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Abstract

Exposure to chemicals via house dust

Humans are exposed to substances present in house dust, but the majority of these substances do not pose a risk to human health. Those substances that do exceed a critical level, however, have the potential to be a health risk. The most common of these are lead and di(2-ethylhexyl)phthalate, followed by arsenic, cadmium, polycyclic aromatic hydrocarbons and PBDEs (flame retardants). These substances come into house dust through the wear and tear of consumer products, the release of products when cooking and burning wood in the fireplace. In addition, some pollutants can fall off the soles of shoes that have come into contact with polluted soil.

By order of the Inspectorate of the Ministry of Housing, Spatial Planning and the Environment of the Netherlands, the Dutch National Institute for Public Health and the Environment (RIVM) has carried out a screening of the potential risks posed by various chemical substances in house dust. The substances investigated include metals, organotin compounds, phthalates, brominated flame retardants, pesticides and polycyclic aromatic hydrocarbons. Substances in house dust are mostly ingested through the contact of the hand or an object with the mouth. This is particularly true for young children. A minor part of house dust enters the body by inhalation.

The mean ingestion rates for adults and children were estimated. Exposure to substances via house dust is calculated based on the mean ingestion rates and typical concentrations of substances present in house dust. Whenever possible, this study has focussed on the situation in the Netherlands. The exposure of adults and children to substances via house dust was compared to the tolerable daily intake, which was used as a criterium for a potential health risk, and to the background exposure (via food and water consumption).

The findings of this investigation provide an overview of the substances in house dust which can exceed the accepted norm and for which the contribution of house dust to the total exposure is substantial. Based on these findings, the RIVM recommends that the substances identified herein be subjected to measurements in research on the indoor environment.

Key words:
house dust; risk assessment; human health; children; exposure

Rapport in het kort

Blootstelling aan chemische stoffen via huisstof

Mensen worden via huisstof aan chemische stoffen blootgesteld. De meeste stoffen vormen op deze manier geen risico voor de gezondheid. Voor enkele stoffen wordt wel de gezondheidskundige norm overschreden waardoor er mogelijk sprake kan zijn van een risico voor de gezondheid. Dit geldt met name voor lood en di(2-ethylhexyl)ftalaat en in minder mate voor arseen, cadmium, polycyclische aromatische koolwaterstoffen en PBDE's (vlamvertragers). Deze stoffen komen op allerlei manieren terecht in huisstof, bijvoorbeeld door slijtage van producten, inloop van verontreinigde bodem, door stoffen die bij het koken vrijkomen of via de open haard.

In opdracht van VROM-Inspectie heeft het RIVM een screening uitgevoerd van de risico's van verschillende chemische stoffen in huisstof (metalen, organotinverbindingen, ftalaten, gebromeerde vlamvertragers, bestrijdingsmiddelen, en polycyclische aromatische koolwaterstoffen). Huisstof wordt vooral ingenomen door contact van de hand of een voorwerp met de mond, wat vooral bij jonge kinderen veel voor komt. Daarnaast wordt een beperkte hoeveelheid huisstof ingeademd.

De inname van huisstof is geschat voor kinderen en volwassenen. De blootstelling aan chemische stoffen via huisstof is berekend op basis van de hoeveelheid huisstof die mensen binnenkrijgen en concentraties van chemische stoffen daarin. Waar mogelijk is dat op de situatie in Nederland toegespitst. De blootstelling via huisstof is vergeleken met de norm voor wat dagelijks is toegestaan, en met de achtergrondblootstelling via voeding en water.

De huidige bevindingen geven een overzicht van de stoffen in huisstof die de gezondheidskundige norm kunnen overschrijden, en waarvan de bijdrage van huisstof aan de totale blootstelling aanzienlijk is. Aanbevolen wordt de hier geïdentificeerde stoffen te meten bij onderzoek naar het binnenmilieu.

Trefwoorden:
Huisstof; risicobeoordeling; gezondheid; kinderen; blootstelling

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Summary

Up till now, various projects on the indoor environment remain inconclusive with regard to the human health risk of substances in house dust. From experience it is known that some substances such as lead in house dust may pose a human health risk, but it is unknown whether and to which extent this is also the case for other substances. In order to better design future projects on the indoor environment, the present investigation examines whether exposure to a great number of substances present in house dust may lead to potential human health risks.

House dust mainly enters the body by ingestion, especially for young children. Mean ingestion rates of house dust of 50 and 100 mg were estimated for adults and children, respectively. Typical concentrations of substances in house dust were extracted from literature. The exposure of a substance via house dust by adults and children was compared to the tolerable daily intake (TDI) as a criterium above which health risks may occur. The present research was restricted to several main chemical groups: metals, organotin compounds, pesticides, phthalates, brominated flame retardants and polycyclic aromatic hydrocarbons (PAHs). Based on calculation of the so-called Risk Index, which is the estimated exposure for any substance divided by its TDI, a list of substances is provided for which there may be a health risk.

We found the majority of substances present in house dust to be without potential human health risk. However, some substances in house dust exceed the TDI criterium, indicating that they may cause a potential risk. Substances which exceed this criterium most frequently are lead and di(2-ethylhexyl)phthalate, followed by arsenic, cadmium, sum PAHs, and BDE99. The finding that several metals (lead, arsenic, cadmium) may cause a potential human health risk via house dust was expected, but for the other substances this is not generally known. We recommend including these substances in the measurements when projects on the indoor environment are designed.

1 Introduction

House dust can be a major exposure route for some substances, leading to potential health risks. Especially young children ingest considerable amounts of house dust via hand-to-mouth and object-to-mouth behaviour. The ingestion of house dust by children is particularly high relative to their lower body weight. In addition, humans inhale dust particles with air, which may also contribute to the exposure.
The human health risks of chemical substances in house dust have only occasionally been investigated in the Netherlands**.** The present investigation examines whether exposure to a great number of substances present in house dust may potentially lead to human health risks. The research was restricted to several main chemical groups: metals, pesticides, including organotin compounds, phthalates, brominated flame retardants and polycyclic aromatic hydrocarbons. **The aim of this research is to provide a list of substances that may cause human health risks due to exposure to house dust. Also substances are identified for which it is highly unlikely that they cause a human health risk via house dust.** In assessing the possibility of health risks due to substances in soil, conditions that are representative for the Netherlands are pursued.
It should be noted that the present report does not assess the health risks associated with particulate matter (in Dutch 'fijn stof') in the air. Potential health risks associated with different *chemicals* in house dust and particulate matter are investigated.
Finally, some measures that can decrease the exposure to substances in house dust are discussed.

1.1 Approach

To investigate the potential health risk of substances in house dust, we used the following approach:

- The rate of ingested and inhaled house dust by children and adults is estimated.
- Typical concentrations of the substances in house dust are obtained from the literature wherever the research was performed.
- The toxicological reference levels (expressed as Tolerable Daily Intake) of the substances are identified as a criterium above which there may be a potential health risk. The TDI is expressed in mg per kg body weight per day. As contained within the definition of the TDI, lifelong exposure to the substance at levels below the TDI will in principle not lead to health effects. Exceptions and other approaches are indicated.
- The background exposures, usually due to food and water consumption, of the substances are also listed.
- The substances are identified for which it is highly unlikely that exposure via house dust can result in a possible health risk. This is accomplished by making a

conservative estimate of the human exposure (both adult and child) to the substance by using the highest encountered house dust concentration found in literature. Background exposure is added to the exposure via house dust and compared to the TDI, so that exposure via other routes (e.g. food) is included. When the added exposure via house dust and background is less than the TDI, a potential health risk is considered to be highly unlikely.

- The substances for which the added exposure via house dust (based on highest reported concentration) and background is higher than the TDI, are investigated in more detail to identify whether exposure via house dust indeed poses a potential health risk. This research includes:
    - estimation of the exposure with a 95th-percentile and a geometric mean concentration value in house dust
    - evaluation of the house dust data used in the calculations (can the data be considered to be representative for the Netherlands, are there enough data)
    - comparison of the exposure via house dust relative to other exposure routes (e.g. background exposure)
    - evaluation of the application of the TDI. In principle it is scientifically justified to integrate childhood and adult exposure. However, there are exceptions depending on the toxicological basis for the TDI.

  In this manner the substances are identified for which exposure via house dust may lead to a potential health risk.

1.2 Assumptions

In order to assess the potential human health risk of substances in house dust, several assumptions have been made. These assumptions are:

- Using the TDI as a toxic measure for comparison to the exposure to a substance, implies the assumption that humans are chronically exposed to that substance. It is realistic to assume that any person is daily exposed to a substance in house dust. However, changes in the concentration of the substance in house dust can occur in time. These changes are unknown and can therefore not be included in the calculation of the exposure.
- The aim of the present investigation is to provide a *screening* whether exposure to house dust may lead to potential human health effects. With this aim in mind the estimation of the exposure to substances in house dust should be conservative.
- Where the present screening indicates a human health risk is unlikely, this does not mean that this cannot occur under any circumstances. Obviously, specific situations may still result in excessive concentrations in house dust of a certain substance leading to a health risk.

2 General information on house dust

2.1 Origin of house dust

House dust is a heterogeneous mixture of substances from numerous sources, including tracked-in or resuspended soil particles, clothing, atmospheric deposition of particulates, hair, fibres (artificial and natural), molds, pollen, allergens, bacteria, viruses, arthropods, ash, soot, animal fur and dander, smoke, skin particles, cooking and heating residues, and building components among others ((Paustenbach *et al.*, 1997), and references herein).

2.2 Sampling

Reproducible sampling of house dust is difficult and highly depending on the method. Methods that are regularly used for dust collection are vacuum cleaners and wipes. Some studies suggest that the sampling efficiency can differ to a factor sometimes higher than 100 between methods (Sterling *et al.*, 1999). Wiping as sampling method is probably more reproducible, especially when wiping is only applied on hard surfaces. The effect of the sampling method on the concentration of the substance in house dust is unknown and probably depending on various factors.

2.3 Resuspension

Meyer *et al.* (1999) determined that the number of persons living in a residence was significantly associated with elevated amounts of dust sedimented per day, probably due to increased indoor activities such as vacuuming, sweeping, cleaning, and children playing. Thatcher and Layton have shown that the resuspension rate is particle size dependent (Thatcher and Layton, 1995). Particles with diameters of 5-25 μm are most readily resuspended and even light activity such as walking into and out of the room can have a significant impact on the concentration of airborne particles greater than 5 μm. Particles of 0.3 - 1 μm, however, are not affected by either cleaning or walking (Thatcher and Layton, 1995).

3 Exposure to house dust

3.1 Ingestion of house dust

Several institutes have estimated the amount of house dust that children and adults ingest. These dust ingestion rates are uncertain as only indirect methods exist to estimate daily dust ingestion. Table 1 provides an overview of the estimated amounts and some information on the derivation of these estimations.

Table 1. House dust ingestion rates for adults and children derived and used in references.

Study	**Ingestion house dust (mg/day)**		**Remarks**
	Adult	**Children**	
Gevao *et al.*, 2006	10	100	Based on Chuang *et al.*, 1999
Chuang *et al.*, 1999	60	100	Based on Lewis *et al.*, 1994; Stanek and Calabrese, 1995
Williams, 2002	50	50-100	Exposure parameters, no derivation mentioned
Calabrese *et al.*, 1989	10-100	20-200	Based on soil ingestion
Lewis *et al.*, 2001	2-10	20-100	Estimation based on inhalation and hand-mouth behaviour
Butte *et al.*, 2002	2-10	20-100	Estimation based on other studies
USEPA, 1997	50	100	Based on soil ingestion
Jones-Otazo *et al.*, 2005	20	50	From Health Canada 1994
Maertens *et al.*, 2004	0.56	50-100	Based on Hawley, 1985
Yamamoto 2006	100	200	Based on Ministry of Environment, Japan 2001
Wilford *et al.*, 2005	4.16	55	Based on USEPA, 1997
Stapleton *et al.*, 2005		20-200	Based on Roberts and Dickey, 1995; USEPA, 2002
Mushak, 1998		100-200	Intake based on other studies
Oomen *et al.*, 2007	39	27	Based on a comparison with soil ingestion rates and hand loading*
Range of studies	**0.56-100**	**20-200**	

* Assuming children to remain outdoor during 2.9 h/day, and adults during 1.1 h/day.

In the present study a conservative but realistic estimate of dust ingestion rate will be used for the calculation of human exposure to substances in dust. This will allow identification of those substances for which it is unlikely that exposure via house dust will cause a human health risk.

As a conservative but realistic estimate of dust ingestion 100 mg/day for children and 50 mg/day for adults will be employed. This expert judgement is based on two arguments. Firstly, it is assumed in the Netherlands that children ingest on average 100 mg *soil* per day via hand-to-mouth behaviour (Lijzen *et al.*, 2001; Otte *et al.*, 2001). When playing outside a child's hand is much more loaded with soil than a loading with house dust during indoor playing. The ingestion of soil per time unit will thus be much greater outdoors than indoors. On the other hand, children spend more time indoors than outdoors. Yet, it is very unlikely that average daily dust ingestion will be greater than average daily soil ingestion.
Secondly, Table 1 shows that in some cases the dust ingestion of children is estimated at 200 mg/day, whereas in most cases 100 mg/day is used as upper level. For adults, in most cases about 50 mg/day was derived as an upper estimate.

3.2 Inhalation of house dust

The amount of inhaled house dust can be estimated from the level of particles in the air (mg/m^3) and the volume of air inhaled by a child or adult. It is generally assumed that a child inhales 7.6 m^3 of air daily and an adult 19.9 m^3 (Otte *et al.*, 2001; Lewis *et al.*, 1999). As default values for body weight 15 kg and 70 kg respectively are used (Otte *et al.*, 2001).

In general, particles with an aerodynamic diameter of 10 μm or smaller can be inhaled by humans and can deposit deep in the lungs (Carrizales *et al.*, 2005). Larger particles mainly deposit in the upper bronchial tubes and in most cases are transferred upwards by mucotransilliarly and subsequently ingested. Therefore, it is assumed that all substances associated with particles of 10 μm in size or smaller contribute to the exposure in the lungs. This may be an overestimation as only part of the particles will be deposited in the lungs.

Concentrations of suspended particles in air, i.e. suspended dust, that are typically observed range between 13 and 35 $\mu g/m^3$ inside homes, between 41 and 58 $\mu g/m^3$ for daycare facilities (Beamer *et al.*, 2002). Higher concentrations are usually found directly around persons (personal cloud) than in other places in a room. A value of 60 $\mu g/m^3$ is probably representative for moderately crowded places such as residents, whereas a value of 100 $\mu g/m^3$ should be used as personal exposure for crowded places such as classrooms (Oomen and Lijzen., 2004).

When assuming a constant concentration of suspended particles in air of 100 μg/m^3, and a volume of inhaled air of 7.6 m^3 for a child and 19.9 m^3 for an adult, the amount of inhaled suspended particles are respectively 0.8 and 2.0 mg per day. This is in line with the inhaled amounts of dust reported by Maertens *et al.* (2004). Hence, the amount of inhaled suspended dust particles is low compared to the amount of ingested dust (50 and 100 mg/day for a child and adult, respectively). When considering the total exposure to a substance in house dust exposure via inhalation is negligible. Obviously, this exposure route should still be considered when a substance may have local effects on the lungs. For example for several metals this may be the case. In order to assess whether concentrations of metals in the indoor air may lead to potential health risks, concentrations in airborne particulate matter were retrieved from literature and compared to Tolerable Concentration in Air (TCA) levels (ng/m^3), see section 5.2. It should be stressed that the literature research on indoor air concentrations for metals was limited. At concentrations of airborne particulate matter below the TCA no health risk is anticipated even after life-long exposure.
Furthermore, it should be noted that substances that enter the blood circulation after deposition in the lungs bypass the first pass effect, i.e. these substances directly enter the systemic blood circulation without possible metabolism in the liver as is the case after oral exposure. This difference may have consequences for the toxicity.
Obviously, volatile substances are not necessarily adhered to dust particles so that information on the concentration of the substance in airborne particulate matter is not useful.

