	30	3	30	Italy, Miranda et al. (2001)
222	87	34	87	Germany, Miranda et al. (2001)
93	87	23	69	Slovenia, Miranda et al. (2001)
350	98	61	113	Finland, Miranda et al. (2001)
390	34	70	33	Sweden, Miranda et al. (2001)
102	92	20	92	Poland, Miranda et al. (2001)
30	21	8	21	Czech Republic, Miranda et al. (2001)
11	6	14	6	Slovakia, Miranda et al. (2001)
71	427	32	437	Spain, Miranda et al. (2001)
21	1	2	1	Kazakhstan, Farmer et al. (2000)
5	1	1	1	Kazakhstan, Farmer et al. (2000)
7	1	3	1	Kazakhstan, Farmer et al. (2000)
2	1	2	1	Kazakhstan, Farmer et al. (2000)
Weighed mean				
134	3071	31	2891	

Appendix 2 Overview of cadmium intake calculation

Table 2.1. The mean consumption of different food commodities, the number of consumers, the mean cadmium concentration per food commodity, the number of non-zero residues, the number of analysed samples and the calculated mean intakes by the Dutch population (whole population and children 1-6 years old) per food commodity.

Commodity	Mean consumption, g/day whole population	No. of consumers (two days) whole population	Mean consumption g/day children 1-6 yrs	No. of consumers (two days) children 1-6 yrs	Mean residue µg/kg	No. of non-zero residues	Total no. of residues	Mean intake ng/day whole population	Mean intake ng/day children 1-6 yrs
Cadmium									
Beef	43.54	8695	20.21	662	4.8	255	257	209.0	97.0
Pork	57.97	9393	26.63	729	1.9	547	550	110.1	50.6
Poultry	20.77	3515	11.59	255	0.8	139	161	16.6	9.3
Turkey	0.36	36	0.53	7	2.4	16	16	0.9	1.3
Horseflesh	1.31	937	1.04	66	49.7	7	9	65.1	51.7
Kidney of manure cow	0	1	0	0	649.3	255	257	0.0	0.0
Liver of chicken	0.05	4	0	0	26.1	154	176	1.3	0.0
Kidney of roe	0.01	1	0	0	47.8	29	30	0.5	0.0
Gurnard	0.05	33	0	0	5.7	4	14	0.3	0.0
Red eel	0.13	41	0	0	9.2	7	28	1.2	0.0
Herring	1.81	206	0.35	4	13.2	8	12	23.9	4.6
Anchovy	0.01	14	0	1	90.2	12	13	0.9	0.0
Sardine	0.06	9	0	0	40.5	40	41	2.4	0.0
Mackerel	0.30	57	0.07	3	10.6	11	14	3.2	0.7
Tuna fish	0.40	94	0.06	4	19.6	32	33	7.8	1.2
Codfish	1.60	340	0.12	13	18.5	3	47	29.6	2.2
Haddock	0.05	33	0	0	4.5	1	6	0.2	0.0
Flounder	0.11	27	0	2	0.8	1	24	0.1	0.0
Dab	0.05	33	0	0	1.3	1	30	0.1	0.0
Salmon	1.22	367	0.07	4	2.1	3	7	2.6	0.1
Trout	0.05	22	0	2	5.0	1	4	0.3	0.0
Perch	0.05	33	0	0	2.6	4	31	0.1	0.0
Crab	0.02	11	0	0	84.3	3	3	1.7	0.0
Lobster	0.01	2	0	0	20.0	1	1	0.2	0.0
Shrimp	0.42	281	0.08	23	19.2	9	12	8.1	1.5
Cephalopod	0.03	8	0	0	386.4	8	8	11.6	0.0
Mussel	0.57	47	0.01	2	66.0	58	62	37.6	0.7
Oyster	0	1	0	0	148.3	13	13	0.0	0.0
Wheat	110.13	12451	69.14	1060	43.4	233	236	4779.6	3000.7
Endive	6.12	985	2.97	82	32.3	40	40	197.7	95.9
Iceberg lettuce	2.68	606	0.61	14	16	8	8	42.9	9.8
Head lettuce	3.39	1229	0.74	34	33.3	20	20	112.9	24.6
Celery	0.24	1177	0.09	53	151.5	2	2	36.4	13.6