3.3 Defaults used for house dust ingestion and inhalation

Based on section 3.1 and 3.2 the default dust ingestion and inhalation values described in Table 2 are used in the calculation of the human exposure to substances in house dust. **Due to the large uncertainties in these default values, and the small contribution of inhalation to the total house dust intake, a total daily intake of house dust of 50 and 100 mg is used for adults and children, respectively.**

Table 2. Default values for house dust ingestion and inhalation

	Ingestion of house dust (mg/day)	Inhalation of house dust (mg/day)	Total intake of house dust (mg/day)
Adult	50	0.8	50
Child	100	2.0	100

4 Intake of substances via house dust

4.1 Chemicals

Many chemicals are present in house dust as a consequence of their widespread use in everyday consumer products present in homes. The present research is restricted to the analysis of five main compound groups covering the chemicals: metals, organotins, pesticides (including organotins), phthalates, brominated flame retardants and polycyclic aromatic hydrocarbons.

4.1.1 Metals

Metals present at trace levels in natural water, air, dusts, soils and sediments, play an important role in human life (Juvanovic *et al.*, 1995; Lapitajs *et al.*, 1995). Sources of trace elements in house dust are atmospheric fall out of petrol, tyre wear, corrosion of metallic parts of automobiles, rooftiles, paint and release from carpets, smoking (Fergusson and Schroeder, 1985; Fergusson and Kim, 1991).

4.1.2 Pesticides

Pesticides may be a chemical substance, biological agent, antimicrobial, disinfectant or device used against any pest. There are several types of pesticides, such as bactericides, fungicides, insecticides and herbicides.

4.1.3 Organotins

Organotins are chemical compounds based on tin with hydrocarbon substituents. Organotins are primarily used in five major commercial applications: PVC heat stabilizers, biocides, catalysts, agrichemicals and glass coatings. Triorganotins have a high toxicity and can be powerful fungicides and bactericides, depending on the organic group present. Tributyltins are industrial biocides used in antifouling paints and in wood treatment and preservation. Tributyltins are also used as disinfectants, molluscicides, antifungal action in textiles and industrial water systems such as cooling tower and refrigeration water systems, wood pulp and paper mill systems, and breweries. Many of these applications have been phased out because of the high aquatic toxicity of tributyltins. Triphenyltins are used as fungicides, miticides and acaricides.

4.1.4 Phthalates

Phthalates, or phthalate esters, are a group of chemicals that are mainly used as softeners in flexible PVC products. Phthalates can be found in a broad range of consumer products like packaging materials, wallpapers, furnishings, clothing and toys, as well as ingredients in cosmetics and perfumes.

4.1.5 Brominated flame retardants

Brominated flame retardants (BFRs) are a group of brominated organic substances that have an inhibitory effect on the ignition of combustible organic materials. The most widely used BFRs are tetrabromobisphenol-A (TBBP-A), hexabromocyclododecane (HBCDD), and polybrominated diphenylethers (PBDEs) (De Winter-Sorkina *et al.*, 2006). BFRs are applied to textiles, wiring, furniture, industrial paints and incorporated into plastics and foams, and they are commonly used in electronic products to reduce the flammability of the product.
Use of pentabromodiphenylether (penta-BDE) technical product was voluntarily phased out by industry within the European Union over the last 10 years. This has led to increased use of HBCDD and TBBP-A. The use of penta-BDE and octa-BDE technical products in all applications for the European Union market has officially been banned since August 2004. The use of penta-BDE, octa-BDE and PBBs in new electrical and electronical equipment is banned from July 2006 (De Winter-Sorkina *et al.*, 2006).

4.1.6 Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals composed of two or more fused aromatic rings made up of carbon and hydrogen. Polycyclic aromatic hydrocarbons are formed by the incomplete combustion of coal, oil, petrol, wood, tobacco, charbroiled meats, garbage, or other organic materials. A few are used in medicines, and to make dyes, plastics, and pesticides. Naphthalene, is used in making dyes, explosives, plastics, lubricants, and moth repellent. Anthracene is used in dyes, insecticides and wood preservatives. PAHs are present in tobacco smoke, smoke from home heating (burning wood or oil), char-grilled food and creosote treated wood products. High concentrations of polycyclic aromatic hydrocarbons have been found in coal-tar production plants, coking plants, bitumen and asphalt production plants, smoke houses, aluminium production plants, and trash incinerators. PAHs are also present in the soil where coal, wood, petrol or other products have been burned. Food produced from these soils may also contain PAHs. Most of the PAHs are considered genotoxic carcinogens.

4.2 Levels of substances in house dust

An overview of concentrations of chemicals in house dust as obtained from literature is presented in Table 3. The highest concentration found in literature is presented. In

addition, for most substances several geometric mean values are found in literature (from different studies). In the present report the highest geometric means (mg/kg) of the concentrations of chemicals in house dust under normal conditions are used. Using these concentration values, ingestion of chemicals (µg/kg body weight/day) was calculated for both adults and children. For this calculation mean body weights of 70 kg and 15 kg were used for adults and children respectively (Otte *et al.*, 2001) and dust ingestion rates of 50 mg/day for adults and 100 mg/day for children were used.

Table 3. Calculated ingestion rates of substances via house dust for an adult (70 kg) and child (15 kg) based on the highest geometric mean and the maximum concentration of the compound in house dust described in literature (see Appendix 1 for additional information and references).

	Geometric mean	**Mean ingestion rate**		**Maximum**	**Maximum ingestion rate**	
Compound		**Adult**	**Child**		**Adult**	**Child**
	(mg/kg)	*(µg/kg/d)*	*(µg/kg/d)*	*(mg/kg)*	*(µg/kg/d)*	*(µg/kg/d)*
Metals						
Aluminium	24281	17	162	51100	36	341
Antimony	26	0.018	0.17	66	0.05	0.44
Arsenic	70	0.050	0.47	192	0.14	1.3
Barium	454	0.32	3.0	1480	1.1	9.9
Beryllium	0.53	0.0004	0.0035	1	0.001	0.01
Bismuth	1.0	0.0007	0.0068	8.6	0.01	0.06
Cadmium	13	0.009	0.087	220	0.16	1.5
Chromium[1]	159	0.11	1.1	5440	3.9	36
Cobalt	17	0.012	0.11	23	0.02	0.15
Copper	261	0.19	1.7	12540	8.9	84
Lead	1200	0.85	8.0	37000	26	247
Lithium	6.1	0.0043	0.041	16	0.01	0.10
Magnesium	9442	6.7	63	52000	37	347
Manganese	260	0.18	1.7	9410	6.7	63
Mercury	1.7	0.0012	0.012	37	0.03	0.25
Molybdenum	2.8	0.0020	0.019	29	0.02	0.19
Nickel	47	0.033	0.31	243	0.17	1.6
Rubidium	25	0.017	0.16	40	0.03	0.27
Selenium	1.0	0.0007	0.007	6.8	0.005	0.05
Silver	1.5	0.0011	0.010	9.3	0.01	0.06
Strontium	242	0.17	1.6	1170	0.83	7.8
Tellurium	0.07	0.00005	0.0005	0.28	0.0002	0.002
Thallium	0.14	0.0001	0.0009	0.24	0.0002	0.002
Tin	22	0.016	0.15	595	0.42	4.0

	Geometric mean	Mean ingestion rate		Maximum	Maximum ingestion rate	
Compound		**Adult**	**Child**		**Adult**	**Child**
	(mg/kg)	*(µg/kg/d)*	*(µg/kg/d)*	*(mg/kg)*	*(µg/kg/d)*	*(µg/kg/d)*
Metals						
Titanium	2854	2.0	19	4983	3.5	33
Tungsten	3.7	0.003	0.025	5.6	0.004	0.04
Uranium	0.55	0.0004	0.004	1.3	0.001	0.01
Vanadium	112	0.080	0.75	193	0.14	1.3
Zinc[2]	628	0.45	4.2	30600	22	204
Organotin compounds						
Dibutyltin (DBT)	0.51	0.0004	0.0034	5.6	0.004	0.04
Dioctyltin (DOT)	0.02	0.00001	0.0001	0.36	0.0003	0.002
Monobutyltin (MBT)	0.16	0.0001	0.0011	1.5	0.001	0.01
Monooctyltin (MOT)	0.01	0.00001	0.0001	0.04	0.00003	0.0003
Tributyltin (TBT)	0.02	0.00001	0.0001	0.08	0.0001	0.001
Sum organotins[3]	*0.7*	*0.0005*	*0.005*	*7.2*	*0.005*	*0.05*
Pesticides						
2,4-Dichlorophenoxy acetic acid	1.24	0.0009	0.0083	7.3	0.005	0.05
Alachlor[4]				1.5	0.001	0.01
Aldrin	0.006	0.000004	0.00004	0.051	0.00004	0.0003
alpha-Chlordane[5]	0.055	0.00004	0.0004	0.26	0.0002	0.002
alpha-HCH	0.0007	0.0000005	0.000005	0.0087	0.00001	0.0001
Atrazine	0.002	0.000002	0.00002			
Azinphos methyl	6.0	0.0043	0.040	16	0.01	0.11
beta-HCH	0.0022	0.000002	0.00001	0.057	0.00004	0.0004
Carbaryl[4]				1.0	0.0007	0.007
Chloroprofam[4]				0.17	0.0001	0.001
Chlorpyrifos	1.0	0.0007	0.0069	6.5	0.005	0.04
DDD	0.0047	0.000003	0.00003	0.048	0.00003	0.0003
DDE	0.007	0.000005	0.00005	0.05	0.00004	0.0003
DDT	0.12	0.0001	0.0008	0.78	0.0006	0.005
delta-HCH	0.0055	0.000004	0.00004	0.17	0.0001	0.001
Diazinon	0.31	0.0002	0.0021	2.0	0.001	0.01
Dicamba[4]				2.5	0.002	0.02

	Geometric mean	Mean ingestion rate		Maximum	Maximum ingestion rate	
Compound		**Adult**	**Child**		**Adult**	**Child**
	(mg/kg)	*(µg/kg/d)*	*(µg/kg/d)*	*(mg/kg)*	*(µg/kg/d)*	*(µg/kg/d)*
Pesticides						
Dieldrin	0.018	0.00001	0.0001	0.050	0.00004	0.0003
Dimethyl organiphosphate	0.37	0.0003	0.0025	1.3	0.0009	0.009
Ethyl parathion	0.56	0.0004	0.0037	0.43	0.0003	0.003
gamma-Chlordane[6]	0.098	0.0001	0.0007	0.47	0.0003	0.003
Glyphosate	0.14	0.0001	0.0009	0.14	0.0001	0.001
Heptachlor	0.12	0.0001	0.0008	0.34	0.0002	0.002
Lindane[7]	0.33	0.0002	0.0022	0.074	0.0001	0.0005
Malathion	0.38	0.0003	0.0025	2.0	0.001	0.013
Mecoprop[4]				0.40	0.0003	0.003
Methamidophos[4]				0.40	0.0003	0.003
Methyl parathion	0.38	0.0003	0.0025	1.9	0.0013	0.013
Metolachlor	0.0057	0.000004	0.00004	0.80	0.0006	0.005
Pendimethalin[4]				3.0	0.002	0.020
Permethrin	0.14	0.0001	0.0009	659	0.47	4.4
Phosmet	5.2	0.0037	0.035	22	0.016	0.15
Picloram[4]				1.2	0.0009	0.008
Resmethrin[4]				0.80	0.0006	0.005
Tetramethrin[4]				0.40	0.0003	0.003
Trichloro-2-pyridinol[8]	0.54	0.0004	0.0036	0.95	0.0007	0.006
Trifluralin[4]				1.8	0.0013	0.012
Phthalates						
Butylbenzyl phthalate (BBP)	319	0.23	2.1	45549	32	304
Di(2-ethylhexyl) phthalate (DEHP)	3214	2.3	21	40459	29	270
Diethyl phthalate (DEP)	45	0.032	0.30	632	0.45	4.2
Diisobutyl phthalate (DiBP)	84	0.060	0.56	84	0.06	0.56
Diisodecyl phthalate (DIDP)	73	0.052	0.49	73	0.05	0.49
Diisononyl phthalate (DINP)	176	0.12	1.2	176	0.12	1.2
Dimethyl phthalate (DMP)	11	0.0077	0.072	158	0.11	1.1

	Geometric mean	Mean ingestion rate		Maximum	Maximum ingestion rate	
Compound		**Adult**	**Child**		**Adult**	**Child**
	(mg/kg)	*(µg/kg/d)*	*(µg/kg/d)*	*(mg/kg)*	*(µg/kg/d)*	*(µg/kg/d)*
Phthalates						
Dimethylpropyl phthalate (DMPP)	55	0.039	0.36	161	0.11	1.1
Di-n-butyl phthalate (DBP)	226	0.16	1.5	5446	3.9	36
Brominated flame retardants (BFRs)/Brominated diphenylethers (BDEs)						
BDE 100	490	0.35	3.3	21000	15	140
BDE 138	37	0.03	0.25	2000	1.4	13
BDE 153	181	0.13	1.2	1510	1.1	10
BDE 154	380	0.27	2.5	18000	13	120
BDE 17	8.9	0.01	0.06	150	0.1	1.0
BDE 183	44	0.03	0.29	650	0.5	4.3
BDE 190	4.5	0.003	0.03	48	0.0	0.3
BDE 196	15	0.01	0.10	39	0.0	0.3
BDE 197	17	0.01	0.12	77	0.1	0.5
BDE 206	51	0.04	0.34	239	0.2	1.6
BDE 207	30	0.02	0.20	109	0.1	0.7
BDE 208	35	0.02	0.23	108	0.1	0.7
BDE 209	10	0.01	0.07	19100	14	127
BDE 28	20	0.01	0.14	550	0.4	3.7
BDE 33/28	21	0.01	0.14	77	0.1	0.5
BDE 47	1621	1.2	11	33	0.0	0.2
BDE 66	37	0.03	0.25	1800	1.3	12
BDE 85	190	0.13	1.3	9700	7	65
BDE 99	2295	1.6	15	2850	2	19
BDE153	470	0.33	3.1	25000	18	167
Polycyclic aromatic hydrocarbons (PAHs)						
Acenaphthene	0.05	0.00004	0.0003	1.9	0.001	0.013
Acenaphthylene	0.08	0.0001	0.0005	0.52	0.0004	0.003
Anthracene	0.12	0.0001	0.0008	5.8	0.004	0.039
Benz[a]anthracene	0.24	0.0002	0.0016	40	0.028	0.27
Benzo[a]pyrene	0.29	0.0002	0.0019	54	0.038	0.36
Benzo[b,k]fluoranthene	0.57	0.0004	0.0038	108	0.077	0.72
Benzo[e]pyrene	0.29	0.0002	0.0019	41	0.029	0.27
Benzo[g,h,i]perylene	0.25	0.0002	0.0017	35	0.025	0.23

	Geometric mean	Mean ingestion rate		Maximum	Maximum ingestion rate	
Compound		**Adult**	**Child**		**Adult**	**Child**
	(mg/kg)	*(µg/kg/d)*	*(µg/kg/d)*	*(mg/kg)*	*(µg/kg/d)*	*(µg/kg/d)*
Polycyclic aromatic hydrocarbons (PAHs)						
Biphenyl	0.002	0.000001	0.00001	0.005	0.000004	0.00003
Chrysene	0.39	0.0003	0.0026	43	0.031	0.29
Coronene	0.13	0.0001	0.0009	7.2	0.005	0.048
Cyclopenta[c,d]pyrene	0.08	0.0001	0.0005	0.62	0.0004	0.004
Dibenzo[a,h]anthra-cene	0.10	0.0001	0.0007	9.0	0.006	0.060
Fluoranthene	0.59	0.0004	0.0039	90	0.064	0.60
Fluorene	0.12	0.0001	0.0008	3.0	0.002	0.020
Indeno[1,2,3-c,d]pyrene	0.26	0.0002	0.0017	41	0.029	0.27
Naphthalene	0.33	0.0002	0.0022	42	0.030	0.28
Phenanthrene	0.44	0.0003	0.0029	43	0.031	0.29
Pyrene	0.49	0.0003	0.0033	69	0.049	0.46
Sum PAHs[9]	*4.8*	*0.0034*	*0.032*	*634*	*0.45*	*4.2*

Table 3 – Remarks

1. From a toxicological point of view chromium should be differentiated into hexavalent chromium, soluble trivalent chromium and unsoluble chromium. No differentiation, however, was made in the papers, which have measured chromium (only total chromium levels measured).
2. Non industrial setting.
3. Sum of organotins: dibutyltin (DBT), monobutyltin (MBT), monooctyltin (MOT), tributyltin (TBT).
4. Of the compounds alachlor, carbaryl, chloroprofam, dicamba, mecoprop, methamidos, pendimethalin, picloram, resmethrin, tetramethrin and trifluralin only maximum values were found in literature.
5. Alpha-Chlordane = cis-Chlordane.
6. Gamma-Chlordane = trans-Chlordane.
7. Lindane is technical gamma-HCH.
8. Trichloro-2-pyridinol is a metabolite of chlorpyrifos.
9. Sum of PAHs: acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b,k]fluoranthene, benzo[e]pyrene, benzo[g,h,i]perylene, biphenyl, chrysene, coronene, cyclopenta[c,d]pyrene, dibenzo[a,h]anthracene, fluoranthene, fluorine, indeno[1,2,3-c,d]pyrene, naphthalene, phenanthrene, pyrene.

5 Substances in house dust with and without potential human health risk

5.1 Comparison exposure via house dust, TDI, and background exposure

In order to select the compounds for which it is *highly unlikely* that exposure via house dust results in a human health risk, the exposure via house dust was estimated in a conservative manner: by using the highest and the highest geometric mean concentration encountered in literature. As a toxicologically-based reference value the Tolerable Daily Intake (TDI) is used since this represents the estimated amount of the chemical that humans can ingest daily during their lifetime without resultant adverse effects. It is thus implicitly assumed that humans are exposed to house dust daily, and that the concentration of the compound in house dust does not change over time.
The TDI represents the upper limit of allowable exposure to a single compound. Exposure to this compound can occur via different exposure routes. Since ingestion of house dust occurs in addition to other exposure routes the background exposure, e.g. exposure via normal food and water consumption, has to be taken into account.

For convenience, a ***Risk Index (RI)*** is used to identify the possible health risk. The risk index (RI) is calculated by:

$$RI = \frac{\text{estimated exposure to substance via house dust + background exposure}}{\text{TDI}}$$

This means that background exposure is incorporated in the calculation of the potential health risk. For the RI, the mean and maximum ingestion rates were used for both adults and children (see Table 4). When RI < 1, no risk is expected for human health. However, when RI >1 this indicates a potential risk for human health. Although it is unlikely that a substance can cause a health risk at RI < 1, an additional safety precaution was taken at this point to further investigate substances for which an RI > 0.8 was obtained. ***Hence, all compounds with a risk index greater than 0.8 are addressed in more detail in section 5.3.*** The main purpose of Table 4 is to identify those compounds for which it is highly unlikely that they can cause a potential health risk via exposure through house dust, even if a conservative approach is used (highest available concentration in house dust is used in the calculation of the human exposure, additional research for compounds with a RI > 0.8, accounting for background exposure).

The TDIs and background exposure used are listed in Appendix 2, including the references to their derivation.

Table 4. Tolerable daily intake and risk index for compounds present in house dust based on highest geometric mean and maximum levels in house dust described in literature (see also Table 3). Risk Indices (RI) greater than 0.8 were taken to indicate a potential health risk (bold values). The potential health risk for these compounds is discussed in more detail in section 5.3. Mean and maximum concentrations of substances in house dust used for the calculation can be found in Table 3.

Compound	TDI	Background		Risk index			
	(µg/kg/d)	(µg/kg/d)		mean adult	mean child	max adult	max child
		Adult	Child				
Metals							
Aluminium[1]	750	180[2]	300	0.26	0.62	0.29	***0.85***
Antimony[1]	6.0	0.48[3]	0.5	0.08	0.12	0.09	0.16
Arsenic[1]	1.0	0.3	0.7[4]	0.35	1.2	0.44	***2.0***
Barium	600	9.0		0.02	0.02	0.02	0.03
Beryllium	0.5	0.3		0.60	0.61	0.60	0.61
Bismuth[5]	n.a.[5]	unknown					
Cadmium	0.5	0.45		***0.92***	***1.1***	***1.2***	***3.8***
Chromium III soluble[6]	5.0	1.0		0.22	0.41	***0.97***	***7.5***
Chromium III insoluble[6]	5000	1.0		0.00	0.00	0.00	0.01
Chromium VI[7]	5.0	0.0		0.00	0.00	0.00	0.00
Cobalt	1.4	0.6		0.44	0.51	0.44	0.54
Copper	83	60		0.73	0.74	***0.83***	***1.7***
Lead[1]	3.6	1.1	1.8	0.54	***2.7***	***7.7***	***69***
Lithium[5]	n.a.[5]	unknown					
Magnesium	6700	4600		0.69	0.70	0.69	0.74
Manganese	160	130		***0.81***	***0.82***	***0.85***	***1.2***
Mercury	2.0	0.1		0.05	0.06	0.06	0.17
Molybdenum	10	4.0		0.40	0.40	0.40	0.42
Nickel[1]	10	4.0	8.0	0.40	***0.83***	0.42	***0.96***
Rubidium[5]	n.a.[5]	unknown					
Selenium	5.0	2.0		0.40	0.40	0.40	0.41
Silver	5.0	1.3		0.26	0.26	0.26	0.27
Strontium	600	18		0.03	0.03	0.03	0.04
Tellurium	2.0	1.4[14]		0.70	0.70	0.70	0.70
Thallium	0.2	0.03[14]		0.15	0.15	0.15	0.16
Tin	2000	290		0.15	0.15	0.15	0.15
Titanium	12000	7.0		0.001	0.002	0.001	0.003

Compound	TDI	Background		Risk index			
	(µg/kg/d)	(µg/kg/d)		mean adult	mean child	max adult	max child
		Adult	Child				
Metals							
Tungsten[5]	n.a.[5]	unknown					
Uranium	2.0	0.06		0.03	0.03	0.03	0.03
Vanadium	2.0	0.3[14]		0.19	0.52	0.22	0.79
Zinc[8]	500	350		0.70	0.71	0.74	***1.1***
Organotin compounds							
Dibutyltin (DBT)							
Dioctyltin (DOT)							
Monobutyltin (MBT)							
Monooctyltin (MOT)							
Tributyltin (TBT)							
Sum organotins[9]	*0.25*	*0.083*		0.33	0.35	0.35	0.53
Pesticides							
2,4-Dichlorophenoxy acetic acid	10	unknown		<0.0001	0.0008	0.0005	0.0049
Alachlor	10	unknown				0.0005	0.0049
Aldrin	0.1[15]	< 0.04		<0.0001	0.0004	0.0004	0.0034
alpha-Chlordane[10]	0.5	unknown		0.0001	0.0007	0.0004	0.0034
alpha-HCH	1.0	< 0.03		<0.0001	<0.0001	<0.0001	0.0001
Atrazine	35	unknown		<0.0001	<0.0001		
Azinphos methyl	5	unknown		0.0009	0.0080	0.0023	0.0213
beta-HCH	0.02	< 0.01		0.0001	0.0007	0.0020	0.0190
Carbaryl	8	unknown				0.0001	0.0008
Chloroprofam	50	unknown				<0.0001	0.0000
Chlorpyrifos	10	unknown		0.0001	0.0007	0.0005	0.0043
DDD	0.5[16]	unknown		<0.0001	0.0001	0.0001	0.0006
DDE	0.5[16]	unknown		<0.0001	0.0001	0.0001	0.0007
DDT	0.5[16]	unknown		0.0002	0.0016	0.0011	0.0104
delta-HCH[5]	n.a.[5]	unknown					
Diazinon	5	unknown		<0.0001	0.0004	0.0003	0.0027
Dicamba	125	unknown				<0.0001	0.0001
Dieldrin	0.1[15]	unknown		0.0001	0.0012	0.0004	0.0033
Ethyl parathion	4	unknown		0.0001	0.0009	0.0001	0.0007
gamma-Chlordane[11]	0.5	unknown		0.0001	0.0013	0.0007	0.0063
Glyphosate	1000	unknown		<0.0001	<0.0001	<0.0001	<0.0001

Compound	TDI	Background		Risk index			
	(µg/kg/d)	(µg/kg/d)		mean adult	mean child	max adult	max child
		Adult	Child				
Pesticides							
Heptachlor	0.1	0.001		0.0108	0.0179	0.0124	0.0323
Lindane[12]	0.04			0.0059	0.0550	0.0013	0.0123
Malathion	300	unknown		<0.0001	<0.0001	<0.0001	<0.0001
Mecoprop	3.3	unknown				0.0001	0.0008
Methamidophos	4	unknown				0.0001	0.0007
Methyl parathion	3	unknown		0.0001	0.0008	0.0004	0.0042
Metolachlor	3.5	unknown		<0.0001	<0.0001	0.0002	0.0015
Pendimethalin	125	unknown				<0.0001	0.0002
Permethrin	50	unknown		<0.0001	<0.0001	0.0094	0.0879
Phosmet	3	unknown		0.0012	0.0116	0.0052	0.0489
Picloram	200	unknown				<0.0001	0.0000
Resmethrin	30	unknown				<0.0001	0.0002
Tetramethrin	20	unknown				<0.0001	0.0001
Trichloro-2-pyridinol[5]	n.a. [5]	unknown					
Trifluralin	15	unknown				0.0001	0.0008
Phthalates							
Butylbenzyl phthalate (BBP)	500	9.00		0.02	0.02	0.08	0.63
Di(2-ethylhexyl) phthalate (DEHP)	50	16[22]	26[23]	0.37	***0.95***	***0.90***	***5.9***
Diethyl phthalate (DEP)	200[14]	unknown		0.0002	0.002	0.003	0.03
Diisobutyl phthalate (DiBP) [5]	n.a.[18]	unknown		see DBP	see DBP	see DBP	see DBP
Diisodecyl phthalate (DIDP)	150	unknown		0.0003	0.03	0.0003	0.00
Diisononyl phthalate (DINP)	150	unknown		0.001	0.01	0.001	0.01
Dimethyl phthalate (DMP) [5]	n.a.[17]	unknown		see DEP	see DEP	see DEP	see DEP
Dimethylpropyl phthalate (DMPP) [5]	n.a. [18]	unknown		see DBP	see DBP	see DBP	see DBP
Di-n-butyl phthalate (DBP)	52	unknown		0.00	0.05	0.08	0.73
Brominated flame retardants (BFRs)/Brominated diphenylethers (BDEs)							
BDE 47[5]	n.a.[5]	A: 0.00030[20] C: 0.0014[20]		[19]	[19]	[19]	[19]
BDE 99 - EU	0.00026	A: 0.00010[20] C: 0.00023[20]		0.45	***1.5***	***22***	***204***

Compound	TDI	Background		Risk index			
	(µg/kg/d)	(µg/kg/d)		mean adult	mean child	max adult	max child
		Adult	Child				
Brominated flame retardants (BFRs)/Brominated diphenylethers (BDEs)							
BDE 99 - VS	0.00026	A: 0.00010[20] C: 0.00023[20]		***6.8***	***61***	***39***	***362***
BDE 100[5]	n.a.[5]	A: 0.00007[20] C: 0.00018[20]		[19]	[19]	[19]	[19]
BDE 183[5]	n.a.[5]	A: 0.00034[20] C: 0.00087[20]		[19]	[19]	[19]	[19]
BDE 209[5]	n.a.[5]	[20]					
Polycyclic aromatic hydrocarbons (PAHs)							
Acenaphthene[5]	n.a.[5]						
Acenaphthylene[5]	n.a.[5]						
Anthracene	40						
Benz[a]anthracene[5]	n.a.[5]						
Benzo[a]pyrene[5]	n.a.[5]						
Benzo[b,k]fluoranthene[5]	n.a.[5]						
Benzo[e]pyrene[5]	n.a.[5]						
Benzo[g,h,i]perylene	30						
Biphenyl	50						
Chrysene[5]	n.a.[5]						
Coronene[5]	n.a.[5]						
Cyclopenta[c,d]pyrene[5]	n.a.[5]						
Dibenzo[a,h]anthracene[5]	n.a.[5]						
Fluoranthene[5]	n.a.[5]						
Fluorene	40						
Indeno[1,2,3-c,d]pyrene[5]	n.a.[5]						
Naphthalene	40						
Phenanthrene	40						
Pyrene[5]	n.a.[5]						
Sum PAHs[13]	*0.05 (as BaP)*	*0.0006 (as BaP)*		*0.08*	*0.65*	***9.0***	***84.6***

Table 4 – Remarks

1. For aluminium, antimony, arsenic, lead and nickel, background values for adults and children are discriminated.
2. Background value of aluminium for adults is between 80 and 180 µg/kg/day.
3. Background value of antimony for adults is between 0.018 and 0.48 µg/kg/day.
4. Background value of arsenic for children is between 0.4 and 0.7 µg/kg/day.
5. TDI is not available (= n.a.).

6. Chromium III must be differentiated into soluble (TDI=5 μg/kg/day) and insoluble (TDI=5000 μg/kg/day).
7. Background chromium VI between 5.7×10^{-6} - 4.3×10^{-4} μg/kg/day.
8. Non industrial setting.
9. Sum of organotins: dibutyltin (DBT), monobutyltin (MBT), monooctyltin (MOT), tributyltin (TBT).
10. Alpha-Chlordane = cis-Chlordane.
11. Gamma-Chlordane = trans-Chlordane.
12. Lindane is technical gamma-HCH.
13. Sum of PAHs: acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b,k]fluoranthene, benzo[e]pyrene, benzo[g,h,i]perylene, biphenyl, chrysene, coronene, cyclopenta[c,d]pyrene, dibenzo[a,h]anthracene, fluoranthene, fluorine, indeno[1,2,3-c,d]pyrene, naphthalene, phenanthrene, pyrene.
14. Provisional value due to limited toxicological data base.
15. Sum of aldrin and dieldrin.
16. Sum of DDD, DDE and DDT.
17. TDI of dimethyl phthalate (DMP) is unknown, as the compound is chemically comparable to diethyl phthalate (DEP), the concentrations of DMP are added to the concentrations of DEP and compared to the TDI of DEP.
18. TDI of diisobutyl (DiBP) and dimethylpropyl phthalate (DMPP) are unknown, as these compounds are chemically comparable to di-n-butyl phthalate (DBP), the concentrations of DiBP and DMPP are added to the concentrations of DBP and compared to the TDI of DBP.
19. For BDE 47, 100, and 183 no toxicological reference dose (e.g. TDI) is available to compare the exposure with. Therefore, the exposure via intake of house dust is compared to the exposure due to food intake in section 6.12.
20. Background exposure to PBDE congeners is based on dietary intake for an adult (A) and a 2-year old child (C) (De Winter-Sorkina *et al.*, 2006).
21. No information is available about the intake of BDE209 via food intake, neither is a toxicological reference dose available. Therefore, the exposure via dust of BDE209 can only be compared to the exposure via dust of other PBDE congeners.
22. Background value of DEHP for adults is between 3 and 16 μg/kg/day.
23. Background value of DEHP for children is between 12 and 26 μg/kg/day.

5.2 Levels of substances in particulate matter in air

The amount of inhaled house dust particles is low (< 2%) in comparison to ingested house dust. However, in some cases such as for toxic metals local effects in the lungs may occur. In order to evaluate the possibility of a potential health risk of several metals in air, the highest concentrations in particulate matter in air as reported in selected literature sources were compared to the corresponding TCA-values (chronic limit values for air as mg/m^3), see Table 5. Below the TCA no health effects are anticipated even after lifelong exposure. None of the highest concentration in airborne particles exceeds the TCA. For arsenic however the guideline value for air of 6 ng/m^3, which will be effective within the EU in

2013, is exceeded, indicating that concentrations of this metal may be undesirably high even though they remain well below the current TCA as used by RIVM.