Spinach	8.08	453	5.73	44	68.9	23	23	556.7	394.8
Turnip tops	0.32	338	0.25	31	53.5	2	2	17.1	13.4
Blanched celery	0.61	456	0.28	35	18	3	3	11.0	5.0
Broccoli	2.91	720	2.3	77	3.7	2	3	10.8	8.5
Cauliflower	11.12	2078	5.99	133	7.7	2	3	85.6	46.1
Red cabbage	3.55	618	2.41	55	7.3	4	4	25.9	17.6
White cabbage	5.25	1219	1.53	78	3	3	6	15.8	4.6
Brussels sprouts	4.07	612	0.97	44	4.5	1	2	18.3	4.4
Kale	3.47	642	1.47	54	21.6	14	14	75.0	31.8
Chinese cabbage	0.77	435	0.37	36	5.3	2	3	4.1	2.0
Savoy cabbage	0.86	669	0.24	43	6	2	2	5.2	1.4
Oxheart cabbage	1.37	271	0.41	14	6	3	3	8.2	2.5
Onion	13.79	5366	4.9	315	8.2	15	17	113.1	40.2
Leek	8.01	4223	2.41	228	34.3	24	24	274.7	82.7
Potato	138.53	10005	80.67	887	22.2	76	80	3075.4	1790.9
Winter carrot	0.04	5	0	0	74.4	3	3	3.0	0.0
Carrot	12.12	4165	7.65	258	27.9	33	41	338.1	213.4
Beetroot	3.51	869	2.29	75	17.1	17	19	60.0	39.2
Scorzonera	0.05	320	0.03	30	11.0	1	1	0.6	0.3
Radish	0.36	587	0.08	38	4.0	1	1	1.4	0.3
Winter radish	0.07	367	0.04	33	5.0	1	1	0.4	0.2
Celeriac	0.84	1156	0.26	66	93.0	1	1	78.1	24.2
Tomato	25.5	6081	10.14	445	1.3	1	7	33.2	13.2
Sugar maize	1.14	431	0.37	25	9.0	1	1	10.3	3.3
Paprika	3.33	2533	0.92	157	2.4	1	5	8.0	2.2
Date	0.04	32	0.02	5	7.0	1	1	0.3	0.1
Pear	8.62	3192	5.79	558	9.7	6	7	83.6	56.2
Strawberry	4.52	6095	3.68	849	3.4	7	14	15.4	12.5
Raspberry	1.14	5942	2.06	889	80.0	1	1	91.2	164.8

Analysed food commodities which had only non-detects are not cited in Table 2.1.

Appendix 3 Overview of lead intake calculation

The mean consumption of different food commodities, the number of consumers, the mean lead concentration per food commodity, the number of non-zero residues, the number of analysed samples and the calculated mean intakes by the Dutch population (whole population and children 1-6 years old) per food commodity.