Table 5. Maximum concentrations of various metals in particulate matter (PM10 or PM2.5) in indoor air.

	Highest conc in air (ng/m^3)	Reference air concentrations	TCA (ng/m^3)	Reference TCA
Aluminium	100	(Rasmussen *et al.*, 2007)	unknown	
Arsenic	31	(Oomen *et al.*, 2007)	1000	RIVM 2001
Cadmium	1.3	(Oomen *et al.*, 2007; Rasmussen *et al.*, 2007)	5	EU 2000
Chromium	29	(Oomen *et al.*, 2007)	60000*	RIVM 2001
Cobalt	25	(Oomen *et al.*, 2007)	500	RVIM 2001
Manganese	10	(Rasmussen *et al.*, 2007)	150	WHO 2000
Nickel	20	(Oomen *et al.*, 2007)	50	RIVM 2001
Lead	51	(Oomen *et al.*, 2007)	500	WHO 2000
Zinc	606	(Oomen *et al.*, 2007)	unknown	

* TCA for insoluble Cr-III

5.3 Substances without potential human health risk

The majority of the substances present in house dust is without potential human health risk. Compounds without human health risk are: antimony, barium, beryllium, cobalt, magnesium, mercury, molybdenum, selenium, silver, strontium, tellurium, thallium, tin, titanium, uranium, vanadium, organotin compounds, 2,4-dichlorophenoxyacetic acid, alachlor, aldrin, alpha-chlordane, alpha-HCH, atrazine, azinphos methyl, beta-HCH, carbaryl, chloroprofam, chlorpyrifos, DDD, DDE, DDT, diazinon, dicamba, dieldrin, ethyl parathion, gamma-chlordane, glyphosate, heptachlor, lindane, malathion, mecoprop, methamidophos, methyl parathion, metolachlor, pendimethalin, permethrin, phosmet, picloram, resmethrin, tetramethrin, trifluralin, BBP, DEP, DiBP, DIDP, DINP, DMP, DMPP, DBP.

5.4 Substances with potential human health risk

Based on the calculated mean and maximum ingestion rates, exposure to the following substances in house dust may lead to potential human health effects. Potential human risk is subdivided into risk for adults and risk for children.

Substances in house dust with potential risk for adults: cadmium, chromium, copper, lead, manganese, BFRs, and sum PAHs.

Substances in house dust with potential risk for children: aluminium, arsenic, cadmium, chromium, copper, lead, manganese, nickel, zinc, DEHP, BFRs, and sum PAHs.

Table 6 shows the substances in house dust with a potential risk for adults and children, based on mean and maximum values. Since the maximum concentration in house dust is not always a realistic value, the P95 is added in the calculations. The highest mean, maximum and P95 of the concentration in house dust are presented. The P95 value was used for the calculation of the risk index and for the contribution of house dust to the TDI as a percentage. Both the P95 risk index and the percentage of TDI were calculated for adults and children separately.

Table 6. Compounds with potential risk for human health

	Concentration in house dust			**Risk index** based on highest P95 conc in house dust		**Exposure via house dust** based on highest P95 conc **compared to TDI** [1]	
	Highest mean	**Highest P95**	**Maximum**				
	(mg/kg)	(mg/kg)	(mg/kg)	(-)	(-)	(-)	(-)
				Adult	**Child**	**Adult**	**Child**
Compound							
Aluminium	24281	44225	51100	0.28	0.79	0.042	0.39
Arsenic	70	114[2]	192	0.38[2]	**1.46**[2]	0.081[2]	0.76[2]
Cadmium	13	17.32	220	**0.92**	**1.13**	0.025	0.23
Chromium III soluble	159	191.8	5440	0.12	0.35	0.027	0.26
Chromium III insoluble	159	191.8	5440	0.00	0.00	0.00	0.00
Copper	261	489	12540	0.73	0.76	0.004	0.039
Lead	1200	1312	37000	0.57	**2.99**	0.26	2.4
Manganese	260	407	9410	**0.81**	**0.83**	0.002	0.017
Nickel	47	116	243	0.41	**0.88**	0.008	0.078
Zinc[3]	628	1570	30600	0.70	0.72	0.002	0.021
Di(2-ethylhexyl)-phthalate (DEHP)	3214	7063	40459	0.42	**1.46**	0.10	0.94
Sum PAHs[4]	0.29	13	54	0.20	**1.8**	0.18	1.7
BDE99 – EU[5]	0.022[5]	0.15[6]	7.8	0.8	**5.0**	0.41	3.8

Table 6 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor:
$$\frac{\text{exposure via house dust (P95) (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$
2. P90 value, calculation of risk index and % of TDI based on P90 value.
3. Non industrial setting
4. Surrogate approach (also referred to the 'indicator approach').
5. For BDE99 no TDI is available. Instead a maximal allowable intake level derived by De Winter-Sorkina *et al.* (IPCS (International Programme on Chemical Safety), 2001) is employed.
6. Geometric mean, and 95th percentile of pooled data of (Ibarra *et al.*, 2006; Knoth, 2003; Pless-Mulloli *et al.*, 2006; De Boer, 2007; Santillo *et al.*, 2003)

6 Discussion substances with potential human health risk

In the present chapter those substances are discussed in more detail for which a potential health risk due to house dust was identified using the highest house dust concentration encountered in literature (chapter 5). In addition, some measures to decrease the exposure to substances via house dust are discussed.

6.1 Aluminium

Table 7. Overview of risk indices for aluminium based on geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is listed in the second columns for an adult and child respectively by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.26	0.023	0.62	0.22
P95 conc.	0.28	0.042	0.79	0.39
Max. conc.	0.29	0.050	0.85	0.45

Table 7 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

Only one study was found that provides information on the levels of aluminium in house dust. When the P95-concentration or the maximum concentration of aluminium in house dust was used in the calculation of the risk index, the risk index was high but not larger than 1 (0.85 for a child with the maximum concentration in house dust, 0.79 for a child with the 95th-percentile data, see Table 7). This indicates only a limited potential health risk. Nevertheless, the contribution of exposure via house dust is not negligible for children (39% of the TDI is filled up by exposure via house dust based on the 95th-percentile data). Background exposure to aluminium via food and water intake accounts for about 40% of the TDI for children and 11-24% for adults. Thus, the only study giving information on aluminium exposure through house dust indicates a substantial contribution of this route compared to other sources of exposure. But the relevance of this

one study performed in Ottawa, Canada, for the Dutch situation is unknown. In conclusion, the available information indicates house dust may substantially contribute to total aluminium exposure. It is however not likely that this exposure would lead to human health risks.

6.2 Arsenic

Table 8 provides an overview of the risk indices for arsenic. The risk index obtained using the highest concentration in house dust encountered in literature was 2.0 for a child and 0.44 for an adult, whereas the risk indices associated with the highest geometric mean concentration of arsenic in house dust were 1.2 and 0.35, respectively. The background exposure to arsenic for a child already fills up 40-70% of the TDI due to intake by food and water.

Arsenic is a naturally occurring element in the environment that may be released from industrial processes, such as mining activities, metal smelting and burning of fossil fuels. High values of arsenic in house dust are often found near smelters. Yet, also in non-industrial settings the arsenic concentration in house dust is occasionally high. In the Netherlands, high arsenic concentrations may be anticipated in the area of zinc smelters (e.g. Budel-Dorplein). Recent research in 15 houses in Budel-Dorplein determined a arsenic concentration of at maximum 60 mg/kg in house dust, whereas in the control area (Liempde, non-industrial setting) in one house an arsenic concentration in house dust of 74 mg/kg was found (Oomen *et al.*, 2007). This house dust concentration of 74 mg/kg combined with highest background exposure for children (0.7 μg/kg bw/day is used as background exposure of the range 0.4-0.7 μg/kg bw/day) and 0.3 μg/kg bw/day for adults, results in a risk index of 0.35 and 1.2 for an adult and child, respectively. In this calculation the exposure via house dust represents 5 and 49% of the TDI, respectively.

Note that in the earlier research by Oomen *et al.* (2007) a lower dust intake was used in the calculation and exposure was integrated over a lifetime. The conclusion there was that arsenic in house dust from Budel-Dorplein did not cause a potential risk for human health (Oomen *et al.*, 2007).

In conclusion, the present analysis based on literature data indicates substantial exposure to arsenic through house dust. The calculated risk index indicates a potential human health risk for children. For adults background estimated exposure is lower than for children (0.3 versus 0.7 μg/kg/day). Thus the exceedance of the TDI will in most cases be limited to the childhood years. Given its derivation, the TDI for arsenic should be treated as a long-term average, which implies that in principle any temporary exceedance early in life could be compensated by a proportionally lower exposure later in life, as seems to be the case for arsenic in house dust. Nevertheless, given the general picture for arsenic health risks of only a limited margin between actual intakes and levels known to produce toxic

effects when humans are exposed to them chronically, arsenic exposure in general should preferably be as low as possible.

Table 8. Overview of risk indices for arsenic based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.35	0.05	**1.2**	0.47
P95 conc.	0.38	0.08	**1.5**	0.76
Max. conc.	0.44	0.14	**2.0**	1.3
Highest conc. Netherlands [2]	0.35	0.05	**1.2**	0.49

Table 8 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

2. Highest concentration encountered in a study in the Dutch Kempen area (Oomen *et al.*, 2007).

6.3 Cadmium

Important for cadmium is that background exposure due to food and water intake already accounts for 90% of the TDI. This limits the allowable additional exposure via other routes. Thus relatively low levels of cadmium in house dust may already lead to risk indices higher than 1.0, indicating a potential health risk. Occasionally cadmium levels in house dust are so high that they may pose a potential health risk even without taking into account background exposure, see Table 9. In most cases, however, the contribution of house dust to total cadmium exposure is limited. Thus for cadmium, exposure through house dust may give rise to a potential health risk when taking the background into account, but its contribution to total exposure mostly is limited only.

The highest cadmium concentration recently encountered in house dust in the Netherlands was 22.8 mg/kg in Budel-Dorplein, an area known to be historically contaminated with cadmium (Oomen *et al.*, 2007). The cadmium concentration in all other houses (n=45) was considerably lower (< 7 mg/kg). This highest concentration in the Netherlands is, according to the present method, associated with a risk index of 0.93 and 1.2 for an adult

and child, respectively (accounting for 3.2% and 30 % of the TDI, respectively), see Table 9. This confirms the picture obtained form literature.

Cadmium is an extremely potent nephrotoxicant. This toxicity develops over a time period of decades of continuing low exposure, with the kidney cortex as the target tissue. Thus a risk index for a child greater than 1 does not necessarily mean an actual health risk during this period of life. Exposure to cadmium should be evaluated integrally over the childhood and adult years. When modelling exposure to the highest cadmium concentration in house dust in Budel-Dorplein (22.8 mg/kg) during 7 childhood years, 11 transition years and 62 adult years, the critical cadmium levels in the kidney cortex were calculated not to be reached, and therefore no health risk was anticipated (Oomen *et al.*, 2007). Despite this absence of an actual health risk, elevated exposure to cadmium is undesirable in principle and a policy of reducing its exposure via food and other routes is followed by health authorities. Thus levels in house dust should also be as low as possible.

Table 9. Overview of risk indices for cadmium based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.92	0.02	**1.1**	0.17
P95 conc.	0.92	0.03	**1.1**	0.23
Max. conc.	**1.2**	0.31	**3.8**	2.9
Highest conc. Netherlands[2]	0.93	0.03	**1.2**	0.30

Table 9 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

2. Highest concentration encountered in a study in the Dutch Kempen area (Oomen *et al.*, 2007).

A further issue with cadmium is its inhalatory carcinogenicity as evident from in studies in industrial workers with high exposures. For cadmium a toxicological reference value for air of 5 ng/m^3 has been derived as protective against both its nephrotoxicity and its carcinogenicity (Oomen *et al.*, 2007). The highest cadmium concentration in air samples in Budel-Dorplein, Maarheeze and Liempde in the Netherlands was 1.4 ng/m^3 (n=45) (Oomen *et al.*, 2007). It can be calculated that theoretical exposure to this highest cadmium concentration in air during an entire life, would lead to an extra cancer risk of 3.2-5.8 × 10^{-6} (32 to 58 additional cases of cancer per 10 million lifelong exposed). Based

on the available evidence it is concluded that cadmium exposure via dust particles in the air does not exceed the toxicological reference value of 5 ng/m^3.

6.4 Chromium

From a toxicological point of view trivalent and hexavalent chromium should be differentiated. Hexavalent chromium is much more toxic than trivalent chromium, having a much higher toxic potential for different toxicological endpoints and most importantly, unlike the trivalent form, presenting a genotoxic and carcinogenic risk. Soluble trivalent chromium in turn is more toxic than insoluble trivalent chromium, which is reflected by their respective TDIs of 5 and 5000 μg/kg/day.
Available data on chromium concentrations in house dust represent total chromium, i.e. without specification of valence and solubility. No general information is available on the contribution of hexavalent chromium in house dust. A priori it is plausible that chromium in house dust is trivalent chromium due to the chemical instability of hexavalent chromium. However, as indicated, this assumption cannot be founded by actual data. Trivalent chromium is expected to be present predominantly as insoluble compound (in parallel to soil in which the insoluble forms as carbonate and oxide dominate, chromium dissolves only when complexation is possible).

Assuming chromium to be present in house dust predominantly as insoluble trivalent ion, all risk indices are close to zero, indicating absence of a potential risk.

6.5 Copper

Copper is an essential trace nutrient to humans. Nevertheless high concentrations of copper can be toxic. Based on the maximum value in house dust, copper can cause a potential risk for children (risk index 0.83 and 1.7 for an adult and child, respectively, see Table 10). When calculations were performed using the P95 or the highest geometric mean, no potential risk was found. The highest copper concentration in house dust encountered in literature (12540 mg/kg) was much higher than the 95^{th}-percentile concentration (489 mg/kg) and the geometric mean (261 mg/kg). This indicates that the highest value may be an extreme situation. It is therefore unlikely that background exposure and exposure via house dust to copper would actually result in a potential risk for human health.
Crucially, in general copper exposure via house dust accounts for only a small percentage of the TDI (about 0.4% for a child at the P95-exposure level). About 72% of the TDI is filled up by background exposure via food and water intake. Hence, house dust is in most cases only a minor exposure route for copper.

Table 10. Overview of risk indices for copper based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.73	0.002	0.74	0.021
P95 conc.	0.73	0.004	0.76	0.039
Max. conc.	0.83	0.11	**1.7**	1.0

Table 10 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

6.6 Lead

As can be seen in Table 11, the TDI of lead can be exceeded considerably when both background exposure and exposure to house dust are taken into account. House dust exposure on its own already exceeds the TDI on a regular basis, as becomes apparent from the risk index of 2.7 for children based on the highest geometric mean value of lead in house dust found in literature.
As is known from the extensive literature on lead health effects, children are a vulnerable group for lead toxicity and the TDI for lead has been derived from data on health effects in this particular group. The basic principle in this derivation is that any increase in blood lead levels in children is unwanted from a toxicological point of view given the high neurotoxic potential of lead as demonstrated in numerous human studies. Thus this TDI does not incorporate the usual margins introduced by uncertainty factors but is based on actual data from the sensitive subgroup in the population. This implies that exposure to lead cannot be integrated over childhood and adult years, and thus that exceedance of the TDI for children represents a potential health risk. As can be seen from Table 12, exposure via house dust results in potential health risks on a regular basis, and house dust is an important exposure route in many cases. It is therefore concluded that lead in house dust results in potential health risks on a regular basis.

In a recent study by RIVM (Oomen *et al.*, 2007) lead concentrations in house dust from 45 houses were determined. Both in the near vicinity of a zinc smelter and in the control area lead concentrations in house dust were occasionally high (up to 2560 mg/kg). The latter lead concentration in house dust is associated with a risk index of 0.81 for an adult and 5.2 for a child, representing 51% and 474% of the TDI of lead without background.

The high lead concentrations in house dust were assumed to be mainly related to certain hobbies or behaviours (soldering, hunting), and in most cases no clear relationship with the environment could be found (Oomen *et al.*, 2007). However, other studies have shown that also outdoor soil may cause high lead levels in indoor house dust, due to the large fraction of soil components in house dust (Gulson *et al.*, 1995).

Table 11. Overview of risk indices for lead based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.54	0.24	**2.7**	2.2
P95 conc.	0.57	0.26	**2.9**	2.4
Max. conc.	**7.7**	7.3	**69**	69
Highest conc. Netherlands[2]	**0.81**	0.51	**5.2**	4.7

Table 11 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

2. Highest concentration encountered in a study in the Dutch Kempen area (Oomen *et al.*, 2007).

For lead it should be noted that for the calculation of the above risk indices a background exposure was used reflecting the intake via food and water consumption and via soil ingestion, i.e. exclusive of house dust. This estimate was based on a document from the Dutch Health Council (Dutch Health Council (Gezondheidsraad), 1997) in which estimates were developed for the daily intake of lead by the Dutch population via different routes. For a child a maximum intake of 1.33 µg/kg bw/day was estimated for food and water intake. For an adult this was estimated at 0.86 µg/kg bw/day. Soil and dust intake together was estimated to account for 1.0 µg/kg bw/day for a child. A child would have about half this amount via soil and dust. Assuming that lead exposures via soil and dust intake contribute approximately equally (0.5 µg/kg bw/day) a background exposure of 1.83 µg/kg bw/day is derived for a child and 1.11 µg/kg bw/day for an adult.

6.7 Manganese

Manganese is an essential trace nutrient to humans. Manganese is present in many foods, including grains and cereals, and is found in high concentrations in many foods, such as tea. Based on the maximum value in house dust, manganese was identified as a potential risk for children (risk index 1.2, see Table 12). When calculations were performed using the P95 or the highest geometric mean, no potential risk was found (risk index 0.83). As can be seen in Table 6, there is a large difference between the maximum concentration (9410 mg/kg) and the P95-concentration (407 mg/kg). The maximum value is assumed to occur in extreme conditions. Only two references with data on manganese levels in house dust were found. Although the two references described similar concentration in house dust, the variation in manganese levels in house dust and the relevance of these data for the Dutch situation are unknown.
Importantly, the contribution of house dust accounts for only a few percent of the TDI in most cases (1.7% for the P95-exposure values for children). It is therefore concluded that it is unlikely that manganese in house dust in will increase background exposure to the extent of posing an actual risk for human health.

Table 12. Overview of risk indices for manganese based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.81	0.001	0.82	0.011
P95 conc.	0.81	0.002	0.83	0.017
Max. conc.	0.85	0.042	**1.2**	0.39

Table 12 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

6.8 Nickel

The risk index for nickel does not exceed 1, not even for the highest encountered house dust concentration in literature. However, the risk index was very close to 1 (0.96 for

highest dust concentration for children, see Table 13). Background exposure of a child already accounts for 80% of the TDI. The contribution of house dust to the total exposure is usually low (7.8% of the TDI is filled up for the P95-exposure data). The risk index for adults is even for the maximum concentration in house dust less than 0.5 (0.42), indicating that a health risk is not anticipated.

Table 13. Overview of risk indices for nickel based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.40	0.003	0.83	0.031
P95 conc.	0.41	0.008	0.88	0.078
Max. conc.	0.42	0.017	0.96	0.16

Table 13 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

6.9 Zinc

Zinc is one of the most common elements in the earth's crust. Zinc is found in air, soil, and water and is present in all foods. Zinc enters air, water, and soil as a result of both natural processes and human activities. The latter involve mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes.

Exposure to zinc via house dust usually accounts for a minor part of the total daily exposure only (2% of the TDI for children is filled up for the P95-concentration in house dust, see Table 14). The background exposure via food already accounts for 70% of the TDI. The risk index is only greater than 1 for children at the highest encountered house dust concentration of 30600 mg/kg. This appears to be an exceptionally high concentration, as the concentration at the 95th-percentile is 1570 mg/kg. In a recent study in the Netherlands in 45 houses, including 15 houses in the direct neighbourhood of a zinc smelter, the highest zinc concentration in house dust was 1724 mg/kg. Hence, it is concluded that it is highly unlikely that zinc in house dust poses a potential health risk to humans.

Table 14. Overview of risk indices for zinc based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.70	0.001	0.71	0.008
P95 conc.	0.70	0.002	0.72	0.021
Max. conc.	0.74	0.044	**1.1**	0.41
Highest conc. Netherlands [2]	0.70	0.003	0.72	0.023

Table 14 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

2. Highest concentration encountered in a study in the Dutch Kempen area (Oomen *et al.*, 2007).

6.10 Di(2-ethylhexyl)phthalate (DEHP)

DEHP is used as a plasticiser in PVC. Because of its toxic potential specifically for human reproductive development (hormonal disruption) DEHP along with several other phthalates has been banned from use in toys and childcare articles within the EU (Directive 2005/84/EC). For other applications these compounds remain in use, including in food contact materials and various consumer products such as carpets and upholstery.

Background exposure to DEHP via food and water intake is estimated at 12-26 µg/kg bw/day for a child and 3-16 µg/kg bw/day for an adult (EFSA, 2005). The background exposure already fills up the TDI of 50.0 µg/kg bw/day to 24-52% for a child, and 6-32% for an adult. In addition to background exposure, house dust is an important exposure route to DEHP. The risk index is exceeded 5.9-fold for the highest house dust concentration described in literature for children, with house dust responsible for a 5.4-fold exceedance of the TDI, see Table 15. Already the highest geometric mean concentration of DEHP in house dust results in a risk index near 1 for children (0.95; of which 0.43 is due to exposure to house dust only). The risk index for adults is not exceeded. Given the toxicological basis for the TDI for DEHP with disruption of reproductive development in males as the critical effect, lower levels of exposure later in life do not compensate for exceedance of the TDI during child age. Hence, exposure to

DEHP should not be integrated over life, and risk indices for children should be evaluated as such. In conclusion, DEHP poses a human health risk, both due to the background exposure and due to house dust intake.

It is unlikely that the other phthalates result in potential health risks, although the risk index for DBP in combination with DMPP and DiBP is rather high for the highest concentration found in literature (0.73 for children). Also the risk index for the highest concentration found in literature of BBP is not negligible (0.63 for children).

Table 15. Overview of risk indices for DEHP based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the TDI.

	Adult		Child	
	Risk Index	Exposure house dust compared to TDI[1]	Risk Index	Exposure house dust compared to TDI[1]
Mean conc.	0.37	0.05	0.95	0.43
P95 conc.	0.42	0.10	**1.5**	0.94
Max. conc.	0.90	0.58	**5.9**	5.4

Table 15 – Remarks

1. Exposure via house dust compared to TDI calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the TDI.

$$\text{Exposure house dust compared to TDI} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{TDI (µg/kg bw/day)}}$$

6.11 Sum PAHs

A number of PAHs, including benzo(a)pyrene (BaP), are genotoxic carcinogens. In the present report the so-called *indicator approach* (also denominated as the 'surrogate approach') was used for PAHs, which involves using benzo(a)pyrene as the marker for the total mixture, both in quantifying risk and exposure. Although the use of the more complex 'potency approach' (in which for individual PAHs potency factors applied to calculate BaP-equivalents) is in principle more appropriate for environmental contaminations (see RIVM, 2001), within the inherent uncertainty boundaries of the present calculation of Risk Indices, we deemed the use of the more simple indicator approach acceptable.
For the total mixture of PAHs the Maximum Permissible Risk (MPR), which according to Dutch environmental policy equals the risk-specific dose for one in ten thousand per lifetime, is 50 ng BaP/kg bw/day (this figure applies to BaP as the marker for the PAH mixture as a whole). Background exposure to PAHs is low compared to this MPR

(6 ng BaP/kg bw/day for an adult and 15 ng BaP/kg bw/day for a child). Remarkably the MPR is sometimes exceeded due to exposure via house dust. For the 95th percentile data, the risk index is 0.31 and 2.0 for adults and children, respectively, see Table 16. The risk index for the geometric mean concentration of the sum of PAHs in house dust is 0.12 and 0.34 for adults and children, respectively. In conclusion, in most cases the PAH contents of house dust does not result in a health risk higher than the MPR. However for high PAH concentrations (e.g. 95th percentile) exposure via house dust is greater than via food, leading even to exceedance of the MPR. Given the general policy of reducing exposures to the genotoxic and carcinogenic PAH via food to levels as low as reasonably possible, this high exposure via house dust is significant.

Indoor sources of PAHs include cooking, heating, cigarette-smoking, wood burning, candle burning, and incense burning. Outdoor sources include vehicle exhaust and industrial processes such as aluminium smelting, coke production, and petroleum refining (Maertens *et al.*, 2004). Maertens *et al.* reviewed the data of 18 studies and concluded that an urban location and the presence of cigarette smokers increased the PAH content of house dust (Maertens *et al.*, 2004). Yet, correlations were weak, indicating that other factors (e.g. flooring type, season, deposition rate, ventilation, social-economic status) may affect the PAH content as well.

Table 16. Overview of risk indices for sum of PAHs[1] based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is accounted for). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the MPR[2].

	Adult		Child	
	Risk Index	Exposure house dust compared to MPR[2]	Risk Index	Exposure house dust compared to MPR[2]
Mean conc.	0.12	0.004	0.34	0.04
P95 conc.	0.31	0.18	**2.0**	1.7
Max. conc.	0.89	0.77	**7.5**	7.2

Table 16 – Remarks

1. Calculation for the sum of PAHs is based on a so-called 'surrogate approach'. The benzo[a]pyrene concentration is considered to be representative for the entire PAH concentration, but is compared to a 10-times lower toxicological reference value to compensate for the other PAHs.
2. For genotoxic carcinogens no TDIs are derived but the denomination 'MPR' is used, defined within Dutch environmental policy as an extra cancer risk of 1 in 10.000 people based on lifetime exposure. Exposure via house dust compared to MTR calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the MPR.

$$\text{Exposure house dust compared to MPR} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{MPR (µg/kg bw/day)}}$$

6.12 Brominated flame retardants

6.12.1 Toxicological reference values

A major issue with brominated flame retardants is that internationally accepted TDI values for either individual congeners or the sum of brominated flame retardants are not yet available (De Winter-Sorkina *et al.*, 2006). To compensate for this, De Winter-Sorkina *et al.* derived a (provisional) maximal allowable intake level for one congener, BDE99, of 0.26 ng/kg bw/day (De Winter-Sorkina *et al.*, 2006; Bakker *et al.*, in press), which is also used here. In the same report also the median of the averaged life-long daily dietary intake of BDE99 is estimated at 0.11 ng/kg bw/day for the Dutch population (0.23 and 0.10 ng/kg bw/day for a 2-year old child and an adult, respectively). As indication of the distribution of the exposure to BDE99 via food, the 99th-percentile of the averaged life-long daily dietary intake to BDE99 is given, amounting to 0.24 ng/kg bw/day.

6.12.2 Ban on several brominated flame retardants

Not all PBDEs are still in use, although differences between countries exist. The penta-BDE technical product (including BDE 99) was voluntarily withdrawn from use in the European Union during the last 10 years. Use of penta-BDE and octa-BDE technical products in all applications for the European Union market has officially been banned since August 2004. The use of penta-BDE, octa-BDE and PBBs in new electrical and electronic equipment has been banned since July 2006 (De Winter-Sorkina *et al.*, 2006). However, hexa-BDE (e.g. BDE 153 and 154) and deca-BDE (e.g. BDE 209) and other groups of brominated flame retardants are still in use, with especially a high production of deca-BDE (e.g. BDE 209) (De Boer and Wells, 2006). It has been postulated that due to the European ban on several PBDEs, concentrations of most PBDEs in house dust in this part of the world might be significantly lower than concentrations in the United States (Harrad *et al.*, in press). However, this is still under discussion.

6.12.3 Possibility of a potential health risk for BDE99

A potential health risk due to exposure via house dust is identified for the only congener for which a provisional toxicological reference value is available (BDE99). This is shown by the calculated risk indices, which are for adults and children 0.45 and 1.5 respectively for the geometric mean concentration data in house dust, 0.8 and 5.0 for 95th-percentile data, and 22 and 204 for the maximum concentration data encountered in the EU (see Table 17). As background exposure the estimated median daily dietary intake levels for a child (0.23 ng/kg bw/day) and an adult (0.10 ng/kg bw/day) were used. The contribution of house dust to the exposure to BDE99 is considerable, especially for children. For example, 6% and 57% of the allowable daily intake level is filled up by dust intake for adults and children based on the EU geometric mean data.
For comparison to the maximum allowable intake level, exposure over an entire lifetime should be considered. As Table 17 shows, the expected exposure due to dust (including

food) intake is expected to exceed the maximum allowable intake level on a regularly basis both for adults and children. In addition, a pilot study on the release of PBDEs in a system that simulates the physicochemical conditions of the human gastrointestinal tract suggests that PBDEs are easily released from the dust into the gastrointestinal fluids and can become available for intestinal uptake (De Boer, 2007). This suggests that the bioavailability of PBDEs in house dust may be high. This leads to the conclusion of a potential health risk due to BDE99.

Table 17. Overview of risk indices for BDE99 in Europe based on the highest encountered geometric mean, P95 and maximum concentration data encountered in house dust (background exposure is based on estimated median daily dietary intake levels for children and adults). The contribution of the exposure via house dust to the total exposure is described in the second column for an adult and child by comparison to the (provisional) maximal allowable intake level.

	Adult		Child	
	Risk Index	Exposure house dust compared to maximal allowable intake level[1]	Risk Index	Exposure house dust compared to maximal allowable intake level[1]
Mean conc.	0.45	0.06	**1.5**	0.57
P95 conc.	**0.8**	0.41	**5.0**	3.8
Max. conc.	**22**	22	**204**	203

Table 17 – Remarks

1. A (provisional) maximal allowable intake level is used because no TDI-value for PBDEs has been derived up till now. Exposure via house dust compared to this (provisional) maximal allowable intake level is calculated as a factor. When the factor is greater than 1, the exposure route via house dust on its own exceeds the intake level.

$$\text{Exposure house dust compared to intake level} = \frac{\text{exposure via house dust (µg/kg bw/day)}}{\text{maximal allowable intake level (µg/kg bw/day)}}$$

6.12.4 Comparison intake via house dust and food

For several other PBDE-congeners than BDE99 for which reliable information on levels in house dust is available, no toxicological reference values are available. Therefore, we only compare exposure to these congeners via intake of house dust to exposure via food. The contribution of house dust seems to be greater for BDE99 than for BDE47, BDE100 and BDE183, see Table 18. Only for high concentrations in dust, intake of BDE47 and BDE100 via this route dominates over the median dietary intake, at least within the EU.

Table 18. Ratio of various PBDE-congeners between estimated intake via house dust and food. Ratios are calculated based on geometric mean and 95th-percentile ingestion levels via house dust and median dietary intake levels for a child and an adult. When the ratio is greater than 1, intake via house dust dominates over the median intake via food.

	Ratio $\frac{\text{intake via house dust}}{\text{intake via food}}$ (unitless)			
	Mean ingestion adult	Mean ingestion child	P95 ingestion adult	P95 ingestion child
BDE 47 - EU	0.06	0.13	**1.2**	**2.3**
BDE 99 - EU	0.16	0.64	**1.1**	**4.3**
BDE 99 – US [1]	16	67		
BDE 100 - EU	0.10	0.35	**1.7**	**5.8**
BDE 183 - EU	0.02	0.07	0.13	0.46

Table 18 – Remarks

1. Levels of PBDE in house dust are much higher (depending on the congener, in most cases at least tenfold) in the United States compared to the European Union.