Commodity	Mean consumption g/day whole population	No. of consumers (two days) whole population	Mean consumption g/day children 1-6 yrs	No. of consumers (two days) children 1-6 yrs	Mean residue µg/kg	No. of non-zero residues	Total no. of residues	Mean intake ng/day whole population	Mean intake ng/day children 1-6 yrs
Lead									
Potable water	979.45	12110	265.43	959	2.2	20	20	2154.79	583.9
Milk	412.59	12429	501.31	1055	0.3	1	45	123.78	150.4
Beef	43.54	8695	20.21	662	6.2	227	257	269.95	125.3
Pork	57.97	9393	26.63	729	0.7	81	550	40.58	18.6
Poultry	20.77	3515	11.59	255	0.3	7	161	6.23	3.5
Turkey	0.36	36	0.53	7	0.1	2	16	0.04	0.1
Horseflesh	1.31	937	1.04	66	12.2	1	9	15.98	12.7
Kidney of manure cow	0	1	0	0	124.2	227	257	0	0.0
Liver of chicken	0.05	4	0	0	3.0	9	176	0.15	0.0
Roe flesh	0.01	1	0	0	32.4	23	30	0.32	0.0
Gurnard	0.05	33	0	0	10.0	5	14	0.50	0.0
Red eel	0.13	41	0	0	59.3	16	28	7.71	0.0
Ray	0.05	33	0	0	120.0	2	2	6.00	0.0
Herring	1.81	206	0.35	4	22.5	10	12	40.73	7.9
Anchovy	0.01	14	0	1	16.9	9	13	0.17	0.0
Sardine	0.06	9	0	0	72.4	38	41	4.34	0.0
Mackerel	0.30	57	0.07	3	27.1	7	14	8.13	1.9
Tuna fish	0.40	94	0.06	4	6.4	13	33	2.56	0.4
Codfish	1.60	340	0.12	13	52.6	27	47	84.16	6.3
Pollack	2.86	318	1.75	30	70.0	3	3	200.20	122.5
Haddock	0.05	33	0	0	20.0	4	6	1.00	0.0
Flounder	0.11	27	0	2	154.6	13	24	17.01	0.0
Plaice	0.56	72	0.17	1	56.4	18	36	31.58	9.6
Sole	0.07	35	0	0	25.3	8	15	1.77	0.0
Dab	0.05	33	0	0	83.7	19	30	4.19	0.0
Salmon	1.22	367	0.07	4	15.7	5	7	19.15	1.1
Trout	0.05	22	0	2	7.5	1	4	0.38	0.0
Perch	0.05	33	0	0	19.4	17	31	0.97	0.0
Crab	0.02	11	0	0	30.0	2	3	0.60	0.0
Lobster	0.01	2	0	0	50.0	1	1	0.50	0.0
Shrimp	0.42	281	0.08	23	68.3	9	12	28.69	5.5
Cephalopod	0.03	8	0	0	15.0	6	8	0.45	0.0
Mussel	0.57	47	0.01	2	419.8	58	62	239.29	4.2
Oyster	0	1	0	0	239.2	10	13	0	0.0
Wheat	110.13	12451	69.14	1060	24.5	92	236	2698.19	1693.9
Endive	6.12	985	2.97	82	24.7	22	40	151.164	73.4

Head lettuce	3.39	1229	0.74	34	7	6	20	23.73	5.2
Celery	0.24	1177	0.09	53	30	1	2	7.2	2.7
Spinach	8.08	453	5.73	44	55.1	22	23	445.208	315.7
Turnip tops	0.32	338	0.25	31	45	2	2	14.4	11.3
Kale	3.47	642	1.47	54	139.4	14	14	483.718	204.9
Onion	13.79	5366	4.9	315	4.7	2	17	64.813	23.0
Leek	8.01	4223	2.41	228	11.7	9	24	93.717	28.2
Potato	138.53	10005	80.67	887	2	6	80	277.06	161.3
Winter carrot	0.04	5	0	0	43.3	2	3	1.732	0.0
Carrot	12.12	4165	7.65	258	17.1	17	41	207.252	130.8
Beetroot	3.51	869	2.29	75	11.1	3	19	38.961	25.4
Scorzonera	0.05	320	0.03	30	30	1	1	1.5	0.9
Date	0.04	32	0.02	5	40	1	1	1.6	0.8
Nectarine	0.8	84	0.25	4	6.7	1	3	5.36	1.7
Grape	13.85	4836	12.17	770	2.1	2	20	29.085	25.6
Raspberry	1.14	5942	2.06	889	78	1	1	88.92	160.7

Appendix 4 Overview of mercury intake calculation

The mean consumption of different food commodities, the number of consumers, the mean mercury concentration per food commodity, the number of non-zero residues, the number of analysed samples and the calculated mean intakes by the Dutch population (whole population and children 1-6 years old) per food commodity.