6.12.5 Comparison of exposure BDE209 via house dust to other congeners

For BDE209 neither a toxicological reference value nor reliable information exposure via food consumption are available. The latter is due to analytical problems related with the analysis of BDE209 in food samples, mainly caused by high background levels (De Boer *et al.*, 2006). The concentrations of BDE209 in house dust are much higher than in food so that these data are assumed to be reliable. Given this, it seems worthwhile to compare exposure of BDE209 via house dust to exposure to other PBDEs via this route. Based on the geometric mean concentrations of the European Union data, the concentration of BDE209 in house dust is higher by factors of 31, 38, 88, and 94 respectively than the concentrations of BDE47, BDE99, BDE100, and BDE183.
This indicates that human exposure of BDE209 via house dust may be (much) greater than via food intake. In addition, when looking at total PBDE exposure via house dust, the major fraction is BDE209. In order to arrive at more definitive conclusions, a toxicological reference value for BDE209 in particular is needed. However, for a full evaluation of the risks of BDEs in general, also toxicity reference values for the other congeners are necessary too. To derive toxicological reference values for BDEs, additional toxicity studies are urgently required.

6.12.6 Other brominated flame retardants

A further brominated flame retardant, tetrabromobisphenol-A (TBBP-A), was not found toxic for rodents in dose levels up to 1000-10000 mg/kg/day (EU RAR, 2003)(De Winter-Sorkina *et al.*, 2006), so this substance does not seem to be of concern for human health.

6.12.7 Non-brominated flame retardants

It should be noted that other flame retardants are emerging, some of which are similarly persistent and bioaccumulative as PBDEs. Compounds such as Dechlorane-plus (a chlorinated flame retardant) (Zhu *et al.*, 2007) and fluor-containing flame retardant are gaining attention as substances possibly posing a human health risk. However, at the moment too little information about these substances is available to be able to draw any conclusions. It is recommended to pay attention to these substances and assess their potential health risk in the near future.

6.13 Measures that can decrease the exposure to substances in house dust

A simple measure to decrease the exposure to substances in house dust is cleaning. But only few scientific papers address this issue, making it difficult to draw general conclusions. Some research has focussed on the effect of cleaning on the exposure to lead in house dust. Yinn *et al.* showed a significant reduction in lead loading on soiled carpets after vacuum cleaning (New Yersey, US) (Yiin *et al.*, 2002). They also performed a randomized study to determine whether a conventional vacuum cleaner could achieve cleaning-results comparable with those of a high-efficiency particulate air filtered vacuum cleaner. They found no differences in lead loading reduction between the two vacuum cleaners, from which they concluded that both vacuum cleaners showed a lead loading reduction. In contrast to this finding, Paustenbach *et al.* showed that most conventional vacuum cleaners do not trap small particles(< 20 μm) but simply re-emit them into the air (references in (Paustenbach *et al.*, 1997)). Therefore, when considering cleaning as a measure to decrease exposure to substances, Paustenbach *et al.* advised to do wet cleaning (e.g. mopping, washing). In addition, the Australian EPA advises to clean wet with high phosphate detergents as a measure to decrease exposure to lead via house dust (http://www.epa.nsw.gov.au/leadsafe). It is also recommended to do the wet mopping at least an hour after vacuuming so that dust particles can settle. Based on these studies, wet cleaning is preferred over vacuuming to decrease the exposure to substances present in house dust.

Campbell *et al.* measured dust and blood lead levels in children to monitor the effectiveness of professional home cleaning (Philadelphia, US) (Campbell *et al.*, 2003). They found lower blood lead levels among children in homes with low precleaning dust lead levels, compared with the blood lead levels of children who lived in high-exposure homes, indicating that house dust is an important exposure route for lead. In addition, professional cleaning produced immediate reductions of 36% in dust lead levels. However, lead dust levels rebounded to levels before professional cleaning within three to six months. Thus, regular cleaning will be required if blood lead or dust lead levels are to be reduced and sustained at low levels.

This re-increase in substance levels in dust will occur primarily if the source of the substances in house dust remains present. Where sources can be identified and removed exposure via house dust is structurally decreased. Examples of such sources are mainly known for lead: soldering, presence of lead bullets in the home for hunting purposes, leaded paint (a major problem in older houses in the US). Furthermore, habits such as smoking may increase the amount of several metals and PAHs in the home substantially.

In conclusion, if possible the source of the substances in house dust should be identified and measures should be taken to prevent further contamination in the future. Dust control may be effective if performed properly (preferentially by wet cleaning) and regularly. Under controllend circumstances measures could be evaluated after some time by analysis of dust samples as resurgence to former substance concentrations may occur.

7 Conclusions

The present report assesses the substances for which a potential human health risk due to exposure to house dust is possible. The research was limited to metals, organotin compounds, phthalates, brominated flame retardants, pesticides, and polycyclic aromatic hydrocarbons. We estimated exposure levels based on house dust data obtained from literature, also taking into account exposure via other routes (background). Subsequently we compared exposure to toxicological reference values by calculating risk indices (exposure divided by tolerable daily intakes). For most substances a human health risk is not anticipated, even with the conservative assumptions made.

The compounds for which a health risk due to exposure to house dust may be possible are: lead, di(2-ethylhexyl)-phthalate (DEHP), followed by arsenic, cadmium, PAHs and polybrominated diphenyl ethers (PBDEs). Of the PBDEs a health risk could only be identified for congener 99, as for this congener a provisionally maximum allowable intake level was available. Further research is recommended to evaluate the toxicity of the other PBDEs in general. In the present framework, a toxicological reference value is especially needed for BDE209 as the major fraction of the exposure to PBDEs via house dust consists of BDE209, whereas the contribution of food to the total exposure is expected to be small. The other BDE congeners may also result in potential health risks but this is unknown due to the lack of toxicity data, but BDE99 indicates that the exposure to this congener is borderline to its human health exposure limit value (Bakker *et al.*, in press). However, for several other congeners the contribution of food to the total exposure is expected to be larger than the contribution of house dust. Yet, it is important to assess risks to substances through various exposure routes so that health risks can be identified and measures can be taken effectively.

In Table 19 we give qualitative indications of these potential risks based on further analysis. The most important issues with these substances are briefly discussed below.

In conclusion, the substances for which a potential health risk due to exposure via house dust is expected to occur most frequently are lead and DEHP, followed by arsenic, cadmium, sum PAHs, and PBDEs (health risk identified for BDE99; risk assessment was not possible for other BDE-congeners due to lack of toxicity data).

Table 19. Qualitative indications on the substances for which there may be a health risk due to exposure via house dust.

Compound	Potential risk for human health [1]
Aluminium	Unlikely
Arsenic	Likely (but at high end of exposure only)
Cadmium	Likely (but at high end of exposure only)
Chromium	Unlikely
Copper	Highly unlikely
Lead	Likely
Manganese	Highly unlikely
Nickel	Highly unlikely
Zinc	Highly unlikely
Di(2-ethylhexyl)-phthalate (DEHP)	Likely
Sum PAHs	Likely (but at high end of exposure only)
BDE99	Likely (but at high end of exposure only)

Table 19 – Remarks

1. A potential health risk is considered to be present if the background exposure and the exposure via house dust are greater than the toxicologically derived reference level expressed as the TDI.

Aluminium. Calculated risk indices remained below 1.0, even for children at the maximum aluminium concentration in house dust. Aluminium concentrations in house dust were reported in one study only; no information is available for the Dutch situation. Although contribution of house dust to total aluminium exposure can be considerable (for example 39% of the TDI for P95-exposure data for children), the possibility of a health risk is unlikely. Conclusion, however, is weak due to limited information.

Arsenic. The risk index for a child is often greater than 1, indicating exposure via house dust and background in excess of the TDI. The contribution of house dust to the total exposure is substantial (the highest geometric mean concentration in house dust corresponds with 47% of the TDI). When comparing with the TDI, arsenic exposure should be treated as a long-term average. Due to the lower exposure during adult years the risk index integrated over childhood and adult years is mostly not exceeded. Nevertheless, given the general picture for arsenic health risks of only a limited margin between actual intakes and levels known to produce toxic effects when humans are exposed to them chronically, arsenic exposure in general should preferably be as low as possible.

Cadmium. Important for cadmium is that the background exposure to cadmium via food and water intake already accounts for 90% of the TDI. Yet, house dust can contribute considerably in some cases. For example, exposure via house dust at the geometric mean concentration accounts for 17% of the TDI for a child. Given the toxic action of cadmium (induction of nephrotoxicity over a period of many years) exposure during childhood and

adult years should be integrated to assess the possibility of a human health risk. This integration would in many cases result in risk indices < 1. Despite this absence of an actual health risk, elevated exposure to cadmium is undesirable and a policy of reducing its exposure via food and other routes is followed by health authorities. Thus levels in house dust should also be as low as possible.

Chromium. From a toxicological point of view trivalent and hexavalent chromium should be differentiated. Hexavalent chromium is much more toxic than trivalent chromium. Soluble trivalent chromium in turn is more toxic than insoluble trivalent chromium. Available data on chromium concentrations in house dust represent total chromium, i.e. without specification of valence and solubility. A priori it is plausible that chromium in house dust is trivalent chromium due to the chemical instability of hexavalent chromium. Trivalent chromium is expected to be present predominantly as insoluble compound (in parallel to soil in which the insoluble forms as carbonate and oxide dominate, chromium dissolves only when complexation is possible). The estimated risk based on insoluble trivalent chromium in house dust is negligible.

Copper. The background exposure to copper via food and water intake already accounts for 72% of the TDI. Exposure via house dust usually represents only a minor exposure route.
Only a potential health risk for children could be calculated with the highest copper concentration found in literature. This highest copper concentration is assumed to be an extreme situation as 95th-percentile and geometric mean concentrations were a factor 26 and 48 lower, respectively. Hence, it is highly unlikely that copper in house dust results in a potential health risk.

Lead. Exceedance of the TDI for children is unwanted since this population group is especially vulnerable to toxicity caused by lead. Available data indicate that house dust regularly contains lead concentrations that cause a potential health risk for children. For example, at the highest geometric mean concentration the risk index is 2.7, mainly due to exposure to lead via house dust. It is assumed that in many case hobbies or specific behaviour are the cause of high lead concentrations in dust but also lead from outdoor soil may contribute substantially to the high lead levels in dust. In conclusion, a potential health risk due to lead in house dust occurs on a regular basis.

Manganese. Only in extreme situations the risk index is exceeded for children (based on the highest manganese concentration described in literature, which was very high in comparison to the P95 value). Background exposure to manganese via food and water intake already accounts for 81% of the TDI. Exposure via house dust usually represents only a minor exposure route. This indicates that it is highly unlikely that manganese in house dust results in a potential health risk.

Nickel. Only in extreme situations the risk index can be exceeded (based on the highest nickel concentration described in literature a risk index close to 1 was obtained).

The background exposure to nickel via food and water intake already accounts for 80% of the TDI. Exposure via house dust usually represents only a minor exposure route. This indicates that it is highly unlikely that nickel in house dust results in a potential health risk.

Zinc. The background exposure to zinc via food intake accounts for 70% of the TDI, whereas exposure via house dust usually represents only a minor exposure route (2.1% of the TDI for children is filled up for the P95-concentration in house dust). The risk index was only exceeded for the maximum concentration, which seems to be an exceptionally high concentration with regard to other data and concentrations determined in house dust in the Netherlands. This indicates that it is highly unlikely that zinc in house dust results in a potential health risk.

Di(2-ethylhexyl)-phthalate (DEHP). The background exposure to DEHP due to consumption of food and drinking water accounts for 24-52% of the TDI for a child and 6-32% for an adult. The extra exposure via house dust may lead to marked exceedance of the TDI for both adults and especially children. Given the toxicological basis for the TDI for DEHP with disruption of reproductive development in males as the critical effect, lower levels of exposure later in life do not compensate for exceedance of the TDI during child age. Accordingly exposure should not be integrated over an entire life for DEHP when comparing to its TDI. In conclusion, DEHP poses a human health risk during child age, both due to the background exposure and due to house dust intake.

Sum PAHs. In the present report the so-called indicator approach was used for PAHs, which involves using benzo(a)pyrene as the marker for the total mixture, both in quantifying risk and exposure. Background exposure to PAHs is low compared to the Maximum Permisible Risk (MPR) (12% of the MPR is filled up by the background exposure for an adult and 30% for a child). Remarkably the MPR is sometimes exceeded due to exposure via house dust. Given the general policy of making exposures to the genotoxic and carcinogenic PAH via food as low as reasonably possible, this potentially high exposure via house dust is significant.

BDE99. A potential health risk due to exposure via house dust is identified for the only congener for which a toxicological reference value is available (BDE99). This is shown by the risk indices for adults and children respectively of 0.45 and 1.5 for the geometric mean concentration data in house dust. The contribution of house dust to the exposure to BDE99 may be considerable, especially for children. For example, 6% and 57% of the allowable daily intake level may be filled up by dust intake for adults and children based on the EU geometric mean data. For comparison of the exposure to the provisional toxicological reference dose, the exposure over an entire lifetime should be considered. As the expected exposure due to dust (and food) intake is expected to exceed the maximum allowable intake level on a regular basis both for adults and children, a potential health risk due to BDE99 is expected to occur regularly.
Comparison between concentrations of BDE209 to other BDE-congeners in house dust indicates that human exposure to BDE209 via house dust may be (much) greater than to the other congeners, and is probably also much greater than exposure to BDE209 via food intake. In order to arrive at more definitive conclusions a toxicological reference value for

BDE209 in particular should become available, which is also highly recommended for the other PBDE congeners. In order to derive toxicological reference values additional toxicity studies are required.

Measures to decrease human exposure to substances in house dust. Little is known about measures to prevent human exposure to substances via house dust. If possible the source of the substances in house dust should be identified and measures should be taken to prevent further contamination in the future. Dust control may be effective if performed properly (preferably by wet cleaning) and regularly. The measures should be evaluated after some time by analysis of dust samples as rebouncing to former substance concentrations may occur.

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Appendix 1. References on substances in house dust

Table Appendix 1. Information on the references in which information on the concentrations of substances in house dust was found.

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Metals							
Aluminium	24281	51100	44225	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Antimony	25.5	66.4		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Antimony	5.5	14.7		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Antimony	5.54	57.4	15.4	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Arsenic	2.6	57.1		container	Germany-Hettstedt	(Meyer *et al.*, 1999)	
Arsenic	9.00			vacuum	USA-Utah	(Lanphear *et al.*, 2003)	
Arsenic	26.3	79.7		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Arsenic	12.2	17.6		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Arsenic	70.1	192	114.2 (P90)	vacuum	USA-Hayden	(Hysong *et al.*, 2003)	Copper mining/smelting town
Arsenic	46.7	130	88 (P90)	vacuum	USA-Winkelman	(Hysong *et al.*, 2003)	Copper mining/smelting town
Arsenic	4.9	79.5	18.5	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Arsenic	2.09	182	6.7	vacuum	Germany	(Seifert *et al.*, 2000)	
Barium	454	1480	803	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Beryllium	0.53	1.0	0.90	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Bismuth	1.02	8.62	6.48	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Cadmium	2.6	52.7		container	Germany-Hettstedt	(Meyer *et al.*, 1999)	
Cadmium	13	52.0		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Metals							
Cadmium	2.2	3.0		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Cadmium	4.42	34.9	17.3	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Cadmium	0.86	220	5.6	vacuum	Germany	(Seifert *et al.*, 2000)	
Chromium	111	188		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Chromium	159	5440		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Chromium	66			wipe	USA-New Jersey	(Freeman *et al.*, 1997)	
Chromium	75.4	330.3	191.8	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Chromium	64.2	1330	178	vacuum	Germany	(Seifert *et al.*, 2000)	
Cobalt	17	20		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Cobalt	12	20		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Cobalt	8.40	22.7	13.1	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Copper	261	396		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Copper	120	364		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Copper	171	601	489	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Copper	79.9	12540	339	vacuum	Germany	(Seifert *et al.*, 2000)	
Lead	1200	18600		wipe	USA-New Jersey	(Adgate *et al.*, 1998a)	
Lead	857			vacuum		(Adgate *et al.*, 1998b)	
Lead	1660	2594		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Lead	477	1150		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Lead	127			vacuum	USA-Utah	(Lanphear *et al.*, 2003)	
Lead	128	1947		container	Germany-Hettstedt	(Meyer *et al.*, 1999)	
Lead	233	3226	1312	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Lead	5.9	37000	178	vacuum	Germany	(Seifert *et al.*, 2000)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Metals							
Lead	120	830		vacuum	USA-Idaho	(Spalinger *et al.*, 2007)	Average of all towns measured
Lithium	6.1	15.5	8.2	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Magnesium	9442	23250	13390	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Magnesium	2110	52000	6400	vacuum	Germany	(Seifert *et al.*, 2000)	
Manganese	260.3	423.5	407.3	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Manganese	109	9410	333	vacuum	Germany	(Seifert *et al.*, 2000)	
Mercury	1.73	37,099	12,558	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Molybdenum	2.8	6.5		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Molybdenum	1.5	6.7		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Molybdenum	1.96	28.64	14.22	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Nickel	47	80		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Nickel	26	50		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Nickel	53.6	243.3	116.4	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Rubidium	24.6	40.2	34.9	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Selenium	1.0	6.8	2.2	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Silver	1.48	9.33	6.50	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Metals							
Strontium	242	410	382	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Strontium	32.1	1170	119	vacuum	Germany	(Seifert *et al.*, 2000)	
Tellurium	0.07	0.28	0.13	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Thallium	0.14	0.24	0.21	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Tin	21.87	595.02	221.33	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Titanium	2854	4527		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Titanium	2835	4983		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Tungsten	3.7	5.6		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Tungsten	2.8	5.2		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Uranium	0.55	1.33	1.06	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Vanadium	112	163		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Vanadium	107	193		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Vanadium	23.7	43.6	39.9	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Zinc	17294	57400		ceiling brush	Australia	(Davis *et al.*, 2005)	Industrial setting
Zinc	577	1160		ceiling brush	Australia	(Davis *et al.*, 2005)	Non-industrial setting
Zinc	628.0	1840	1460.8	vacuum	Canada-Ottawa	(Rasmussen *et al.*, 2001)	
Zinc	475	30600	1570	vacuum	Germany	(Seifert *et al.*, 2000)	
Organotin compounds							
Dibutyltin (DBT)	0.51	5.60	3.28	vacuum	Germany-Berlin	(Fromme *et al.*, 2005)	
Dioctyltin (DOT)	0.02	0.36	0.03	vacuum	Germany-Berlin	(Fromme *et al.*, 2005)	
Monobutyltin (MBT)	0.16	1.50	0.70	vacuum	Germany-Berlin	(Fromme *et al.*, 2005)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Organotin compounds							
Monooctyltin (MOT)	0.01	0.04	0.03	vacuum	Germany-Berlin	(Fromme *et al.*, 2005)	
Tributyltin (TBT)	0.02	0.08	0.07	vacuum	Germany-Berlin	(Fromme *et al.*, 2005)	
Pesticides							
2,4-D	1.24	7.29		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
2,4-D	330 µg/kg			surface sampler	USA-Iowa	(Curwin *et al.*, 2005)	Non-farm
2,4-D		1.5		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Alachlor		1.5		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Aldrin	0.006	0.051		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
alpha-Chlordane[1]	0.055	0.256		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
alpha-HCH	0.7 µg/kg	0.0087		airconditioning	Singapore	(Tan *et al.*, 2007b)	
Altazine		0.5		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Atrazine	2.3 µg/kg			surface sampler	USA-Iowa	(Curwin *et al.*, 2005)	Non-farm
Azinphos methyl	0.29	1.1		vacuum	USA-Washington	(Lu *et al.*, 2000)	Non-farm
Azinphos methyl	0.330	0.816		surface sampler	USA-Washington	(Simcox *et al.*, 1995)	Non-farm
AZM	5.9	16		surface sampler	USA-Oregon	(Rothlein *et al.*, 2006)	
beta-HCH	2.2 µg/kg	0.057		airconditioning	Singapore	(Tan *et al.*, 2007b)	
Carbaryl		1.0		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Chloroprofam		0.17		vacuum	The Netherlands	(Hogenkamp *et al.*, 2004)	Non-farm
Chlorpyrifos	1.04	6.45		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Chlorpyrifos	0.54			vacuum	USA-Washington	(Fenske *et al.*, 2002)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Pesticides							
Chlorpyrifos	0.38			vacuum	USA-Washington	(Fenske *et al.*, 2002)	
Chlorpyrifos	30 µg/kg			surface sampler	USA-Iowa	(Curwin *et al.*, 2005)	Non-farm
Chlorpyrifos		1.7		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Chlorpyrifos	0.20	1.2		surface sampler	USA-Oregon	(Rothlein *et al.*, 2006)	
Chlorpyrifos	0.168	0.483		surface sampler	USA-Washington	(Simcox *et al.*, 1995)	Non-farm
Cis- Chlordane[1]	2.6 µg/kg	0.039		airconditioning	Singapore	(Tan *et al.*, 2007b)	
DDD	4.7 µg/kg	0.048		airconditioning	Singapore	(Tan *et al.*, 2007b)	
DDE	0.007	0.047		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
DDE	5.9 µg/kg	0.05		airconditioning	Singapore	(Tan *et al.*, 2007b)	
DDT	0.121	0.782		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
DDT	56 µg/kg	0.7		airconditioning	Singapore	(Tan *et al.*, 2007b)	
delta-HCH	5.5 µg/kg	0.17		airconditioning	Singapore	(Tan *et al.*, 2007b)	
Diazinon	0.044	0.216		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Diazinon	0.14	0.61		surface sampler	USA-Seattle-Washington	(Lu *et al.*, 2004)	Non-farm
Diazinon		2.0		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Diazinon	0.31	0.72		surface sampler	USA-Oregon	(Rothlein *et al.*, 2006)	
Dicamba		2.5		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Dieldrin	0.018	0.050		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Dimethyl OP	0.37	1.3		vacuum	USA-Washington	(Lu *et al.*, 2000)	Non-farm
Ethyl parathion	0.076	0.425		surface sampler	USA-Washington	(Simcox *et al.*, 1995)	Non-farm
Ethyl parathion	0.56			vacuum	USA-Washington	(Fenske *et al.*, 2002)	
Ethyl parathion	0.04			vacuum	USA-Washington	(Fenske *et al.*, 2002)	
gamma-Chlordane[2]	0.098	0.471		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Pesticides							
gamma-HCH[3]	2.9 µg/kg	0.074		airconditioning	Singapore	(Tan *et al.*, 2007b)	
Glyphosate	140 µg/kg			surface sampler	USA-Iowa	(Curwin *et al.*, 2005)	Non-farm
Heptachlor	0.119	0.335		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Lindane[3]	0.33	0.046		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Malathion		2.0		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Malathion	0.38	1.4		surface sampler	USA-Oregon	(Rothlein *et al.*, 2006)	
Mecoprop		0.4		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Methamidophos		0.4		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Methyl parathion		0.125		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Methyl parathion	0.38	1.9		surface sampler	USA-Oregon	(Rothlein *et al.*, 2006)	
Metolachlor	5.7 µg/kg			surface sampler	USA-Iowa	(Curwin *et al.*, 2005)	Non-farm
Metolachlor		0.8		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Pendimethalin		3.0		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Permethrin	0.14	187.00	11.5	vacuum	Germany	(Becker *et al.*, 2006)	
Permethrin	53.65 (arithmetic)	659.15	129.1 (P90)	vacuum	Germany-Hannover	(Berger-Preiß *et al.*, 2002)	
Phosmet	0.227	0.658		surface sampler	USA-Washington	(Simcox *et al.*, 1995)	Non-farm
Phosmet	0.09	0.2		vacuum	USA-Washington	(Lu *et al.*, 2000)	Non-farm
Phosmet	5.2	22		surface sampler	USA-Oregon	(Rothlein *et al.*, 2006)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Pesticides							
Picloram		1.2		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Resmethrin		0.8		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Tetramethrin		0.4		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
trans-Chlordane[2]	5 µg/kg	0.073		airconditioning	Singapore	(Tan *et al.*, 2007b)	
Trichloro-2-pyridinol[4]	0.535	0.950		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Trifluralin		1.8		vacuum	USA-New York state	(Obendorf *et al.*, 2006)	
Phthalates							
Butylbenzyl phthalate (BBP)	157			vacuum	Sweden	(Bornehag *et al.*, 2004)	
Butylbenzyl phthalate (BBP)	86.1	815.7	218.5	vacuum	Germany-Berlin	(Fromme *et al.*, 2004)	
Butylbenzyl phthalate (BBP)	319	45549	599	vacuum	Sweden	(Bornehag *et al.*, 2005)	Dust from bedrooms
Butylbenzyl phthalate (BBP)	5.86	15.6		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Butylbenzyl phthalate (BBP)	84		416		Europe	(Wormuth *et al.*, 2006)	
Di(2-ethylhexyl) phthalate (DEHP)	508	5330	1840	vacuum	Germany	(Becker *et al.*, 2004)	
Di(2-ethylhexyl) phthalate (DEHP)	775.5	1763	1542	vacuum	Germany-Berlin	(Fromme *et al.*, 2004)	
Di(2-ethylhexyl) phthalate (DEHP)	741			vacuum	Sweden	(Bornehag *et al.*, 2004)	
Di(2-ethylhexyl) phthalate (DEHP)	1310	40459	4069	vacuum	Sweden	(Bornehag *et al.*, 2005)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Phthalates							
Di(2-ethylhexyl) phthalate (DEHP)	3214		7063	vacuum	Denmark	(Clausen *et al.*, 2003)	Dust from schools
Di(2-ethylhexyl) phthalate (DEHP)			2600	vacuum	Germany	(Butte, 2001)	
Di(2-ethylhexyl) phthalate (DEHP)	858		2595	vacuum	Denmark	(Clausen *et al.*, 2003)	
Di(2-ethylhexyl) phthalate (DEHP)			2000	vacuum	Germany	(Pohner *et al.*, 1997)	
Di(2-ethylhexyl) phthalate (DEHP)	640			vacuum	Norway	(Oie *et al.*, 1997)	
Di(2-ethylhexyl) phthalate (DEHP)	1198		3470		Europe	(Wormuth *et al.*, 2006)	
Diethyl phthalate (DEP)	44.6	632.2	159.6	vacuum	Germany-Berlin	(Fromme *et al.*, 2004)	
Diethyl phthalate (DEP)	26		114		Europe	(Wormuth *et al.*, 2006)	
Diisobutyl (DiBP)	84		130		Europe	(Wormuth *et al.*, 2006)	
Diisodecyl (DIDP)	73		240		Europe	(Wormuth *et al.*, 2006)	
Diisononyl (DINP)	176		674		Europe	(Wormuth *et al.*, 2006)	
Dimethyl phthalate (DMP)	10.8	157.9	46.4	vacuum	Germany-Berlin	(Fromme *et al.*, 2004)	
Dimethyl phthalate (DMP)	1.1		1.8		Europe	(Wormuth *et al.*, 2006)	
Dimethylpropyl phthalate (DMPP)	54.6	161.3	144.4	vacuum	Germany-Berlin	(Fromme *et al.*, 2004)	
Di-n-butyl phthalate (DBP)	1.21	3.03		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Phthalates							
Di-n-butyl phthalate (DBP)	178			vacuum	Sweden	(Bornehag *et al.*, 2004)	
Di-n-butyl phthalate (DBP)	55.6	141.4	129.6	vacuum	Germany-Berlin	(Fromme *et al.*, 2004)	
Di-n-butyl phthalate (DBP)	226	5446	568	vacuum	Sweden	(Bornehag *et al.*, 2005)	
Di-n-butyl phthalate (DBP)	98		311		Europe	(Wormuth *et al.*, 2006)	
Brominated flame retardants (BFRs)	BFRs in µg/kg	BFRs in µg/kg					
BDE 100	1.15			vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 100	82,825			vacuum	Spain	(Regueiro *et al.*, 2006)	Average of 4 samples
BDE 100	274	2090		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 100	65	1200		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 100	20.8	314		vacuum	Germany	(Knoth, 2003)	
BDE 100	490	21000	790	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 100	429				USA-Dallas	Schecter-2005	
BDE 138	17.3	111		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 138	37	2000	38	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 153	30.7	420		vacuum	Germany	(Knoth, 2003)	
BDE 153	1.31			vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 153	3,025			vacuum	Spain	(Regueiro *et al.*, 2006)	Average of 4 samples
BDE 153	181	1510		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 154	13.8	210		vacuum	Germany	(Knoth, 2003)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Brominated flame retardants (BFRs)							
BDE 154	1.39			vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 154	2,885			vacuum	Spain	(Regueiro *et al.*, 2006)	Average of 4 samples
BDE 154	156	1250		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 154	43	960		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 154	380	18000	570	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 154	189				USA-Dallas	(Schecter *et al.*, 2005)	
BDE 17	8.9	21.6		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 17	4.3	150	12	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 183	23.3	464		vacuum	Germany	(Knoth, 2003)	
BDE 183	3.57			vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 183	30.7	168		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 183	18	180		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 183	44	650	200	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 183	19.3				USA-Dallas	(Schecter *et al.*, 2005)	
BDE 190	4.5	10.5		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 190	0.75	48	<LOQ	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 196	14.5	38.6		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 197	17.4	77.2		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Brominated flame retardants (BFRs)							
BDE 206	51.1	239		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 207	30	109		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 208	34.7	108		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 209	0.98	19100		vacuum	Germany	(Knoth, 2003)	
BDE 209	0.1288	0.338		vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 209	2.09	8750		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 209	2,200	13		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 209	1.1	10	4.1	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 209	8,567				USA-Dallas	(Schecter *et al.*, 2005)	
BDE 209	0.425				Europe	(Santillo *et al.*, 2003) (Sjodin *et al.*, 2004) (Al Bitar, 2004) (Knoth, 2003)	
BDE 209	4,028	65,777			USA	(Stapleton *et al.*, 2005) (Schecter *et al.*, 2005) (Sharp *et al.*, 2004) (Costner *et al.*, 2005)	
BDE 209	2,000				USA	(Sjodin *et al.*, 2004)	
BDE 209	0.732				Australia	(Sjodin *et al.*, 2006)	
BDE 209	0.619	2,230			Australia	(Toms *et al.*, 2006)	
BDE 209	10,290				UK	(Santillo *et al.*, 2003) (Sjodin *et al.*, 2006)	
BDE 28	0.9	4.4		vacuum	Germany	(Knoth, 2003)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Brominated flame retardants (BFRs)							
BDE 28	0.35			vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 28	1.2	5.84		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 28	15	550	28	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 28	20.3				USA-Dallas	(Schecter *et al.*, 2005)	
BDE 33, 28	20.7	76.5		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 47	122	910		vacuum	Germany	(Knoth, 2003)	
BDE 47	27.2 ng/g				UK	(Santillo *et al.*, 2003) (Sjodin *et al.*, 2006)	
BDE 47	21.6 ng/g				Europe	(Santillo *et al.*, 2003) (Sjodin *et al.*, 2004) (Al Bitar, 2004; Knoth, 2003)	
BDE 47	6.57 ng/g	65 ng/g		vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 47	280			vacuum	Spain	(Regueiro *et al.*, 2006)	Average of 4 samples
BDE 47	1220	7610		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 47	110 ng/g	1500 ng/g		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 47	55 ng/g	210 ng/g			Australia	(Toms *et al.*, 2006)	
BDE 47	60 ng/g				Australia	(Sjodin *et al.*, 2006)	
BDE 47	1100 ng/g	33000 ng/g	2600	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 47	230 ng/g				USA	(Sjodin *et al.*, 2004)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Brominated flame retardants (BFRs)							
BDE 47	1595 ng/g	10538 ng/g			USA	(Stapleton *et al.*, 2005)(Schecter *et al.*, 2005) (Sharp *et al.*, 2004) (Costner *et al.*, 2005)	
BDE 47	1621				USA-Dallas	(Schecter *et al.*, 2005)	
BDE 49	25.8	282		vacuum	Germany	(Knoth, 2003)	
BDE 66	28.5	142		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 66	37	1800	45	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 85	7.1	74.7		vacuum	Germany	(Knoth, 2003)	
BDE 85	0.72			vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 85	1,365			vacuum	Spain	(Regueiro *et al.*, 2006)	Average of 4 samples
BDE 85	83.4	620		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 85	190	9700	200	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 99	180 ng/g	2850		vacuum	Germany	(Knoth, 2003)	
BDE 99	79.8 ng/g				UK	(Santillo *et al.*, 2003) (Sjodin *et al.*, 2006)	
BDE 99	32.8 ng/g				Europe	(Santillo *et al.*, 2003) (Sjodin *et al.*, 2004) (Al Bitar, 2004) (Knoth, 2003)	
BDE 99	1977 ng/g	13841 ng/g			USA	(Stapleton *et al.*, 2005; Schecter *et al.*, 2005) (Sharp *et al.*, 2004) (Costner *et al.*, 2005)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Brominated flame retardants (BFRs)							
BDE 99	6.00 ng/g	36 ng/g		vacuum	Kuwait	(Gevao *et al.*, 2006)	
BDE 99	79.8 ng/g	294 ng/g			Australia	(Toms *et al.*, 2006)	
BDE 99	880 ng/g				USA	(Sjodin *et al.*, 2004)	
BDE 99	106 ng/g				Australia	(Sjodin *et al.*, 2006)	
BDE 99	31,525			vacuum	Spain	(Regueiro *et al.*, 2006)	Average of 4 samples
BDE 99	1700	13800		vacuum	USA-Washington	(Stapleton *et al.*, 2005)	
BDE 99	340 ng/g	6300 ng/g		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE 99	1800 ng/g	60000 ng/g	4700	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE 99	2295				USA-Dallas	(Schecter *et al.*, 2005)	
BDE99	8.5 ng/g	7771			Netherlands	(De Boer, 2007)	
BDE153	76	1400		airconditioning	Singapore	(Tan *et al.*, 2007a)	
BDE153	470	25000	520	vacuum	Canada-Ottawa	(Wilford *et al.*, 2005)	
BDE153	199				USA-Dallas	(Schecter *et al.*, 2005)	
Polycyclic aromatic hydrocarbons (PAHs)							
Acenaphthene	0.05	0.18		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Acenaphthene	0.032	1.9		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Acenaphthene	0.008	0.019		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Acenaphthylene	0.08	0.27		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Acenaphthylene	0.026	0.52		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Acenaphthylene	0.006	0.023		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Anthracene	0.12	0.75		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Polycyclic aromatic hydrocarbons (PAHs)							
Anthracene	0.065	5.8		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Anthracene	0.017	0.066		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Benz[a]anthracene	0.22	0.69		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Benz[a]anthracene	0.241	40		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Benz[a]anthracene	0.090	0.519		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Benzo[a]pyrene	0.23	0.63		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Benzo[a]pyrene	0.285	54	13	different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Benzo[a]pyrene	0.134	0.768		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Benzo[b,k]fluoranthene	0.55	1.34		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Benzo[b,k]fluoranthene	0.570	108		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Benzo[b,k]fluoranthene	0.253	1.44		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Benzo[b,k]fluoranthene	0.050	0.496		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Benzo[e]pyrene	0.26	0.75		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Benzo[e]pyrene	0.286	41		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Benzo[e]pyrene	0.144	0.809		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Benzo[g,h,i]perylene	0.25	0.61		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Benzo[g,h,i]perylene	0.252	35		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Benzo[g,h,i]perylene	0.173	0.961		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Biphenyl	0.002	0.005		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Chrysene	0.39	2.41		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Chrysene	0.372	43		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Chrysene	0.169	0.838		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Coronene	0.13	0.50		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Polycyclic aromatic hydrocarbons (PAHs)							
Coronene	0.095	7.2		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Coronene	0.067	0.32		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Cyclopenta[c,d]pyrene	0.08	0.22		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Cyclopenta[c,d]pyrene	0.034	0.62		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Cyclopenta[c,d]pyrene	0.035	0.172		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Dibenzo[a,h]anthracene	0.10	0.41		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Dibenzo[a,h]anthracene	0.082	9.0		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Dibenzo[a,h]anthracene	0.060	0.294		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Fluoranthene	0.52	1.89		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Fluoranthene	0.588	90		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Fluoranthene	0.297	1.56		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Fluorene	0.12	1.22		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Fluorene	0.054	3.0		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Fluorene	0.011	0.028		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Indeno[1,2,3-c,d]pyrene	0.23	0.70		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Indeno[1,2,3-c,d]pyrene	0.255	41		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Indeno[1,2,3-c,d]pyrene	0.169	0.963		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Naphthalene	0.33	4.30		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	