Commodity	Mean consumption g/day whole popula-tion	No. of consu-mers (two days) whole popula-tion	Mean consump-tion g/day children 1-6 yrs	No. of consu-mers (two days) children 1-6 yrs	Mean residue µg/kg	No. of non-zero resi-dues	Total no. of resi-dues	Mean intake, ng/day whole popula-tion	Mean intake, ng/day children 1-6 yrs
Mercury									
Milk	412.59	12429	501.31	1055	0.4	3	45	165.04	200.52
Beef	43.54	8695	20.21	662	0.8	58	124	34.83	16.17
Pork	57.97	9393	26.63	729	0.4	35	150	23.19	10.65
Kidney of manure cow	0	1	0	0	4.7	58	124	0	0.00
Gurnard	0.05	33	0	0	57.5	4	4	2.88	0.00
Red eel	0.13	41	0.35	4	167.1	219	219	21.72	11.97
Herring	1.81	206	0	1	34.2	12	12	61.90	0.00
Anchovy	0.01	14	0	0	46.0	13	13	0.46	0.00
Sardine	0.06	9	0.07	3	23.3	36	36	1.40	2.30
Mackerel	0.30	57	0.06	4	32.8	8	8	9.84	9.95
Tuna fish	0.40	94	0.12	13	165.8	29	29	66.32	7.08
Codfish	1.60	340	0	0	59.0	10	10	94.40	0.00
Haddock	0.05	33	0	2	40.3	4	4	2.02	0.00
Flounder	0.11	27	0.17	1	120.0	2	2	13.20	5.75
Plaice	0.56	72	0	0	33.8	7	8	18.93	0.00
Sole	0.07	35	0	0	74.0	5	5	5.18	0.00
Dab	0.05	33	0.07	4	80.0	7	7	4.00	1.89
Salmon	1.22	367	0	2	27.0	5	6	32.94	0.00
Trout	0.05	22	0	0	10.0	2	3	0.50	0.00
Perch	0.05	33	0	0	87.3	9	11	4.37	0.00
Crab	0.02	11	0.08	23	51.3	3	3	1.03	2.14
Shrimp	0.42	281	0	0	26.7	6	6	11.21	0.00
Cephalopod	0.03	8	0	0	37.5	6	6	1.13	0.00
Oyster	0	1	0	0	9.3	3	3	0	0.00

Appendix 5 Mailing list

1 Dr. P.W.J. Peters, VWA
2 Ir. J.I.M.. de Goeij, VWS
3 Drs. H.J. Jeuring, KvW
4 Drs. H. de Sitter, KvW
5 Dr. J.M.de Stoppelaar, VGB, VWS
6 Drs. B.W. Ooms, VWA
7 Dr. ir. W. de Wit, VWA
8 Prof. dr. W.F. Passchier, Gezondheidsraad
9 Dr. ir. H. v.d. Schee, KvW, Amsterdam
10 Dr. K.M. Jonker, KvW, Zutphen
11 Dr. C.D. de Gooijer, RIKILT, Wageningen
12 Dr. ir. R.F.M. van Gorcom, RIKILT, Wageningen
13 Dr. P.E. Boon, RIKILT, Wageningen
14 Dr. H. v.d. Voet, Biometris, Wageningen
15 Dr. E.H. Larsen, Institute of Food Research and Nutrition, Denmark
16 Dr. M. Seifert, Friedrich Schiller University, Germany
17 Dr. M. Anke, Friedrich Schiller University, Germany
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25 Dr. ir. A.G. Oomen
26 Prof. dr. W. Slob
27 Dr. C.H.M. Versantvoort
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32 SBC/afdeling Communicatie
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35 Archief SIR
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