Substance	Concentration in dust (mg/kg)			Sampling	Location	Reference	Remarks
	Geometric mean	Maximum	P95				
Polycyclic aromatic hydrocarbons (PAHs)							
Naphthalene	0.068	42		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Naphthalene	0.010	0.035		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Phenanthrene	0.44	2.15		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Phenanthrene	0.416	43		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Phenanthrene	0.144	0.596		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	
Pyrene	0.43	1.65		surface sampler	USA-North Carolina	(Chuang *et al.*, 1999)	
Pyrene	0.490	69		different methods		(Maertens *et al.*, 2004)	Average of 18 studies
Pyrene	0.229	1.20		surface sampler	USA-North Carolina	(Wilson *et al.*, 2003)	

Appendix 1 – Remarks

1. Alpha-Chlordane = cis-Chlordane.
2. Gamma-Chlordane = trans-Chlordane.
3. Lindane is technical gamma-HCH.
4. Trichloro-2-pyridinol is a metabolite of chlorpyrifos.

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Appendix 2 List of TDIs and background exposure estimates

Table Appendix 2. TDIs and background exposures

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Metals						
Aluminium	750	(Van Engelen *et al*., in press)	80-180	300	food, drinking-water	(Van Engelen *et al*., in press)
Antimony	6	(Van Engelen *et al*., in press)	0.018-0.48	0.53	food, drinking-water	(Van Engelen *et al*., in press)
Arsenic	1	(Van Engelen *et al*., in press)	0.3	0.4-0.7	food, drinking-water	(Van Engelen *et al*., in press) (Baars *et al*., 2001)
Barium	600	(Van Engelen *et al*., in press)	9		food, drinking-water	(Van Engelen *et al*., in press)
Beryllium	0.5	(Janssen *et al*., 1995)	0.3		food, drinking-water	(Janssen *et al*., 1995)
Bismuth	n.a.		unknown			
Cadmium	0.5	(Oomen *et al*., 2007)	0.45		food, drinking-water	(Van Engelen *et al*., in press)
Chromium III soluble	5.0		1		food, drinking-water	(Baars *et al*., 2001)
Chromium III insoluble	5000	(Baars *et al*., 2001)	1		food, drinking-water	(Baars *et al*., 2001)
Chromium VI	5	(Baars *et al*., 2001)	5.7×10^{-6}-0.43×10^{-3}		air	(Baars *et al*., 2001)
Cobalt	1.4	(Van Engelen *et al*., in press)	0.6		food, drinking-water	(Van Engelen *et al*., in press)

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Metals						
Copper	83	(Van Engelen *et al*., in press)	60		food, drinking-water	(Van Engelen *et al*., in press)
Lead	3.6	(Van Engelen *et al*., in press)	1.11	1.83		(Gezondheidsraad (Dutch Health Council) , 1997)
Lithium	n.a.		unknown		food, drinking-water	
Magnesium	6700	(Food Standards Agency)	4600		food, drinking-water	(Food Standards Agency)
Manganese	160	(Van Engelen *et al*., in press)	130		food, drinking-water	(Van Engelen *et al*., in press)
Mercury	2	(Van Engelen *et al*., in press)	0.1		food, dental fillings	(Van Engelen *et al*., in press)
Molybdenum	10	(Baars *et al*., 2001)	4		food, drinking-water	(Baars *et al*., 2001)
Nickel	10	(Van Engelen *et al*., in press)	4	8	food, drinking-water	(Van Engelen *et al*., in press) (Baars *et al*., 2001)
Rubidium	n.a.		unknown			
Selenium	5	(Van Engelen *et al*., in press)	2		food, drinking-water	(Van Engelen *et al*., in press)
Silver	5	(Van Engelen *et al*., in press)	1.3		food, drinking-water	(Van Engelen *et al*., in press)
Strontium	600	(Van Engelen *et al*., in press)	18		food, drinking-water	(Van Engelen *et al*., in press)
Tellurium	2	(Janssen *et al*., 1998)	1.4		food	(Janssen *et al*., 1998)
Thallium	0.2	(Janssen *et al*., 1998)	0.03		food	(Janssen *et al*., 1998)
Tin	2000	(Van Engelen *et al*., in press)	290		food, water	(Van Engelen *et al*., in press)

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Metals						
Titanium	12000	(Janssen and Baars, 2004)	7		food	(Janssen and Baars, 2004)
Tungsten	n.a.		unknown			
Uranium	2	(ATSDR, 1999)	0.06		food, drinking-water	(Bruggen *et al*., 1998)
Vanadium	2		0.3		food	(Janssen *et al*., 1998)
Zinc	500	(Van Engelen *et al*., in press)	350		food	(Van Engelen *et al*., in press)
Organotin compounds						
Dibutyltin (DBT)						
Dioctyltin (DOT)						
Monobutyltin (MBT)						
Monooctyltin (MOT)						
Tributyltin (TBT)						
Sum organotins	0.25	(Van Engelen *et al*., in press)	0.083		food, drinking-water	(Van Engelen *et al*., in press)
Pesticides						
2.4-D	10	(JMPR, 2001)	unknown		food, drinking-water	
Alachlor	10	(USEPA, 1998)	unknown		food	

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Pesticides						
Aldrin	0.1 (som aldrin+dieldrin)	(Baars *et al*., 2001)	<0.04		food	(Baars *et al*., 2001)
alpha-Chlordane	0.5	(Janssen *et al*., 1995)	unknown		food	
alpha-HCH	1	(Baars *et al*., 2001)	<0.03		food	(Baars *et al*., 2001)
Atrazine	35	(USEPA, 1993)	unknown		food	
Azinphos methyl	5	(Janssen *et al*., 1995)	unknown		food, drinking-water	
beta-HCH	0.02	(Baars *et al*., 2001)	<0.01		food, drinking-water	(Baars *et al*., 2001)
Carbaryl	8	(JMPR, 2001)	unknown		food, drinking-water	
Chloroprofam	50	(JMPR, 2005)	unknown		food, drinking-water	
Chlorpyrifos	10	(JMPR, 2004a)	unknown		food, drinking-water	
DDD	0.5 (som DDT, DDD, DDE)	(Baars *et al*., 2001)	unknown		food, drinking-water	
DDE	0.5 (som DDT, DDD, DDE)	(Baars *et al*., 2001)	unknown		food, drinking-water	
DDT	0.5 (som DDT, DDD, DDE)	(Baars *et al*., 2001)	unknown		food, drinking-water	
delta-HCH	n.a.		unknown		food, drinking-water	
Diazinon	5	(JMPR, 2006)	unknown		food, drinking-water	

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Pesticides						
Dicamba	125	(Hoeven and Engelen, 1997)	unknown		food, drinking-water	
Dieldrin	0.1 (som aldrin+dieldrin)	(Baars *et al*., 2001)	<0.04		food	(Baars *et al*., 2001)
Dimethyl organiphosphate						
Endrin	0.2	(Baars *et al*., 2001)	<0.04		food, drinking-water	(Baars *et al*., 2001)
Ethyl parathion	4	(JMPR, 1995)	unknown		food, drinking-water	
Flutolanil	90	(JMPR, 2002)	unknown		food, drinking-water	
gamma-Chlordane	0.5	(Janssen *et al*., 1995)	unknown		food, drinking-water	
Glyphosate	1000	(JMPR, 2004b)	unknown		food, drinking-water	
Heptachlor	0.1	(Janssen *et al*., 1995)	0.001		food, drinking-water	(Janssen *et al*., 1995)
Lindane [= gamma-HCH]	0.04	(Baars *et al*., 2001)	< 0.03		food, drinking-water	(Baars *et al*., 2001)
Malathion	300	(JMPR, 2003)	unknown		food, drinking-water	
Mecoprop	3.33	(WHO, 1996)	unknown		food, drinking-water	

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Pesticides						
Methamidophos	4	(JMPR, 2002)	unknown		food, drinking-water	
Methyl parathion	3	(JMPR, 1995)	unknown		food, drinking-water	
Metolachlor	3.5	(WHO, 2003)	unknown		food, drinking-water	
Pendimethalin	125	(EU, 2003)	unknown		food, drinking-water	
Permethrin	50	(JMPR, 2002)	unknown		food, drinking-water	
Phosmet	3	(EU, 2006)	unknown		food, drinking-water	
Picloram	200	(BfR, 2006)	unknown		food, drinking-water	
Resmethrin	30	(JMPR, 1991)	unknown		food, drinking-water	
Tetramethrin	20	(AG, 1992)	unknown		food, drinking-water	
Trichloro-2-pyridinol	n.a.		unknown		food, drinking-water	
Trifluralin	15	(BfR, 2006)	unknown		food, drinking-water	
Vinchlozolin	10	(JMPR, 1995)	unknown		food, drinking-water	

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Phthalates						
Butylbenzyl phthalate (BBP)	500	(EFSA, 2005a)	5.0-9.0		food, drinking-water	(Baars *et al*., 2001)
Di(2-ethylhexyl)phthalate (DEHP)	50	(EFSA, 2005b)	3-16	12-26	food, drinking-water	(EFSA, 2005b)
Diethyl phthalate (DEP)	200	(Baars *et al*., 2001)	unknown		food, drinking-water	
Diisobutyl (DiBP)	n.a.		unknown		food, drinking-water	
Diisodecyl (DIDP)	150	(EFSA, 2005c)	7		food, drinking-water	(EFSA, 2005c)
Diisononyl (DINP)	150	(EFSA, 2005d)	10		food, drinking-water	(EFSA, 2005d)
Dimethyl phthalate (DMP)	n.a.		unknown		food, drinking-water	
Dimethylpropyl phthalate (DMPP)	n.a.		unknown		food, drinking-water	
Di-n-butyl phthalate (DBP)	52	(Baars *et al*., 2001)	unknown		food, drinking-water	
Brominated flame retardants (BFRs)						
BDE 47						
BDE 99	0.00026	(Winter-Sorkina *et al*., 2006)				
BDE 100						

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Brominated flame retardants (BFRs)						
BDE 183						
BDE 209						
Polycyclic aromatic hydrocarbons (PAHs)						
Acenaphthene					food	
Acenaphthylene					food	
Anthracene	40	(Baars *et al*., 2001)			food	
Benz[a]anthracene					food	
Benzo[a]pyrene	0.0005 (BaP-indicator approach)	(Baars *et al*., 2001) (SCF 2002)	in EU via food: 0.0006 (BaP)		food	(SCF, 2002)
Benzo[b,k]fluoranthene					food	
Benzo[e]pyrene					food	
Benzo[g,h,i]perylene	30	(Baars *et al*., 2001)			food	
Biphenyl	50	(USEPA, 1989)			food	
Chrysene					food	
Coronene					food	
Cyclopenta[c,d]pyrene					food	
Dibenzo[a,h]anthracene					food	
Fluoranthene					food	
Fluorene	40	(Baars *et al*., 2001)			food	
Indeno[1,2,3-c,d]pyrene					food	
Naphthalene	40	(Baars *et al*., 2001)			food	

	TDI	Reference	Background		Specification background	Reference
	(µg/kg bw/day)		(µg/kg bw/day)			
			Adult	Child		
Polycyclic aromatic hydrocarbons (PAHs)						
Phenanthrene	40	(Baars *et al*., 2001)			food	
Pyrene					food	

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